The Stories, Voices, and Key Insights of the Pioneers Who Shaped the Way We Invest

IN PURSUIT OF THE PERFECT PORTFOLIO

ANDREW W. LO and STEPHEN R. FOERSTER

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We dedicate this book to the most perfect of all portfolios,
our families:
Nancy, Derek, and Wesley
Linda, Jennifer, Christopher, Thomas, and Melanie

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PREFACE

AT THE CONCLUSION of a conference in 2011 honoring the contributions of Harry Markowitz to the world of finance, one of the conference organizers speculated what the investment world would be like without Markowitz's contribution to portfolio theory. Imagine, the organizer wondered, if Markowitz had approached the great investor, Warren Buffett, asking for advice on how to invest. Buffett's likely response would be "Give me your money, and I'll manage it." Clearly, given his track record, Buffett would have done an exceptional job. But where would that have left other investors, ones who weren't so fortunate to have Buffett as their money manager? Now imagine if Buffett were to approach Markowitz, asking "What could you do to help me?" Markowitz's response would be "Here is a framework and an approach for portfolio management."

We readily acknowledge the investment success of Buffett, John Templeton, Peter Lynch, David Shaw, Jim Simons, George Soros, and many other great investors whose styles and approaches to investment aren't easily replicated. However, the academic financial research by Markowitz as well as his fellow Nobel laureates such as James Tobin, Paul Samuelson, Bill Sharpe, Myron Scholes, Bob Merton, Gene Fama, and Bob Shiller and by other exceptional researchers has created a framework and repeatable process for investors that has led to the democratization of investment management. This book is about their contributions to portfolio management.

Is there a Perfect Portfolio of assets for investors, one that offers the ideal mix of risk and reward? Over the past decade of our journey, we asked this question to ten prominent iconic figures and thought leaders in the industry—Harry Markowitz, Bill Sharpe, Gene Fama, Jack Bogle, Myron Scholes, Bob Merton, Marty Leibowitz, Bob Shiller, Charley Ellis, and Jeremy Siegel—and their answers were both expected and unexpected. Our pioneers, while admittedly not a diverse group (and, as you'll see in the chart in a few pages, a group with many interconnections), were reflective of the field at the time. Thankfully, the investment community is much more diverse today, and we hope our book will inspire an even more diverse group of pioneers in the next generation. While we may never reach such an elusive and shifting target as the Perfect Portfolio in the constantly evolving world of investment, this book is about the people and their pursuit of such a portfolio. Like John Locke's "constant pursuit of true and solid happiness," we examine how academic and practitioner research has contributed to the evolution and understanding of what the Perfect Portfolio might look like and the key lessons learned from it.

As individual investors and professional portfolio managers alike search for the right mix of investments that will provide as high an expected return as possible for a given level of risk, they face a number of important questions:

- What do we really mean by diversification, and why is it important?
- How should we combine riskless assets such as Treasury bills with risky assets such as stocks?
- Should investors simply invest in index funds, or should they actively manage a portfolio?
- How important are security selection and market timing?
- How should performance be measured?
- How important are foreign versus domestic investments?
- What are derivative securities, and what role do such nontraditional assets play?
- How important are different equity styles, such as small cap and value?
- How should one approach investing when other investors may not be acting rationally?

In Pursuit of the Perfect Portfolio provides insight into these questions and more. We examine the key contributions to portfolio management in these areas from both academic researchers and industry-leading practitioners. We're writing for a general audience—including novice and professional investors alike—as well as those taking investment or portfolio management courses. We review the intellectual history and evolution of portfolio management by highlighting and explaining the key contributions of some of its most significant researchers over the past seventy years—the era known as modern portfolio theory. We have added color and context through interviews—which took place in San Diego, Monterey, San Francisco, New York, Cambridge, Chicago, Malvern, and Philadelphia—with a different academic or industry thought leader featured in each chapter. We integrate the lessons learned from our interviews with these key portfolio management players in the concluding chapter and present an investing checklist to help you develop your own investment philosophy so you can determine the Perfect Portfolio that's right for you.

In Pursuit of the Perfect Portfolio comes with an important investment disclaimer: we aren't providing you with financial advice! (The "we" refers to Princeton University Press, the authors, and the interview subjects.) Our intent is to inform and entertain, providing you with general information and opinions, not legal, tax, investment, financial, or other advice. We can't guarantee the book is error-free or will be useful to everyone. Some of our interviews took place a while ago, so the relevance of the information is subject to change. The information, opinions, and views contained in this book have not been tailored to the investment objectives of any one individual. All investment strategies and investments involve risk of loss. Any reference to an investment's past or potential performance isn't a recommendation or a guarantee of any specific outcome. We strongly encourage you to consult with a financial professional for the purpose of assessing whether the ideas or strategies discussed in this book are suitable to you based on your own personal financial objectives, needs, and risk tolerance. We wish you all the success in your investments, but any losses are yours alone.

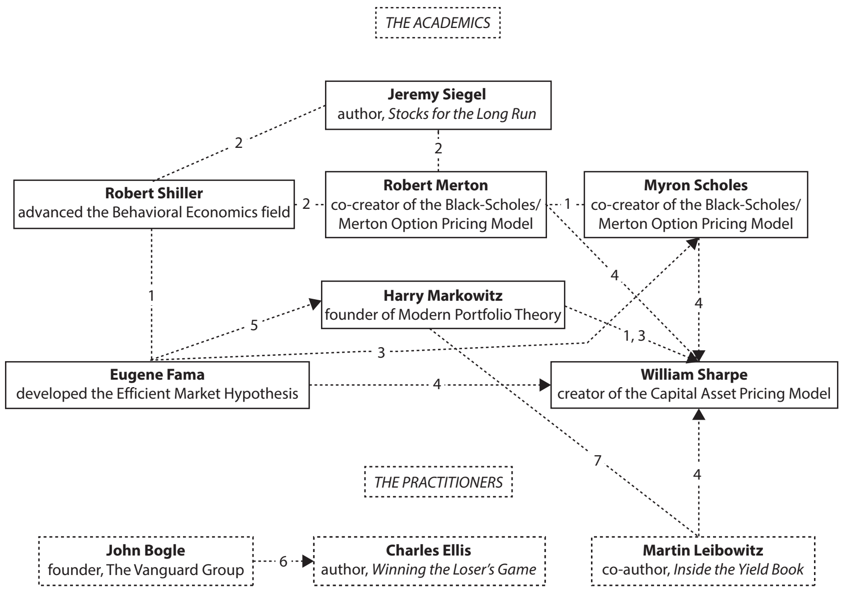
As in any such endeavor, we wish to acknowledge the important contributors on whose inputs and insights we have relied while stressing that any inadvertent errors are our own. We thank Jayna Cummings for carefully reviewing our preliminary drafts and general editorial support, Jeff Silberman for helpful suggestions, John Cochrane for exhaustive and insightful comments that greatly improved this book, Will Goetzmann for offering his unique historical perspective on chapter 1, Michael Nolan and John Bogle Jr. for comments related to chapter 5, senior editor Joe Jackson as well as Jackie Delaney, Josh Drake, and the excellent team at Princeton University Press, and Deborah Grahame-Smith and Yvonne Ramsey at Westchester Publishing Services. We are grateful to MaryEllen Oliver for proofreading the manuscript and Alexandra Nickerson for preparing the index. Thanks also to Gifford Fong, editor of *Journal of Investment Management*, who organized a conference that included many of our interviewees, which helped to spark the idea for this book. We're particularly indebted to Jack Bogle, Charley Ellis, Gene Fama, Marty Leibowitz, Harry Markowitz, Bob Merton, Myron Scholes, Bill Sharpe, Bob Shiller, and Jeremy Siegel for their research and teaching, for inspiring us throughout our careers with their intellectual leadership, and for devoting their valuable time in interviews with us and reviewing their chapters.

We hope you enjoy the journey as much as we have!

Andrew W. Lo and Stephen R. Foerster
Cambridge, Massachusetts, and London, Ontario

IN PURSUIT OF THE PERFECT PORTFOLIO

THE PIONEERS AND THEIR CONNECTIONS



LEGEND OF CONNECTIONS

1. Co-recipients of the Nobel Prize in Economics (same year)
2. PhD classmates
3. PhD supervisor/student
4. Tested or extended the Capital Asset Pricing Model
5. First to teach Markowitz's theories at the University of Chicago
6. Encouraged to start the first mutual index fund after reading Ellis's article
7. Crossed paths while working at competing firms developing programming languages

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A Brief History of Investments

Mesopotamia and the Dawn of Investing

The art of investing has been practiced since the dawn of *Homo economicus*. Investing in its earliest form can be linked to the risk/reward decisions of long-distance trading. During the late Pre-Pottery Neolithic period in the prehistoric Middle East, between 9500 and 8500 BCE, settled village life emerged. Settlers from the Jordan Valley engaged in the long-distance trade of obsidian, domesticated wheat, and sheep with the people of the Central Anatolian Plateau and the Zagros-Taurus arc in what is now modern-day Turkey.[1] The enterprising traders of this period faced significant dangers in these commercial treks, making risk/reward decisions every day they continued in their quest for economic profit. Thanks to some very savvy investment decisions on the part of these merchants, long-distance trade flourished like never before, spanning a distance of fifteen hundred miles and involving a striking variety of raw materials.

If we think of a portfolio in a broad sense, as capital that's saved or invested for a future purpose, then recent evidence suggests that these Pre-Pottery Neolithic settlers treated grain the way we would treat a portfolio today. Food storage is a vital component of economic development. Twenty-first-century excavations near the Dead Sea in Jordan uncovered strong evidence of sophisticated granaries even before the domestication of plants.[2] This evidence suggests that the settlers were able to reduce seasonal food risks and settle in a particular area for more than one season a year. These storage facilities, a break from earlier periods, represented a critical form of risk management, allowing the settlers to smooth their consumption, ensure against droughts, and plan for the next sowing season.

Investing is also directly linked to the time value of money, the notion that a dollar today is worth more than a dollar tomorrow. Investing is really about moving economic value across time—for instance, providing an entrepreneur with a needed source of cash today in return for a promise to share in future profits. Even before writing was invented, accounting still played an important role, since it was critical to have a record of transactions and contracts between two parties. Evidence for accounting in the form of commodity record keeping may extend back to 7000 BCE, based on the interpretation of the use of tokens—about the size of board game pieces—in the early urban settlements of Mesopotamia.[3] What these tokens were used for wasn't initially clear to archaeologists, but one archaeologist eventually recognized that old Uruk tablets dating back to 3100 BCE, complete with cuneiform writing, also contained pictographs of these very tokens. For example, the symbol for food evolved from a token shaped like a dish. Most pictographs represented everyday commodities such as sheep and loaves of bread. Virtually all of these old tablets were accounting records or contracts presumably used by some kind of central authority, such as a temple, to account for what goods were coming in and going out of the temple.

These tablets also provide us with records of ancient loans. For example, a Sumerian record from around 2400 BCE may be the oldest known personal loan: Ur-garima lent Puzur-Eshrat forty grams of silver and nine hundred liters of barley.[4] Around that time the first known surety bond was issued, with a second party guaranteeing repayment if the first party failed to reimburse the lender. A stone tablet written in cuneiform characters indicates that such a bond, guaranteeing the payment of grain, was issued in Nippur in Mesopotamia. The bond was drawn up by a scribe, included the names of four witnesses, and, typically for its time, was executed in triplicate.[5]

Other ancient records indicate more complex business arrangements, including forerunners to what we think of as modern financial instruments. For example, a type of derivative contract actually dates back to 1900 BCE. Derivatives are named because their prices are derived from some underlying security, such as the price of a commodity. The first known derivatives contracts—what today would be called futures contracts—were written in Mesopotamia in cuneiform script on clay tablets and involved the future delivery of goods, often combined with loans. One such contract was between a merchant, Magrattum Akshak-shemi, and his client, Damqanum, agreeing to the future exchange of thirty planks of wood of specified lengths.[6]

When famed archaeologist Sir Leonard Woolley excavated the Mesopotamian city of Ur, one of his startling discoveries was of the earliest known financial district, along with the possible birth of the bond trading market. Woolley discovered that in 1796 BCE an educated businessman named Dumuzi-gamil along with his partner, Shumi-abiya, borrowed five hundred grams of silver from another businessman, Shumi-abum. Dumuzi-gamil agreed to return his share of the silver in five years—a relatively long-term loan—at an annual rate of interest of 3.8 percent.[7] But rather than simply hold on to the loan, Shumi-abum turned around and sold it to some well-known merchants, who successfully collected it when the loan was due, thus indicating a market for bond trading. The Ur documents suggest that there was a liquid market for such personal promissory notes. Reflecting the principles of time value of money, Dumuzi-gamil likely used the loan as a productive source of immediate cash to finance his entrepreneurial venture as a bread distributor. He also used some of the funds to act as a banker, lending at a monthly interest rate of 20 percent—which works out to an annual compound rate of almost 800 percent!

Not all investments and trades panned out for everyone. Even centuries before social media, reputation mattered, and around 1750 BCE a copper trader in Dilmun named Ea-Nasir certainly didn't have a good one. In fact, what are arguably the world's oldest complaint letters (albeit ones written on tablets) cast him in an unflattering light. His career seemed to have started well, and he was considered a good credit risk while buying and selling for the palace at Ur. However, many traders' complaints about the quality of his copper were uncovered, etched in stone for all eternity. One man named Nanni was so upset that he covered both sides of an entire tablet with his complaints: "You have offered bad ingots to my messenger. . . . Who am I that you are treating me in this manner—treating me with such contempt? . . . You will learn that here in Ur I will not accept from you copper that is not good." Archaeological evidence suggests that Ea-Nasir's wealth eventually declined, and he was forced to branch out from copper trading into less lucrative markets such as real estate and secondhand clothes trading.[8]

From BCE to CE: Coins, Bonds, Stocks, and More

The lifeblood of any financial system is money. Money acts as a medium of exchange, allowing for a more efficient system than a world of barter. Money also acts as both a unit of account that indicates our wealth level and a store of value that can be saved and used later. To perform these functions, money needs to be durable, interchangeable, portable, and reliable. While barter is thought to have been around for at least one hundred thousand years, the earliest known coins were found by archaeologists in the Temple of Artemis at Ephesus, in present-day Turkey, and thought to be minted in 600 BCE.[9] Made of gold and silver alloy, the coins featured the head of a roaring lion. Comparing value across historical eras is difficult, but it's thought that each coin could buy about ten goats.

Subsequent to the early derivatives in Mesopotamia, another type of derivatives contract, the call option, was used around 600 BCE in ancient Greece. Call options allow the buyer the option to buy a particular asset at an agreed-upon price at a future date. One of the first recorded accounts of such a transaction is related to the underlying price of olive oil presses. At the time, olive oil was used for making soap and for cooking and was also used as fuel for lamps and as a skin softener.[10] After several years of poor harvests, the Greek philosopher and mathematician Thales of Miletus (known as one of the Seven Sages of Greece) used astronomy to predict an upcoming bumper olive crop. During the winter, he negotiated call options to buy the presses in the spring at their depressed current prices. He bought all the olive presses he could find from discouraged growers and made a fortune when the predicted bumper crop arrived. As recounted later by Aristotle in his famous *Politics*, Thales "succeeded in proving it is easy for philosophers to become rich if they so desire, though it is not the business in which they are really about."[11]

In the fourth century BCE, the well-known Greek orator Demosthenes was grappling with an investment issue. His father, with the same name, had died owning a furniture factory, a weapons factory, several loan investments, and other assets—early evidence of an investment portfolio, believed to be valued at over $11 million today. The estate, however, was mismanaged by his guardians, so when Demosthenes turned twenty-one, he took them to court. In his argument, he sought to establish both the original value of the estate and what it should have been valued at had it been managed properly, performing what today would be called a net present value calculation.[12] He was successful before the court but ultimately only received a fraction of the estate's value.

Since the third century BCE and perhaps earlier, endowment funds had been established in Greece[13] and later in the Roman Empire. The purpose of an endowment is to collect charitable donations and distribute funds generated from the endowment's investments while preserving the capital. Some of the earliest endowments were used to distribute cash awards to various tribes at annual celebrations, to pay teachers' salaries to educate youths, or to fund oxen sacrifices in religious rites. In some cases the principal was lent at a rate of 12 percent, although a rate of 10 percent was common later. As is the case today, there was even a tax angle to donations.[14] Many of the best-known endowments from this period were structured in such a way that elite and wealthy donors could limit their tax liabilities by sheltering real estate from possible tax assessment and perhaps even enhance their private wealth.

Around 221 BCE the standardized bronze coin was introduced to China by its first emperor, Qin Shi Huangdi, as the first currency of the now-unified empire and as its only acceptable currency, although archaeological records show that similar coins may have been produced hundreds of years earlier.[15] These coins had a standardized weight of half a liang, or about eight grams. The coins were ring-shaped with a square hole in the middle, allowing them to be strung together, and continued to be minted until the end of the empire under Emperor Puyi in 1912. These coins (historically called "cash" in English) are important, because as with present-day money they were fiat currency, not backed by any precious metals such as gold but only having value because of decree and convention.

Once coins became accepted as fiat currency and the weight and type of metal of the coin were no longer important, it was only a matter of time until paper currency became accepted. Banknotes, the most common form of currency today, originated in China during the Tang dynasty (618–907 CE). A banknote or bill is a guaranteed promise to pay the bearer or owner of the note on demand. Chinese merchants invented the first bill around 800 CE.[16] The idea was that a certain amount of currency would be deposited in a local merchant's guild, and the merchant would receive a written receipt. That receipt could then be brought to another town and exchanged for currency through that guild. The different guilds would periodically settle the amounts owed, thus avoiding the danger of transporting a lot of cash. By 841 CE, the government prohibited this custom so as to monopolize the issue of paper money.

During the Song dynasty (960–1279 CE), under Emperor Zhenzong (r. 997–1022), the world's first official paper money was designed. Notes were printed that were worth 1 to 10 guan (or strings) that equaled 1,000 to 10,000 cash equivalents, respectively. Upon redemption, however, only a portion was actually paid in cash. For example, 1 guan could be redeemed for 770 cash. Centuries later European explorers such as Marco Polo introduced the concept of paper money to the Western world. Today, paper money is ubiquitous. On the front of U.S. paper money is the promise "this note is legal tender for all debts, public and private," and on the back is the statement "in God we trust." In fact, you are really trusting the U.S. Treasury and the Federal Reserve to make good on this promise.

The precursor to government bonds—and the first form of public finance—occurred in Venice in 1172.[17] What we think of as bonds today were actually born by accident. The republic of Venice was in a struggle with Byzantium, the eastern successor to the Roman Empire, over control of the Adriatic Sea. On fabricated charges that the Venetians had set fire to a neighborhood in Constantinople, the emperor of Byzantium, Manuel I Komnenos, created a hostage crisis by seizing Venetian merchants, locking them in prison, and taking their goods. The doge of Venice, Vitale II Michiel, needed to quickly build a fleet of ships to wage a war in order to free the hostages and recover the Venetian property. Due to religious usury laws, however, loans were illegal.

To fund the fleet, the doge devised a borrowing scheme (technically not a loan) known as a *prestito*, like a mandatory tax but with a promise to pay 5 percent interest until the debt was retired. The scheme created a lender-borrower relationship between the city and its citizens rather than putting creditor control in the hands of a few investors. The *prestiti* became quite popular and were eventually traded frequently in the Rialto Market. Unfortunately, things failed to go well for the doge. While his fleet of 126 ships was anchored off the coast of Asia Minor, Manuel I Komnenos stalled for time by promising a negotiated resolution. However, the Venetian fleet was suddenly ravaged by plague. Thousands died, with only about a quarter surviving. The mission was cut short, and the survivors returned home in defeat. When the Venetians saw that the doge had survived but so many others had perished, a mob chased him down and executed him. Furthermore, the weakened republic, while continuing to make interest payments, was never able to retire the principal of the loan.

Public finance became very useful to the expanding European powers. The first government bonds were issued in Amsterdam in 1517, long before the Netherlands existed as a country,[18] and the first bonds were issued by a national government in 1694, through the Bank of England, to fund England's war against France.[19] One of the oldest known perpetual bonds, paying a set interest rate in perpetuity to whoever holds the bond, was issued by the Dutch water board of Lekdijk Bovendams in 1648 and written on goatskin; the money raised was used to pay workers who constructed a series of piers near a bend in the river to prevent erosion.[20] What's unique about the bond is that it still pays interest today. One of five known bondholders is Yale University, where the bond is displayed in the Beinecke Library. In 2015, Timothy Young, the library's curator of modern books and manuscripts, traveled to Amsterdam to collect twelve years of interest, worth €136.20, or $153, while in 2003 the university collected twenty-six years of back interest.

The world's oldest shareholding company dates back to 1369, when a group of French millers formed Société des Moulins de Bazacle.[21] The mill owners who shared a perpetual lease on the river arranged a profit-sharing plan. A few years later, one of the millers was a decade late in a debt repayment to a merchant, and the resolution to the subsequent lawsuit resulted in a new corporate structure that included the now common innovation of an elected board of directors to protect shareholders. The company was considered a distinct legal entity apart from the shareholders. The Société des Moulins de Bazacle survived floods that destroyed the dam, ice floes, famine, plagues, and a revolution while still paying out 100 percent of its profits in dividends. Shares were transferable, and in some years there was turnover of about 20 percent of the shares. There was one noteworthy constraint on share turnover: in addition to paying a large notary fee, new shareholders had to host a dinner for the entire board of directors.

The first "modern" joint-stock companies were the British East India Company (EIC), founded in 1600, and the Dutch East India Company, also known as the Vereenigte Ost-Indische Compagnie (VOC), founded in 1602.[22] The EIC was formed as a monopoly to trade in India and later China, while the VOC was a government-directed amalgamation of several Dutch companies that were granted a monopoly on trade in India. In 1609, the VOC was the first modern joint-stock company to raise a large amount of capital by issuing dividend-paying shares. For over a century, the shares paid dividends of an incredible 22 percent. Of course, these rewards were associated with tremendous risks: the dangers associated with long-distance trading and the uncertainty surrounding the new corporate form itself. Initially, the shareholders could either reinvest in future voyages or receive the distributed dividends. If shareholders were disappointed, they could demand their share capital back and withdraw. By 1609, however, VOC directors deemed the shares to be nonrefundable. An active secondary market developed for the shares, as there were over one thousand share subscribers in Amsterdam alone. By 1607, one-third of the original shares had changed hands. While the original plan called for the liquidation of its shares in ten years, the company wasn't formally dissolved until 1796.

Early Purported Bubbles

A bubble, in the financial sense, is a sometimes fuzzy word referring to the rapid increase of the price of an asset not explained by fundamental factors. (There will be more on bubbles later in this book.) One of the earliest purported bubbles was alleged to have occurred in the Netherlands in the seventeenth century, was popularized in a nineteenth-century book, and was called into question in the late twentieth century: the infamous tulip bubble. The tulip was originally a Middle Eastern flower that became immensely popular in Dutch gardens. Prior to the 1630s, tulip bulbs were physically traded between growers in the summer, when the bulbs could be pulled from the ground.[23] Subsequently, florists started buying and selling bulbs still in the ground, using promissory notes. Given the lag between the buying and selling of the notes and the actual delivery months later, speculators emerged who were often highly leveraged.

According to Charles Mackay in his 1841 classic *Extraordinary Popular Delusions and the Madness of Crowds*,[24] in 1637 when the mania was at its peak, twelve acres of land were offered for one rare bulb, Semper Augustus. Mackay recounts the anecdote of a sailor who mistakenly ate a rare bulb, at the time worth the cost of feeding an entire ship's crew for a year, that he thought was an onion. However, according to Mackay, in February 1637 the market dried up because traders could no longer find buyers, and prices plummeted. Robert Shiller, recounting the mania in our time, said that "the Dutch referred to it as a 'windhandel,' which, when translated directly, means 'wind trade.' What they meant was that the prices of those tulips were like the wind; there was nothing to them. So, it's just air."[25]

However, more recent research by Peter Garber has debunked many of the tulipmania myths.[26] Many of the cited prices were based on futures contracts, which were illegal at the time and thus unenforceable. Buyers paid only a fraction of the contract price up front. Many of the purported offers for rare bulbs can be traced to moralistic pamphlets distributed at the time, basing their examples on what it might cost to enter into a futures contract at the peak of speculation rather than actual offers. There were also fundamental reasons for the initial price increases, as it became fashionable in France for women to display fresh tulips at the top of their gowns. There is no evidence of a large inflow of foreign money or lending for speculation. Similarly, there are no reliable price data for just after the purported crash in the price of rare bulbs. Subsequent history suggests that it's natural for the price of rare tulip bulbs to decline dramatically over time. Garber's observation regarding "the implausibility of a Dutch businessman leaving a highly valuable bulb lying about for a loutish sailor to eat for lunch" seems to have escaped Mackay's retelling of the story.[27] Interestingly, Garber does note a quick rise and sudden crash of common, generic tulip bulbs—not part of the tulip lore—that he can't explain.

Another early stock bubble is forever associated with one of the most colorful, innovative, and controversial figures in investment history, the Scotsman John Law, born in 1671.[28] John's father, William, was a goldsmith but successfully moved into the moneylending business. In 1683, shortly before his death, he bought an estate north of Edinburgh, which was to go to his eldest son, John. William's second wife, Jean Campbell, was assigned as John's principal guardian. Mother and son quarreled, and at age sixteen John left home (or perhaps was tossed out). He sued his mother in court for lack of support. In her court testimony, Jean complained of John going out late at night and gambling. The case was eventually settled out of court, and John Law apparently used some of the money to settle his gambling debts.

At age twenty-three, Law killed a man in a duel in Bloomsbury Square and was sentenced to death, but English authorities arranged for his escape from prison. He traveled to the continent and used his mathematical skills to become a bookmaker. At the same time, he wrote essays on monetary innovation. He submitted many proposals to French authorities for the establishment of a bank in France. After King Louis XIV died in 1715 and France was in a state of bankruptcy, Law was appointed controller general of finances by young King Louis XV's regent, the Duke d'Orleans.

Law, as a friend of the French regent, was able to establish a bank authorized to issue fiat money, or paper notes, as legal tender, the first such full-scale use of fiat currency in Europe. Law also established the Mississippi Company to develop French territory along the Mississippi River in North America. Later he was granted a twenty-five-year monopoly on colonial trade as well as on the beaver fur trade in Canada and the ability to collect French taxes in return for taking over France's public debt, as part of a system or, as some later argued, a scheme. This system had several moving parts but essentially involved converting government debt into a sort of government equity.[29] Law allowed the public to invest in the company, but he also had an incentive to maximize the price in order to entice debtors to convert to equity, thus helping to create hype around the worth of the stock. The Mississippi Company also grew through mergers and acquisitions.

In 1719, a speculative frenzy in Mississippi Company shares occurred in France. In current terminology, the target price-to-earnings (P/E) multiple was around 45, almost three times higher than what would be considered a typical P/E multiple today. In 1720, however, when expected profits were slow to materialize, the stock price plummeted. Law was forced to flee the country and went to live in Venice, where he continued to gamble and traded in paintings.

A parallel bubble was playing out in England around the same time.[30] The South Sea Company was a joint-stock company, founded in England in 1711. The company had monopoly trading rights to much of South America, even though Spain and Portugal had well-established empires there. This trade, however, was of minor importance, since it was established to help the government organize the national debt (much like the Mississippi Company), which was incurring high borrowing rates after nearly twenty years of expensive warfare. In 1719, the South Sea Company submitted a comprehensive scheme to Parliament to offer its own equity to public creditors in return for their assets (akin to the government bonds they owned). The proposal to Parliament, accompanied by considerable bribery, succeeded. The company was able to lure public creditors with a rising stock price and extended purchase terms. At the beginning of 1720 the share price was at £130, but by June it had risen to almost £1,000. However, confidence in the stock waned as the South Sea Company's future prospects were questioned, and by October the share price had fallen to around £200.

Rising prices by themselves don't imply a bubble. They may reflect increasingly profitable opportunities. Were the rapid stock price increase and subsequent collapse of the Mississippi Company and the South Sea Company true bubbles? Again, Garber disputes this characterization, as does the historian Francois Velde.[31] According to Garber, Law had a plan to revitalize the French economy through financial innovation and reform. As Law gained more power, his chances of economic success grew. The decline in the Mississippi Company share price coincided with the ascension of his enemies, who were bent on dismantling the company. Velde contrasts the common English name of the episode, the Mississippi Bubble, with the original French name, *le système de Law*. Velde notes that the purported bubble didn't arise spontaneously but rather was part of Law's system; according to historian Antoin Murphy, "a grand design."[32] Unlike other purported bubbles, it included only one stock. Velde emphasizes that the stock prices weren't market prices as we think of them today; the values of the prices were influenced (or manipulated) by Law. The real question is whether the price collapse revealed true value. Velde concludes that at the highest point, the price pegged by Law was probably two to three times too high, implying overvaluation not by a "frenzied and irrational market, but by Law himself."[33]

In Britain, the South Sea Company stock declined at the same time as many other stocks, including the so-called bubble companies, perhaps as many as 190 that formed between 1719 and 1720. This decline also occurred when the Bubble Act, passed by Parliament that June to ban the formation of unauthorized companies, began to be enforced on August 18, 1720. Since many stocks were bought on margin, with only a small down payment, the price declines forced liquidation by many sellers who were required to put up additional margins, thus exacerbating the downward pressure on stocks.

According to Garber, a common thread between all three of these purported early bubbles was the existence of fundamental reasons why prices should have risen in the first place. Even today, many companies have promising business models that don't pan out, but this doesn't imply that investors in these companies were necessarily acting irrationally. The bubble debate continues, as we'll see later in this book.[34]

Early Diversification

While modern portfolio theory didn't emerge until the middle of the twentieth century, the benefits to diversification appear to have been grasped by the late eighteenth century. It began in France with the finance minister to Louis XVI, who wanted to permit the French to take part in the American War of Independence without burdening French taxpayers. Therefore, the finance minister organized a large number of loans from private investors. Repayment of these loans was in the form of life annuities, with a twist: the lender could determine the person on whose life the annuity was issued. As long as that person remained alive, the creditor received an annual payment. There was a stipulation that the creditor needed to present the person before the French authorities, twice a year, to certify that the person was still living. While it seems obvious today that an annuity based on a younger person would be more valuable and hence more expensive, around 1757 the French government abandoned age grading and returned to flat pricing for all annuities. Initially this had little impact, because most life annuity purchasers were adults who bought annuities on their own lives or on the lives of their spouses or servants. However, it didn't take long for clever Swiss bankers to figure out how to game the system.

Thus, in 1771 an investment scheme, referred to as "Trente demoiselles de Geneve," was born. This involved a number of Genevan banks developing investment trusts that represented pools of life annuities issued by the French government. The banks created a list of young Genevan girls, typically aged five to ten, who were carefully selected and, after surviving smallpox, were named as the contingent lives. Most of the annuity pools involved thirty young girls, hence the name "Trente demoiselles." The girls, also known as "the immortals," became like rock stars in their communities because so much wealth was riding on their lives. Genevans from all walks of life invested in the scheme, and an estimated 90 percent of Geneva's wealth was invested in these annuities, as was money from abroad. Banks resold fractions of these pools to individual investors, just like the modern securitization of mortgages, a major cause of the 2007–2009 financial crisis. Everything was going well until the unexpected bankruptcy of the French treasury, when annuity payments slowed and thousands of investors lost money.

When we think of a diversified security today, we often think of a mutual fund. The first mutual fund, Eendragt Maakt Magt, was actually created centuries ago, in 1774, by an Amsterdam broker named Abraham van Ketwich. Funds were invested in foreign government bonds, bank bonds, and loans to plantations in the West Indies. The fund promised a dividend of 4 percent, with a planned liquidation and return of proceeds after twenty-five years. The offering of two thousand subscriptions sold out, and a secondary market developed for those wishing to sell their subscription. This investment vehicle was similar to today's closed-end mutual funds. Like a modern mutual fund, one of the articles in the prospectus listed the categories of potential investments. The articles also specified that the fund needed to be diversified at all times with twenty classes of investments, each of which consisted of at least twenty to twenty-five securities.

After its initial success, in 1779 van Ketwich introduced a second mutual fund, named Concordia Res Parvae Crescunt.[35] While similar to the first fund, a major difference in this fund was that its investment policy was more liberal, only specifying that the fund invest in "solid securities and those based on decline in their prices would merit speculation and could be purchased below their intrinsic value . . . of which one has every reason to expect an important benefit." This strategy sounds much like today's value investing, pioneered by Ben Graham and his most famous disciple, Warren Buffett.

While these types of investment trusts or closed-end mutual funds eventually spread outside of the Netherlands, first to London in 1868 and then to the United States in the 1890s, a new investment concept eventually developed. In 1924, Massachusetts Investors Trust became the first U.S. open-end mutual fund.[36] Such open-end funds allowed for the continuous issuance or redemption of shares at a fair price to the underlying securities. Coincidentally, it was a *Fortune* magazine article a quarter century later featuring the Massachusetts Investors Trust that caught the eye of a young Princeton undergrad, Jack Bogle, who was to revolutionize the mutual fund industry—but there will be more about Bogle later in this book.

The Science of Investing in the Twentieth Century

While the *art* of investing has been practiced for centuries, the *science* of investing is a thoroughly modern invention, the brainchild of money and mathematics. Although mathematical models of gambling emerged in the 1500s thanks to Girolamo Cardano's famous 1565 tract *Liber de Ludo Aleae* (*The Book on Games of Chance*), it wasn't until the 1900s that serious investment theories were formulated.

Following the stock market crash of 1929, the Great Depression created the ideal, if unfortunate, circumstances for four major academic treatises on investing. Between 1930 and 1939, Irving Fisher's *The Theory of Interest, as Determined by Impatience to Spend Income and Opportunity to Invest It* (1930), John Maynard Keynes's *The General Theory of Employment, Interest, and Money* (1936), John Burr Williams's *The Theory of Investment Value* (1938), and John Hicks's *Value and Capital: An Inquiry into Some Fundamental Principles of Economic Theory* (1939) were published. Meant primarily for economists, these tomes had little impact on the investment industry and even less impact among individual investors. In fact, Fisher's now infamous proclamation that the stock market had reached a "permanently high plateau," made just three days before the stock market crashed in October 1929, did little to enhance the reputation of financial economists among practitioners.

However, the investment theories of the 1930s were surprisingly sophisticated, even from a contemporary perspective, and included such ideas as net present value, the dividend discount model, arbitrage pricing, and a precursor to the famous Modigliani-Miller theorems on the irrelevance of capital structure. None was more sophisticated or ambitious than Keynes's *The General Theory of Employment, Interest, and Money*, which attempted to integrate investment theory with macroeconomic policy and subsequently served as the user manual for most central banks until the late twentieth century. However, even Keynes had to punt when it came to describing the behavior of financial markets: he likened the stock market to beauty contests and attributed price fluctuations to "animal spirits."

Nevertheless, as an investor, Keynes performed spectacularly. He managed the endowment of his alma mater, Cambridge University, from 1921 until his death in 1946, and a recent study by David Chambers, Elroy Dimson, and Justin Foo has painstakingly reconstructed the investment returns of Keynes's portfolio.[37] From the end of August 1921 to the end of August 1946, the annual compound return on his discretionary portfolio was 14.41 percent, versus 8.96 percent for the equally weighted UK equity market index during the same period. But Chambers and Dimson discovered a fact far more remarkable than Keynes's overall performance: Keynes made a sharp improvement in his investment approach in 1932. From 1921 to 1931 he generated a compound rate of return of only 8.06 percent, only marginally better than the equally weighted UK equity market index return of 6.67 percent. But from 1931 to 1946 Keynes produced a compound return of 18.84 percent, far outstripping the equally weighted UK index return of 10.52 percent during this fifteen-year interval. What did he change?

According to Chambers and Dimson, Keynes discovered the benefits of long-term investing, switching his investment philosophy from a top-down macro-driven trading style to a bottom-up fundamental stock-picking value investor style. This striking shift in portfolio strategy was no doubt precipitated by the disappointing returns Keynes experienced during the first half of his tenure as bursar of the Cambridge endowment. When he was criticized for flip-flopping on his position with respect to the gold standard, he purportedly replied, "When the facts change, sir, I change my mind. What do you do?"[38] The same could be said for his investment theories.

Unfortunately, none of this learning made its way into Keynes's *The General Theory of Employment, Interest, and Money* or any of his subsequent writings. Therefore, apart from Cambridge University and its happy alumni, few others have benefited from the insight Keynes developed during his career as an investor. Despite his enormous impact on macroeconomics and government policy, he had surprisingly limited impact on investing, even as he succeeded beyond all expectations as an investor. Give people a fish, and you feed them for a day; teach people to fish, and you feed them for a lifetime. Keynes provided Cambridge with many fish, but when he died in 1946, he took his rod and reel with him.

This state of affairs changed permanently in 1952.

2

Harry Markowitz and Portfolio Selection

THE COMMON PHRASE "don't put all your eggs in one basket" is thought to have originated in the seventeenth century, but the notion of diversification dates back at least to the works of William Shakespeare and can even be found in the Bible. While it's commonplace now to think of creating a diversified portfolio rather than investing in a collection of securities that each on their own look promising, that wasn't always the case. It was Harry Markowitz who provided a theory and a process to the notion of diversification. He helped to create the industry of portfolio management. Before his seminal "Portfolio Selection" article in 1952, Markowitz recalled, there was no "notion that you should have a theory about what makes a well-diversified portfolio and what is the trade-off between risk and return. It's surprising that the human race went so long to leave me to discover that."[1] In the search for the Perfect Portfolio, investors everywhere should applaud his discovery.

Harry's Problem

The young Harry Markowitz had a problem, and because of its serendipitous solution, he would change the investment world forever. But first, a bit of background that led to that fateful day in 1950.[2]

Markowitz was born in Chicago in 1927. He grew up in a pleasant apartment in a middle-class neighborhood nine miles from downtown, unaware of the Great Depression that caused so much suffering and hardship for millions of Americans. As he recounted, "I was an only child; I had my own room. I would listen to classical music on my radio and do my homework."[3] His parents owned a grocery store, and the family lived next to a butcher shop. "We never lacked for food. If we had a lot of green beans left over, we had a lot of green beans."[4] Having a family of grocers living next to a butcher shop meant that "we had meat, and they had vegetables."[5] Markowitz grew up a carefree child, playing baseball, and tag football, and chess, and he also played violin in the high school orchestra. He was a member of the national club for amateur cryptographers, and he enjoyed reading and quickly progressed from the twice-monthly ten-cent adventure magazine *The Shadow* to Darwin's classic, *The Origin of Species*. Markowitz was particularly impressed with the succinct logic that Darwin employed in making his arguments.

The young Markowitz enjoyed physics and especially astronomy. During high school he would read the original works of the great philosophers, such as David Hume's *A Treatise of Human Nature*, often purchased from delightful old musty used bookstores in downtown Chicago. Hume was his favorite philosopher, and Markowitz was struck by many of Hume's thought-provoking logical arguments. For example, Hume argued that if a ball is dropped a thousand times and hits the floor, there is not sufficient proof that it will do the same thing the thousand-and-first time.

Markowitz attended his hometown university, the University of Chicago. He completed a two-year bachelor of philosophy degree and his master's there. Based on his placement exams before entering into the program, he had been excused from taking courses in the physical sciences. As part of the bachelor's requirement, however, the University of Chicago offered a variety of survey courses, which emphasized the reading of original material. After Markowitz had completed these courses and it was time to choose an upper division or a department, his mind was far from the physical sciences. Since he enjoyed mathematics and had just done some reading in the social sciences as part of those surveys, he decided to choose economics.

Markowitz's attraction to economics was based on both the theoretical structure of the field and its applications. His reading of Hume had piqued his interest in philosophical questions such as "What do we know?" and "How do we know it?" and the uncertainty surrounding those questions. Consequently, Markowitz was drawn to the economics of uncertainty, particularly the theory of games and utility theory developed by John von Neumann and Oskar Morgenstern, and soon to the work on subjective probability by the University of Chicago's own Leonard Jimmie Savage. Expected utility theory is the framework in economics for understanding how people make decisions over their lifetimes based on their preferences in consumption and savings—how much and when they want to consume or save. Savage presented brilliantly self-evident arguments that when there is a need to make an economic decision under uncertain conditions, individuals should act in such a manner as to maximize their expected utility using subjective probability beliefs. Savage was able to persuade many people (including Markowitz) that rational decision makers would maximize their expected utility using these beliefs in situations when objective probabilities did not exist. In other words, it was rational to use one's beliefs in the absence of the objective. Markowitz later described Hume, von Neumann, and Savage as the three people to whom he owed the greatest intellectual debt: "These are the shoulders upon which I stood."[6]

In addition to Savage, Milton Friedman, Tjalling Koopmans, and Jacob Marschak were some of the distinguished professors whom Markowitz enjoyed at the University of Chicago. Friedman had joined the University of Chicago in 1946 to teach economic theory, and it was to become his intellectual home for the next thirty years. He would later go on to win the Nobel Prize in Economics in 1976.[7] Savage also joined the University of Chicago in 1946 and published his well-known work with Friedman in 1948 in an article titled "The Utility Analysis of Choices Involving Risk."[8] Friedman later said that Savage was "one of the few people I have met whom I would unhesitatingly call a genius."[9]

In 1944, the economist Tjalling Koopmans joined the Cowles Commission for Research in Economics, then associated with the University of Chicago, on the invitation of the economist Jacob Marschak, who in turn had been lured by the head of the commission, the Chicago newspaper heir and economist Alfred Cowles III. This was "the beginning of a long period of close interaction, collaboration, and personal friendship with Marschak, a gentle, wise, and witty scholar," Koopmans said, one who "created a rare kind of research environment, by shrewd selection of staff members and by a truly open style of work and discussion."[10] Koopmans would later go on to win the Nobel Prize in Economics in 1975. In 1948, he succeeded Marschak as director of research at the Cowles Commission. Among his many important contributions, Marschak wrote an influential article that translated von Neumann and Morgenstern's concept of utility theory into language more readily accessible to his fellow economists.[11]

By 1950, Markowitz was working toward his PhD in economics at the University of Chicago. Like most doctoral students, he had reached the stage where he had to pick a dissertation topic. And like many doctoral students, here was Markowitz's problem: he didn't know what topic to choose. He went to his doctoral adviser, Marschak, who was busy when Markowitz arrived, so Markowitz waited in Marschak's anteroom. As fate would have it, Markowitz wasn't alone as he waited. There was a man in the anteroom who turned out to be a stockbroker waiting for Marschak. They chatted for a while about Markowitz's potential dissertation until Marschak was available to meet with Markowitz and invited him into his office.[12] In their ensuing discussion Markowitz said to Marschak, "The guy out there says I should do a dissertation on the stock market. What do you think?" And on that fateful day, based on a chance meeting with a stranger in a waiting room, Markowitz was about to embark on a path that would lead to a Nobel Prize in Economics as the founder of modern portfolio theory. Later he acknowledged fondly that this was the best advice he ever received from a stockbroker.[13]

Afternoon Delight

After his chance meeting and his discussions with his adviser, Markowitz decided to pursue a dissertation topic on applying mathematical and statistical techniques to the stock market.[14] Ironically, as a student without extra money for investing, Markowitz did not have any experience as an investor. "I didn't know anything about what was going on [related to investments]. I just needed to write a dissertation, and someone suggested I write a dissertation on the stock market, and one thing led to another. . . . It was a matter of getting a degree."[15] At that time, Markowitz had been invited to be a student member and research associate at the Cowles Commission for Research in Economics. Marschak thought that Markowitz's dissertation topic was a reasonable avenue to pursue, since Alfred Cowles himself had been interested in such applications.

The Cowles Commission was founded by Alfred Cowles III in Colorado Springs in 1932 and moved to Chicago in 1939, where it was associated with the University of Chicago until 1955, when it moved to Yale University.[16] Cowles was president of an investment-counseling firm, and part of his service was to offer investment forecasts. He became interested in comparing his forecasts with those of other investment firms in order to determine how investors who followed his advice would have fared. After the stock market crash in 1929 and the subsequent sustained decline in stock prices, Cowles felt that most forecasters were simply guessing the future outlook of the market, and he consequently discontinued his forecasting service in 1931. He decided to initiate a systematic investigation into stock market returns. This in turn piqued his interest in fundamental economic research, which led to his financial support toward the establishment of the commission, with an initial budget of $12,000. The Cowles Commission would become known for its leadership in economic thought and the incredible number of Nobel laureates it was to produce: Kenneth Arrow, Tjalling Koopmans, Milton Friedman, Herbert Simon, Lawrence Klein, James Tobin, Gerard Debreu, Franco Modigliani, and, of course, Harry Markowitz. "If you count the number of Nobel Prizes which have been given to people who were at the Cowles Commission . . . you might say 'Oh, this must be a huge player cranking out thousands of dissertations, and two percent of them get to be Nobel Prizes.' [Actually] it was sort of like everyone there got Nobel Prizes—my exaggeration. Certainly the density of Nobel Prizes in Economics was greater at Chicago than any other university. . . . Milton Friedman was on the right side as you came out of the elevator, and the Cowles Commission was on the left side—and I believe that was deliberate—but the left side won a lot more Nobel Prizes than the right side."[17] At the time, however, Markowitz described the commission in simpler terms, as a "small but exciting group" then led by its director, Koopmans, with Marschak as its former director.[18] "I stumbled into economics, and I stumbled into economics at the University of Chicago, and I had no idea I was about to be a part of something that was going to crank out Nobel Prizes."[19]

As background reading for his dissertation, Marschak had provided Markowitz with a copy of Cowles's 1932 forecasting paper and a 1938 monograph on the history of the stock market.[20] Marschak then referred him to the dean of the business school, Marshall Ketchum, for a list of suggested readings. Markowitz had never taken a course in finance before, although he had taken statistics and linear programming from Koopmans. Ketchum suggested Graham and Dodd's now classic book *Security Analysis*,[21] Wiesenberger's survey of investment companies[22] to provide basic background information on the industry, and another classic, less well known today, John Burr Williams's *The Theory of Investment Value*.[23]

In his book, Williams referred to the area of investments as a new subscience of economics, addressing it to "the intelligent investor and the professional investment analyst." Many of his concepts have a strikingly modern sound today. For instance, he defined "investment value"—what we now commonly refer to as the intrinsic value or the fair value—as the present value of future dividends, a model we now refer to as the dividend discount model.[24] In essence, Williams advocated buying stocks that were selling below their investment value as a way of avoiding pure speculation. The book relied on mathematical methods as "a new tool of great power, whose use promises to lead to notable advances in Investment Analysis." Given its mathematical rigor, which was unusual for its time, one can imagine Markowitz's intrigue with such a book.

Peter Bernstein, the well-known asset manager, educator, and author of numerous books, including the superb *Capital Ideas*,[25] has provided us with a view of stock investments in the early 1950s. There were still many unhappy memories of the crash of 1929 and the Great Depression. Stock prices were still well below their peak levels of 1929, and stocks "never had more than a frail claim to legitimacy among prudent investors."[26] Legal restrictions limited investments in stock to less than 50 percent of personal trusts and estates, and only around 6 percent of the population owned shares of stock. To compensate for their perceived riskiness, many of the best stocks were paying dividends more than three times the rate of interest on savings accounts. After several high-profile cases, the stock market was closely associated with financial wrongdoing in the public mind. The perception of the stock market was that it was "a playground for speculators." Markowitz recalled that Bernstein once commented at an investment conference that "'You don't know what the investment process was like before the 1950s.' . . . He described how you would sit around a table, and this guy thought that this industry would go up and that industry would go down, and they would persuade the committee what was best, like a bunch of amateurs."[27] Thus, it isn't surprising that there had been little academic interest in the area of portfolio management when Markowitz began thinking about his dissertation, although there was some research devoted to security analysis and picking individual stocks, and there were also some popular how-to books and articles related to investing.

One afternoon in 1950, while Markowitz was in the University of Chicago Business School library, he had an epiphany while researching his newly chosen dissertation topic.[28] He was reading through Williams's book when he noted that Williams was implicitly assuming that the risks of stocks were not correlated. "How could a financial expert writing in 1937 think that returns are uncorrelated when [stocks moved dramatically] from the peak in 1929 down to the trough in 1933, all together, down the toilet?"[29] It struck Markowitz that if an investor was only concerned with the expected value of a stock, then by extension such an investor should only be concerned with the expected value of the entire portfolio of stocks. But Markowitz quickly saw that the logical conclusion of such an approach would be that investors would only include one stock in their portfolios: the one with the highest expected return. Markowitz realized that this couldn't be correct.

Markowitz noticed in Wiesenberger's survey that many investors were concerned with diversification and invested through mutual funds. Common sense suggested that one should not put all of one's eggs in one basket, since investing all of one's money in one stock was quite risky. What Markowitz felt was missing from Williams's analysis, however, was some kind of notion of the risk of an overall portfolio. Markowitz found a solution in J. V. Uspensky's *Introduction to Mathematical Probability*[30] in a formula that could be adapted to measure the risk of a stock portfolio as a whole. What mattered in a portfolio wasn't simply the riskiness of each individual stock but rather the extent to which various stocks moved either up or down relative to one another. "My great insight was that you need to take into account correlation," Markowitz remembered. "This was the first of my 'aha' moments of my career. . . . Some people have asked me, 'Did you know you would get a Nobel Prize?' I said no, but I figured I'd get a PhD."[31]

If you are mathematically inclined, have taken a course in high school algebra, or simply like to understand how things work, here's what the portfolio risk formula is all about and why Markowitz was so excited to discover it (spoiler alert: not every formula is as simple or as elegant as $E = mc^2$). We'll make it fairly simple by imagining you own only two stocks in your portfolio, ABC and XYZ. You place a certain weight in each of the stocks, w_{ABC} and w_{XYZ}, say, 40 percent in ABC and 60 percent in XYZ (it doesn't really matter in our example as long as the weights add to 100 percent). Our goal is to estimate how risky or volatile your *portfolio* is compared with how risky owning *only* ABC or XYZ is.

To achieve this goal, we first need to estimate five numbers, five different inputs into our formula: the return you expect from owning ABC stock, the return you expect from owning XYZ stock, how volatile or risky ABC is if that's the only stock you own, how volatile or risky XYZ is if that's the only stock you own, and how the return on ABC changes in relation to the return on XYZ. The first two inputs are the expected returns of the stocks, the next two inputs are their variances (Var), and the final input is the correlation between ABC's stock return and XYZ's stock return (Corr). There is also a related way to measure the volatility of a stock, as any mathematician can tell you (although you may be sorry you asked), through the standard deviation (SD), which is the square root of the variance: $\text{SD} = \sqrt{\text{Var}}$. Using that last piece of information, here's the formula for the riskiness, or the variance, of our two-stock portfolio:[32]

$$\text{Var}_{\text{portfolio}} = w_{\text{ABC}}^2 \times \text{Var}_{\text{ABC}} + w_{\text{XYZ}}^2 \times \text{Var}_{\text{XYZ}} \\ + 2 \times w_{\text{ABC}} \times w_{\text{XYZ}} \times \text{Corr}_{\text{ABC,XYZ}} \times \text{SD}_{\text{ABC}} \times \text{SD}_{\text{XYZ}},$$

where $\text{SD}_{\text{portfolio}} = \sqrt{\text{Var}_{\text{portfolio}}}$.

The key insight hidden in this formula that you can work out mathematically (or just trust us!) is that in almost every instance, the overall portfolio risk will be *less* than the weighted average of each stock's individual risk measure. Mathematically, $\text{SD}_{\text{portfolio}} < (w_{\text{ABC}} \times \text{SD}_{\text{ABC}} + w_{\text{XYZ}} \times \text{SD}_{\text{XYZ}})$. What's the one exception? Imagine owning a portfolio with just two stocks, say ExxonMobil and Chevron, and suppose the two stocks move together in *perfect lockstep*.[33] Let's also imagine that each stock has an expected annual return of 10 percent and a return volatility of 30 percent (where the return volatility is just the standard deviation of returns). For the typical stock with this profile, about two-thirds of the time returns will be plus or minus one standard deviation, or in this case between negative 20 and positive 40 percent.[34] Having only ExxonMobil and Chevron in your two-stock portfolio would give you the same risk profile as investing in each individual stock separately—in other words, there wouldn't be any benefit from diversification.

Now imagine owning ExxonMobil along with Delta Air Lines or any two stocks whose returns don't move in lockstep. When oil prices go up, that's good news for ExxonMobil but bad news for Delta, so the two stocks are negatively correlated. In this case, the overall portfolio volatility is less than the average volatility for each of the two stocks, because, as Markowitz discovered, correlations matter, and that's what Williams had overlooked.

In his course with Koopmans on activity analysis, Markowitz had been exposed to the concept of linear programming, a technique for which Koopmans is credited as a codiscoverer.[35] Linear programming is a method for determining an optimal outcome for a given model, particularly useful for those models that involve trade-offs. Koopmans had asked the class to describe a resource allocation problem and determine whether linear programming was a suitable technique to apply to such a problem.[36] Markowitz described the case of an investor seeking high returns while attempting to mitigate his risk, but he concluded that the situation wasn't appropriate for linear programming. He received an A on the assignment, but Koopmans encouraged him to try to solve the problem regardless, which provided Markowitz with further motivation for his dissertation topic.

On the same day that Markowitz read Williams's book in the business library, he drew a simple graph. Since he was dealing with two quantities, expected return and risk, he placed the expected return of a stock on the horizontal axis and its risk on the vertical axis and began constructing his first portfolios.[37] Koopmans, in his course on linear programming, distinguished between efficient and inefficient combinations of production activities: efficient in the sense that you couldn't get more of one thing without giving up something of something else, a classic trade-off. Markowitz labeled his portfolios of stocks as either efficient combinations of return and risk or inefficient combinations that were dominated by other combinations. The efficient combinations of risky stocks would later be known as the efficient frontier. Markowitz had just discovered the basis for modern portfolio theory.

This epiphany, which happened on a single afternoon, led to Markowitz's proposal of a dissertation topic on portfolio selection. His proposal was accepted, eventually leading to his first major publication. That simple diagram he drew was what Markowitz later referred to as "the world's first efficient frontier."[38]

Portfolio Selection: The Article

Two years prior to receiving his doctorate, Markowitz's study appeared in March 1952 in the *Journal of Finance*, the publication of the American Finance Association.[39] At that time, finance was a relatively new branch of economics, and the journal had only begun publication in 1946. In contrast, *American Economic Review*, the main publication of the American Economic Association, had begun its publication in 1911.[40]

Almost seventy years later, Markowitz's article is visibly different from recent *Journal of Finance* publications. The title of the article, "Portfolio Selection," is short and simple. The article had a single author, compared to today's much more common practice of multiple authorship. Markowitz's affiliation was with the RAND Corporation in Santa Monica, California, a nonprofit policy think tank, unlike the typical author of today with a university affiliation. The article was succinct, at eleven pages of text plus four pages of graphs, and referred to only three previous studies, all books, compared with today's standard of referencing upwards of fifty articles and books. What was very unusual for its time, however, but common practice today was its use of numerous mathematical equations.

Markowitz began by describing the two-stage process that one should employ while selecting a portfolio. Interestingly, he did not initially make any reference regarding the constituents of the portfolio—stocks versus bonds, for example—but later in the article he talked about *securities,* which today would be referred to as common share investments. The first stage of the process described how investors would develop beliefs about future performance, such as the expected returns of stocks. The second stage, the focus of his study, began with these expectations and culminated with the choice of a stock portfolio. Markowitz described the first stage of the process, essentially a quantitative approach to security analysis, as "'another story' . . . of which I have read only the first page of the first chapter," and thus not examined in his current study.[41] His reference to "another story" foreshadowed the pending growth of quantitative investment strategies.

Markowitz referred to John Burr Williams's *The Theory of Investment Value* as an example of one approach that an investor might follow in order to choose a portfolio. Markowitz then proceeded to critique Williams's approach. Williams suggested that an investor should maximize discounted expected returns. Let's look at that more closely. Suppose an investor bought a dividend-paying stock and planned to hold on to that stock for, say, ten years. The investor would need to determine what dividends were expected to be paid over the next ten years and also would need to anticipate the price at which the stock could be sold in ten years.

Using the time value of money (the idea that a dollar received a year from now is worth less than a dollar received today), one could discount the anticipated cash flows to the present to determine a fair price.

Alternatively, taking the selling price as a given, the investor could determine the implied rate of return, which is referred to today as the *internal rate of return*. For example, if we buy a stock today for $20.00, anticipate a dividend of $1.00 in one year, and then sell the stock shortly afterward for $22.00, the implied return would be 15 percent (i.e., $2.00 in capital gains plus $1.00 in dividends, for a total gain of $3.00 on the $20.00 investment). While the mathematics is more complicated for holding a stock more than one year, the principle is the same.

With some basic mathematics, Markowitz was able to show that if an investor was only concerned with maximizing the expected return, then all of one's funds should be placed in the one security that offered the highest expected return. If more than one security offered the identical highest return, then investing in one was as good as investing in any other such security. Markowitz assumed that investors were not allowed to *short* stocks, the common practice of borrowing a stock that one does not own and selling it in hopes of buying it back later at a lower price, having made a profit. If, however, they were allowed to short stocks, then one would place an infinite amount of money in the stock with the highest expected return. In such a scenario, there would be no role for diversification. Markowitz was quick to reject such a rule as both a hypothesis to explain behavior—since we don't observe these strategies in the real world—and a guide for how investors should behave.

Instead, Markowitz suggested a different approach. He considered investors who were concerned about both the desirability of high expected returns *and* the undesirability of the variance of returns. The variance, as mentioned earlier, is a statistical measure that captures the variability of returns, or, more precisely, how much each year's return deviates from the average return across a number of years, as does the closely related standard deviation. In practice, the variance can be used to capture the risk in stock performance. If one stock, call it stock A, had constant returns of 10 percent in each of the past five years, then its variance (and its standard deviation) would be zero. Suppose that another stock, call it stock B, had an average return over that period of 10 percent, but its annual returns over each of the past five years were 16 percent, −9 percent, 14 percent, 6 percent, and 23 percent, respectively. While the average returns of stock A and stock B are the same, stock B is much more variable.

How do we quantify the difference between these two stocks? In each period, the deviation from stock B's average of 10 percent would be 6 percent, −19 percent, 4 percent, −4 percent, and 13 percent, respectively. To measure the variance of stock B, we would take each of these deviations, square them (to make sure that all the numbers are positive), add these squared deviations, and then divide the total by the number of years. The resulting number gives us the measure of variance: the larger the annual deviations of stock B's returns are from the average, the larger is the variance. By taking the square root of the variance, we have a standardized measure of the deviations, known as standard deviation, which we can express as a percentage—in this example, 12.2 percent. Given the choice between stock A and stock B, investors would choose stock A. While both stocks had the same expected return, stock A had a lower variance (and lower standard deviation) of returns.

The above example implies that we might estimate a stock's expected return and variance by examining its historical performance. Markowitz was careful to finesse this issue, although he did indicate that one might consider the past performance of a stock as a starting point and then somehow "take into account more information."[42] The main point of his article, however, was not whether we should choose stock A or stock B but rather how we should determine what *portfolio* of stocks to choose, among a larger set of options.

Markowitz presented the reader with a simple diagram that captured the essence of an investor who was seeking high expected returns and, simultaneously, low variance of returns. On the vertical axis of this diagram, we see the expected return, and on the horizontal axis, we see the variability of return.[43] An investor who is choosing a portfolio would look for one that had the least amount of variability, farther to the left on the horizontal axis, and the highest amount of expected return, higher on the horizontal axis, as in figure 2.1.

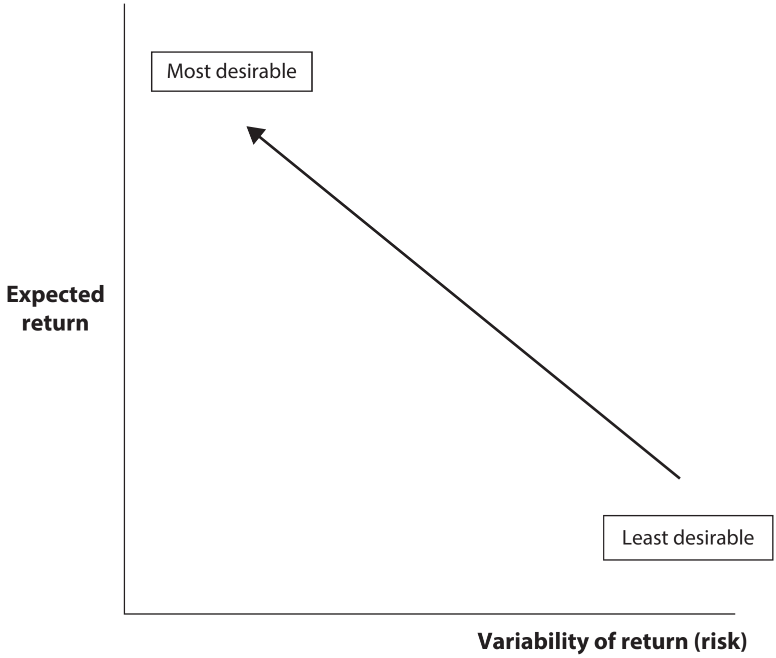

FIGURE 2.1: Expected return versus risk. The northwest corner is the most desirable place to be.

Markowitz then described the simple mathematical equations to determine the expected return as well as the variance (or standard deviation) of a *portfolio* of securities, as described above. He pointed out that for any portfolio, the resulting standard deviation would actually be *less* than the weighted average of each stock's standard deviation. This mathematical property created the benefit of diversification by reducing the amount of risk relative to the expected return. The key to diversification was the correlation, or covariance, between the securities.

While the calculation of the variance of a portfolio becomes quite messy as the number of securities in the portfolio increases, Markowitz's key insight was that in a larger portfolio, the covariances of returns between stocks mattered much more than the variance of returns of each individual stock. For example, in a two-stock portfolio, the calculation of the variance of that portfolio adds together 4 terms: 2 variance terms of individual stocks and 2 covariance terms between stocks. In a three-stock portfolio there are 3 variance terms and 6 covariance terms. In a twenty-stock portfolio there are 20 variance terms, but they are dominated by 380 covariance terms.[44] As long as all the stocks in the portfolio were not perfectly positively correlated, then the portfolio's standard deviation would be less than the average of each stock's standard deviation.

The consequence of Markowitz's key insight is that the resulting combination of various stocks (i.e., randomly selected two-stock portfolios, three-stock portfolios, etc.) would give rise to a special set of portfolios that he referred to as "efficient." This efficient set, or efficient frontier, is indicated in figure 2.2. This set of portfolios would dominate all other individual stock investments and less efficient portfolios. Each efficient portfolio had the highest expected return for a given level of risk as measured by the variance or, conversely, the lowest amount of risk for a given level of expected return.

In what, in retrospect, can be described as a tremendous understatement, Markowitz noted that "the calculation of efficient surfaces might possibly be of practical use."[45] Once an efficient set of portfolios could be determined, then investors might state the preferred portfolio for their desired risk-return combination. Markowitz was quick to point out that in order to be of practical use, two broad conditions first needed to apply. First, investors had to act "according to the E-V maxim."[46] In other words, investors needed to find higher expected returns more desirable, the "E" of the E-V maxim, while at the same time finding more variance (or variability) less desirable, the "V" of the E-V maxim, and only consider these two factors. Second, investors had to be able to arrive at reasonable expected return and variance (or standard deviation) estimates.

Markowitz also emphasized the importance of the right kind of diversification for the right reason, not simply basing the diversification of a portfolio on its number of securities. He gave the example of a portfolio of sixty railroad stocks as the wrong kind of diversification, preferring one that includes "some railroad, some public utility, mining, various sort of manufacturing, etc."[47] His intuition was that stocks within a particular industry tend to move in the same direction. This

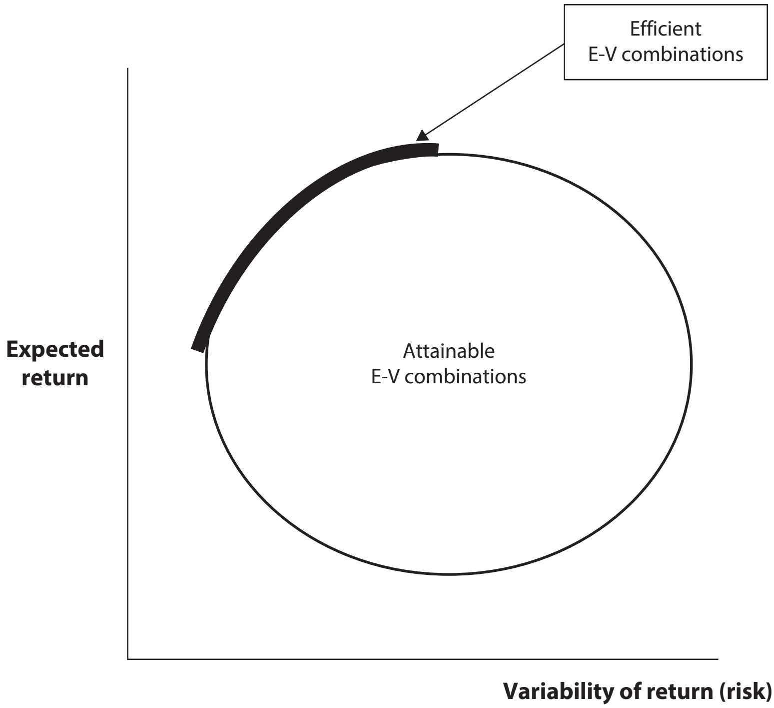

FIGURE 2.2: The efficient frontier. Among attainable portfolios with various expected return and variability (E-V) combinations, the "efficient" portfolios have the lowest risk for a given level of expected return, or the highest expected return for a given level of risk.

again emphasized the importance of considering the covariance of stocks rather than the variance.

Markowitz also made an important distinction between investment and speculative behavior. Implicit in this distinction was the notion that investments are meant for the long term, while speculation is short term in nature. However, Markowitz also described the speculator as a person who is concerned not only with the average expected return—in statistical terms, known as the *first moment*—or the variance of the return—known as the *second moment*—but also the skewness of the return, the *third moment* of the probability distribution. Skewness refers to the tendency for returns to be distributed in a somewhat lopsided manner. For example, in the case of positive skewness, or skewness to the right, more returns on a stock would be above average, while in the case of negative skewness, or skewness to the left, the returns would be skewed in the opposite direction.

Markowitz noted that an investor who is only concerned with expected returns and variance will never accept an actuarially fair bet, such as flipping a coin with an equal chance of the same gain or loss. However, an investor who is also concerned with the skewness of returns might accept such a bet. Markowitz surmised that his model of E-V efficiency would be most appropriate for investors who were not gamblers.

Harry Had Another Problem

After writing his article, Markowitz continued at the University of Chicago to finish his PhD, a process that wasn't without some white-knuckle moments.[48] Having already started working at the RAND Corporation in California, he stopped off in Chicago to defend his dissertation after a business trip to Washington, D.C. "I remember landing at Midway Airport and thinking to myself, I know this field cold, not even Milton Friedman will give me a hard time." In retrospect, this was probably not a wise thought.

"So about five minutes into my defense," Markowitz recalled, "Friedman says, 'well Harry I've read this. I don't find any mistakes in the math, but this is not a dissertation in economics, and we cannot give you a PhD in economics for a dissertation that is not in economics.' He kept repeating that for the next hour and a half. My palms began to sweat. At one point he says, 'you have a problem. It's not economics, it's not mathematics, it's not business administration,' and Professor Marschak said, 'It's not literature.' So after about an hour and a half of that, they send me out to the hall, and about five minutes later Marschak came out and said 'congratulations Dr. Markowitz.'"[49]

Friedman later informed Markowitz that he was never in any danger of *not* receiving his doctorate. However, even fifty years later Friedman stood by the gist of what he said, making what was probably one of the first important distinctions between economics and the then-emerging academic branch of finance.[50] As Markowitz noted at the end of his Nobel lecture in 1990, "As to the merits of [Friedman's] arguments, at this point I am quite willing to concede: at the time I defended my dissertation, portfolio theory was not part of economics. But now it is."[51]

Almost Scooped?

The well-known academic financial historian Mark Rubinstein has described the truly unexpected nature of Markowitz's article. "What has always impressed me most about Markowitz's 1952 article is that it seemed to come out of nowhere."[52] However, sometimes a great idea emerges from numerous sources simultaneously once the groundwork has been laid, as we will see again in later chapters. Many patriarchs and matriarchs are recognized as the founders of a new field, but distant cousins, unknown aunts or uncles, or even siblings separated at birth can later emerge to share some of the accolades. In this case, at least part of what has become known as modern portfolio theory was almost "scooped" (to use Markowitz's generous word) by an Italian scholar in 1940, twelve years before Markowitz was published in the *Journal of Finance*; by a Briton who published in 1952, only a few months after Markowitz; and by Markowitz's own doctoral dissertation supervisor.

The sociologist Robert K. Merton (whose son, Robert C. Merton, we feature in chapter 7) coined the term "Matthew effect" in reference to the well-known Parable of the Talents in the gospel of Matthew. In this parable, the good servants who used their talents (ancient coins) wisely were rewarded, while the poor servant who hid his talent underground was punished. In essence, the Matthew effect states that the rich tend to get richer, and the poor tend to get poorer.[53] In a sociological context, Merton was referring to the phenomenon whereby well-known scientists often receive more credit than lesser-known researchers, even for similar work. Whether such a phenomenon is applicable to Markowitz's work and his subsequent Nobel Prize is debatable. However, Markowitz went out of his way to acknowledge the contribution of others, such as Bruno de Finetti, A. D. Roy, and, of course, his supervisor Jacob Marschak, when he became aware of their work.

De Finetti, an Italian statistician, graduated from the University of Milan in applied mathematics in 1927, then was hired by the Italian

Central Statistical Institute, where he worked until 1931.[54] He then worked for the Assicurazioni Generali insurance company as an actuary. De Finetti supplemented his work with a variety of academic appointments until 1947, when he became a full professor at the University of Trieste. He is regarded as one of Italy's greatest mathematicians of the twentieth century, writing over three hundred scholarly articles.[55] It's speculated that he wrote his precedent-setting 1940 article during his time as an actuary but then became absorbed in other research projects.[56]

Yet it was only recently that de Finetti's work in the area of mean-variance analysis came to light in the world of English-speaking academic finance. Two sociological barriers prevented his work from becoming better known among English-speaking economists: first, the language barrier, and second, the intellectual barrier between actuarial science and financial economics. Interestingly, de Finetti was also known for his research in the area of subjective probability and was invited to a conference in the United States in 1950 by Leonard Jimmie Savage, whom de Finetti had previously met in Italy.[57] Nevertheless, when Markowitz's article appeared in 1952, de Finetti's 1940 work was overlooked.

In 2006, upon the publication of the English translation of de Finetti's 1940 article, Markowitz wrote a review that he graciously titled "De Finetti Scoops Markowitz."[58] De Finetti's research question was in the context not of a stock portfolio but rather the choice of the optimal level of reinsurance. De Finetti essentially proposed the same approach of mean-variance analysis using correlated risks as Markowitz but did not solve the problem, and one of his conjectures concerning a solution was incorrect (according to Markowitz). De Finetti's analysis also included what we now refer to as the efficient frontier. However, Markowitz also noted that the historical significance of the 1940 article was essentially "nil." The importance of the work wasn't understood at the time "not because it deserved to be a dead end, but that was, in fact, its historical destiny."[59]

An article much more closely related to Markowitz's *Journal of Finance* article, this one written in English, appeared in 1952. In a 1999 retrospective on the development of portfolio theory, Markowitz graciously acknowledged that "on the basis of Markowitz (1952), I am often called the father of modern portfolio theory (MPT), but Roy (1952) can claim an equal share of this honor."[60] Markowitz was referring to A. D. Roy, who in 1952 was teaching at Sidney Sussex College at Cambridge.[61] Roy had studied mathematics and physics, serving in World War II in the Royal Artillery. As Roy later explained to Peter Bernstein, the main motivation for his article wasn't because of any investment experience but instead was due to intellectual curiosity, enigmatically stating, "The practical experience of gunnery may have played a part."[62]

Roy's article,[63] titled "Safety First and the Holding of Assets," appeared in the economics journal *Econometrica* in July 1952, only three months after Markowitz's article appeared in the *Journal of Finance*. (Coincidentally, Alfred Cowles not only established the Cowles Commission where Markowitz was a student researcher but also provided the initial funding to establish *Econometrica* in 1933.) Roy's article was much more technically minded than Markowitz's, with many more equations and figures, which wasn't unusual given *Econometrica*'s emphasis on statistical methods. The notion of "safety first" in its title referred to how an individual would seek to reduce the chance of a "disaster" or severe economic loss as much as possible.

Comparing the two articles years later, Markowitz himself highlighted the similarities and differences between their two approaches.[64] Both articles proposed making investment choices on the basis of the mean and variance of the portfolio as a whole. Roy proposed maximizing the return above some fixed level of a "disastrous" (minimum) return, relative to the amount of risk as measured by the standard deviation. His formula for portfolio variance also included covariance terms. However, he allowed positive or negative investments in his portfolio, while Markowitz, in contrast, required nonnegative investments (i.e., no short selling). In another difference, Markowitz allowed investors to choose among any of the efficient portfolios, while Roy recommended one specific portfolio.[65]

In pondering why he received a Nobel Prize and Roy did not share in it, Markowitz speculated that Roy's lack of visibility with the Nobel committee caused this oversight. Markowitz believed that Roy's 1952 article was his only one in the area of finance,[66] while Markowitz went on to write numerous articles, including full-fledged books in 1959 and 1987,[67] and was still an active researcher in 1990. Another possibility is that Markowitz in his article was more focused on what proved to be the more applicable and realistic points of portfolio theory rather than less important model complications. Writing an entire book on the topic also likely made a difference.

Markowitz's dissertation adviser, Jacob Marschak, is also credited with foreshadowing Markowitz's 1952 article. In April 1950, the same year as Markowitz's epiphany in the University of Chicago library, Marschak published an article in *Econometrica*[68] in which he sketched some of the same details of what was to appear in Markowitz's first efficient frontier drawing, including a discussion of means, variances, and correlations.[69] Also of interest is that Roy was aware of this work and cited this Marschak article in his 1952 article. As wryly noted by Fiona Maclachlan in a recent discussion of famous diagrams in economics, "Given that Marschak was Markowitz's dissertation adviser, it would be ironic if his competitor for claims of primacy for the diagram was given an edge from reading Marschak's article."[70]

However, Marschak made an even earlier contribution to the prehistory of portfolio theory, which Markowitz recounted years later in a 1999 retrospective.[71] Markowitz quoted from well-known economists who praised Marschak's work in general but in particular an article Marschak had written in 1938.[72] In that article, Marschak attempted to deal with the probabilistic notion of expected return and risk in a way that was similar to Markowitz's treatment in 1952. Markowitz commented that "an account of Marschak is, therefore, mandatory in a history of portfolio theory through 1960, if for no other reason than that these scholars judged it to be important. On the other hand, I know of one authority who apparently did not think the article to be important for the development of portfolio theory. My thesis supervisor was Marschak himself, and he never mentioned Marschak (1938)."[73]

Markowitz posed a rhetorical question: Was Marschak's article in 1938 a forerunner of portfolio theory? His conclusion was "Yes and no."

No in the sense that while Marschak considered assets, he didn't consider them in a portfolio context. And yes in the sense that Marschak paved the way to a theory of markets whereby its participants act in a world of uncertainty and risk.

Portfolio Selection: The Book

In 1951 after the coursework for his doctorate was complete but while he was still working on his dissertation, Markowitz left the University of Chicago to work at the RAND Corporation, where his work had nothing to do with portfolio theory.[74] During the 1955–1956 academic year Markowitz took a leave of absence from RAND to be at the Cowles Foundation, which had moved to Yale, at the invitation of the economist and future Nobel laureate James Tobin. Markowitz's 1959 book *Portfolio Selection: Efficient Diversification of Investments* was primarily written at this time.

Markowitz's views on portfolio theory had evolved since his dissertation. The publication of his 1952 article foreshadowed his further research, noting that "the writer intends to present, in the future, the general mathematical treatment."[75] The principal aim of his 1959 book, as Markowitz stated in interviews, was to explain portfolio theory to someone who did not have advanced mathematical training—an expository how-to book.[76] He placed many of the fundamental assumptions of portfolio theory at the back of the book because he was worried that otherwise no one would read it. Markowitz later asked Bill Sharpe, with whom he would later share the Nobel Prize in Economics, where Sharpe learned matrix algebra. Sharpe replied, "From chapter 8 of your book." Subsequently, when teaching portfolio theory to students, Markowitz would make the tongue-in-cheek comment that "if Bill Sharpe can learn matrix algebra then you can learn it too!"

While Markowitz was developing the book that year at the Cowles Foundation, he realized to his relief that he still agreed with much of what he had written in his 1952 article, once even commenting to an associate, "That was a smart kid!" While Markowitz's 1952 article had both positive elements in the economic sense, describing the world "as it is," and normative elements, describing the world "how it should be," the 1959 book would be strictly normative.

Portfolio Selection began with chapters that introduced the concepts of mean (average) returns, variance, covariance, and portfolio mean and variance as well as the derivation of the efficient frontier through mean-variance analysis. Later in the book, Markowitz introduced mathematical concepts that allowed for a more general discussion of portfolio theory beyond the simple examples of three- and four-security portfolios in his 1952 article. He also presented a computer procedure, still unusual for the time, called the critical line algorithm for computing efficient frontiers with large numbers of securities. Markowitz later claimed that he only really learned about computing once the mathematician George Dantzig, the codiscoverer with Tjalling Koopmans of linear programming, came to the RAND Corporation,[77] "and I became one of his many proteges."[78]

Markowitz argued that analyzing a large portfolio and estimating the covariances would be a tough challenge. Imagine a portfolio with one hundred securities. In order to estimate an efficient frontier—that is, portfolios of risky securities that had the highest expected return for a given level of risk or portfolios with the lowest risk for a given level of expected return—an analyst would be required to estimate one hundred expected returns, one hundred variances (or standard deviations), and ninety-nine hundred covariances. In 1959, there were no computers or calculating devices readily available on a practical basis to perform such calculations. However, Markowitz conjectured that a team of securities analysts might be able to develop and estimate the parameters of a covariance model. Although he did not present any related empirical analysis in his discussion, in a detailed footnote he outlined an approach to simplifying mean-variance analysis that would become known as the *diagonal* or *market model* in the hands of his future Nobel cowinner, Bill Sharpe (more on that in chapter 3).

Markowitz discovered what he later called "the law of the average covariance." Assume that a portfolio includes an equal amount invested in each security. As the number of securities in the portfolio increases, the variance of the portfolio will approach the average of all of the covariances among securities. If all the securities in the portfolio were uncorrelated, then the portfolio risk would approach zero. However, with correlated securities, even unlimited diversification would still leave a substantial amount of risk. This procedure would later be known as diversifying away firm-specific risk, also known as unsystematic risk, while leaving market risk, also known as systematic risk.

Markowitz had already discussed some of the limitations of his analysis in his 1952 article. While he presented examples for portfolios of three or four securities, he had not derived the general case for any number of securities. Another limitation of his early article was his assumption that an investor's beliefs would remain constant. In *Portfolio Selection*, he remedied these limitations by providing the analytical proof of the general case as well as applying the theory of rational behavior developed by Savage, von Neumann and Morgenstern, and others to his hypothetical investor.

In retrospect, the breadth of topics covered in *Portfolio Selection* that laid the foundation for future research was astounding. According to Mark Rubinstein, Markowitz's book foreshadowed a number of important research avenues.[79] Markowitz recommended the use of the statistical concept of semivariance as a risk measure, since it captured the notion of downside risk of such concern to investors, who are happy to live with upside surprises of variance. His outline toward simplifying mean-variance analysis in *Portfolio Selection* was an idea he later suggested that Bill Sharpe further investigate, which became Sharpe's PhD dissertation and his first published work in finance. Markowitz also laid the groundwork for solving how an investor would maximize the utility of consumption over a number of periods.

How He Did It

Years later, Markowitz reflected on his many influential and seminal publications. How was he able to come up with such brilliant insights? "I've thought about this: what do I do that somebody didn't do before? In the case of Markowitz 1952 [his "Portfolio Selection" article] I simply just read what John Burr Williams said and tried to think through the consequences of acting that way. And the consequence of acting that way is that you do not diversify. Shakespeare knew you diversify; everybody knows you diversify. Why was I the first one? . . . I don't know. I understand why I saw it—I don't understand why nobody else saw it. . . . It's a matter of good habits. I am not brilliant. I do not do mental arithmetic like von Neumann did. I do not have the mental capability that [the mathematical genius Carl Friedrich] Gauss had. All I know is how to read, and in my meager way I try to think through the implications. . . . If it is prescriptive, what are you going to do if you follow the prescription? If it is a hypothesis, what are the verifiable implications? Why didn't everyone do that?"[80] Of course, despite Markowitz's modesty, one way to define brilliance is to note that many people have tried to do what Markowitz described, but few have reached the same results.

The Grandparent of Behavioral Finance

Only recently has Markowitz, widely recognized as the founder of modern portfolio theory, been recognized as the grandparent of behavioral finance. Behavioral economics is a subfield of economics that attempts to explain the nonrational behavior of investors and financial markets. While most traditional models assume that all investors and decision makers are rational, behavioral finance recognizes that this is not always the case.

The origin of behavioral economics is often traced to the development of prospect theory in 1979 by the famous social scientist duo of Daniel Kahneman and Amos Tversky.[81] This theory describes the way individuals make risky choices when they are unsure about the probability of the outcome. Prospect theory attempts to capture mathematically the value of this choice relative to monetary gains and losses. According to prospect theory, such a relationship isn't always one-to-one. For example, suppose you were contemplating a bet on a coin toss where if the coin came up tails, you would lose $100. What is the minimum amount you would need to win if the coin came up heads for you to engage in this coin toss? You might naively think it's only $100, making the bet fair. According to prospect theory, however, most people would need to have the chance to win much more, say $250, before they would take the bet. In other words, losses loom much larger than gains in terms of utility.

In 1952, the same year that his “Portfolio Selection” article was published, Markowitz published another article that he affectionately refers to as “Markowitz 1952b,” titled “The Utility of Wealth.”[82] This article was inspired by Milton Friedman’s microeconomics class, where Markowitz read “The Utility Analysis of Choices Involving Risk” by Friedman and Savage, which attempted to explain why some people have insurance and yet also buy lottery tickets. According to Friedman and Savage, individuals at a certain *lower* level of wealth wouldn’t buy lottery tickets. This puzzled Markowitz, because “then I don’t know who’s lining up in front of me when I’m trying to buy a *Wall Street Journal* on Third Avenue in New York.”[83] In his article, Markowitz was able to explain this apparent contradiction in the Friedman-Savage model. What was the key insight this time in Markowitz’s article? “It said that if you want to explain actual behavior, do not attach utility to wealth. Attach it to *change* in wealth.”[84]

A quarter century later, Kahneman and Tversky were working on a theory of decision making that ultimately became prospect theory.[85] Tversky asked Kahneman to review academic articles on experiments that attempted to capture the utility of wealth. Kahneman shared his concern with Tversky that he was puzzled how scientific inferences could be drawn from experiments that modified their subjects’ wealth by only a few dollars. Instead of being set straight, as he expected, Kahneman was surprised that Tversky agreed with his observation. Tversky then remembered Markowitz’s article, which he thought hadn’t gained much attention. Reading it, Kahneman and Tversky both quickly realized they should base their theory, like Markowitz, on an individual’s change in wealth.

Markowitz’s Perfect Portfolio

Almost seventy years after his first publication, what does Markowitz’s work imply for today’s investors and money managers? Markowitz himself noted that much has happened since his aha moment in that

University of Chicago library "to transform that thought, that moment in time, into an industry."[86] At a conference they both attended, Peter Bernstein described what investment management was like before Markowitz and modern portfolio theory. According to Markowitz, Bernstein said, "You younger people don't know what institutional investing was like before the 1950s. We would sit around and have discussions like you see on television about 'I think this industry or I think this company,' and somehow we would cobble together a portfolio.' And he said, 'Now you have a process.' And when he said 'now you have a process' a chill went up and down my spine, and then at that moment I realized what I had started."[87] With a single article, Markowitz established the modern investment industry. "I created the discipline in which people make their living on portfolio theory."[88]

As Mark Rubinstein has observed, Markowitz's study in 1952 was the first mathematical formulation of the idea of diversification of investments.[89] Markowitz helped us understand that risk can be reduced (although not completely eliminated) without sacrificing expected portfolio return, and he showed us how to do it. What matters is not only a security's own risk but also how that security contributes to the overall riskiness of the portfolio: through each security's covariance with the returns of the other securities in the portfolio.

We now take for granted that diversification matters, but we're also much more attuned to the importance of correlations across securities and also across assets. It's now commonplace among institutional portfolio managers of pension funds and endowments to use Markowitz's efficient frontier analysis to determine the appropriate mix of different asset classes.

According to Paul Kaplan, a quantitative researcher with Morningstar Europe, and Sam Savage, a consulting professor at Stanford University (and the son of Markowitz's University of Chicago professor Leonard Jimmie Savage), what Markowitz did for portfolio construction is like what the Wright brothers did for aviation: he built an important new model.[90] However, there is a major difference. While the airplane still maintains the same basic structure, it has undergone many changes, such as allowing for more passengers, more comfort, more speed, more distance, and more safety. However, since Markowitz's initial contribution was so simple and so powerful, it has not undergone the same kind of continuous improvement despite attracting a large following.

Mark Kritzman, the CEO of Windham Capital Management and a senior lecturer in finance at the Massachusetts Institute of Technology (MIT) Sloan School of Management, observed that after sixty years, Markowitz's notion of mean-variance optimization has "aged extremely well" and "is a long way from retirement."[91] Kritzman notes that it wasn't until the mid-1970s that institutional investors really embraced mean-variance analysis to structure portfolios, for two reasons. First, in 1974 Congress enacted the Employee Retirement Income Security Act (commonly known as ERISA), which imposed a fiduciary duty on pension fund managers. Fiduciaries were required to act with the care, skill, and diligence that a prudent person would use. Fiduciaries who did not follow these principles of conduct could be held responsible for losses. Second, between 1972 and 1974, the U.S. stock market was down an inflation-adjusted 35 percent, so portfolio managers were searching for systematic ways to better manage risk and avoid legal issues. Markowitz's modern portfolio theory caught on then "and prospered because it works."

Markowitz himself described how the process he created became established in the investments industry. "Now the process of course is a top-down process, which Gary Brinson [founder of asset management firm Brinson Partners] talked us into."[92] Brinson and his colleagues became known for attention-grabbing studies that suggested that the vast majority of the variability of professionally managed pension fund returns could be explained by the variability of returns of a portfolio that didn't involve selecting individual securities or changing the relative weighting among cash, bonds, and stocks. Brinson concluded that the overall allocation to asset classes such as stocks and bonds was the important part of a portfolio. "What matters is that a lot of people who cannot pick stocks like Warren Buffett . . . can nevertheless give good, sound advice to their clients. They can be good advisers as long as they understand what an efficient frontier is and that one of the most important parts of being a financial adviser is not to get the guy on the efficient frontier but to get a guy roughly at the right point on the efficient frontier. You don't want the widows and orphans to be at the same place [on the efficient frontier] with the young businessmen. So that was the process."

Markowitz continued with his analysis. "The thought that I had had in the library had been amplified by many including the top-down approach of Gary Brinson, data like [Roger] Ibbotson and [Rex] Sinquefield [who became known for data collection and the publication of an annual stock market yearbook] . . . , with models of covariance like Bill Sharpe and BARRA [a firm founded by Barr Rosenberg, a pioneer in adapting and applying modern portfolio theory concepts to investments], with expected return models, etc. I started our industry. I was standing in a forest. I lit a match, and the whole thing came alive."[93]

Prior to modern portfolio theory, investments were solely in the hands of select professionals. What Markowitz did was to democratize investments. He provided a framework that allowed everyone to participate. "I do believe that Warren Buffett can stock pick. Now, he doesn't buy and sell quickly. He buys a stock and holds it for a decade. If he likes it he holds it for another decade. . . . The point is there are a few people who can pick stocks. But there aren't thousands of people who can stock pick. So indeed, I democratized portfolio management financial advice because thousands of advisers can give good advice by using the top-down process."[94]

As the founder of modern portfolio theory, what does the Perfect Portfolio mean to Markowitz? In his answer, Markowitz reflected on his first investment decision and how his thinking has evolved. He also wanted to set the record straight on stories that claim—erroneously—that even he didn't use mean-variance analysis. "When I wrote my 1952 article I had never invested. I was a student without funds. The first time I had the opportunity to invest was when I had joined the RAND Corporation in Santa Monica. They offered TIAA versus CREF, stocks versus bonds. At that time, I thought if the stock market goes up and I'm completely out of it, then I'll look silly. And if it goes down and I'm 100 percent in it, I'll look silly. So, I went fifty-fifty. So, I was, at that time, minimizing maximum regret."[95]

"That's what I did in 1952, but that's not what I would do today and is not what I would recommend a twenty-five-year-old do now. Now, I'd probably put them 100 percent in stocks."[96] Markowitz reflected that much has happened since 1952. There is an infrastructure in place to form portfolios. There are long series of data going back a century that show stock returns for various types of equity investments, such as smaller market capitalization firms, as well as for other asset classes. These historical return series are useful for developing forward-looking estimates of means, variances, and covariances of various asset classes—the key inputs into efficient frontier analysis. And there is software that quickly analyzes mean-variance portfolios in order to optimize return versus risk. Today, Markowitz's recommendations would be quite different. "I know from repeated exposure the approximate asset class mix I prefer, and I invest in that mix, roughly. I implement my choice with ETFs [exchange-traded funds] for equities and with individual bonds for fixed income."[97]

Markowitz's thinking evolved between his 1952 "Portfolio Selection" article and his subsequent book by the same name. "By 1959, I had come to realize that you might want other constraints on the choice of your portfolio. You might want upper bounds on individual securities, you might want upper bounds on how much you have in certain [industries] or sets of securities, you might have other linear constraints like you want to have income at a certain level, and so on."[98]

Not surprisingly, Markowitz remains a firm believer in mean-variance analysis. What may be surprising is that he doesn't feel the market portfolio—theoretically consisting of all assets but, practically speaking, a broad index of stocks such as the S&P 500—is special, nor is it *the* investment one should necessarily make. In 2005, he wrote the article "Market Efficiency: A Theoretical Distinction and So What?" in which he made the distinction between the concept of market efficiency—processing information correctly—and the statement that the market portfolio of all stocks is a mean-variance efficient portfolio (we'll return to the topic of market efficiency in chapter 4).[99] Bill Sharpe's capital asset pricing model, discussed in chapter 3, makes an important assumption that all investors can borrow or lend without constraint at the same rate of interest. Without that key assumption, Markowitz argues, there is nothing special about the market portfolio.

To further describe his approach to the Perfect Portfolio, Markowitz took the perspective originally attributed to Thomas Bayes, the mathematician who created a new branch of probability theory that relied on the notion that when individuals receive new information, they update their beliefs about the probability of events they expect to take place. "Assume we are Bayesians. If we don't have the same prior [beliefs], we shouldn't have the same portfolios. Are we the same ages? Do we have the same risk preferences? If not, we shouldn't have the same portfolios. The thing that is perfect for you is not perfect for me. . . . It depends on our ages, our objectives, our risk tolerance, and even given that, there is wiggle room."[100]

The notion of a Perfect Portfolio for Markowitz is one that we all pursue, how we each individually construct our own portfolio. His work allows all of us to pursue the Perfect Portfolio that's right for us. Markowitz gave an example of a waitress who, following his advice, had invested in a portfolio that was weighted 50 percent in stocks and 50 percent in bonds. "If she were younger I would put her more heavily in stocks. . . . The basic decision is what is the right mixture of stocks and bonds? That is still the fundamental decision. And you've got to get a feel for what the volatility is for various combinations [of stocks and bonds], either by yourself or with your financial adviser. . . . The most important thing is to get you to the right part of the frontier."[101] In other words, you have to understand the expected return, the volatility, and the correlations for various combinations of stocks and bonds at a given level of risk in order to reach the point of highest expected return—in Markowitz's words, to get you to the right part of the efficient frontier.

Another important consideration for the Perfect Portfolio is taxes. Markowitz noted that mean-variance analysis should be done on an after-tax basis, "and that is tricky because [of] different investment time horizons. You invest in a 401(k) plan, you can't get it back out without penalty" before age fifty-nine.[102] Again, it depends on the individual's situation.[103]

Markowitz expressed concerns about the possible misinterpretation of his work. He provided some examples. "I am trying to get learned people, scholarly people, to know that I did not and do not assume normal distributions."[104] A normal distribution is the familiar bell-shaped distribution that's often observed in nature and society, such as in the exam scores of a large class of students. Any normal distribution can be described simply by its mean (its average value) and its standard deviation. By the properties of the normal distribution, approximately two-thirds of expected exam scores in our example would be within plus or minus one standard deviation of the mean. Approximately 95 percent of the exam scores would be within plus or minus two standard deviations.

In the past, some investment professionals relied on risk management models with the built-in assumption of a normal distribution, and during major market corrections, such as in the 2007–2009 period and in 2020, some investors suffered greater losses than they were led to believe was possible. It's now recognized that while stock return distributions tend to have the general shape of a normal distribution—a bell-shaped curve—the tails of the curve are much fatter than expected (see more in chapter 4). In other words, there tend to be more really good and really bad stock return outcomes than suggested by the normal distribution. But such an observation is not a valid criticism of Markowitz's work. The principles of diversification are applicable to a portfolio regardless of whether security returns follow a normal distribution or any other reasonable assumption about their distribution.

Markowitz is also concerned about the misuse and misrepresentation of modern portfolio theory. He relayed the sad story told to him by a professor at a midwestern college who had been asked to be an expert witness in a case brought by a woman, who was unable to work for health reasons, against a large financial institution around the time of the tech bubble in the late 1990s. "She put her fortune in the hands of a financial adviser . . . [who] not only put her high on the frontier in an all-equity portfolio, but instead of implementing with a diversified index fund, he put her in lots of tech stocks. And when the crash came, she lost a lot of money. It was all in the name of modern portfolio theory. . . . [The result of the arbitration was that] she lost, [and the arbitrators noted that the financial adviser] was doing the best he could in light of his knowledge and beliefs, etc."[105] There was nothing in modern portfolio theory to suggest such a portfolio allocation.

Markowitz conveyed one final story. His former secretary "brought in some advertising material which said that their services were based on Nobel laureates Markowitz's and Sharpe's theories. . . . But I looked at their ad, and they were not using my theory. They're not using an efficient frontier. They've got some kind of stock selection rule and mumble-jumble. . . . I would more trust a voodoo doll [than their product]!"[106]

What does the future of portfolio management look like to Markowitz? One of his clients is Acorns Advisors LLC, a micro-investing, robo-advisory firm that provides online portfolio management with minimal human intervention. "The way I see things going in the next sixty years . . . is for the human-computer division of labor to cover more fully the various aspects of financial planning."[107] To that end, having laid the foundation in his first and second volumes, Markowitz recently completed the third volume of a projected four-volume series titled *Risk-Return Analysis: The Theory and Practice of Rational Investing*.[108] These books expand on the analysis Markowitz first presented in his 1959 book, justifying the use of mean-variance analysis as a rational approach to decision making under uncertainty. According to Markowitz, despite its title, the series is "not about rational *investing*, it's about rational *decision making* for financial planning."[109] Markowitz noted that portfolio selection needs to be considered in a broad context: "Just analyzing the portfolio selection decision in isolation is like trying to decide how bishops should move in a chess game without considering the chess game as a whole." His rational approach has certainly helped investors in their pursuit of the Perfect Portfolio.

3

William Sharpe and the Capital Asset Pricing Model

A TELLTALE SIGN of a brilliant idea is difficulty in imagining what life was like before the idea was conceived. Such is the case for William (Bill) F. Sharpe's capital asset pricing model (CAPM), an idea that forever changed the way portfolio managers approach their trade. Even though Harry Markowitz's seminal work was a decade old by the time Sharpe was working on his model, the investment industry hadn't noticeably changed. While Markowitz had shone his light on the importance of diversification, he didn't provide specific guidance about where to invest.

Sharpe took Markowitz's portfolio optimization as his starting point and derived a remarkably simple yet powerful result: if all investors hold the same optimal portfolio, albeit in different dollar amounts, then this optimal portfolio can only be the portfolio of all assets, with each asset weighted according to its size or market capitalization. In other words, the optimal portfolio on Markowitz's efficient frontier is the market portfolio—the portfolio of all assets bought or sold in the market—and all investors are indifferent between choosing among all individual assets and choosing among two assets: the risk-free asset and a fund that holds all risky assets in proportion to their market capitalization. This was the Perfect Portfolio!

This result was a critical milestone in both academia and industry. Once Sharpe deduced that in a CAPM world everyone would hold the market portfolio, he was able to derive the expected return for each stock that was part of that portfolio. It's no exaggeration that the CAPM provided the intellectual foundations for passive investing and the multitrillion-dollar index mutual fund business. By taking portfolio management out of the hands of the "gunslinger" stock picker of the 1960s and placing it into the hands of passive index funds, Sharpe narrowed the focus of Markowitz's portfolio idea and did more than any other financial economist to make the investment process more accessible for all of us. Along the way, he built much of the modern framework for portfolio management, performance attribution, and risk-adjusted cost of capital estimation. The CAPM also generated a host of theoretical and empirical predictions that created a renaissance of financial research for several generations of academics.

The Formative Years

Bill Sharpe was born in Boston in 1934.[1] Both of his parents had undergraduate degrees, a huge accomplishment that only 6 percent of males and 4 percent of females had achieved by 1940.[2] At the time, his father was working in the placement office at Harvard University. It was Sharpe's parents who helped instill his love of learning and education. His father was a student of the classics at Harvard and had spent a year in Europe on scholarship before returning. When his National Guard unit was activated in 1940, the Sharpe family moved to Texas and then California. Sharpe's father took a job with the Veterans Administration in San Francisco and taught part-time at Golden Gate College (which became Golden Gate University). He then received a PhD in education at Stanford, eventually returning to Golden Gate as its president from 1958 to 1970. Sharpe's mother returned to school after World War II and obtained education credentials, and then became an elementary school principal.

Sharpe attended public schools in Riverside, California. At the time, teachers in his school taught different sessions to different classes in the morning and afternoon, and as a result Sharpe was moved around in the system many times, sometimes ahead grades and sometimes behind. In fourth grade, he was tested on his multiplication tables. While he had memorized tables up to 10 times 10, he was tested on tables up to 12 times 12 and subsequently failed, forcing him to repeat fourth grade. He graduated from Riverside Poly High School in 1951 with numerous classmates who would go on to serve in Korea with the armed forces. Sharpe was one of two distinguished classmates featured in an article highlighting Riverside Poly's class of 1951 sixty-year reunion. The other classmate, Ann McIntosh, would go on to become Miss Riverside.[3]

Sharpe then enrolled in the University of California at Berkeley. His mother had wanted him to major in a science and get a medical degree, but Sharpe wasn't enthralled with science courses such as chemistry and physics, and he couldn't stand the sight of blood. He decided to transfer to the University of California at Los Angeles (UCLA) for a business major. In his first year, he took two courses that he remembered vividly: accounting (basic bookkeeping) and microeconomics. He "loathed and despised" accounting but thought economics was "swell."[4] Sharpe loved the idea of making perfectly plausible assumptions about behavior and choice and then aggregating them and getting unexpected results related to the overall economy. He "liked the poetry of it . . . [, which was] aesthetically appealing."[5] He changed his major to economics, receiving a bachelor of arts degree in 1955. In his senior year, he applied for several jobs at banks. In his interviews his strong grades were often noted, and he was asked why he didn't continue his education further. As it turned out, many of the banks were looking for the "B" students, not the "A" students. In his last attempt at an interview, Sharpe tried a different tack: he reached over, turned over his résumé, and said, "But look, I attended a fraternity and was involved in yachting. . . . I was a human being," but to no avail.[6] He continued in education, obtaining a master of arts degree in 1956, and spent a short period in the U.S. Army.

Sharpe joined the nonprofit think-tank RAND in 1956 and there learned his programming skills, which would serve him well during his career. "At RAND, although I was not a programmer, we were all . . . encouraged to learn programming in order to better work with the real programmers. I took internal classes on programming and absolutely loved it. I loved algorithms as well, and that was the era in which operations research, we thought, was going to save the world. So, RAND was just a hotbed of operations research and computer science, and we had some very powerful, for the day, equipment. So, I became hooked on programming. I even created a programming language and wrote a compiler. That's the dark side of my life, I suppose. I still program almost every day."[7] Sharpe became such a proficient punch-card user—those now-obsolete stiff paper cards containing computer programming commands—that he quipped that should his educational pursuits stall and "if things didn't go well in the economics business or finance business I could always [be] a key punch operator."[8]

While at RAND, Sharpe pursued a PhD in economics at UCLA. He had two influential professors, Fred Weston and Armen Alchian, both of whom were members of his dissertation committee, with Alchian as his chair. Weston was trained as an economist but was teaching at the business school at a time when the field of finance was much more simplistic than it is today (or even "moronic," to use Sharpe's word),[9] without much theory or serious empirical work. He hired Sharpe as one of his many research assistants. Sharpe found out he could take finance as one of his five field courses even though he was pursuing a PhD in economics. "Fred was just a dynamo" and would go into a class with a recorder, taping notes for his next book.[10] He would have PhD students learn a subject and then teach that particular subject in a class. Weston thought that one book, *Portfolio Selection* by Markowitz, would be interesting for Sharpe to learn and teach, which Sharpe did. Weston was one of the first to bring into the classroom the economic ideas of time, money (now and in the future), and uncertainty (now and maybe in the future), now taught in mainstream economics.[11]

Sharpe's other mentor, Alchian, was very different from Weston. Alchian would ask complex fundamental questions in class and then make them simple to his students. In PhD seminars, Alchian would say that 95 percent of the economics literature wasn't worth reading, so therefore he would not have his students read the literature. He would often start a class with seemingly random musings, such as "Why don't we buy babies instead of having adoptions?"[12] In many of his sessions, it seemed Alchian was desperately trying to figure out what profit really was from scratch. According to Sharpe, “It was watching a brilliant mind wrestle with tough, practical problems.”[13] Alchian taught Sharpe how to question everything and how to analyze a problem from first principles. More than basic knowledge, it was technique that Alchian taught. Through Alchian, Sharpe learned to critique his own work and to play the devil’s advocate when necessary.

Serendipity

As is common in doctoral programs, Sharpe first completed his coursework and his field exams, found a topic of interest, and then began working on his dissertation.[14] He became interested in the topic of transfer prices, based on the concept that within a large corporation with different divisions, one division will create a product and “sell” it or transfer it to another division at some predetermined price. What the proper price should be was related to internal accounting procedures and the incentives within a corporation for each division to earn a profit. Sharpe started working on the problem using linear programming, utilizing methods developed by the prominent economist Jack Hirshleifer, who was then at the University of Chicago. Sharpe had produced the first fifty pages of what he thought was a pretty good dissertation-to-be.

“I had actually started a dissertation on internal transfer pricing using all kinds of operations research tools, which I thought was really quite good, and building on the work of Jack Hirshleifer,” Sharpe recounted.[15] Operations research was coming into prominence at RAND, where it was being developed and where Sharpe worked. “It turned out, Jack came to UCLA about the time I was, I thought, halfway through my dissertation. So, Armen Alchian, my adviser, said, ‘Well, why don’t you go talk to Jack Hirshleifer?’ And I did, and I gave him the chapters that I had finished and went back in a week, and he said, ‘I don’t think there’s a dissertation here.’ So, I went to Fred Weston, who was also my adviser and a big influence on me, and said, ‘What am I gonna do, Fred?’ And Fred said, ‘Well, remember in the seminar you really liked the work of this guy Markowitz, and I think he’s just come to RAND,’ where I was at the time, 'let's go talk to him.' So, I introduced myself to Harry, and we chatted for an extended period of time. And basically, Fred Weston, Armen Alchian, on the faculty at UCLA, made a deal that Harry would in effect be my dissertation adviser, although he was not on the faculty. So, Harry was very much a big influence." The rest is history. By 1961, Sharpe had received his PhD.

The Diagonal Dissertation

Sharpe's dissertation was titled, "Portfolio Analysis Based on a Simplified Model of the Relationships among Securities." Securities are generally any type of investment, such as a stock, bond, cash, or real estate, but Sharpe's application was to stocks. His dissertation consisted of 103 pages, with twenty-four figures and technical appendices, including Fortran programming code. In retrospect, one can see why this document was the genesis of a Nobel Prize–winning idea. It was likely the first rigorous theoretical analysis of stock returns and the first attempt at what is now commonly known as quantitative investing. In his dissertation, Sharpe acknowledges that his "greatest debt is to Harry M. Markowitz."[16]

By way of background, Sharpe observed that prior to Markowitz, there was a simple notion of risk: people should not put all their eggs in one basket. "I remember a reporter asking Harry . . . 'Did you get a Nobel Prize for saying don't put all your eggs in one basket?' to which Harry said 'Yes' and the reporter wandered off puzzled."[17] Markowitz's approach was to quantify risk. Sharpe's dissertation expanded on that approach.

Sharpe investigated the process of selecting securities in a portfolio, given certain simplifying assumptions about how these securities related to one another. For example, if on a particular day or week one stock goes up in price, to what extent does another stock also go up? Consider a portfolio with ten stocks numbered 1 through 10. If we examine the price change relationships between those ten stocks, there are forty-five different pairs of stocks we would need to examine: between stocks 1 and 2, 1 and 3, and so on up to stocks 9 and 10. We can

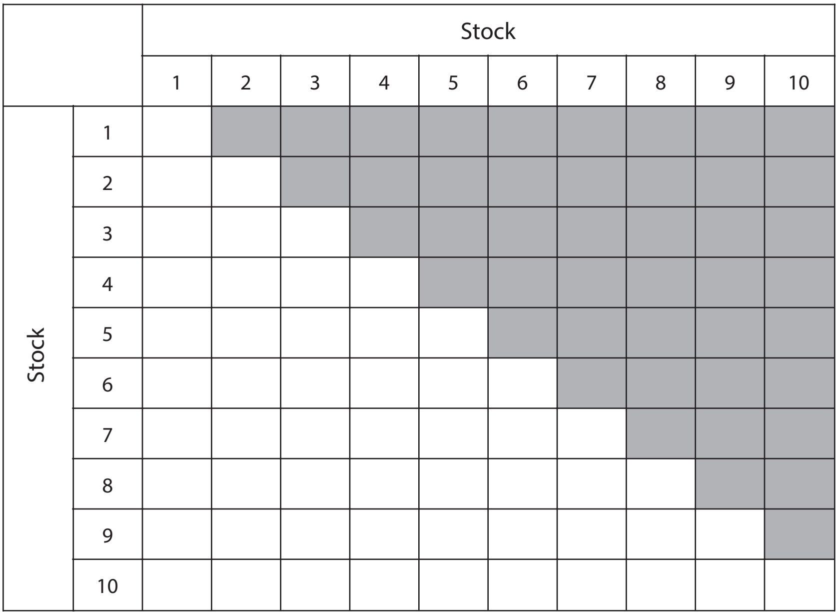

FIGURE 3.1: Pairings among ten stocks. The shaded areas indicate the unique pairings.

visualize the pairings in the 10 × 10 matrix in figure 3.1, with the shaded areas representing the unique pairings between stocks.

If we look at Markowitz's efficient frontier model (described in chapter 2), one of the necessary inputs to determining the portfolio's standard deviation was an estimate of the correlation or covariance between each pair of stocks. For a portfolio of one hundred stocks, there are 4,950 different pairs. While we take for granted the ease and speed with which computers can perform calculations, this wasn't the case in the early 1960s. Any technique that would simplify this computation had tremendous practical implications if Markowitz's ideas were to be applied in an actual investment portfolio. "I developed an algorithm that could very efficiently solve a problem in that special case, general portfolio theory, a portfolio optimization problem," Sharpe recalled.[18]

Sharpe had discussions with securities analysts to determine what characteristics they looked for in a security that might be an indicator of its future return. "At Fred's urging, I worked on an actual human financial adviser. I tried to capture his predictions probabilistically and then do the efficient portfolio thing."[19] There were three elements then in use, Sharpe discovered. First, a security was classified as either low yield or high yield. In other words, was the stock expected to deliver a low or high yield or return? Second, a security was classified based on the risk that the expected return may not be realized. Third, a security was classified according to how the individual security price changed *relative to the overall stock market.* For example, some securities were considered to be more sensitive to overall market movements, or more cyclical, while others were much less affected. It was Sharpe's simple but brilliant insight to model this relationship, which he credited to a suggestion by Markowitz, who had developed a similar model in his *Portfolio Selection* book.

Sharpe's "diagonal model," also known as the market model, made these elements explicit. The simplicity of this approach was that these characteristics were the only elements of a security that an investor considered. In other words, these were the only elements that any investor *ought to* consider, and any other information about the security, such as whether the stock price had been trending up or down, simply wasn't relevant to determining its price and future performance.

How does this model work? Sharpe summarized the model in one simple equation:

$$Y_i = A_i + B_i \times I + \varepsilon_i,$$

where Y_i was the yield or return for security i, and A_i and B_i were fixed parameters unique to each security. A averaged the rate of return on the riskless asset, representing how much a security might return when the overall market return was zero. B averaged 1.0 across all securities, representing how sensitive a security's yield was to the stock market index, I. I was the return on some overall stock market index, such as the Dow Jones Industrial Average and the S&P 500 index. Finally, ε_i was some random variable with an expected value (or average) of zero.

Suppose we're examining monthly stock returns, and every stock is assigned arbitrary amounts to these two variables, A and B. A incorporates whether the stock is high yield or low yield. B incorporates how risky the stock is relative to the overall market. For stock XYZ, suppose

A is fixed at 0.2 percent, and B is fixed at 1.2. We can characterize stock XYZ as a low-yield stock that's somewhat more risky than the market. (B for the overall market will always be 1.0, since we're comparing each stock's return to the overall market.)

Now imagine an all-powerful wizard who each month spins two dials in order to generate returns on all stocks and on the overall market as well. The first dial, I (for index), determines that month's return on the overall market, say 1.0 percent for that month. The second dial, ε (a firm-specific random return), determines a random return effect specific to stock XYZ, say −0.3 percent for that particular month. Putting it all together, for that month, stock XYZ's return is $A + B \times I + \varepsilon$, or 0.2 percent + 1.2 × 1.0 percent − 0.3 percent = 1.1 percent.

The beauty of this model is that we don't need to worry about how stock XYZ's price is changing relative to stock ABC or any other stock, for that matter. All we care about is how stock XYZ changes relative to the overall market (or, in practice, some index such as the well-known S&P 500), as captured by B. If we're considering ten stocks, all we care about is the relationship each stock has with the overall market. In the 10 × 10 matrix of stocks, all we care about are the diagonal factors, the relationships visualized in figure 3.2.

In other words, we can think of each of the "stock *i*–to–stock *i*" boxes along the diagonal as each stock's relationship with the overall market. The relationships between any stocks *i* and *j*, the off-diagonal relationships, don't matter to this analysis. As Sharpe recalled in more technical language, "I called it the diagonal model because, if you take advantage of the structure, you can write the covariance matrix [how one security varies relative to another] as a diagonal matrix with zeros on the off diagonal and an additional equation."[20]

In addition, since the random firm-specific effect for each stock has an expected value of zero, if we hold a large number of stocks, we can be quite confident that the average of these effects each month will effectively cancel out.

The key assumption of Sharpe's diagonal model is that stocks are related to one another solely through how a stock reacts to the overall market (or, more generally, to some other common factor). This model

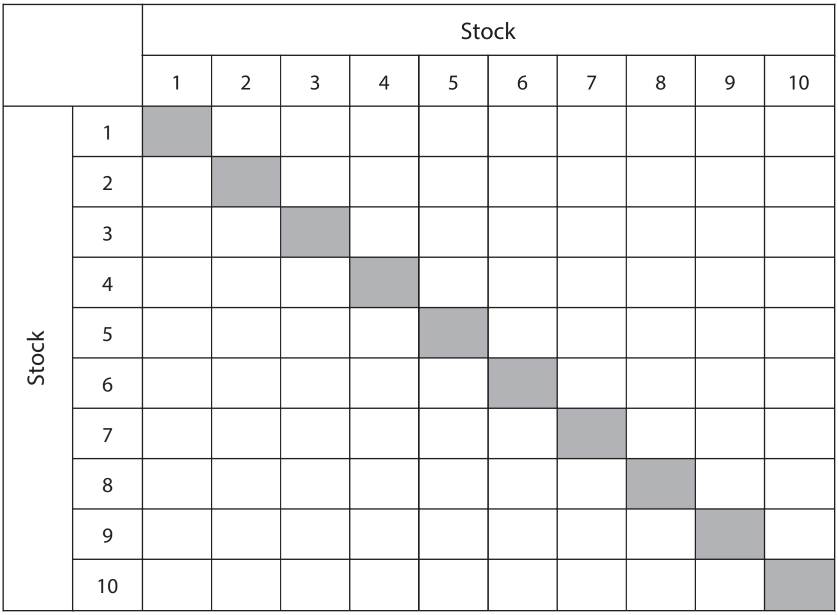

FIGURE 3.2: The diagonal model interprets the shaded diagonal boxes as each stock's relationship to the overall market. The relationships between any stocks *i* and *j* off the diagonal don't matter.

eventually became known as the single-index model, the one-factor model, and the market model.

In his dissertation, Sharpe gave an example of the magnitude of the potential cost savings of the diagonal model for an analyst trying to implement quantitative portfolio analysis. To examine all of the pairwise relationships between 100 securities using a state-of-the-art IBM 7090 computer[21] required thirty-three minutes of computing time at a cost of $300 (just over $2,400 in 2021 dollars), with a maximum of 253 securities that could be analyzed. By employing the diagonal model, the computing time was reduced to thirty seconds at a cost of only $5, and as many as 2,000 securities could be analyzed.[22]

Sharpe then took two different approaches to testing the diagonal model. His first approach was to use objective prediction techniques. He estimated the model using ninety-six securities randomly chosen among the industrial stocks listed on the New York Stock Exchange between

1940 and 1951 and then tested the model over the period 1952 to 1959. In general, the diagonal model performed well compared to examining all pairwise securities and was reasonably accurate in ranking future returns of these securities versus risk. Sharpe's second approach was to rely on the input of an experienced investment counselor to estimate the model's parameters. Again, the model performed fairly well, while the investment counselor who participated in the experiment envisioned how this type of analysis might assist in the task of portfolio selection in the future.

However, people remember Bill Sharpe not for his work on the diagonal model but instead for the CAPM. The last chapter in Sharpe's dissertation, "A Positive Theory of Security Market Behavior," included results that would lead to its development. "It wasn't really Armen's idea, I don't believe, but it was just what he had taught me to do."[23] Sharpe assumed that investors acted as though they were applying Markowitz's portfolio analysis to their probabilistic beliefs about securities and that their beliefs would be expressed in terms of the diagonal model. Sharpe ended his dissertation with an accurate prediction, perhaps with his CAPM in mind: "The Markowitz formulation represents the process of investment selection in [utility maximization] terms; for this reason, it is likely to be a major element in future successful theories of security market behavior."

Give Me a C, Give Me an A, Give Me a P, Give Me an M

In September 1961, Sharpe took a position as an assistant professor of finance at the School of Business at the University of Washington in Seattle.[24] "I finished the dissertation in June, started at the University of Washington in September, and thought, 'This is a really great result. I wonder if I can generalize it?' So, I spent several months trying to figure out how to do it without putting the rabbit in the hat. Was there a way to pull the rabbit out of the hat without putting it in to begin with? I figured out yes, there was."[25]

In December of that year, Sharpe submitted an article to the well-respected academic journal *Management Science* titled "A Simplified Model for Portfolio Analysis," which contained a summary of the normative results of his dissertation: why the diagonal model was a useful practical tool.[26] The article was eventually published in 1963, his third publication and his first in the area of finance (his other two publications were related to a smog tax and military aircraft design).[27]

While at the University of Washington, Sharpe began working on a generalization of the theoretical model he developed in the last chapter of his dissertation. "I thought there were some really nifty results here—I had the capital market line, the security market line, betas, the whole nine yards. But it seemed hostage to this very severe assumption about inter-relationships of security returns. So, I set about seeing if I could generalize the model. It turned out that it didn't take much effort to get the same results without the restrictive assumption. That is how the published version of the CAPM came to be. I had the generalization within a few months after finishing the dissertation, but given the vagaries of publishing and refereeing, it took a while to publish."[28]

Let's unpack Sharpe's "whole nine yards," including the capital market line and the security market line, two of the most famous graphs in finance, known to (and perhaps loved by) virtually every MBA graduate in the last forty years. Sharpe approached his model as most economists would, by thinking about what would happen if the supply and demand for securities were precisely in balance, in other words, in equilibrium. Since every theoretical model is a simplification of the real world, Sharpe started by making assumptions.

Sharpe assumed that investors could not only invest in risky securities but could also borrow or lend at the same riskless rate, such as the Treasury bill rate, the rate at which the U.S. government can borrow money over the short term. Lending and borrowing at the risk-free rate extended the investment possibilities for an investor. Lending was the same as buying a Treasury bill. Borrowed money was then invested in risky assets.

Another assumption was that in the theoretical world Sharpe created, everyone would want to hold the "best" possible portfolio of securities, in the Markowitz sense. This meant holding securities that had the highest expected return for a given level of risk. Recall that Markowitz had been able to identify various portfolios of risky securities that met this criterion, which he referred to as "efficient portfolios."

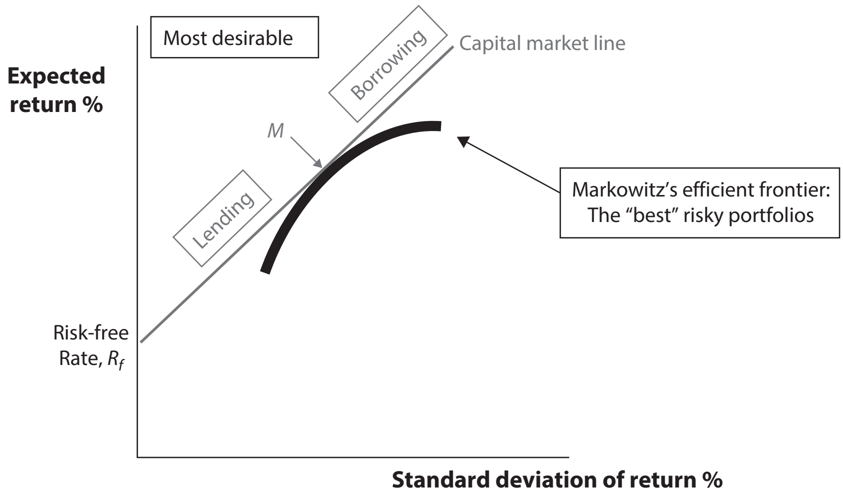

FIGURE 3.3: Lending and borrowing at the risk-free rate extends investment possibilities. The optimal risky portfolio—the one closest to the "most desirable" area in the graph—is the portfolio *M*, which is also the market portfolio. The capital market line shows combinations of borrowing or lending at the risk-free rate and investing in *M*.

By combining risk-free lending (or borrowing) with investing in risky assets, it turns out that among the various efficient portfolios that Markowitz had identified, there was only one special portfolio of risky assets that *all* investors would want to hold: the *market* portfolio. This was the portfolio that, in theory, contained all marketable securities—stocks, bonds, real estate, commodities, etc. That portfolio is represented by *M* in figure 3.3. Sharpe called the various combinations of risk-free borrowing or lending and investment in the one best risky portfolio (the market portfolio, *M*) the capital market line.

While, in theory, the market portfolio contains all marketable securities, to keep things simple, think of the domestic market for stocks, where a good proxy for that market is a broad basket of securities such as the S&P 500 index. Sharpe's model implies that every investment strategy should be a very simple two-step process. First, all investors would lend to the government a portion of their money—in other words, they would buy some Treasury bills. Second, all investors would invest the remaining portion of their wealth in a market portfolio, something like the S&P 500 index. The proportion of the portfolio invested in Treasury bills versus the index would depend on the individual's inclination to take on risk: the more risk an investor was willing to take, the greater the proportion invested in the index. For those rare investors who liked to take on a substantial amount of risk, they could borrow at the risk-free rate and invest all of their own money and their borrowed money in the market portfolio.

With the benefit of some additional assumptions, Sharpe was able to tease out some other important consequences of his model. Once he knew that the only portfolio of risky securities that every investor would hold was the market portfolio, he could then determine the price of each *individual* security or asset in the financial (or capital) markets—hence its name, the capital asset pricing model, or CAPM. From there, if an investor knew the price of a security, then the investor could also determine the expected return of that security.

It turned out that in Sharpe's CAPM world, investors would be rewarded for bearing risk but only for risk that couldn't be diversified away—the reason why all investors held a diversified portfolio. In Sharpe's model, the price one paid for a particular stock didn't depend on how volatile that stock's return was expected to be in isolation. All that mattered was the *relative* riskiness of that stock as part of a broad and diversified portfolio.

Given these assumptions, Sharpe was able to derive a linear relationship between a stock's expected return and its riskiness, what is now referred to as the security market line. The greater the sensitivity of a stock's return to the market's return (a variable now known as beta, or β), the greater the expected return for that stock, as shown in figure 3.4.

The equation for the security market line is also the now-famous CAPM equation:

$$\mathrm{E(R)} = R_f + \beta \times (R_m - R_f),$$

where E(R) is a stock's expected return, R_f is the risk-free rate of return, β is a stock's riskiness relative to the overall market, and $(R_m - R_f)$ is the expected return on the market in excess of the risk-free rate of return, also known as the market risk premium, or MRP.[29]

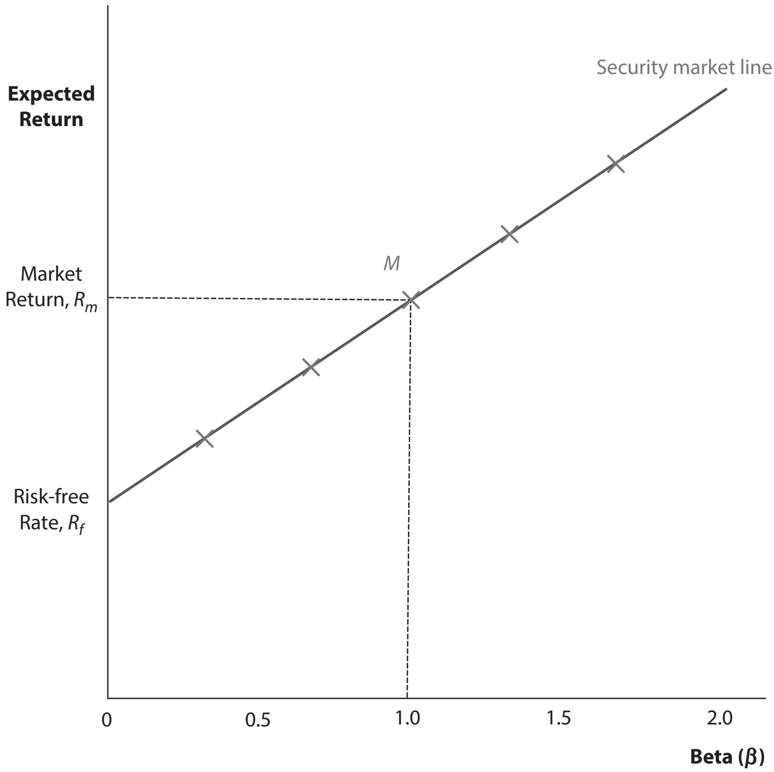

FIGURE 3.4: The security market line compares a stock's expected return with its risk as measured by beta (β). According to the CAPM, all stocks (held in a diversified portfolio) should fall along the security market line.

Although at first glance simple, on further examination this model has a deep sense of both beauty and complexity. It shows why some securities have higher returns than others but only as compensation for risk. As long as an investor holds a diversified portfolio, the only measure of risk that matters is beta, the covariance of a security's return with the market portfolio. Nothing else matters. This can be a hard pill to swallow for many investors. There may be important characteristics if a security is held on its own, such as the standard deviation of a security's returns, but according to Sharpe's model, beta drives out every other characteristic.

In the CAPM, Sharpe had developed an equilibrium model. However, the measure of relative riskiness for each security in the CAPM was similar to the measure he had developed in his dissertation with his diagonal model: the fixed parameter, *B*. This measure was later popularized as the Greek letter beta, or *β*.[30] Beta has a very intuitive appeal. High-beta stocks, those measured to be greater than 1.0, are riskier stocks; low-beta stocks measured to be less than 1.0 are safer stocks; and the beta of the overall market is 1.0 by definition. If a stock has a beta of 1.5, this implies that if the stock market were to rise by 1.0 percent (say, over the next month), then we would expect the price of that particular stock to increase by 1.5 percent. Similarly, if we expected the stock market to fall by 1.0 percent, then we would expect the price of that particular stock to decrease by 1.5 percent.

Sharpe viewed his equilibrium model as a natural extension of his dissertation. "I then did in the dissertation, and subsequently expanded on, what anybody trained in microeconomics would do: [ask the question] if everybody does this, what happens when they all come to market, and prices adjust and the markets clear . . . [,] referred to as equilibrium. And what I found was that under some very, very rigid simplifying assumptions, that 'Yes, Virginia,' there would be higher expected return for higher risk . . . but not just any risk . . . [;] the risk for which there will be a reward if the markets are functioning at all well . . . is risk that . . . cannot be diversified away."[31]

By the fall of 1961, Sharpe's work on the CAPM had progressed sufficiently for him to draft a working paper that was then shared with other academics at workshops and seminars. The usual academic process in finance and economics is to ask for feedback from academic colleagues in order to improve a paper, then submit it to a respected peer-reviewed journal in hopes of publication. In January 1962, Sharpe first presented his results at a University of Chicago seminar. Shortly afterward he submitted the paper, titled "Capital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk," to the prestigious *Journal of Finance*, at the time the top academic publication in the field and also where Markowitz had published his seminal paper.

Sharpe received an initial negative report from an anonymous referee. Sharpe's assumptions, the report commented, including the important assumption that all investors would make the same predictions about the expected returns and risks of securities, were so "preposterous" that all subsequent conclusions were "uninteresting."[32] Sharpe kept trying with the *Journal of Finance*. Nevertheless, he was only successful after the arrival of a new editor.[33] According to Sharpe, "the editorship was in the process of being changed. Eventually other referees were brought in and the new editor agreed to publication, which took place in 1964."[34]

By 2021, Sharpe's now-classic article[35] had received an incredible number of Google Scholar citations, over twenty-six thousand.[36] Thousands of finance professors and hundreds of thousands of business school students have come to know and love Sharpe's model as "CAP-M," pronounced "cap-em." Perhaps one of the few people who still refer to it as C-A-P-M is Sharpe himself.[37] "Now I like to, when I try to motivate people for the results of the C-A-P-M . . . I prefer to start with Ken Arrow's view, the Arrow-Debreu[38] view of the world. . . . The basic idea is if you want money in times when money is scarce, then you are going to have to pay more for it up front; and if you pay more for it, your expected return is going to be less. . . . The two big implications are first, 'Yes, Virginia,' there is a reward for bearing risk but only nondiversifiable risk; the second implication is why do you want to bear that nonrewarded risk, which says for God's sake diversify! And that's really the intellectual basis for index funds . . . [,] which are basically funds that just buy a whole lot of securities and keep the costs as low as possible."[39]

Sharpe knew his article was to be his best work. "I remember the CAPM article, which went around through a refereeing editorial process for three years, finally was published in '64. And I knew at the time, and I'm sure I was right, that was going to be the best paper I ever wrote. Nothing has convinced me that I wasn't right about that. So, the question was, how good was it? So, I sat by the phone—we didn't have email then[40]—waiting for the phone to ring or people to send letters and nothing, zero, nada. Finally, after about a year, people started paying some attention to it. I was focused more then on the adoption of the ideas by the academic profession. But that took a while. But once that got started, you know, there was a lot of activity for and against.

"The implementation was just glacial, it just took forever, because it sort of went against everything people in the investment industry did. There was even an ad taken out by somebody, a full-page ad in one of the investment trade magazines, professional magazines, with an Uncle Sam saying, 'Indexed investing is un-American.'[41]

"There was also the idea that it was really dumb to just buy everything in market proportions, that you needed intelligent people doing research, etc. There was the whole 'random walk' movement, out of MIT mainly, Paul Cootner's book with that name. Paul, who was at one point addressing 500 securities people in New York after the *Random Walk* book had come out, and the person who introduced him was a leading person from the industry. And he said, as he finished the introduction, 'I have one question for you, Professor Cootner. If you're so smart, why aren't you rich?' Of course, that got a big applause. So, Paul went to the podium and said, 'Well, I have one question for you . . . if you're so rich, why aren't you smart?,' thereby setting back the academic-professional interaction by at least a decade."[42]

With the development of the CAPM, Sharpe had effectively taken investing out of the hands of the so-called experts or gunslingers and put it into the hands of individual investors. He made investing accessible, in the sense that people without much investing knowledge could still get a decent rate of return by investing in a passive portfolio or index fund. Sharpe reflected, "That's a good thing. It's a very good thing. On the other hand, I think it's important to understand that all index funds are not equally socially responsible. So, as we know, a lot of the narrower [funds], we call them index funds, are being used egregiously for . . . day trading and Lord-knows-what, in all kinds of gambling and betting activity."[43]

Not Alone

However, Sharpe wasn't alone in his quest for a convincing model of security prices. "Since Markowitz had provided a model for the requisite maximizing behavior, it is not surprising that I was not alone in exploring its implications for market equilibrium. Sometime in 1963, I received an unpublished paper from Jack Treynor containing somewhat similar conclusions.[44] In 1965, John Lintner published his important paper with very similar results. Later, Jan Mossin published a version that obtained the same relationships in a more general setting."[45]

The economist Jack Treynor probably developed the earliest version of what is now known as the CAPM, although he refers to Sharpe in his paper without a specific citation.[46] Treynor did not begin his career as an economist. He attended Haverford College in the 1950s, studying mathematics, and went on to obtain an MBA from Harvard Business School in 1955. In 1958, during a summer vacation, he read Franco Modigliani and Merton Miller's now-famous article that showed that under certain restrictive assumptions, the capital structure of a firm, with a mix of debt and equity, did not have an impact on the value of the firm.[47] Inspired, Treynor wrote forty-four pages of mathematical notes that eventually became the unpublished paper "Market Value, Time, and Risk." He showed the paper to the only professional economist he knew at the time, John Lintner at Harvard. "He didn't give me much encouragement. I suppose my paper seemed like a bunch of gobbledygook to John."[48] Eventually, Miller obtained a copy of the paper and shared it with Modigliani, who contacted Treynor to encourage him to study economics. Treynor followed Modigliani's advice, took a sabbatical from his job at consulting firm Arthur D. Little, and studied under Modigliani at the Massachusetts Institute of Technology (MIT). At Modigliani's suggestion, Treynor split his earlier paper into two parts. The first paper, written in 1962, called "Toward a Theory of Market Value of Risky Assets," wasn't published until 1999, as part of a book. After his sojourn at MIT, when Treynor returned to Arthur D. Little, he received a call from Modigliani telling him that Sharpe was working on the CAPM and suggesting that Treynor and Sharpe exchange papers, which they did. Treynor recalled, "I thought that if Sharpe was going to publish, what's the point of my publishing my paper?"[49] Unfortunately for Treynor, Nobel Prizes aren't awarded for unpublished research.

The objective of Treynor's paper was to create a theoretical model of the market value of assets that incorporated risk. Treynor's perspective differed from Sharpe's, as Treynor was interested in estimating the cost of capital faced by a firm. The cost of capital is important to firms for budgeting purposes and investment decisions. A key component of estimating the cost of capital is the cost of equity. However, the cost of equity from a firm's perspective is the same as the expected return from an equity investor's perspective. Treynor's model emphasized that investors wanted to be compensated with a risk premium, a higher expected return, for taking on more risk. Without using the term "market portfolio," Treynor showed that the holdings of any two investors would be identical under his assumptions except for the amount of the holdings. He also distinguished between what Sharpe referred to as market risks and diversifiable firm-specific risks.

Like Treynor, Lintner's work on the CAPM appears to have been inspired by Modigliani and Miller's work. John Lintner received an undergraduate degree from the University of Kansas, then completed his graduate work at Harvard in 1945, where he continued as a professor in business administration. Lintner hoped to refute Modigliani and Miller by developing a theory for valuing risky assets. Lintner probably read Treynor's draft in 1960 or 1961, years before his own work was published in 1965.[50] Of the competing versions of the CAPM, Lintner's was probably the most mathematically elegant. In fact, it includes close to one hundred equations and seventy-seven footnotes. In his own article Lintner acknowledges Sharpe's article, noting that it appeared in print when Lintner's paper was in final form and on its way to the printer. Interestingly, while Lintner acknowledges discussions and commentary from a number of colleagues, he doesn't mention Treynor.

Like Sharpe, Lintner was also concerned with the problem faced by investors of selecting optimal securities and included similar assumptions in his model, such as the ability to borrow or lend at a risk-free rate. Also like Sharpe, Lintner concluded that it wasn't the riskiness or standard deviation of returns that mattered for the pricing of a stock but rather how that stock's return varied relative to the overall market.

In a 1968 article by Eugene Fama that examined various versions of the CAPM, Fama noted that Sharpe's model and Lintner's model were equivalent approaches but that Sharpe himself failed to notice the significance of his results, the major one of which was in his twenty-second footnote.[51]

Similarly, Treynor failed to notice the significance of his results: "We can look back now and talk about the significance of the CAPM, but if it has any real significance, it wasn't evident at the time to anybody."[52]

The Norwegian economist Jan Mossin was the fourth person to come up with a version of the CAPM at roughly the same time as Sharpe. A 1959 graduate of the Norwegian School of Economics and Business, Mossin did his graduate studies at the Carnegie Institute of Technology (now Carnegie Mellon). Like Sharpe, it was the last chapter of Mossin's dissertation, "Studies in the Theory of Risk Bearing," that formed the basis of his capital asset pricing analysis. Mossin realized the importance of his work, publishing his paper in 1966,[53] before he had even completed his dissertation in 1968. While Sharpe's article was published in the *Journal of Finance*, Mossin chose to publish in an equally prestigious but more mathematically oriented economics journal, *Econometrica*. Unfortunately for Mossin, economics journals have a reputation for much slower turnaround compared with finance journals, a reputation that has lasted to this day. Mossin submitted a revised manuscript to *Econometrica* in December 1965, suggesting that he originally submitted the paper no later than 1964, when Sharpe first published his CAPM paper.

Mossin's primary interest was in the equilibrium conditions of the market as a whole and the supply and demand of assets. Mossin cited and critiqued Sharpe's paper, noting that their main conclusions were consistent with one another but that Sharpe's "lack of precision in the specification of equilibrium conditions leaves parts of his arguments somewhat indefinite."[54] Mossin discussed Sharpe's "so-called 'market line,'" or capital market line, but perhaps in a manner fitting a mathematically rigorous academic journal, he didn't present a graph of the line itself. Mossin discussed the "price of risk," the return-to-risk trade-off akin to the now-famous Sharpe ratio, but critiqued it as an unfortunate term, instead using the term "the price of risk reduction," making the analogy that we would "certainly hesitate to use the term 'price of garbage' for a city sanitation fee."

Academics can be a critical bunch, and there are often differences of opinion with respect to the appropriate level of mathematical rigor in economic analysis. However, Sharpe's formulation of the CAPM has stood the test of time, and others have filled in the mathematical gaps where needed.

Post-CAPM

Sharpe remained at the University of Washington through 1968 (with the exception of a year spent at the RAND Corporation), during which time he taught sixteen courses across a range of topics including finance, economics, computer science, statistics, and operations research.[55] Today, the teaching norm for academics in finance over a similar period might be only two or three courses. Sharpe quickly progressed through the academic ranks, being promoted from assistant professor to associate professor in 1963, then to professor in 1967. While at the University of Washington, he also consulted with the Boeing Company, the International Business Machines Corporation (today known as IBM), the RAND Corporation, Arthur D. Little Inc., McKinsey and Company, and Western Airlines. He also was an associate editor of the prestigious *Journal of Financial and Quantitative Analysis* based at the University of Washington.

Sharpe's description of his time at the University of Washington as "busy but highly productive" is a modest understatement. His curriculum vitae from this time lists twenty-four academic publications that appeared in print between 1961 and 1968—an incredible number by today's standards—plus a book on the BASIC computer language. Two more books were to follow by 1970. His academic research focused on expanding the CAPM and testing its empirical applications.[56]

In 1968, Sharpe moved south, to the University of California at Irvine. He was attracted to Irvine by the chance to participate in the experimental development of a school of social sciences that would have an interdisciplinary and quantitative focus, which sounded to Sharpe like a perfect fit. Unfortunately, it failed to meet his expectations. When an opportunity to take an academic position at Stanford University's Graduate School of Business arose, Sharpe jumped at it. However, while still at Irvine he was able to complete his book, *Portfolio Theory and Capital Markets*, which summarized his work on the CAPM.

Sharpe remained at Stanford from 1970 onward, first as an active professor, then in 1973 as a chaired professor, and subsequently as emeritus (1989–1992 and then since 1999). Later he reflected, "My years at Stanford have been all that anyone with interests in both research and teaching could have desired."[57] In the 1970s, Sharpe continued his research in the area of equilibrium models of capital markets, focusing on the implications of investor portfolio choice. His research interests were timely. In 1974, the Employee Retirement Income Security Act (ERISA) was passed, establishing private pension plan rules and requirements. These included the "prudent person rule," which required fiduciaries who were managing pension funds to act prudently in their investments, including a requirement to diversify investments. These rules and requirements dovetailed with the CAPM, which implied investments in a diverse market portfolio.

In the academic year 1976–1977, Sharpe visited the National Bureau of Economic Research as part of a team studying issues related to the minimum required amount of capital that banks should maintain relative to the amount of loans that banks were extending. Sharpe focused on the relationship between deposit insurance and default risk. The project warned of excessive risk taking among financial institutions. After the savings and loans crisis of the 1980s, Sharpe reflected, "Would that our results had been heeded by those concerned with savings and loans institutions in the United States in the subsequent decade!"[58] Much the same thing could be said of global financial institutions during the financial crisis of 2007–2009.

In 1978, Sharpe wrote a highly successful textbook simply titled *Investments*, which went through six editions up to 1999. During his book preparation, he created a simplified version of the well-known Black-Scholes/Merton option-pricing model. In the late 1970s and 1980s, Sharpe also consulted with Merrill Lynch, Wells Fargo Bank, and the Frank Russell Company, putting his research into practice. As Sharpe noted, "Theory is good for practice, and practice is good for helping you figure out what theory to work on and whether a theory is useful. So, I had been very much in the sort of ambidextrous state of having a foot in each camp. Sometimes I had more weight on one foot, sometimes more on the other."[59] At Merrill, Sharpe was primarily involved with designing services to estimate beta and measure risk-adjusted portfolio performance. At Wells Fargo he was involved in the creation of index funds, a visionary idea to develop the now-ubiquitous products that replicate overall market portfolios such as the S&P 500 index.

During this time, Sharpe also developed a simple reward-to-variability measure, the now-famous Sharpe ratio. Mathematically speaking, the Sharpe ratio is the return on a stock or portfolio in excess of a risk-free return, divided by the standard deviation of the return. This simple measure is used extensively today to measure investment performance.

In 1980, Sharpe was honored with his election as president of the American Finance Association. His presidential address, titled "Decentralized Investment Management," addressed the common practice among large institutional investors of hiring numerous portfolio managers.[60] In the CAPM world, this practice should be redundant, since the optimal portfolio of risky assets is simply the market portfolio. However, Sharpe was able to emphasize the importance of distinguishing between diversification of *judgment*, hiring several managers to invest in one subset of securities, and diversification of *style*, investing in different sets of securities.

In 1985, Sharpe took up a new research focus: dealing with the key issues investors faced when deciding on how much to invest in various asset classes such as stocks, bonds, real estate, and cash. He prepared a package of educational materials for investors that included the book *Asset Allocation Tools*, optimization software, and relevant databases. In 1986, Sharpe took a two-year leave from Stanford to establish William F. Sharpe Associates, a consulting firm that focused on the research and development of procedures to assist pension funds, endowments, and foundations with their asset allocation decisions. His academic status at Stanford changed in 1989 from active professor to professor emeritus, allowing him to give up regular teaching and devote more time to his firm.

The following year, Sharpe was again honored, along with Harry Markowitz and Merton Miller, with the Nobel Prize in Economics, for, in the words of the committee, "their pioneering work in the theory of financial economics." Sharpe's achievements and contributions to financial economics were spotlighted in a tribute by the Wharton School's Robert Litzenberger: "The impact of [Sharpe's] pathbreaking research goes far beyond the academic community by ultimately improving, through numerous applications to practical problems in both investments and financial management, the allocative efficiency of capital markets. These applications range from risk-adjusted performance measurement for mutual funds and pension funds to the determination of prices for regulated natural monopolies such as electric and telephone utilities."[61] In particular, Litzenberger highlighted Sharpe's 1964 CAPM article as "a tour de force in simple economic logic."

It seemed that Sharpe had reached the apex of his career. However, he remained active in his research. In 1996 he cofounded Financial Engines, a firm that pioneered independent online investment advice, with a focus on investing for retirement.[62] "A colleague of mine in the law school, in securities, Joe Grundfest, who had been on the SEC [Securities Exchange Commission], and I were having coffee. He gave me a long song-and-dance about how if I really wanted to impact real people making these decisions, we needed to form a firm, etc. That was sort of how Financial Engines began. He introduced me to a fellow who was a lawyer, who also could help start firms, Craig Johnson. The three of us, basically, created Financial Engines. The goal was to help individual employees better use the 401(k) plans that were available to them for retirement savings. And, of course, the idea was to apply all the work that had been done in the academic finance field, which we set about doing."[63]

Sharpe explained his interest in retirement planning and investing. "I and many others focused for many years on what we call the accumulation phase. You're saving for your retirement. And while that was difficult, because it was a multiperiod problem en route, we could sort of take a shortcut and say, 'Well, what you care about is the probability distribution of your wealth on the day you retire.' We could sort of stop at that point. There were multiple periods getting there, but at least there was one distribution that was the object of choice or of analysis.

"If you had access to a truly diversified, true broad market portfolio, you just divide your money between that and something low or very low risk. Either low real risk or possibly low nominal risk. Now, in a 401(k) plan, you don't have that luxury. You have to work with whatever the investment vehicles are that the employer makes available, so that's a more difficult problem. But you could say, 'Well, we could characterize your preferences by some measure of risk-aversion, vis-à-vis the money you have the day you retire.' That's a one-parameter kind of thing that's helpful. I'm now devoting my effort to the decumulation phase. What do you do after you retire, or on the day you retire? How do you allocate money and investment, etc., over the years you have left, whatever they may be? That's a much, much, much harder problem.

"First of all, you don't know how long you're going to live or how long your [spouse] or partner is going to live. Second, you know, there are many alternative investment strategies, even though they may, ideally, all have some market base. But they don't all have to be just the market and something riskless. And third, we really don't know what people's preferences are. . . . You kind of need a multiperiod equilibrium model, not the one-period kind of CAPM, but that's not horribly hard to get."[64]

In addition to his practical work with Financial Engines, Sharpe continued to undertake innovative research. In 1992, he developed a simple approach to measuring fund performance that helped to "make order out of chaos" through what he called an asset-class factor model: attributing the overall return on a fund to the return on various stock and bond indices.[65] He also produced a book based on his Princeton lectures on finance that reviewed his previous work and presented methods for analyzing security prices that accounted for investor behavior.[66]

If You Can't Beat the Market, Join It

Sharpe has three key messages that summarize the fundamental insights of the CAPM. The first message is the importance of the market portfolio as the one and only important risky asset. "The three principles in real estate are location, location, and location; in some ways in investments it's diversify, diversify, diversify."[67] Investing in the market portfolio ensures the ultimate amount of diversification.

The second message is to keep transaction costs low. "Regarding costs, quite frankly it's sort of like the Lake Wobegon[68] thesis: The average investor cannot beat the average investor before costs; and if you are trying to find hot stocks or the best new growth fund manager, or listening to Jim Cramer[69] . . . you are going to end up bearing extra risk, on average not getting any reward for it, and spending a lot of money in the bargain."[70]

The third message is about the uncertain compensation for assuming more risk. "What the theory says, at least broadly, if you take more, let's call it market risk, economic risk—in other words if you put yourself in a position to do really badly in bad times . . . then in some sense you should 'expect'—and that's a mathematical or statistical concept—to do better; or another way of saying it is in the very long run maybe you will do better. But that package gives you higher expected return and greater risk. And in any given period . . . you could get higher return, you could get really higher return, you could also get your head handed to you—and a lot of people forgot that [during the financial crisis when stock prices dropped substantially]."[71]

When asked about index investing, Sharpe answered, "I think indexing covers a multitude of sins, but I think indexing is a good idea for a nontrivial part of your money. I'm not saying you have to index everything, but I'm a big proponent of indexing. It also has to be cheap indexing."[72]

Sharpe pointed out another cost related to active management for individual investors. "Taxable investors have yet another reason to worry about active management. It generates realized capital gains far more frequently than does passive management. This requires the payment of taxes that could otherwise be either deferred or, in some cases, avoided entirely."[73]

Do any active managers outperform the market? "Of course, many active managers will beat the market and their passive brethren before costs in any given period. And a substantial minority will beat the market and the index funds after costs. The trick is to identify the winners in advance. While it would be tempting to say that this only requires looking for those that have won in the past, the evidence is not very supportive of this assertion. To some extent this is due to the fact that many past winners were simply lucky. In other cases, competition among professional investors results in prices adjusting so previously winning methods no longer work."[74] Another crucial insight contained in the CAPM is that there may be strategies that outperform a market benchmark such as the S&P 500 by providing a higher average return. However, many of these strategies at their core are just covert ways to produce higher beta. Sharpe has been credited with popularizing a coin-flipping exercise in MBA classes as a demonstration of this principle. Students are asked to flip coins in this example. Some students may toss a long string of heads, like untalented analysts who appear to be doing well, but are really just lucky.[75]

Sharpe summarized his four simple principles of good financial advice as, "Diversify, economize, personalize, contextualize." Expanding on this, Sharpe continued, "Diversify, diversify, diversify! The closer you come to holding the entire market portfolio, the higher your expected return for the risk you take. Economize by avoiding unnecessary investment expenses, especially management fees and trading costs. Personalize by taking into account the things that make your situation unique, especially the risks you face outside the financial markets. . . . Finally, contextualize. Remember, if you bet that market prices are wrong [by investing heavily in a single stock or sector], you have to be able to justify why you're right and the market isn't. Asset prices are not determined by someone from Mars."[76]

Sharpe's Perfect Portfolio

Finally, what does Sharpe think is the representative Perfect Portfolio?[77] "Ideally, it would be a combination of a riskless real portfolio, something like TIPS [Treasury Inflation-Protected Securities, government bonds that tie principal and coupons to the inflation rate] . . . and all the tradable bonds and stocks in the world in market proportions. What I'm calling, at least at the moment, the 'World Bond-Stock Fund.' The question was then, 'All right, if you really wanted to invest in this thing today, given what's available, what would you do?' So, I looked at various index funds, ETFs [exchange-traded funds], with a very, very careful eye on expense ratios, because expense ratios, as you know, can add up hugely.

"I put some of my money in this exact portfolio. . . . [I]t has four components. . . . The reason it's four is the fees are lower if you use these four than some other. They all happen to be Vanguard. You could come close with Schwab or Fidelity. They are a U.S. total stock market fund, a non-U.S., what amounts to a proxy for total stock market fund, a U.S. total bond market fund, and then a non-U.S. total bond market fund. Now, I should say the non-U.S. bond fund is currency hedged, and I'm not sure how I feel about that, but that's what it is."

Sharpe added an important caveat to his comments, aimed at the typical individual investor. "That's how you invest, but you've got to save enough first. Most people, many people, are not." Asked how investors should save more, he replied, "Sacrifice, you know? I mean, the numbers are staggering when you look at longevity and just do simple calculations. You've just got to save an awful lot, because nobody else is going to do it for you, except Social Security. While some of us might wish to have more generous Social Security, at least for lower income, that's probably not going to happen."

Sharpe also discussed the "crusade" he's on, trying to make investors aware of the fees they paid for many investment products. "Expenses really matter. I think it is really important to understand that [a large] amount of money is being transferred from individuals trying to save, and finance their retirement in particular, to the financial industry . . . so much needless expense," with investors not getting any real value from the expenses. Sharpe noted that many individuals are approaching retirement with "serious amounts of money," which wasn't previously the case. He singled out the growing wealth in defined contribution plans: everyone is "trying to get a piece of that pie." From a behavioral perspective, many products are being created that "[sound] just great" but end up extracting value from savings through the fees charged. From an academic perspective, investor education is required so that individuals aren't "suckered into these systems that play to people's behavioral tendencies." Sharpe's Perfect Portfolio would include the lowest fees possible—but the investor must be cautious. While financial advisers may add considerable value to your portfolio, make sure you know what you're paying in fees and what you're getting in return.

4

Eugene Fama and Efficient Markets

WE'RE CONSTANTLY EXPOSED to quotations of stock *prices*, but we rarely give a thought to what this has to do with the true *value* of stocks. Eugene (Gene) Fama probably influences our thinking about price versus value more than anyone else today with his very simple hypothesis: when it comes to stocks, what you see is what you get. In other words, if the market for stocks is efficient, then market prices reflect our collective best guess as to the underlying intrinsic value of stocks.

Fama first proposed the "efficient market hypothesis" (EMH) and then spent his career developing a wide range of tests of the EMH. Research in efficient markets kept academics busy for decades. In a special issue devoted to the topic in 1978, Michael Jensen, editor of the prestigious *Journal of Financial Economics*, wrote, "I believe there is no other proposition in economics which has more solid empirical evidence supporting it than the Efficient Market Hypothesis. This hypothesis has been tested and, with very few exceptions, found consistent with the data in a wide variety of markets."[1]

The concept of market efficiency had a deep effect on the investment industry, one that still resonates today, in the debate over active versus passive investment strategies and the role that risk plays in determining the fair value of equities. This matters because if stocks are fairly priced, then we shouldn't spend time trying to outperform the overall market, incurring active management costs. Even if a market is not efficient, after Fama's results you have to ask yourself why, how much, and whether an apparent inefficiency is exploitable and whether you're really different from other investors in the way you think and act. Fama himself doesn't claim that markets are always and everywhere perfectly efficient, just that in most cases they are closer to efficiency than not, and the differences are small and hard to profit from. The existence and popularity of index funds comes entirely from the viewpoint of efficient markets and dovetails nicely with Markowitz's message of the importance of diversification and Sharpe's highlighting of the importance of the market portfolio. Fama's empirical research has forever changed the practice of investment management and, consequently, what might go into the Perfect Portfolio.

The Two Camps

In order to appreciate Fama's contribution to the Perfect Portfolio, we need to step back and understand two opposing important academic camps, both with several Nobel laureates to their credit: those who advocate the EMH, such as Fama, and its behavioral critics, such as Robert Shiller (the subject of chapter 9). In the mid-1960s, Fama coined the phrase the "efficient market hypothesis" to describe a market in which prices always reflect all relevant information. Market efficiency is the result of competition and free entry. Basic economic logic implies that markets contain available information for the simple reason that if they didn't, people could make money by trading. For example, if a stock with promising earnings growth was priced cheaply, people would buy it, sending the price up to the discounted value of those promising earnings. Competition in markets turns out to have subtle consequences in a variety of ways, including the behavior of stocks around news events and the surprising difficulty that asset managers have in delivering better performance than indices, an acid test of efficiency.

The first prediction of the EMH is that stock prices should follow random walks. The successive changes of a random walk are unpredictable, and stock price changes in an efficient market should be unpredictable; otherwise, people could make easy money. It should not matter today what yesterday's price change was, since only new and relevant information should move stock prices. (To be fully precise, the stock price should follow a random walk after adjustment for dividends and a risk premium.)

The notion of random walks can be traced back to 1827, when botanist Robert Brown used a microscope to examine dust grains floating in water and noticed their erratic behavior, later memorialized as Brownian motion. On March 29, 1900, a French postgraduate student, Louis Bachelier, successfully defended his dissertation, "The Theory of Speculation," in which he proposed a model of Brownian motion to explain a similarly random movement but in security prices rather than dust grains—five years before Albert Einstein famously determined the cause of Brown's observations, providing evidence that atoms and molecules existed.[2] Bachelier's research was largely forgotten for half a century until it was rediscovered by University of Chicago mathematician Leonard Jimmie Savage, who translated the work and brought it to the attention of Paul Samuelson, the first American recipient of the Nobel Prize in Economics. The translation was published in 1964 in a book by economist Paul Cootner, *The Random Character of Stock Market Prices*, along with other empirical studies on that topic. The following year, Fama published his dissertation showing the randomness of stock price changes. Shortly afterward, in 1970, he published an important article that emphasized strong empirical support for the EMH.[3]

Later in that decade, a new view of market efficiency emerged. Market efficiency, like all classical microeconomics, assumes that investors are rational. Market efficiency is just simple supply and demand economics brought to asset markets. A camp of academics, known as the behavioralists, questioned this assumption. The best-known behavioral critics of rationality included Nobel laureate Daniel Kahneman and his longtime collaborator Amos Tversky (whose untimely passing almost certainly prevented him from sharing the award with Kahneman) as well as fellow Nobel laureates Robert Shiller and Richard (Dick) Thaler. As described in chapter 2, Kahneman and Tversky's famous 1979 prospect theory presented a decision-making model in which people made decisions by weighing losses much more heavily than their gains. This model captured laboratory evidence from psychological tests that was inconsistent with expected utility theory, in which a distinction between losses and gains is present but is not so stark. The behavioral critics of rationality also devised empirical studies in which investors seemed to deviate from the predictions of simple models of rational behavior. According to the behavioralists, these apparent deviations from rationality could be attributed to investor biases, such as excessive optimism, overconfidence, overreaction, loss aversion, herding, miscalibration of probabilities, and mental accounting. There will be more on the behavioralists in chapter 9.

Trying to Beat the Market

Eugene Fama's grandparents emigrated from Sicily and came to the United States in the early 1900s, making him a proud third-generation Italian American.[4] His parents, aunts, and uncles started their working lives around the beginning of the Great Depression. With few opportunities, they worked manual jobs. His father was a truck driver but worked on battleships at the Boston shipyard during World War II. Fama himself was born just prior to the start of the war, on Valentine's Day 1939, in Somerville, Massachusetts, a suburb of Boston. Soon after the family moved a short distance across the Mystic River to Medford, the home of Tufts University.

As a young boy, Fama attended St. James, a Catholic grammar school, and later he attended Malden Catholic High School, a private Catholic secondary school for young men established in 1932 by the Xaverian Brothers religious order in Malden, Massachusetts. He was like others who attended the school, a friendly young man from a working-class family but with one difference: the time and intense effort he devoted to both academics and athletics. Despite his unassuming physique—he is less than five feet, eight inches in height—Fama was heavily involved in sports and was good at a number of them. He played basketball and baseball and also high-jumped, coming second in the state meet. He later recounted, "The only guy that beat me was the first American to jump over seven feet. But he didn't take off his sweat suit before he beat me. He left it on and still beat me."[5]

Fama's passion, however, was football. In fact, he claims to have invented the split end position, the offensive player who is a lineman but lines up some distance from the offensive line, attributing his innovation to survival instincts—trying to avoid being beaten by much larger defensive tackles.[6] But unlike many in the modern game, he could play both sides of the ball. A classmate commented, "I just remember him as a very aggressive and fearless defender in football. The effort he gave in practice drills, he was all out, all the time. I remember specifically a spring practice game against Woburn. Gene's playing on the outside linebacker slot. He knocked down all the interference and made the tackle. He would stick his head in there and do what he could."[7] Fama was inducted into the school's athletic hall of fame in 1992 for his achievements in football, baseball, and track. A fellow high school student noted that he "was a very determined kind of character, which reflects the way things turned out in his life."[8]

Fama attended Tufts University between 1956 and 1960, the first in his family line to attend college. In his second year, he married his high school sweetheart, Sallyann Dimeco, who was a student at Girls' Catholic High School, across the street from his own school. Fama fully intended to become a high school teacher and sports coach. However, after two years majoring in Romance languages, he became bored and took an economics course. He was immediately enthralled, so he took more.

One of Fama's economics professors at Tufts was Harry Ernst, who, like Fama, was also a gifted athlete. Ernst was a recent Boston College graduate with an outstanding performance in golf as a student—he was inducted into the Varsity Club Hall of Fame in 1999—and an award-winning golf career after graduation.[9] (Ernst would go on to make twelve holes in one, all after he turned sixty.[10]) But Ernst also ran a stock market forecasting service. Between his junior and senior years, Fama worked for Ernst. Part of his job was to create methods to forecast the market. The strategies always worked on the historical data he had gathered. However, there was a problem: "I tried to figure out ways to beat the market for Harry Ernst, who taught economics. I came up with mechanical kinds of strategies. He always made me have a hold-out sample to see if the strategy worked on new data—and it never did."[11] This lesson would have an important impact on Fama's later research into efficient markets.

The Phone Call That Changed Everything

Fama's professors at Tufts (most of whom, including Ernst, had PhDs in economics from Harvard) encouraged him to apply to the University of Chicago's business school for graduate work. Although Fama also applied to other schools and was accepted by many, by April 1960 he still hadn't heard back from Chicago. So, he called the university directly, where the dean of students, Jeff Metcalf, answered. There was no record of his application, Metcalf explained, but the two of them hit it off, and Metcalf inquired about his grades. Metcalf indicated that Chicago had a scholarship reserved for a qualified Tufts graduate and offered it to Fama, who quickly accepted. He later mused, "I wonder what path my professional life would have taken if Jeff didn't answer the phone that day. Serendipity!"[12]

Fama attended Chicago's PhD program in economics between 1960 and 1964. In his second year, near the completion of his coursework, he began to attend the department's Econometrics Workshop. An occasional presenter was Benoit Mandelbrot, a highly regarded mathematician on staff as a researcher at the IBM Thomas J. Watson Research Center and a visiting professor at Harvard University, today best known for his work on fractals and their irregular geometry. Fama enjoyed strolling the campus with Mandelbrot and learned much about probability distributions from him, including Mandelbrot's research on cotton prices. As noted earlier, most people are familiar with the normal distribution or bell curve, in which a population clusters around an average much like the shape of a bell. However, Mandelbrot studied other distributions that had "fatter" tails than the normal distribution, meaning a greater likelihood of extreme events.

Other key influences on Fama were the future laureate Merton Miller, who became a mentor in both finance and economics, and Harry

Roberts, a statistician who inspired Fama with his careful and concise empirical work. All these individuals, along with Lester Tesler at the University of Chicago, were extremely interested in the emerging research of the behavior of stock prices. With the advent of more powerful computers, the timing for empirical work was just right.

At the end of his second year, on the advice of Miller, Fama chose for his dissertation to investigate the distribution of stock returns of the well-known blue-chip Dow Jones 30 stocks, such as AT&T, Chrysler, General Electric, General Motors, and Procter & Gamble. He was among the first researchers to use a computer to study the stock market, programming it in the Fortran computer language. Fama recounted, "I was using [the University of Chicago mainframe computer], and there was a guy in the physics department using it at night . . . because they were very limited in capacity. We were the only ones. We would call IBM and say, 'This compiler is not working, it's doing this,' and they'd laugh. And after the second time they didn't laugh anymore."[13]

Fama completed his doctorate work in 1963 but officially obtained his PhD in 1964 after his dissertation was formally approved for publication in *Journal of Business*, an academic journal affiliated with the University of Chicago. In those days manuscripts were typed, an onerous process. "You didn't have to have your thesis typed if it was published. If you submitted a typed manuscript, it had to conform to very strict rules. The guy who checked it over was a fanatic about it, so if you could get it published you'd save yourself a lot of time trying to meet all the rules about typing it," he recalled.[14]

Before his graduation, however, Fama obtained a teaching position at Chicago in 1963, where he has remained. He said, reminiscing about those early years, "Looking back at that time, finance courses were ridiculous. . . . When I joined the faculty here, nobody teaching investments was teaching portfolio theory. This is 1963; Markowitz's thesis here was 1953, but nobody was teaching it. When I went to Merton Miller and said, 'What should I teach?,' he said, 'We hired you to teach the new stuff.' So, I just took Markowitz's book and handed it to the students and said, 'This is what we do.'"[15] Fama was promoted from assistant professor to associate professor in 1966, to full professor in

1968, and then to a chaired position in 1973. "The school fits my personality. I can be pretty sarcastic and forceful, and I'm not too tactful at commenting on people's work. That's a characteristic of everybody here. People are ruthless with one another. But it's not personal."[16]

A Random Walk Uncovers Fat Tails

Fama's doctoral dissertation, "The Behavior of Stock-Market Prices," was, in fact, a tour de force.[17] In it, he conclusively answered a question that had dogged investors and analysts for decades: To what extent can past stock prices predict future stock prices?

Recall that Fama had unsuccessfully tried to devise profitable trading strategies while at Tufts. "When I came to the University of Chicago," he recounted, "and people were talking about these things, it suddenly dawned on me that maybe that was the nature of the game, that there just wasn't much predictability of returns because markets were working efficiently. That was the beginning of the story."[18]

Investors and analysts who tried to detect geometric patterns in past stock prices that would point to a trend (a discipline known as technical analysis, and also charting) contended that there was important information in past prices. These analysts assumed that history repeated itself. For example, if past prices formed a head-and-shoulders pattern, then chartists predicted that the stock would continue to fall below the shoulder level, just as had happened to other stocks that had price charts resembling the head-and-shoulders pattern. In contrast, the random walk hypothesis suggested that it's no easier to predict stock prices than it is to pick the correct lottery numbers: just because certain numbers turned up in the past, they were no more and no less likely to turn up next time. Fama showed, in what he described as "nauseating detail," that the random walk model was valid—none of these alleged schemes for forecasting price changes work reliably—when applied to his extensive database of daily returns of Dow Jones 30 stocks from 1958 to 1962, an incredible amount of data at the time.[19]

There are several different types of random walks. In general, it's a random process that describes a path of successive unpredictable random steps. Consider a simple example: You play a coin-toss game with your partner based on three successive coin tosses, with each flip having an equal chance of a head (H) or tail (T). Assign +1 to a head-flip (you win a dollar), and −1 to a tail-flip (you lose a dollar). Clearly, the average value you will win or lose at each step and in the whole game is zero. The key point is that each possible path within a game is random. If you flipped two heads in a row, the odds of another head are still fifty-fifty, the same as if you had flipped two tails in a row.

Now, consider stock price changes instead of coin flips. Like coin flips, Fama showed that successive price changes could not be predicted by past patterns in stock prices. Just because a stock price increased by 1 percent yesterday (like flipping a head) did not imply that it would increase or decrease today. Fama also showed that successive price changes conformed to a probability distribution—not the heads/tails of the coin flip but instead something closer to the classic bell curve or normal distribution.

Fama concluded that "chart reading, though perhaps an interesting pastime, is of no real value to the stock market investor."[20] Furthermore, he found statistical evidence, consistent with Mandelbrot's research into cotton prices, that stock price changes or returns were distributed with fatter tails than one would expect with a normal distribution. In other words, on numerous occasions there were more extreme daily gains and losses of the sort that would only occur once in several decades if stock returns were truly following a normal distribution.

In the subsequent fifty-plus years since Fama's seminal study, markets have witnessed numerous additional occasions of fat-tail events. For example, on October 19, 1987, the Dow Jones stocks declined on average by an unprecedented 22.6 percent. Yet two days later, the same stocks increased in price by 10.1 percent. During the financial crisis of 2007–2009 and in the early stages of the 2020 COVID-19 pandemic, extreme daily gains and losses of several percentage points were common. These fat-tail events, more recently called "black swan" events, are no longer believed to be as rare as previously thought.[21] The important conclusion is that given fatter tails, stock returns are much riskier than the widely used normal distribution models predict. These fat tails are often confused with violations of the EMH. Yet fat tails have been part of the EMH since Fama's dissertation. The unpredictability of stock returns has nothing to do with the shape of the distribution of stock returns.

The Big Event

When Fama was working on his dissertation, the Center for Research in Security Prices (CRSP)—a well-known source of stock market data and a financial think tank based at the University of Chicago—was still in its infancy, and its data files weren't yet available for his use. Once those files became available, after Fama had finished his dissertation, one of the cofounders of CRSP, business professor and former associate dean James Lorie, approached Fama, worried that no one would use the data and the center would lose its funding. "'Can't you do something with this?,'" Lorie asked Fama. "And I said, 'Well, what's on the tape?'[22] I had just finished my thesis where I collected my own data. And he said, 'Well, we've got prices and we have stock splits' and that's the only thing that was on there [besides prices], stock splits. So, I said 'Okay, we'll do a study of stock splits.'"[23]

A stock split is an event whereby a firm with a stock price of (for example) \$60 replaces each existing share with (again, for example) two new shares. This particular split would be known as a two-for-one stock split. The shareowner now has twice as many shares, but since every shareholder has twice as many shares, there is no change in the percent of shares owned. You might expect that the shares would now be worth half their previous value. However, instead of each new share being worth \$30 apiece, on the day of the split the stock sometimes ends up being worth more than expected, say \$31 per new share. In the efficient markets interpretation of that outcome, market participants consider the announcement of stock splits to contain new information about the stock, such as a sign of anticipated growth in earnings and dividends.

Fama joined with the cofounder of CRSP, Lawrence Fisher, and graduate students Michael Jensen and Richard Roll to conduct rigorous research on stock splits.[24] He later dryly noted that "Jensen and Roll were PhD students at the time, so I handed it off to them to do the dirty work, and then that's how that paper developed."[25] The group gathered information on 940 split "events" across numerous firms over a thirty-three-year period from 1927 to 1959, developing the first "event study," as this type of research is now called. To isolate any information around the split, the group adjusted each stock split during the month of its announcement relative to the overall stock market during that month. They then aggregated the data across all firms and examined the thirty months before and after the split. Finally, they calculated the cumulative total of the excess returns relative to the market, known as the "residual" returns, from month –30 through month 0 (the month of the split) and continuing through month +30, as shown in figure 4.1.

They found that the cumulative average residuals rose well before the split, particularly in the few months leading up to the announcement, but after the split the average residuals were randomly distributed around zero. Prior to the split, companies were doing well and experienced "dramatic increases in expected earnings and dividends."[26] Stock splits tend to be associated with companies announcing dividend increases. Since companies are reluctant to decrease dividends, the increase in dividends signals that the firm's prospects are strong. The run-up in cumulative average residuals isn't surprising. What's striking about the chart is the relative flatness of the cumulative average residuals after splits. After the split, nothing unusual happened. Whatever news the split conveyed was instantly and permanently incorporated into stock prices. There was no subsequent drift up, for example, in which news slowly diffused through investors.

Fama, Fisher, Jensen, and Roll (often abbreviated to FFJR) repeated this exercise, dividing their data between a sample of stocks that experienced subsequent dividend increases (anticipated by investors) and those that did not. In the former sample they found a similar picture to that above, except after the split the residuals were slightly more positive around the time dividends were actually increased. In the latter sample, however, the postsplit residuals were negative, as the anticipated increase in dividends did not materialize. They concluded by the positive residual on the day of the split announcement and near-zero residuals subsequently that markets indeed reacted quickly to the information contained in stock split announcements.

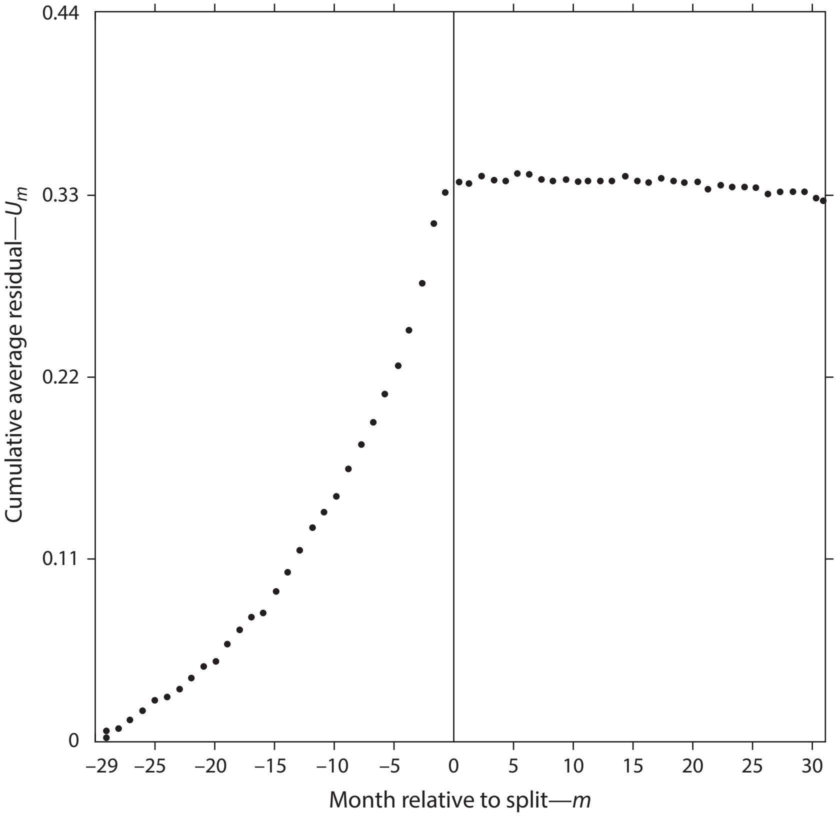

FIGURE 4.1: Cumulative average residuals for firms in months prior to and subsequent to the stock spilt. This chart is reprinted from Eugene Fama, Lawrence Fisher, Michael Jensen, and Richard Roll, "The Adjustment of Stock Prices to New Information," *International Economic Review* 10 (1969): 13.

The authors submitted their results to the *International Economic Review* for consideration. In the typical process, the journal editor assigns the paper to one or more referees who review it blind—that is, without knowing the identity of the authors. The referees critique the paper and either recommend that the editor reject it or ask the authors to make revisions to make it publishable. After more than a year had passed without hearing from the editor, Fama assumed that the paper had been rejected. Instead, the authors received a short letter indicating that the referee had in effect said "it's great, publish it"—an almost unheard-of reply! This referee turned out to be Franco Modigliani, himself a future recipient of the Nobel Prize in Economics.

Fama later noted that what was unique about the paper, relative to later event studies, was that it contained no formal statistical tests, a testament to the strength of their results. Since then, thousands of event studies—with statistical tests—have been conducted.

In Fine Form: Efficient Markets

If there is one part of Fama's work that the average person on the street might have heard about, it's probably the EMH. Fama created a phrase for the ages when he wrote "efficient market hypothesis" in a paper for the University of Chicago Business School, later republished as the 1965 *Financial Analysts Journal* article "Random Walks in Stock-Market Prices."[27] In that article, as Fama originally put it, "on the average, competition will cause the full effects of new information on intrinsic value to be reflected 'instantaneously' in actual prices." An efficient market was one "where there are large numbers of rational profit-maximizers actively competing, with each trying to predict future market values of individual securities, and where important current information is almost freely available to all participants. . . . Actual prices of individual securities already reflect the effects of information based on events that have already occurred. . . . In other words, in an efficient market at any point in time the actual price of a security will be a good estimate of its intrinsic value."

The term caught on. In fact, Fama's review paper on the subject might be his greatest early contribution to the theory of efficient markets, appearing in the *Journal of Finance* in 1970.[28] As you might guess from the name, a review paper reviews the previously published research findings in an area by various academics, sometimes including the author.

In his highly influential review, Fama synthesized most of the known theory and empirical work on market efficiency and classified them into three distinct versions of the EMH. Given a definition of market efficiency where "prices always fully reflect available information," he distinguished among three different types of information that researchers could use to test the EMH. He defined weak-form tests as those that only considered historical information, such as the information used by technical analysts or chartists. He defined semistrong-form tests as those that considered any public information, such as the announcement of earnings or stock splits or the information released in annual reports and used by fundamental analysts. Finally, he defined strong-form tests as those that considered all available information, including information only known to insiders or professionals.

The weak-form tests in Fama's review presented overwhelming support for the EMH. He summarized the results of studies that showed stock price changes following a random walk, including the brilliant study from 1900 by Bachelier. Moreover, other researchers had tried to uncover patterns in stock prices, much like Fama's dissertation, to little avail. Additionally, attempts at systematically replicating the processes used by technical analysts—for example, filter rules that called for purchasing once its price increased by a certain percentage and holding until it declined by another percentage—failed to generate any excess profits.

The semistrong-form tests also failed to reject the EMH. In addition to being the first event study, the FFJR paper discussed earlier showed that the information in announced stock splits expressed itself in excess returns well before and around the announcement but not after the announcement. This was consistent with the semistrong-form EMH. Further support for the semistrong form came from Fama's PhD students (and soon-to-be professors) Ray Ball and Philip Brown at the University of Chicago, who applied the same methodology to study earnings announcements.[29] They divided their sample into firms that experienced an increase or a decrease in earnings relative to the overall market during the year. In advance of the year-end earnings announcements, the excess returns above the market as a whole were positive for the increased-earnings firms and negative for the decreased-earnings firms throughout the year. No more than 10–15 percent of the information in the earnings announcements was anticipated by the announcement month, providing further support for the semistrong form of the EMH. As part of his PhD dissertation, another of Fama's students, future

Nobel laureate Myron Scholes (featured in chapter 6), found that markets reacted negatively around the announcement of secondary common share offerings, which reflected negative information related to someone selling a large block of stock.

On the other hand, the empirical evidence often contradicted the strong form of the EMH. Insider information wasn't typically incorporated into market prices and could be used to generate profit. For example, researchers found that specialists on the New York Stock Exchange, whose roles were to make a market in certain stocks by determining a price that matched buyer and seller, were unsurprisingly able to earn monopolistic profits with their monopolistic information, visibly refuting the strong form of the EMH. Scholes's dissertation, mentioned above, also suggested that officers of a company had monopolistic information they could use to their advantage. The failure of the strong form with inside information wasn't surprising. Fama never said that efficiency holds always and everywhere but instead implied that markets are always inefficient, but it's only a matter of degree. Laws and ethics against trading on inside information turn out to have some bite, so private information that's known to someone generally doesn't appear in market prices. The fact that inside information rejects the EMH is a nice proof that the EMH is in fact a testable proposition.

The logical next step of Fama's strong-form test was to examine whether any professionals, such as mutual fund managers, were able to earn excess returns more than one could expect by chance, using their extensive analysis of public information beyond past stock prices. For his sample of 115 mutual funds and data between 1945 and 1964, Jensen was able to answer the question with a resounding "no" in a groundbreaking study that used the capital asset pricing model (CAPM), discussed in chapter 3, as a baseline for expected returns.[30] Since managers can always just hold a combination of bonds and a passive market portfolio, a regression plot of the returns of mutual funds above a risk-free asset versus the returns on the market as a whole above a risk-free asset will measure how much managers can beat the market by using private information. This intercept is usually referred to as alpha. If fund managers have information superior to general market participants and thus are able to earn superior returns compared to what one can obtain from a passive stock portfolio plus bonds, then their alphas should be positive and significant. Jensen found that, on average, fund managers were generating negative alpha—now referred to as Jensen's alpha—even before accounting for fees. This implied that, on average, funds weren't able to outperform a "buy and hold the market" strategy. Furthermore, only three individual funds statistically significantly outperformed—even fewer than what one would expect by chance.

Fama recently commented on the phenomenal impact of Jensen's study. "[On] Wall Street [in the 1960s], there were no standards [and] there were very few mutual funds, and you were free to say anything you wanted about what your performance looked like. And this was a direct challenge to say, 'Let's start measuring.' And when the CAPM came along a couple of years later and Mike Jensen wrote his thesis on the performance of mutual funds, that kind of lit the bomb, really, in a sense that, now, you couldn't get away without actually testing how well you were doing, or somebody else was going to do it, for sure. So that started the whole performance evaluation business which goes on to this day."[31] To this day, though academics are able to find all sorts of apparent violations of the EMH in research data, the fact that so few investment managers reliably beat indices is a hard nut to crack for the view that markets are inefficient in an economically meaningful sense.

These three forms of the EMH were not the only advances in Fama's 1970 *Journal of Finance* paper. In his review, Fama expounded the "joint hypothesis problem." Testing whether or not a market is efficient involves two tests: (1) whether markets are incorporating all available information into prices and (2) the particular method by which prices are formed, in particular how much prices are discounted due to risk. Because we don't know how markets form prices, we have to rely on models such as Sharpe's CAPM. Fama noted, "The results of tests based on this assumption [of expected returns] depend to some extent on its validity as well as on the efficiency of the market."[32] Therefore, if a particular test of efficiency has been rejected, it may not be because markets aren't efficient and could be due to the fact that we have the wrong model of price formation. Thus, a test of market efficiency is always a joint test of both market efficiency and the validity of the asset-pricing model used in the test. The corollary of market efficiency tests is that most tests of asset-pricing models assume that markets are efficient, so those tests are joint tests as well. As Fama put it, "Asset pricing and market efficiency are forever joined at the hip."[33]

Twenty-one years later, Fama wrote a follow-up review to his 1970 classic, noting how large the literature on market efficiency had grown.[34] He updated his three categories of efficient markets testing to focus on three related tests—return predictability in general (instead of the weak form of the EMH), event studies (instead of the semistrong form of the EMH), and tests of private information (instead of the strong form of the EMH)—while reiterating the importance of the joint hypothesis problem.

However, Fama's article also featured studies that, over the past twenty years, had begun to reject the EMH. Researchers had uncovered positive relationships between returns from one week to the next, particularly for smaller stocks. There were also relationships over much longer horizons; for example, stocks that had done poorly for three to five years tended to do much better over the subsequent three to five years and vice versa for stocks that had done well. Research by Shiller (featured in chapter 9) suggested stock prices were much more volatile than dividends, which called into question market efficiency at its roots because today's price is supposed to be the market's average assessment of future realized dividends, and an average is always smoother than the individual elements used to compute the average. Fama's counterargument, embellished by a large volume of research, was that this was merely a result of the real market average changing through time, a fact that itself was a major challenge, if not to efficiency then to models of market equilibrium. Throughout this debate, every finance researcher learned that the expected market return varies a great deal through time. This not only generates Shiller's price volatility but also confirms Fama's and Ken French's observations (among others) that prices do forecast returns at longtime horizons.

Fama argued that despite these conflicting results and the lingering uncertainty of interpretation caused by the joint hypothesis problem, market efficiency was still of critical importance. Research into market efficiency, Fama wrote, "has changed our views about the behavior of returns, across securities and through time. Indeed, academics largely agree in the facts that emerge from the tests, even when they disagree about their implications for efficiency. The empirical work has also changed the views and practices of market professionals."[35]

The debate about market efficiency continues to play out most vigorously in the arena of investment management, pitting active managers who try to beat the market versus passive managers who try to mimic the market. As Fama recently said, "There's quite a bit of evidence that even professionals don't show any ability to pick stocks or to predict market rollbacks. Most of the people we identify as skilled based on returns have probably just been lucky."[36] It may be better to be lucky than smart, but luck in the future isn't guaranteed.

The notion of market efficiency has expanded well beyond the stock market, even into the basketball arena. During the 2015–2016 National Basketball Association (NBA) season, all eyes were on the defending champion Golden State Warriors during their record-breaking season of seventy-three wins and only nine losses. Much of their success was attributed to their star guard, Stephen Curry, and his agility in making three-point baskets (outside the twenty-three-foot, nine-inch three-point line versus the two points awarded for those successful shots made inside the line, closer to the basket). According to a *Wall Street Journal* article, the team was built around exploiting "a market inefficiency that was hiding in plain sight," specifically the three-point line.[37] While there is little difference in accuracy among NBA players in sinking a basket from twenty-three feet versus twenty-four feet, the additional points awarded from twenty-four feet and beyond can lead to higher points per game and more wins, as the Warriors were able to show. In his seven seasons, Curry sank an incredible 44 percent of baskets attempted from beyond the three-point line, one of the best percentages on record. By building a team skilled at three-point success and encouraging more three-point attempts, the Warriors were able to "outperform" and beat expectations, thus *The Wall Street Journal*'s reference to market inefficiency. Of course, in a competitive landscape the sustainability of such an advantage might be questionable. After all, while the Warriors made it to the NBA finals, they were defeated in seven games by the Cleveland Cavaliers. Perhaps the NBA is an efficient market after all.

CAPM Tests: Beta Is Alive!

When Fama first joined the faculty at the University of Chicago, most investment courses were devoted to learning how to pick undervalued stocks. In 1963, he taught the first course at Chicago devoted to Markowitz's portfolio theory and Sharpe's CAPM. According to Fama, "The arrival of CAPM was like the air clearing after a thunderstorm."[38] Sharpe's model was a theoretical leap forward in asset pricing, while Robert Merton (featured in chapter 7) and others made additional leaps by extending the original model, such as creating a multiperiod or intertemporal version. But how well did the model actually work in practice?

One of the earliest tests of the CAPM—and certainly among the most innovative—was conducted by Fama and his former PhD student James MacBeth. The Fama-MacBeth methodology has become the gold standard for testing asset-pricing models and has been used extensively in the almost fifty years since its creation.[39] As Fama said recently, "That paper became kind of the founding paper in the cross-section regression approach to testing asset pricing models."[40] Fama-MacBeth used regression analysis to look for a straight-line relationship between the return on stocks relative to an estimate of a firm's CAPM beta. If the regression shows a positive and significant relationship, then the model is supported. If other variables, such as the variability or standard deviation of the stock's returns, are added to the model, they shouldn't show any significance.

Fama and MacBeth designed their analysis in a number of clever ways. First, they examined portfolios of stocks rather than individual stocks in order to reduce noise in the data and hence have a better chance of finding a relationship. Second, they were careful to estimate betas over an earlier period than the period of study in order to avoid a well-known statistical problem caused by estimating over the same time period as testing. Third, rather than regressing the *average* of portfolio returns on their betas, they performed regressions each month and then tallied the resulting *time-series* estimates.

Fama and MacBeth's results generally supported the CAPM. They were not alone in their support, however. At roughly the same time, Black, Jensen, and Scholes used a slightly different method to reach a similar conclusion, although their study supported an alternative version of the CAPM that included a zero-beta portfolio rather than a risk-free rate.[41] Given the apparent soundness of the model, the CAPM became the standard by which to measure performance not only in academia but also among practitioners. It was no longer acceptable for a money manager to boast about the returns a fund had generated. Now the performance of the fund *relative to the market* was important, as was the *riskiness* of the fund as captured by its beta. As Fama noted, "Passive management got a foothold, and active managers became aware that their feet would forever be put to the fire."[42]

The Three-Factor Model: Beta Is Dead!

While its early tests supported the validity of the CAPM, results that apparently contradicted the model began to emerge over time. Rather than interpreting them as a repudiation of the CAPM, however, these results were politely referred to as "anomalies." For example, Sanjoy Basu found that high earnings-to-price stocks tended to perform better, on average, than low earnings-to-price stocks, even after controlling for market risk as captured by beta.[43] Similarly, Rolf Banz found that stocks with small market capitalizations tended to perform better, on average, than stocks with large market capitalizations, also even after controlling for market risk as captured by beta.[44] Barr Rosenberg and his coauthors found a similar anomaly, with high book-to-market stocks doing better than low book-to-market stocks.[45]

Fama and his frequent coauthor, Ken French, assimilated the ideas from these previous studies and published the results in two articles, in 1992 and 1993. These Fama-French models are now found everywhere in both academia and the investment world.[46] As Fama recently noted, "The CAPM had a 20-year run, basically. And then, like all models, so-called anomalies [were uncovered]. The first one was Rolf Banz's thesis on the small stock effect, and then we had leverage and other things. So, we wrote this paper in 1992 which was 'The Cross-Section of Expected Stock Returns' in which we just pulled all this stuff together. I didn't think that paper was a big deal, actually. I said, 'There's nothing really new in here.' The 1992 paper basically said there are all kinds of anomalies; you can't put them aside anymore. And in addition, the central prediction of the CAPM just has never worked. The relation between average return and beta has always been too flat."[47] Fama further reflected, "My guess is that viewed one at a time, the anomalies seemed like curiosities that showed that the CAPM was just a model, an approximation that could not be expected to explain the entire cross section of expected returns. I see no other way to explain the impact of Fama & French (1992), which contains nothing new. . . . Apparently, seeing all the negative evidence in one place led readers to accept our conclusion that the CAPM just does not work."[48]

Fama and French's 1992 article reviewed the key message of the CAPM: that the market portfolio, which in theory contains all invested wealth, is the optimal portfolio for all investors. To use Markowitz's language, the market portfolio is mean-variance efficient, having the highest expected return for a given level of risk. If this is true, it implies two things. First, the expected returns on individual securities that are part of the market portfolio will be a positive linear function of their betas. In other words, the higher the beta of a stock, the higher the return it will earn, on average. Second, market betas by themselves are enough to describe the cross section of expected returns. If there are any other factors that explain stock returns, they should, in principle, be incorporated into beta.

In their 1992 article, Fama and French evaluated not only the market beta of a stock to explain the cross section of average returns but also its size (market capitalization, measured as the share price multiplied by the number of shares outstanding), earnings-to-price ratio, leverage (the amount of debt relative to its total assets), and book-to-market equity. They concluded, "Two easily measured variables: size and book-to-market equity, combine to capture the cross-sectional variation in average stock returns. . . . Moreover, when the tests allow for variation in beta that is unrelated to size, the relation between market beta and average returns is flat, even when beta is the only explanatory variable."[49] In other words, when they formed portfolios sorted on betas from before the test period, there was no longer a relationship between beta and portfolio returns, while the CAPM predicted a positive relationship.

This startling conclusion caused an uproar in both academic finance and the investment community. In a *New York Times* interview, Fama minced no words with his interpretation of the results: "The fact is, beta as the sole variable explaining returns on stocks is dead."[50] This comment led to the now infamous cult refrain "Beta is dead!"[51]

However, Fama recently provided an important clarification to this obituary for beta. "That's not the right way to characterize it, though. The right way to characterize it is: There are too many other things that help explain average returns so that even if you had a strong positive relation between average return and beta, you still have this problem that there are lots of other things that seem to be able to capture variation in average returns that that model doesn't get."[52]

It is often said that it takes a model to beat a model. If beta was truly dead from an empirical standpoint, then what would replace it? The Fama-French follow-up article in 1993 provided the world with an alternative to the CAPM, albeit an ad hoc alternative based on their empirical findings rather than deep theoretical underpinnings.

In their 1993 article, Fama and French extended their earlier work by creating additional factors based on size and the book-to-market equity. In the CAPM, the expected returns of a security above a risk-free rate are only dependent on one factor, the market. Only the market beta matters, that is, the sensitivity of a stock's return to the market's return but in the statistical sense that the market beta explains the cross section of returns, or why in any given period some stocks have higher (or lower) returns than others.

Fama and French proposed two additional factors to create their three-factor model. They called their first additional factor "small minus big" (SMB), which captured the difference in returns between stocks with small market capitalization and those with large market capitalization. They called their second additional factor "high minus low" (HML), which captured the difference in returns between high book-to-market equity stocks and low book-to-market equity stocks—the former often referred to as value stocks and the latter as growth stocks. (Value stocks also tend to have low price-to-earnings ratios.)

These two additional factors were based on previous empirical results rather than being considered theoretical justification. Fama and French claimed that these were risk factors not captured by the market portfolio alone, as suggested by the CAPM. To test their model, they gathered monthly stock returns from 1963 to 1991 to see the extent to which the three factors explained the return on stocks above the risk-free rate of return, using simple regression techniques. Fama and French divided the universe of U.S. stocks into twenty-five portfolios, first dividing the stocks into five "buckets" based on market capitalization and then dividing each bucket further into five separate buckets based on the book-to-market ratios. While the market factor still explained much of the level of average returns, the betas on all twenty-five portfolios were close to one. In other words, beta was dead in the sense that once the two additional factors were included in the regressions, it could no longer explain the cross section of returns. In contrast, both the SMB and HML factors added substantial explanatory power to the model, and their betas—unlike the market beta in the CAPM—were quite dispersed. The gauntlet had been thrown, and there was a new model in town.[53] Thanks to Fama and French, there was now a new way to select stocks and evaluate portfolio performance.

Fama recently reflected on how the Fama-French three-factor model evolved. Any asset-pricing model such as the CAPM first begins with a market portfolio, he explained. "And then you have Merton's [intertemporal CAPM] extensions in which you have lots of other portfolios that are possible candidates, hopefully attached to state variables [used to describe certain states of the world such as boom or bust]. And we kind of framed ours in terms of that model, although that's really a stretch because we didn't identify any state variables. So, I've come to the opinion that it's really what I call an exercise in empirical asset pricing in the sense that none of our theoretical models work. The most fundamental theoretical model is the consumption CAPM. It's awful [in terms of empirical support]."[54]

Fama further related his thoughts to Markowitz's mean-variance (return-risk) idea, through which Sharpe determined that the risky portfolio—combined with a riskless asset—was the market portfolio, or the tangent portfolio on Markowitz's efficient frontier. "The CAPM is kind of dead in the water. So, I've kind of come to the opinion that maybe all we're doing is finding a set of portfolios that span the mean-variance efficient tangency portfolio, and for a while, maybe that's the best you can do. So, you use the characteristics of the data to identify what might be an appropriate model. We haven't come to the end of it because you want some constraints on that process; you want to boil down to a small number of so-called factors of portfolios that you use to explain returns."[55]

Like shaving razors that started with a single blade, growing to two and then proliferating to three or more, the standard asset-pricing model has gone from one factor to three and now to five, thanks to a 2015 study by Fama and French.[56] After more recent research resulted in average return differences unexplainable by the three-factor model, they added two new variables, a profitability variable, RMW, or returns from "robust minus weak" profitability firms, and an investment variable, CMA, or returns from "conservative minus aggressive" (low-investment minus high-investment) firms. They concluded that their five-factor model did a better job explaining patterns in average stock returns than the three-factor model. However, Fama recently noted, "We came up with a five-factor model, and that seems very robust, but I don't think it's been fully vetted yet. And I'm suspicious about the investment factor, because there is this phenomenon that all asset-pricing models have problems with unprofitable small stocks that invest a lot."[57]

But what did these three- and five-factor models mean for market efficiency? Did Fama become a market efficiency skeptic? It comes down to a matter of interpretation. While these new factors aren't necessarily based on any particular financial theory, if variables such as SMB and HML reflect unknown risk factors not captured by the CAPM, then there may not be a way to outperform the market or earn abnormal returns by investing in small stocks or value stocks. Rather, these investments will take on risk in addition to the market risk. Thus, those investors who earn higher returns by investing in small stocks or value stocks are simply being compensated for taking on the additional risk. As for the question of whether these factors represent unknown risk or indicate market inefficiencies, as Fama noted, "The academic research on size and value premiums in average stock returns has transformed the investment management industry, on both the supply side and on the demand side."[58] Another perspective is that out of hundreds of possible investment strategies, there are really only a handful of risk-related exposures that matter.

Predictability

In addition to his important contributions related to the concept of market efficiency, Fama made major contributions in the area of asset predictability, including Treasury bills, Treasury bonds, and stocks. Predictability of asset returns is the holy grail of active portfolio managers. Much of the work occurred from the mid-1970s through the late 1980s and beyond. This work dovetailed with Fama's market efficiency research.

One of Fama's earliest predictability studies focused on Treasury bills.[59] This was important from a methodological perspective because he compared current prices with historical price changes to see whether historical price changes contained any additional information not already reflected into current prices, which was a test of the EMH. A well-known relationship connects nominal and real or inflation-adjusted interest rates. Simply stated, nominal rates should equal real rates plus expected inflation rates. Fama compared one- to six-month Treasury bills with subsequent inflation: Did such nominal rates predict future inflation, or were there other factors besides nominal rates that predicted inflation? Fama found that nominal rates sufficiently captured all the relevant information to predict future inflation.

In a similar spirit, Fama looked at forward interest rates as predictors of future spot interest rates.[60] Forward contracts are agreements between two parties on interest rates in a financial transaction in the future. In particular, Fama wanted to see whether past spot interest rates had predictive power beyond the forward rates. Consistent with the EMH, he found that forward rates did just as well as past spot rates.

Fama teamed with Bill Schwert to investigate the relationship between asset returns, including stocks, and inflation.[61] Surprisingly, they found a significant and negative relationship between stock returns and expected inflation. In other words, stocks didn't appear to be a good hedge against inflation, at least in the short to medium term. The relationship appeared to hold as well with unanticipated inflation. Fama further investigated the relationship between stock prices and inflation to better understand the unexpected result.[62] He found that the negative relationship was actually proxying for a positive relationship between stock returns and real or inflation-adjusted activities such as capital expenditures, which in turn were explained by money demand.

Fama, partnered with Robert Bliss, returned to further examine whether forward rates predict future interest rates, focusing this time on one- to five-year Treasury bonds rather than shorter-maturity Treasury bills.[63] Fama and Bliss's article is another example of how Fama showed his empirical savvy. Think of predicting future interest rates akin to forecasting tomorrow's weather.[64] If you predict tomorrow's weather as being the same as today's weather (from a statistician's perspective, through a regression equation), your prediction will look pretty good. But that's a fairly hollow test, because we know that that's typical with weather: in statistical terms this is known as serial correlation. A better test of your predictive powers is to compare the *change* in the weather from today to tomorrow relative to the *difference* between your forecast and today's weather. That's what Fama and Bliss did. Consistent with Fama's earlier research, forecasting interest rate changes one year ahead is essentially like reporting today's weather as the forecast for tomorrow—there's not much more to add. However, it's a different story forecasting changes in interest rates two to four years ahead, where the forward rate actually has predictive power and where the forecast gets better the longer the horizon. They attributed this predictability to changes over time in the business cycle. In other words, they found a cyclical behavior of interest rates, highlighting why some things should be forecastable.

Fama teamed with French, his longtime collaborator, to examine the predictability of long-horizon stock returns.[65] Prior to the mid-1980s, most of the predictability of stock return research focused on trying to predict next month's stock returns, or week-to-week or day-to-day patterns. Fama and French looked at portfolios of stocks (based on their size or industry composition) and their returns beyond the next year. They found strong negative correlation among three- to five-year horizons. In other words, portfolios of stocks that did well over the past three to five years tended to do poorly over the subsequent three to five years and vice versa. They highlighted two distinct possible explanations: either investors are irrational, or expected returns vary through time.

In a related follow-up paper, Fama and French looked at the relationship between dividend yields (dividends divided by prices) and expected stock returns of the overall U.S. market.[66] For two- to four-year horizons, dividend yields explain about a quarter of the variability of returns, compared with less than 5 percent for monthly or quarterly returns. Part of the intuition is that when stock prices are relatively low (and hence dividend yields are relatively high), then expected returns are high and vice versa. While not a new finding in and of itself, Fama and French showed that the forecast power increased with longer horizons, and like some of Fama's earlier work, there was an economic story behind it: negative shocks to expected returns were associated with opposite shocks to prices.

Bookmarks

Fama is unique among Nobel laureates in economics for the combined breadth and depth of his contributions to the finance profession. Economics laureates tend to peak early, and yet he has created high-impact research in every decade of his career since the 1960s. His three most highly cited works were published in different decades. In an article highlighting his impact on the field, two finance scholars, the longtime *Journal of Financial Economics* editor Bill Schwert (a former Fama student) and the longtime *Journal of Finance* editor René Stulz, mused on his productivity: "We speculate that it is the product of a fierce intellect who loves what he is doing and has an unparalleled work ethic."[67]

Fama's two books, written in the 1970s, were must-reads for any serious student of finance. *The Theory of Finance*,[68] written with Nobel laureate Merton Miller, presented the theoretical underpinnings of corporate finance with so much authority that it has been referred to as the "white bible."[69] It became mandatory reading in doctoral programs, which was not the originally intended audience. "We wrote it in the process of teaching an introductory finance course to MBA students. That was it. I'm not sure how many of them ever really got through it, but that's what we wrote it for. That's how poor our perceptions of the market were."[70]

Fama's other book, *Foundations of Finance*,[71] synthesized and extended his earlier work on market efficiency and laid a careful path for later empiricists to follow. Its genesis was an ongoing argument that Fama had with his colleague Fischer Black. "Black, Jensen, and Scholes had written a still famous paper on testing the CAPM. Fischer was here at the time, and he would come in every morning early, seven o'clock, and I'd be working there. And we would argue and I kept saying to him, 'Fischer, that thing that you're doing in that Black-Jensen-Scholes paper, it's just running a cross section regression, that's all it is.' They had this complicated portfolio approach, and I said, 'You're just running a regression there,' and he said, 'No, I'm not.' So finally, I wrote that chapter of the book [*Foundations of Finance*] to prove to him that it was a cross-section regression, and then I said, 'Well, why not write the rest of the book?' So that was how that arose."[72]

Beyond the areas of asset pricing and market efficiency for which he is best known, Fama has made significant contributions to many other topics. One is known as the "agency problem." While shareholders are the ultimate owners of a firm—the principals—they leave running the business to managers or agents. Unintended "problems" can arise by having agents run the firm; for example, managers who aren't aligned with the shareholders may have an incentive to pay themselves an overly nice salary and consume unnecessary perks of the office. Fama, by himself and with his former PhD student Michael Jensen, explored ways in which the agency problem could be mitigated, such as through a strong board of directors. In fact, two of his most highly cited papers are in this area. He was particularly proud of this achievement. "I think of myself as an empiricist (and a simple-minded one at that), so I like my work in agency theory, as it suggests that occasionally theoretical ideas get sprinkled into the mix."[73]

Fama was also an early adopter of financial databases, prefiguring the use of Big Data in modern financial economics. In addition to his reliance on the University of Chicago's CRSP database, he was an early user of the Compustat database, created in 1962 and now owned by Standard & Poor's. He has used these databases for research on dividends since the 1960s. One area of interest has been the extent to which companies have target dividend payouts and how these targets change as companies increase their earnings. Another has been the "curious case of disappearing dividends." Issuing dividends was once common practice, performed by four out of five U.S. firms in the 1970s but only one in five by the late 1990s. He has also contributed to macroeconomics, including the role of money, the predictability of inflation, the extent to which exchange rate uncertainty is really a risk, and the role of banks and deposits.

Fama fondly recalls his association with his numerous PhD students over the course of his career at Chicago, including the "once-in-a-lifetime cohort" soon after he joined the faculty, a group that included Jensen, Roll, Ball, Marshall Blume, Scholes, and other prominent scholars.[74] "Any investment in these and about 100 other PhD students I have supervised has been repaid many times by what I have learned from them during their careers."[75] In addition to a Nobel Prize in Economics winner (Scholes), six have been presidents of the discipline's premier association, the American Finance Association, and four have been editors of the most prestigious journals in finance and accounting.[76]

Other former students of Fama went on to become successful investment managers. David Booth and Rex Sinquefield started Dimensional Fund Advisors (DFA) in 1981, with over $600 billion in assets under management in 2021 and with many of its products based on Fama-French research. (In 2008, Booth donated $300 million to the newly named University of Chicago Booth School of Business.) Cliff Asness and John Liew cofounded AQR Capital Management in 1998, recently with close to $150 billion in assets under management.

Fama has had a long association with DFA. "Booth came to me and said, 'I'm starting a company. Do you want to be involved?' And I said, 'Sure. I've never been involved with a business, so I'll be involved with it,' and I've been working with him ever since. . . . Initially all they had was the micro-cap funds, the 9/10 deciles of the equivalent NYSE stocks. It was a tiny stock portfolio. And then I had done a lot of stuff in the 1970s on using the structure of forward rates to predict returns on longer-term bonds, and they came out with products based on that pretty quickly. And then, when the Fama-French stuff came out, they had clients for so-called value portfolios before that paper was even published. He brought one of his clients out here to the university, and on my computer screen I showed him the results, and he said, 'Okay, I'll take 20 million [dollars] of that.' . . . Now, all their products are kind of centered on [the Fama-French] model, U.S. products and international products. Their business is an enormous business. . . . It grew right through 2008–2009. It's kind of a testimony that if people buy into efficient markets, they don't bomb out as easily as people who buy into active investing."[77]

Fama felt that the performance of DFA funds was an example of efficient markets at work rather than a counterexample. "I always distinguish between asset pricing and efficient markets. Those are the [conjoined] twins of asset pricing. You can't separate them. And the risk-return part of it is what they're dealing with. So, I think their products are just riskier. They have straight-value portfolios, small-stock portfolios, and big-stock portfolios. They're basically value-tilted portfolios of all sorts."[78]

Fama has been called "the founder of empirical research in modern finance."[79] It is a testament to his influence that most authors use his definition of market efficiency but rarely cite him, so embedded is the concept. Editors Schwert and Stulz note, "'Efficient markets' is a household name throughout the world. The efficient markets view has inspired countless laws, regulations, and policies. It affects how investors make their investment decisions and evaluate their performance."[80] They observe that none of Fama's papers is "a technical tour-de-force" or uses the most advanced econometrics. "Instead, each one of these [three most-cited] papers [on market efficiency, corporate governance, and asset pricing] opens up a new way for financial economists to think about their field."[81] And finally, here's John Cochrane's observation of some of Fama's contributions: "He announced the random walk. And then he provided the most crucial evidence against it in the return forecasting regressions. He tested the CAPM and then provided the most crucial revision in the three-factor model. Both Newton and Einstein all wrapped in to one."[82]

Fama's Perfect Portfolio

Fama was recently asked to comment on what would be the Perfect Portfolio for investors. His Perfect Portfolio starts with the market portfolio. "Every asset pricing model basically says the market portfolio is the core and you start with that."[83] However, his investment philosophy has evolved past that, since his famous 1992 article with French. "Before 1992, before we did 'The Cross-Section of Expected Stock Returns,' I'd have said everybody should hold the market portfolio. Now I'd say no, your taste might cause you to tilt a little more towards smaller or value or whatever. I still think the market is the centerpiece, and most people should sit there because it's a cheap way to go. It's very inexpensive to hold a market portfolio from Vanguard or somebody like that. There are lots of providers that do it at a very low cost, but you have to be careful because there are some that do it at high cost."[84]

Fama continued, "I don't think there is *a* Perfect Portfolio. I think, at least, in my current view of the world, you have a multidimensional surface that's characterized by a continuum of portfolios with different sorts of tilts, and the market portfolio is the center of that universe. In aggregate, people have to hold the market portfolio. That's it, and that's an efficient portfolio in any model you want to think of. And then you can decide to tilt away from that, towards other dimensions that we think capture different kinds of risk, and that's a personal decision. As David Booth says, 'Diversification is your buddy.' If you decide to tilt away, you want to do it in the most diversified way you can."[85]

When asked whether he thinks there is a possibility of overdiversifying, Fama responded, "I don't think that's possible. If you ask Warren Buffett what people should do with their portfolios, he says, 'Go passive.'"[86] Fama referred to the guidance in Buffett's will to the trustee of his estate: "Put 10 percent of the cash in short-term government bonds and 90 percent in a very low-cost S&P 500 index fund."[87] Fama also commented on Buffett's investment performance as an active investor. "I think he provides an interesting case in the sense that everybody points to him as evidence of a market inefficiency of some sort. But there are two problems with that. One is, nobody says that if you run companies, you can't add value. Nobody says there's no such thing as human capital. The other is, if we have several hundred thousand [businesspeople] and we pull out the most successful one, what's the probability that that was luck, not skill, even over a long period of time? So, you've got a big statistical issue there because that's the way these people get identified."[88]

Fama voiced other concerns about active management, in particular the hiring and firing of managers based on past performance. "I think the big problem facing investors is that they don't understand the importance of uncertainty about outcomes. So, for example, I get to do a lot of talking to institutional people and financial advisers. Institutional people, especially, tend to change their portfolios based on three to five years of past returns, and I show them simulations in which that's basically noise. Three to five years of past returns: There is almost no information in there about expected returns. They were kind of shocked by it. The reality is that there's no free lunch out there. The higher expected returns on stocks comes about with a large amount of risk."[89] So, the bottom line for Fama's Perfect Portfolio begins with a fund that tracks a broad market such as the S&P 500 index and then, if you decide to do so, tilts away a bit toward a style you prefer, such as value or small cap, while recognizing that higher expected returns only come with additional risk.

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John Bogle and the Vanguard Portfolio

INVESTING IN LOW-COST index funds is common these days, an approach advocated by William Sharpe, Eugene Fama, and many of our other luminaries. In fact, trillions of dollars are invested in U.S. index funds alone. Yet it all started with a pioneer—John C. Bogle, or Jack, as he preferred—who in late 1975 started the world's first index mutual fund, the First Index Investment Trust, which started with $11 million in assets. This and its sister fund grew into the Vanguard Group, which at the time of Bogle's death in 2019 had over $5 trillion in assets under management.

While Bogle wasn't an academic, his Princeton undergraduate thesis on the mutual fund industry has arguably had a greater impact on the investment industry than almost every other finance dissertation combined. In fact, Princeton economics professor Burton Malkiel mused that Bogle's cost matters hypothesis by itself made him deserving of tenure.[1] The Vanguard Group rose dramatically from the ashes of a failed merger of funds. Bogle was inspired by one of the greatest financial economists of all time, Paul Samuelson, whose *Journal of Portfolio Management* article challenged practitioners to create a low-cost fund that replicated an index such as the S&P 500. Bogle answered that challenge and helped to create more wealth than perhaps almost any other manager. For example, comparing Vanguard's expense ratio to the average fees charged by U.S. mutual funds, it's been estimated that

Vanguard's lower fees saved investors $20 billion in 2018 alone.[2] Bogle has been referred to as "the greatest investor advocate ever to grace the fund industry"[3] and has made his case for the inclusion of index funds as part of any Perfect Portfolio.

Big Money in Boston

Bogle and his twin brother David were born in Vernon, New Jersey, on May 8, 1929, a few months before the stock market crash and the Great Depression.[4] Their parents, William Yates Bogle Jr. and Josephine Lorraine Hipkins, had a well-to-do lifestyle. William had served as a pilot in the British Royal Flying Corps during World War I and after the war worked for the companies founded by his father, William Yates Bogle Sr., the American Brick Corporation and the American Can Company.[5]

During the Crash of 1929, however, the family inheritance was wiped out. Bogle was determined to help restore the family legacy, first working at age ten delivering newspapers. He and his twin brother later attended Manasquan High School on the New Jersey shore, where Bogle was a strong student. However, his family life was strained. His father lost his job at American Can, and his parents separated.

Bogle struggled to keep the family together as a functional unit. His mother decided that the twins should attend the prestigious Blair Academy boarding school in Blairstown, New Jersey, which their older brother attended. Bogle's uncle, an investment banker, arranged for them to obtain work scholarships. Bogle graduated from Blair cum laude in 1947.

Princeton University offered Bogle a generous scholarship and student employment, which he accepted. He majored in economics but also took courses in Shakespeare, English history, and art history. Bogle struggled in calculus and international trade. In his economics courses, he was first introduced to Paul Samuelson's recently published *Economics: An Introductory Analysis*. Unknown to Bogle at the time, Samuelson was to have a great impact on his later career.

In his junior year, Bogle began thinking about topics to fulfill his senior year thesis, a requirement for his economics major. It was a sunny

December day in 1949 in Princeton, New Jersey, that would set him on a path that would revolutionize the investment industry. "Then, almost halfway through my junior year at Princeton University, I was in the reading room of the newly built Firestone Library,[6] trying to keep up with current developments in economics, my major study. I was reading the December issue of *Fortune* magazine.[7] When I turned to page 116, there was an article entitled 'Big Money in Boston.' That serendipitous moment would shape my entire career and life," Bogle recalled. "That article was the springboard for my decision—made almost immediately—to write my thesis on the history and future prospects of open-end investment companies."[8]

The magazine article described the workings of Massachusetts Investors Trust, abbreviated as M.I.T., one of the oldest and largest ($246 million) open-end investment companies (today more commonly called mutual funds), low-cost and well diversified. M.I.T. was also the largest shareholder in America at the time. Its chairman, Merrill Griswold, helped to draft the Investment Company Act of 1940 and wanted to promote the investment trust as the ideal vehicle for small investors. M.I.T. was selling peace of mind with its investment. Unlike most other funds at the time, M.I.T. was almost fully invested in common stocks. Eighty-six percent of its assets were in stocks that had paid dividends consistently for at least the last decade, and it owned twenty of the thirty Dow Jones Industrial Average stocks. The *Fortune* article noted that "M.I.T. is interested in the long-range dividend-paying power of its investments; it is not an in-and-out trader, is not looking for short-term profits, never sells short, and never buys on margin." The article also highlighted the growth potential for the tiny industry. According to Bogle, "The industry was described as tiny, but contentious. Its total assets were around two or two and a half billion [dollars]. And I thought, 'Well, by God, I'm tiny, and I'm contentious, and no one's ever written a thesis on the mutual fund industry before.'"[9]

Bogle reflected on the history of mutual funds and their original benefits. "The first actual mutual fund, Mass[achusetts] Investors Trust, was started in 1924. What makes the industry go is the common sense behind it: I would say, number one, diversification, a very underrated benefit; number two, efficiency; number three, for those days, relatively low cost; and number four—I always put this last—management, because management cannot add value, but people somehow feel more comfortable with management looking over their investments. In those days, by the way, the typical mutual fund was very much like an index fund. They were managed, but they tracked the market for years and years."[10] According to Bogle, "What *Fortune* described [in 1949] was an industry in which the idea was to sell what we made: Funds that offer the small investor peace of mind, an industry that focused primarily on stewardship. By contrast, the industry we see today is one focused primarily on salesmanship, an industry in which marketing calls the tune in which we make what will sell, and in which short-term performance is the name of the game."[11]

Bogle also recalled how the industry has changed in some ways for the better but in other ways less so. Funds are now bigger, more numerous, and more varied in terms of objectives and policies. Instead of nine out of ten funds paralleling the market, fewer than one in eight do so (as of 2003). Fund management has shifted from investment committees to star managers; however, "most proved to be comets, illuminating the fund firmament for a moment in time before they flamed out."[12] Turnover has become much higher. Intermediaries such as pension funds, rather than individuals, now own the vast majority of stocks. Mutual funds are primarily sold rather than bought. Expenses as a percent of assets have climbed considerably. Bogle reflected, "When that old *Fortune* article noted that most funds did no more than give investors 'a piece of the Dow Jones Average,' it presciently added, 'the average is not a bad thing to own.' But today, for better or worse—probably worse—selecting mutual funds has become an art form."[13]

The Princeton Thesis

In April 1951, Bogle completed his thesis, giving it the title "The Economic Role of the Investment Company."[14] He did not have an easy start, due to his difficulty gathering data on the subject. For instance, he wrote to the National Association of Investment Companies asking for information. Seven months later he received a reply, containing only a limited amount of data. He also collected data from Wiesenberger's annual compendia on investment companies and read all he could about the Investment Company Act of 1940. "We didn't have as much data as we do today, but I looked at performance of a great number of funds, and found that they couldn't beat the market. That was the seed that was planted that by 1974 had burst into flower when I created the first index mutual fund."[15]

To put the state of the industry into context as Bogle saw it circa 1950, mutual funds were lower cost than today, investment horizons were longer term, and funds were generally middle-of-the-road in terms of diversification.[16] "Just about every major fund looked like the Dow Jones Industrial Average. This was apparent by looking at the volatility. Wiesenberger reported the volatility of funds relative to the index in its annual volumes of mutual fund data. There were a couple of funds that were maybe 105 percent or 107 percent—7 percent more volatile [than the market]. And you could find some funds that were 10 percent less volatile. But funds that were 30 percent more volatile or 30 percent less volatile just weren't there. Balanced funds were a different case, of course. They were just as volatile as they were supposed to be—that is, two-thirds the volatility of the market."[17]

However, by the 1960s aggressive "Go-Go funds" were promising much higher returns. According to Bogle, some of these funds would use questionable methods to report great performance by, for example, buying stock from a company at fifty cents on the dollar and then putting it in their portfolio at one hundred cents on the dollar. "This is a very easy way to get good performance. A fund named Enterprise actually had a year—talk about changing the industry—where they went up 104 percent in one year. That caught everybody's eye and everybody jumped on the bandwagon including, later, me."[18]

Bogle added, "But one thing I do recall vividly, and it's in the thesis, is there was a quote from the Securities and Exchange Commission's review of the industry[19] that said, essentially, that mutual funds could provide a useful service by providing intelligent voting with a factual basis, a statistical basis, that would be impossible for any individual shareholder to fill."[20] In other words, institutions such as mutual funds should normatively look out for the best interests of individual shareholders.

What did Bogle conclude in his thesis about the future of "open-end investment companies," that is, mutual funds? "One, that mutual funds should be managed 'in the most efficient, honest, and economical way possible,' and that fund sales charges and management fees should be reduced. Two, mutual funds should not lead the public to the 'expectation of miracles from management,' since funds could 'make no claim to superiority over the (unmanaged) market averages.' Three, that 'the principal function (of funds) is the management of their investment portfolios'—the trusteeship of investor assets—focusing 'on the performance of the corporation . . . (not on) the short-term public appraisal of the value of a share (of stock).' And four, that 'the prime responsibility' of funds 'must be to their shareholders,' to serve the individual investor and the institutional investor alike."[21]

Several decades later, Bogle reflected on his Princeton thesis and what he was trying to accomplish with it. "It could be regarded as a design for Vanguard. I didn't intend it as a design for anything. I was just an idealistic young guy trying to get something right in the world, and I wanted mutual funds to reduce their management fees. I wanted them to reduce their sales charges. I wanted them to be run in the most economical, efficient, and honest way possible. I wanted them not to claim superiority over the market indexes, because they couldn't beat them. So, the main point of my thesis was, above all, put the interest of the fund shareholder first."[22] As he wrote in his thesis, the future growth of the investment fund industry "can be maximized by concentration on a reduction in sales loads [or commission charges, then typically 6 to 9 percent] and management fees."[23]

Wellington Fund

While Bogle was pursuing his undergraduate studies, his family was experiencing a difficult time in Philadelphia. His parents were separating, and his mother was dying. After his graduation, he naturally wanted to find nearby work in Philadelphia. He looked for jobs at different local banks and even a brokerage firm before he found the Wellington Fund.[24] The Wellington Fund had been founded by Walter L. Morgan on December 27, 1928, and began operations in mid-1929. One might think this wasn't the most auspicious moment to begin a fund, but it took a balanced approach to investing, with broad diversification in stocks and bonds.[25] The fund was originally called Industrial and Power Securities Company but was renamed the Wellington Fund, Inc., in 1935. Morgan remained chairman until 1972, after which Bogle took the reins for the next twenty-seven years. (Morgan died in 1998, three months past his one hundredth birthday.)

Morgan was a great mentor to Bogle and treated him like the son he never had. "He was an extraordinary man, a pillar of integrity, very much a Renaissance man," Bogle recounts. "He was interested in all aspects of the business."[26] Morgan's philosophy was to keep things simple: combine individual investor accounts into one large and diversified fund, managed efficiently by experts. Bogle was hired in 1951.

"Walter Morgan said hiring me was the best business decision of his life. I did anything Mr. Morgan wanted me to do, including hanging pictures where he said to hang them. Later on, I was able to decide where they went. We had a wonderful relationship. Not really all that close, but certainly mutual admiration and respect. He saw something in me that he liked. It's kind of weird that I considered myself a totally normal person without a lot to bring to the table—probably above-average intelligence, but not a lot above average. And here I am in this funny position today of being considered by some a bomb-throwing Marxist revolutionary."[27] Bogle marveled at Wellington's consistent investment approach. Even though balanced fund returns were less than returns from all-equity funds, money continued to pour in to the Wellington Fund. However, its growth began to slow, and in the 1960s Wellington began to underperform relative to its balanced fund peers.

In 1960, Bogle wrote a *Financial Analysts Journal* article titled "The Case for Mutual Fund Management" under the pen name John B. Armstrong.[28] This article reads rather ironically today, since Bogle was arguing *against* a mutual fund that tracked a broad index such as the

Dow Jones Industrial Average. In the period 1930–1959, he wrote, "leading common stock funds have shown better results than the Dow Jones Industrial Average." This study was based on the four oldest diversified common stock funds, three of which outperformed the Dow. Interestingly, Bogle cited a 1960 *Financial Analysts Journal* article[29] that made the case for an "unmanaged" index fund; however, he took issue with the common misperception that the Dow Jones Industrial Average was "unmanaged."

Bogle noted that the Dow was managed "in accordance with its objectives—just as in a mutual fund. Whereas a mutual fund aims for growth or income, etc., the Dow Jones Industrial Average aims to be representative of the general market, and is changed accordingly."[30] He also went on to argue that an "unmanaged" mutual fund that bought the Dow Jones Industrial Average had a number of weaknesses: the market volatility may be higher, as his study suggested; an unmanaged fund could not be fully invested, since it would need to hold some cash for liquidity; and turnover costs would hurt performance.

Bogle recently commented on his 1960 article and its attack on "passive" management compared to an actively managed fund. "My argument in that article was really that there shouldn't be a Dow Jones Industrial Average index fund. When you go through what it takes to run an index fund tracking the Dow, it's an extremely complex average to track, and would require a high rate of fund turnover, because the index is price-weighted—and the number of stocks always has to total thirty. It would have been very costly to operate a fund tracking the Dow in those days. I was defending the status quo, but it was a reasoned status quo," given diversification and relatively low costs of many of the funds at that time.[31]

The 1960s saw a shift in investment philosophy away from the conservative ideas of the past. As Bogle observed, "The Go-Go years were in full flower, and the idea that we were in a new era was rife. In 1965, Mr. Morgan entrusted me with the responsibility to prepare our organization for the future, and I responded swiftly—and, alas, unwisely. I believed that we needed smart new managers to run the [Wellington] Fund, that we needed to add an aggressive growth fund to our 'product line,' and that we should diversify beyond the mutual fund field into pension management."[32] Bogle later elaborated how Morgan called him in to his office and shared his private thoughts. "'I don't want to deal with this present era. I don't understand it. I'm too conservative. And I want you to start running the company today.' I thought, 'Of course, you surely picked the right man.' I was thirty-five years old with a little more self-confidence than my experience would have indicated."[33]

Bogle looked at several ways to bring an equity fund into the business. He talked to a few firms—Incorporated Investors (which became Putnam), the West Coast firm Capital Group, and the predecessor to the Franklin Templeton Fund—but they were not interested. He recounts what happened next. "Along comes this little Boston advisory firm, Thorndike, Doran, Paine & Lewis, which manages a fund called Ivest—a Go-Go fund with a hot, if dubious, record. It really was a little bit of thin air. And they also offered these 'brilliant investment managers,' put that in quotes. So, the Wellington Fund merged with the Ivest Fund. It worked perfectly, but only until it didn't."[34]

Bogle used one of his favorite analogies to reflect on why he chose to bring in Go-Go managers to the Wellington Fund. "I've got this nice little bagel shop, and it sells bagels that are nutritious, hard, crusty, and good for you. Yet all around are these doughnut shops selling sweets that are completely bereft of nutritional value. They crumble. But if everybody else on the street is selling doughnuts and nobody is buying bagels, the bagel shop owner has one option. Start selling doughnuts."[35]

Seeking to earn a higher return through an aggressive strategy in a fund that had been conservatively run for forty years proved to be, in Bogle's own words, "an abject failure. The [Wellington] Fund's returns were abysmal, and assets plunged from $2.1 billion in 1966 to $475 million in 1975, a staggering drop of 74 percent."[36] Reflecting on the merger with Ivest, he recently said, "I knew it was a gamble. I knew it wasn't going to be durable. So, I gave each of [the Ivest senior executives] at our celebration dinner a little silver card tray. In the middle of each one I had soldered a U.S. silver dollar. Inscribed on each coin was the word 'Peace.' But there was to be no peace. Everything fell apart. They told me I was arrogant and I didn't like group decisions, to which I can only say those two things are, by and large, true. Yet they never had any group kind of thinking. They had one dominant person, but they talked as though they had a group consensus. So, it finally came down to power. I had given them a little more power in the merger than I should have. Mr. Morgan said, 'Do whatever you want with it,' and I can say I'm a bad negotiator."[37]

"The first five years you would have described Bogle as a genius. And at the end of the first 10 years, roughly, you would have said: the worst merger in history, including AOL and Time Warner. It all fell apart. Their management skills were zero. They ruined the fund they started, Ivest. They started two more and ruined both. And they ruined Wellington Fund. The company started to shrink radically, and they who had done the damage decided to fire me. I told the board the best thing for us to do is to unscramble the omelet of all those years ago and give them back their counseling business. The funds business is worthless, and we'll buy them out. That proved to be much too much for the directors to follow, but they were willing to say 'give us some options of what we can do.'"[38]

So, Bogle presented options. He came up with not one but two ideas that would revolutionize fund management. "I'm a small company guy, but I happen to have had two great ideas. One is a mutual company, which is focused not on the management company shareholder but on the fund shareholder. That's the structural thing we bring to the table. And the strategic thing we bring to the table is the index fund. We created the first index mutual fund, and it took 20 years before it started to catch on, in the mid-1990s. Now it's dominating the conversation in the financial field, and it's changing the fund industry forever."[39] The result of these two great ideas was the Vanguard Group.

Vanguard and "Bogle's Folly"

After Bogle was fired from the Wellington Management Company—while still remaining chairman and CEO of the Wellington Fund—he considered what to do next. "How do I recoup at the poker table what I lost at the craps table? I looked around at a couple of institutions here in town to see if they wanted to get more active in the mutual fund business, and there was no interest. I thought about buying a little company down in Delaware owned by the DuPont family. Somehow, that never came to pass. So, I'm left with one option: to persuade the directors of the Wellington Fund, where I'm chairman of the board and chief executive, to not do what they did at Wellington Management Company, their supplier of services, which is fire the chairman of the board and chief executive."[40] The board allowed Bogle to start a firm that would stay out of investment management and distribution.

"You could say that the creation of Vanguard was my attempt to 'walk the walk' that would justify the 'talk the talk' words in my thesis years earlier. It was action that reinforced those initial words."[41] Bogle explained where its name came from: "I called the new firm Vanguard. It comes from naval history: The Battle of the Nile, one of the great victories of all time, with the British sinking the French fleet in Aboukir Bay. There was a dispatch in there by Admiral Horatio Nelson off the deck of *HMS Vanguard*."[42]

Bogle described the introduction of the first index mutual fund, initially called the First Index Investment Trust and later the Vanguard 500 Index Fund. "The Vanguard Group was incorporated in September 1974 and started operations in May 1975. The understanding was that Vanguard was to limit itself to administration and not get into investment management or distribution; those functions would stay with Wellington Management Company. However, for strategic reasons, I decided we needed to be in the management business. I was interested in building Vanguard as a company where we could control the kind of funds we ran, how they were run, who would run them, to whom our shares would be distributed, and through whom our shares would be distributed."[43]

Bogle thought about the unmanaged index fund mentioned in his thesis. He further researched the average returns of about sixty equity mutual funds in business in the previous thirty years. He found that the average fund underperformed the S&P 500 index by about 1.5 percent annually, without accounting for index costs. Accounting for turnover costs (but not sales charges), he estimated average annual fund returns of 9.6 percent compared to index returns of 11.1 percent. He showed his directors that $1 million invested in 1945 in these funds would have grown to $16 million by 1975, compared to $25 million for the market index. "The directors thought I was overstepping my mandate by starting such a mutual fund, reminding me I was not allowed to get into management. I told them that the fund wasn't managed, and—believe it or not—they bought that."[44]

In June 1976, *Fortune* magazine published a well-timed article: "Index Funds—An Idea Whose Time Is Coming."[45] More and more academic research suggested that the prices of stocks tended to follow a random walk, and there was growing support for the efficient market hypothesis (especially Fama's work, discussed in chapter 4) to suggest that prices fully and immediately reflected all relevant information. In other words, according to academia, no amount of fundamental analysis would lead to returns better than the market itself. A handful of pension funds were investing in index strategies, primarily through Wells Fargo.[46] Yet according to the *Fortune* article, prestigious Wall Street firms, such as Morgan Guaranty Trust Co., "reacted to index funds with disdain. . . . Harrison Smith, executive vice president of Morgan's trust department, does not consider index funds an issue worth the bank's serious attention; he is offended at the very idea that Morgan cannot outperform the averages."[47]

Nonetheless, index funds for the masses were coming. On August 31, 1976, the first index *mutual* fund was born at the initial public offering (IPO) of First Index Investment Trust, sponsored by the Vanguard Group. It had a difficult birth. "We were confident that the IPO would be a roaring success," Bogle recounted. "Not only was the math that assured the index fund's superiority unarguable, but the principal underwriters included the four biggest retail brokers on Wall Street. Their target was $150 million. But when the books were closed, the underwriting of First Index Investment Trust produced just $11.3 million, a 93 percent shortfall from the goal. When the underwriters brought me the news of the abject failure, they suggested we cancel the deal, for the tiny proceeds were insufficient to own all 500 stocks in the S&P 500 Index. I remember saying: 'Oh no we won't! Don't you realize that we now have the world's first index fund?'"[48]

The reaction by competing firms to the introduction of an index fund was harsh. Bogle still remembers one particular excessive reaction. "A Midwestern brokerage firm [Leuthold Group] flooded Wall Street with posters screaming 'INDEX FUNDS ARE UN-AMERICAN. Help Stamp Out Index Funds!'[49] Very little new money was attracted to the fund in the years after inception. It wasn't until 1982 that the fund was able to break the $100 million in assets mark. No competing fund existed until 1984.

Burton Malkiel later praised Bogle's foresight. "Index funds are so popular now that it's easy to forget how courageous and tenacious Jack Bogle was in starting them. They were called Bogle's Folly because all they did was replicate the returns of the market. But, of course, that's a great deal. In the academic world many people saw the wisdom of this—but Jack is the guy who actually made it happen."[50]

The Samuelson Effect

Between September 24, 1974, the date of the incorporation of Vanguard, and the beginning of operations the next year, Bogle read a soon-to-be influential paper in the inaugural issue of *Journal of Portfolio Management* by the Nobel laureate Paul Samuelson. It was titled "Challenge to Judgment."[51] Samuelson argued that superiority in portfolio selection and investment performance was an unproven idea. While some managers may outperform the market averages in any particular year, they cannot do so on a repeatable, sustainable basis. Even respected academics such as Sharpe, Black, and Scholes as well as many others have been unable to identify "those minority groups or methods endowed with sustainable superior investment prowess."

As Bogle recalled, reading the article was "the magical part. The door opens, and that idea of the index fund I had written about in my thesis is exhumed."[52] The article caught him at the perfect moment. "As I read Samuelson's essay, a bolt of lightning struck. I quickly realized the soundness of this self-evident proposition—costs meant everything to index fund investors, whereas active fund managers were primarily interested in their own profitability, and gave the costs borne by their clients short shrift."[53]

The article "pleaded 'that some large foundation set up an in-house portfolio that tracks the S&P 500 Index—if only for the purpose of setting up a naïve model against which their in-house gunslingers can measure their prowess.'" Bogle remembered, "Presented with that challenge, I couldn't resist.[54] While all of our peers had the opportunity to create the first index fund, Vanguard alone had the motivation. The newly formed Vanguard Group (owned not by outsiders but by its own shareholders), I reasoned, ought to be 'in the vanguard' of this new concept. Our goal was to offer well-diversified funds at minimal costs, focused on the long term."[55]

Bogle was to have many connections to Samuelson over his career, but his first connection went back to his undergraduate days. "At the beginning of my sophomore year [1948] at Princeton University, I took my first economics course; our textbook was the first edition of Samuelson's *Economics: An Introductory Analysis*. Truth told, I found the book tough going and fared poorly in my first stab at this new subject, receiving a grade of 4+ (D+ in today's lexicon) at midterm. Since I was required to maintain an average of at least 3− (C−) to maintain the full scholarship that Princeton had provided me, if my grade did not improve by the end of the semester, my college career would be over. I struggled, but I made it—barely."[56]

Bogle only met Samuelson a half-dozen times by the time of Samuelson's death in 2009, but they corresponded regularly. In 1993, Samuelson wrote the foreword to *Bogle on Mutual Funds*. In correspondence from 2005, Samuelson wrote to Bogle, "Any small influence on you has been more than offset by what Vanguard has done for my 6 children and 15 grandchildren. May Darwin bless you!"[57] But the highest praise from Samuelson came in his 2005 address to the Boston Security Analysts Society. "I rank this Bogle invention along with the invention of the wheel, the alphabet, Gutenberg printing, and wine and cheese: a mutual fund that never made Bogle rich but elevated the long-term returns of the mutual-fund owners. Something new under the sun."[58]

And yet some of Samuelson's praise came much earlier. In August 1976 in his *Newsweek* article titled "Index-Fund Investing," Samuelson described how, in a column he wrote in the previous year, he had noted that some wealthy investors and corporate pension funds were starting to take advantage of index investing, but there was no convenient investment vehicle for most investors: one that "apes the whole market, requires no load [sales commission], and that keeps commission turnover and management fees to the feasible minimum."[59] By August 1976, however, Samuelson was delighted that his "implicit prayer has been answered—something called the First Index Investment Trust [Bogle's Vanguard index fund]."[60] In this article, Samuelson noted that the fund met four of his five prudent requirements: it was available to anyone with a relatively modest $1,500, matched the performance of the S&P 500, had very low fees (about 0.20 percent) and low turnover, and provided the broadest possible diversification. The only downside was that it came with a 6.01 percent load. But that final prayer would soon be answered.

Once the idea of creating an index mutual fund gained traction, the next step was to test its technical feasibility. Bogle turned to a portfolio manager who worked for him, Jan Twardowski, a recent Wharton graduate who was familiar with computer programming. As Twardowski recently recollected to Bogle, "I remember like it was yesterday. You walked by my desk one day and asked, 'Do you think you could run an index fund?' And I said, 'Well, let me look into it a little bit.' And then you stopped back a couple of days later and said, 'Jan, how are you doing on the index project?' I responded, 'I think I can run an index fund.' The next thing I know, you file one with the SEC [Securities Exchange Commission]."[61]

Bogle chose to replicate the S&P 500 index because it was a value-weighted index, reducing technical complications, and was universally used by pension funds as a benchmark. Initially Vanguard had a sales commission of 6.01 percent, quite typical for the time. Less than six months later, however, in February 1977, Vanguard initiated the no-load distribution system. "When the directors reminded me that I could not take over distribution, I told them that I was not taking it over, I was eliminating it," Bogle said. "That was not without a grain of truth, but probably could be considered a bit disingenuous. By February 1977, we were where we wanted to be: a full-line mutual fund complex providing administrative, investment management, and distribution services on the way to building Vanguard as the industry's low-cost provider, with the elimination of sales charges and the index fund as the obvious manifestation of these benefits."[62]

Bogle also commented on the contribution of academics to the investment world. "You could credit academics with the creation of this intermediation—or agency—society that we have today. When I wrote my thesis, individual investors owned 92 percent of all stocks, with the other 8 percent owned by institutions. If we look at the idea of diversification—the fundamental Markowitz theory—and add in Sharpe's theories on the level of risk that you decide to accept in your investment program, all of this leads to investors requiring an intermediator. So, investors, with the help of modern portfolio theory or the efficient market hypothesis, began to move to diversified programs instead of trying to do it themselves. I think that's a plus."[63]

The Growth of Vanguard

Vanguard's growth has been nothing short of phenomenal, from its humble beginnings to over $5 trillion of assets under management. Yet Bogle downplayed his role. "Vanguard 500 Index Fund is unequivocally the first index mutual fund. I don't dwell on my contributions such as they may be to the investing public. I've tried to do my best to build a better world for the average investor and, for that matter, for pension funds and institutional investors, too. Central to that was the creation of Vanguard, which was and is the only truly *mutual* mutual fund organization."[64] While part of Vanguard's growth corresponded with strong financial markets starting in 1982, it had far outpaced the industry. According to Bogle, "We had marched to a different drummer. Our indisputably successful drive to become the world's lowest-cost provider of financial service was sine qua non."[65]

In Bogle's opinion, there are very few companies that stand for something, but Vanguard does—in a word, stewardship. "A company that is of the shareholder, by the shareholder, and for the shareholder."[66] He explained, "The management company is owned by the funds. Its profits, running about $12 billion a year (in 2007), are largely rebated—98 percent or something—to our fund shareholders in the form of lower expenses. Without that kind of structure, it would be very difficult to bring out an index fund. We went no-load around the time the index fund was introduced. We then focused on being a low-cost provider in the mutual fund industry. When we began operations in May 1975, the first thing on my agenda was to start an index fund, which depended on low cost to work. The chicken-and-the-egg is that Vanguard was the chicken, and the index fund, the egg. But which was the most important?"[67]

Bogle reflected on the keys to Vanguard's growth. "You start with the mutual structure. You're designed to serve shareholders. You're talking about cost advantages. Particularly in the bond area, you don't have to reach for yield to have a competitive yield in the marketplace, because your expense ratios are going to run 12 basis points [or 0.12 percent] compared to 82 for your competitors. Money market funds are even easier. The higher the cost, the lower the return because you can't do much to increase yield in the money market area. And in the long run, the same thing proves to be true in the stock market, though it isn't always evident in the short run. So, it's structure, structure, structure. And then, strategy. Focus on the place where cost makes the most obvious difference, and that would be the index fund. Any given index fund is going to be more or less identical to another tracking the same index, so the fund that has the lowest cost will win. The same is true with bond funds, money market funds, or any fund that's more like a commodity in nature. And so, it's structure—not quite me, as [Ludwig Mies] van der Rohe, here, I think he said the opposite—but strategy follows structure. That's the mechanical part. But beyond that, there is the missionary part."[68]

According to Bogle, "What's clear is we're in the middle of a revolution caused by indexing. It's reshaping Wall Street, it's reshaping the mutual fund industry. And it's doing something very simple: shifting the allocation of stock market returns away from Wall Street and toward Main Street. We're beyond the beginning, but nowhere near the end."[69] He later added, "One meaning of the word 'vanguard' is leadership and a new trend. And I must say, I must be a wonderful leader because I have yet to find my first follower."[70]

The Cost Matters Hypothesis

In 2003 in a *CFA Magazine* article,[71] Bogle coined the phrase "cost matters hypothesis" (CMH), a play on words on the more famous efficient market hypothesis (EMH). In his article, he poked gentle fun at Samuelson's original grand language about the EMH when he wrote "CMH posits a conclusion that is both trivially obvious and remarkably sweeping: The mathematical expectation of the speculator is a loss equal to the amount of transaction costs incurred." In other words, "Whether markets are efficient or inefficient, investors as a group must fall short of the market return by the amount of the costs they incur."

As Bogle described the two hypotheses, "The one thing everybody knows—academics, brokers, investors—is the efficient markets hypothesis is often right, but it is not always right. And if you think the markets are highly efficient, and they're not, you're going to pay a penalty for that. And that happens periodically. But the CMH always works."[72] In light of the CMH, his call to arms is unambiguous and resounding: "It's high time we turn more of our attention to the CMH. We need to know just how much our system of financial intermediation has come to cost, to know whether high turnover pays, to know the real net returns that managers deliver to investors, and to evaluate the perverse impact on investors of the irrational investment choices offered by the mutual fund industry. And it's high time we become more serious about accepting the merits of passive all-stock-market investing as a separate and distinct asset class. It is never too late to begin to build a better world for the investors of tomorrow."[73]

Bogle subsequently expanded on his CMH by comparing the EMH against it in several dimensions.

Efficient Market Hypothesis	**Cost Matters Hypothesis**
Strong evidence	Overwhelming evidence
Sound explanation	Obvious explanation
Mostly true	Tautologically true

Bogle based the reasoning behind the CMH on the cold logic of subtraction. Gross returns in the financial markets minus the costs of financial intermediation equal the net returns actually delivered to investors. "No matter how efficient or inefficient markets may be, the returns earned by investors as a group must fall short of the market returns by precisely the amount of the aggregate costs they incur. It is the central fact of investing,"[74] he states. But what goes into this aggregate?

Bogle categorized three different types of costs to consider when owning mutual funds.[75] "The one that we talk about the most and the one that is the easiest to calculate is the fund's expense ratio," or its annual fees expressed as a percentage of assets. "Working with low-expense ratio funds—as I call it, fishing in the low-cost pond—is one way to make sure your returns are improved. There's a second cost that we don't pay nearly as much attention to and which we don't quantify very often, and that's the impact of a sales commission—if you buy a fund with a load. The third cost is hidden, but we know it exists; we just don't know exactly how large it is. That's the portfolio turnover cost. Mutual funds turn over their portfolios at an astonishing rate, averaging about 100 percent per year. By my estimates, any fund that turns its portfolio over at that rate is costing you an extra 1 percent per year: a half percent to buy all those securities, including market impact costs, and a half percent to sell them."

How can an investor reduce turnover costs? Bogle had some simple advice: "If you want to eliminate turnover cost, the third cost I mentioned, it's like rolling off a log—it's the easiest thing in the world: Buy an index fund." In addition to turnover costs in mutual funds, he also cautions against turnover in one's personal portfolio. "Trading is your enemy, because it's based on emotion."[76]

More recently, Bogle quantified the "all-in costs" of actively managed funds compared to Vanguard's index funds.[77] Actively managed funds, according to the calculations, had an average expense ratio of 1.12 percent, transaction costs of 0.50 percent, a “cash drag” (since funds typically hold cash reserves) of 0.15 percent, and sales charges and fees of 0.50 percent, totaling 2.27 percent. Vanguard’s index funds, however, only had an expense ratio of 0.06 percent. Furthermore, actively managed funds had a tax inefficiency differential (resulting from realized capital gains that are taxed, compared with untaxed unrealized gains) of 0.45 percent compared to the index fund, resulting in a 2.66 percent differential. Using the example of a thirty-year-old investor with a forty-year investment horizon and stock returns of 7 percent, Bogle showed that the index fund investor would have 65 percent additional retirement wealth over the actively managed investor. Bogle’s conclusion: “Do not allow the tyranny of compounding costs to overwhelm the magic of compounding returns.”

Predictions

On December 17, 2007, Bogle participated in a question-and-answer session with *Fortune* magazine readers—the same publication whose 1949 article inspired his Princeton thesis. The Dow was at 13,167 on that day, and he was asked where he saw the Dow in ten years and why. Bogle replied that “it would be slightly over 20,000.”[78]

On January 25, 2017, the Dow surpassed the 20,000 level for the first time, a prediction many a stage magician would envy. Bogle recently reflected on the session: “I don’t know why I fell for doing it. But I don’t do it without first doing my homework.”[79] But how exactly did he do it?

In a series of articles, including a recent one coauthored with Michael Nolan Jr.,[80] Bogle explained his secret. He relied on Occam’s Razor, the heuristic that “the simplest solution to a problem is the solution most likely to be correct,” and built on concepts introduced by John Maynard Keynes in his 1936 classic, *The General Theory of Employment, Interest, and Money.* According to Keynes, there are only two sources of return: enterprise, including things such as business profits, and speculation, related to the psychology of the market.

Bogle defined the enterprise or investment return as the initial period dividend yield plus the expected earnings growth. This definition is consistent with the well-known dividend discount model $R_t = D_0 + G_t$, where R_t is the expected return over some time period, such as ten years, D_0 is the dividend yield at the beginning of period t, and G_t is the annual growth in nominal earnings per share during period t, a proxy for the expected dividend growth.[81] He then added a term to capture Keynes's return on speculation: $\Delta P/E_t$, or the expected rate of change of the price-earnings (P/E) multiple over period t.

Bogle called the resulting model the "Bogle Sources of Return Model for Stocks," abbreviated BSRM/S, which he used as the basis for expectations of future stock returns. He noted that while the investment return has been reasonably stable throughout the past century and beyond, the speculative return component has not. On the other hand, the speculative return tends to revert to the mean. In other words, if the market P/E ratio is above the historical average of around 16, then it will tend to decline over the subsequent ten-year period, and the opposite will occur when the ratio is below average.

Bogle's full response leading to his 2007 ten-year forecast was as follows: "The Dow yield is 2.2 percent now, versus the S&P's 2 percent. Since I'm expecting a 6 percent to 7 percent return on stocks, the Dow ought to grow at 4 percent to 5 percent a year. So over ten years, growing 4.5 percent a year, it would grow by 55 percent, and so it would be slightly over 20,000, give or take. But anybody who is expecting that ought to be prepared for a lot of bumps along the way."[82] In other words, according to his formula, given a dividend yield of 2.2 percent and expected growth of around 4.5 percent, the expected stock market return (including dividends) was around 6.7 percent, excluding any speculative return.

Why exclude the speculative return component? As Bogle commented, "If you go back and look at the history of American business over the last century, you will find the [price/earnings] effect of stocks is zero. All of the returns are created as investment returns, dividend yields and earnings growth, and P/E effect—the speculative return—goes up and goes down and goes up and down for 100 years and ends up just where it started. So, try to ignore these machinations and stick with getting the underlying returns that provide stocks as good investments."[83]

Ultimately, though, Bogle did not see himself in the predictions business. "I don't look at it as predicting. It may have looked that way [in his Dow 20,000 prediction], but I look at it as creating reasonable expectations."[84]

Bogle's Perfect Portfolio

After Bogle's amazing calculation, we now turn to his thoughts on what constitutes the Perfect Portfolio. He provided the following basic advice to an investing newcomer: "Rely on simplicity; own American or global business in broadly diversified, low-cost funds."[85] He advised against trying to pick that one particular fund that you think might offer stronger than usual performance. As he put it, "Stop trying to find the needle. Invest in the haystack. Own the entire U.S. stock market. Today that is as easily said as done"[86] by investing in low-cost index funds, such as (of course) those offered by Vanguard.

According to Bogle, there are four key elements to investing: reward, risk, time, and cost. "There is only one element we cannot control: Reward. But we can control the other three."[87] Risk can be mitigated through diversification by eliminating "the risk of individual stocks, the risk of market sectors, and the risk of manager selection."[88] To the last point, he was blunt: "Fund investors are confident that they can easily select superior fund managers. They are wrong."[89] Longer time horizons can help to build a nest egg. Thus, his recommended investment horizon: "Holding it forever."[90] His advice to more sophisticated investors: "Ignore the short-term noise of emotions reflected in our financial markets and focus on the productive long-term economics of our corporate businesses."[91] And lower costs increase wealth, as articulated in his CMH.

How should one's asset allocation change over time? Bogle's rule of thumb was this: "You should start out heavily invested in equities. Hold some bond index funds as well as stock index funds. By the time you get closer to retirement or into your retirement, you should have a significant position in bond index funds as well as stock index funds."[92]

According to Bogle, taxes are an important consideration. "Watch out for taxes. If the funds are in your retirement plan, you can ignore taxes, but if they're in your own account, you want to take into account the tax cost involved."[93] By his estimation, "In terms of tax efficiency alone, active managers lost to the index by about 120 basis points a year."[94]

What did Bogle's own portfolio look like before his passing? He practiced what he preached. "I'm largely indexed, 85 (percent) to 90 percent in my equity funds, but I've hung onto some of my, what I call 'legacy funds' that I'd been investing in over the years ever since I was running Wellington Management Co. That would include Wellington Fund, Windsor Fund, Explorer Fund, Primecap Fund, other funds like that. I've owned them, and they're going to give me more or less a market return because they're very diversified, but that's 20 percent of my funds and I don't intend to change that. I should say that on the bond side, in my retirement plan account, which is my largest investment. . . , and in my personal account I own 100 percent municipal bond funds, which are very index-like in their nature."[95]

Bogle's bond portfolio was roughly half in intermediate-term bonds and half in shorter-term bonds.[96] In terms of percentage invested in bonds, "Investors could do a lot worse than using the rule-of-thumb calling for their bond portfolio to equal their age."[97] Commenting on the growth of target-date funds he noted, "They're fine, but I don't think they're a panacea. It remains to be seen whether the age-based system [investing a percent in bonds equal to one's age] does better than other systems."[98] In addition, "You shouldn't be investing in bonds on a short-term basis."[99]

Bogle wasn't a huge fan of frequent rebalancing to an asset allocation target, nor was he a fan of tactical asset allocation or market timing. At best, rebalancing should occur no more than once a year.[100] His asset mix was around 50 percent in stocks and 50 percent in bonds.[101] In his opinion, it was also important to understand what kind of an investor you are. "Are you an investor, or are you a speculator? If you're going to keep changing things, you are speculating."[102] For example, he felt that investing in commodities was speculating—anything in which your main intent is to sell to someone else for more than your purchase price.

Bogle's advice for stock investors who may be concerned about volatility: "Close your eyes."[103] He encouraged investors to stay invested. "If we're going to have lower returns, well, the worst thing you can do is reach for more yield. You just have to save more."[104]

Bogle cautioned that investors tend to place too much emphasis on assets and not enough on anticipated retirement income, including Social Security payments. "Investors make a big mistake by thinking too much of the value of the account and not enough about the monthly income they want to get. We could have a significant decline in the market with dividends unchanged."[105]

While Bogle was clearly a big fan of index investing, he made an important distinction between traditional index funds (TIFs) compared with exchange-traded funds (ETFs)—one of his final favorite subjects. "TIF is an acronym that I created to identify *traditional index funds,* such as that original broad-market, low-cost, no-load index fund, designed to be bought and then held 'forever.'"[106] One example is the Vanguard fund that replicates the S&P 500 index, but the category includes international and bond index funds as well. ETFs, on the other hand, can be much more specialized; however, even broad-based ETFs, such as State Street's SPDR that also replicates the S&P 500 index, experience huge swings in their volume of trading and redemptions. With TIFs, "you're not picking a segment of the market. You're picking the whole market, at very low cost. And the TIFs are much less volatile in their cash flows. With ETFs, well, you never know what's going to happen. During the 2007 to 2009 period, there was not a single month in which TIFs had an outflow. The exchange-traded funds had one month where they took in $70 billion toward the market high and another month toward the market low when they redeemed $40 billion—in just those two months a hundred-billion-dollar swing in cash flow between the high month and the low month. And the swing for the traditional index funds might have been $2 billion. So, there's a difference in holdings, a difference in how you look at the market in the years ahead. ETFs represent a very different market, and it's a trading market, it's a speculative market, it's an entrepreneur's market—entrepreneurs like those of the Go-Go era."[107] Bogle's advice was to stick with TIFs.

In terms of the personal Perfect Portfolio, Bogle put his money where his mouth was. He was almost entirely invested in stock and bond indexes. Interestingly enough, however, he had a slightly different take on endowment investments. Bogle had a scholarship fund at Blair Academy that he was allowed to manage. Ten years prior to his passing, he allocated 90 percent between the Wellington Fund—a fund with a broad mix of U.S. stocks and bonds—and a balanced index fund. "The idea was not to put the entire investment in the balanced index fund because there could be things that happen that a manager needs to adjust to. And then, against two contingencies, just in case, I put 5 percent in an emerging market index and, I hope you're sitting down, 5 percent in gold. The portfolio is designed to be held through all extremes. That's going to give you, with the two balanced funds, roughly 62 percent in equities."[108]

For asset allocation in one's Perfect Portfolio, Bogle noted that there wasn't a real need for rebalancing or for major changes around retirement. "I've concluded that regular rebalancing is not terrible, but not necessary. I've come to conclude that a 60/40 [percentages in equities and bonds] portfolio is probably the best option, rather than going from 80/20 to 20/80 in a target retirement plan."[109] When he was eighty-eight years old his investments were still split evenly between equities and bonds, "although," he said, "I spend half my time worrying if I have too much in stocks and the other half of my time worrying that I have too little in stocks."[110]

In his classic 1994 book *Bogle on Mutual Funds* (updated in 2015), Bogle set out a number of pillars of wisdom.[111] Among them is that when facing a number of possible solutions to an investment problem, the simplest solution is often the best. Time dramatically enhances capital accumulation, given the magic of compounding. Diversification is key to any investment. Remember that risk, return, and cost are the three sides of the "eternal triangle of investing." The mean is a powerful magnet—market returns are pulled toward it. You can have a stable principal value or a stable income stream but not both. You rarely, if ever, know something that the market doesn't. And think long term.

Bogle rearticulated his four main investment ideas, all others of which he believes can be ignored.[112] First, don't obsess over rebalancing your portfolio. If you must, once a year is often enough.

Second, focus on the U.S. market for equity investments. "We have the best investor protections and legal institutions."[113] Indirect international exposure already comes from multinational firms based in the United States. For many—including Vanguard's research group[114]—such a position is extreme. He admits that a 20 percent allocation to international equities is fine. However, the marginal benefit of investing a greater proportion of equities internationally was minimal in his opinion: "If you go from 20 percent to 40 percent, and foreign stocks outperform by two percentage points per year—which would be astonishing—that's a 0.40 percentage point benefit."[115]

Third, the only asset class diversification required is into bonds. No other asset class investments, such as real estate or other alternatives, are required.

And fourth, keep it simple. This means considering low-cost investments such as index funds. "There's no ideal portfolio, no Perfect Portfolio that ignores cost."[116] In other words, regardless of your investment, be it stocks, bonds, or in another asset class, consider the impact that the cost of acquiring and owning an asset is going to have on your ultimate return. For example, if your chosen investment has ongoing costs of, say, 3 percent more than another similar investment, over thirty years you will end up with a value of only 40 percent of the lower-cost alternative.[117]

Given the sound investment advice that Bogle has doled out over the years, it isn't surprising that he received fan mail. "One of the nicest was from an airline pilot who had retired. My advice to investors is just to throw their 401(k) statements into the wastebasket. Don't peek. Open the envelope when you retire and have a cardiologist standing by, because you're going to be totally amazed. 'Dear Mr. Bogle,' this pilot wrote me. 'I peeked. And all I want to do is thank you.'"[118]

Finally, one of Bogle's main pieces of advice was to avoid the temptation for action regardless of what is happening in markets—for example, in reaction to an announcement from the Federal Reserve. “When you hear news that moves the market and your broker calls up and says, ‘Do something,’ just tell him my rule is ‘don’t do something, just stand there.’”[119] In his 2012 book *The Clash of the Cultures: Investment vs. Speculation*, Bogle emphasized the differences between the culture of short-term speculation, such as day trading, and the buy-and-hold culture of long-term investing—and it’s clear where he stood. His closing piece of advice: “The secret to investing is that there is no secret. . . . There is only the majesty of simplicity. . . . When you own the entire stock market through a broad stock index fund, all the while balancing your portfolio with an allocation to an all-bond-market index fund, you create the optimal investment strategy. . . . Owning index funds, with their cost-efficiency, their tax-efficiency, and their assurance that you will earn your fair share of the markets’ returns, is, by definition, a winning strategy. . . . *Stay the course!*”[120]

6

Myron Scholes and the Black-Scholes/Merton Option Pricing Model

FAMOUS MATHEMATICIANS and physicists often have arcane formulas permanently associated with their names as their legacy. Pythagoras has $a^2 + b^2 = c^2$, Isaac Newton has $F = ma$, and Albert Einstein has $E = mc^2$. However, it's an exceptionally rare honor for economists, who are known more for being dismal than for their mathematical precision. Myron Scholes is that rare exception.

Myron Scholes is the co-originator of the Black-Scholes option-pricing formula, a mathematical expression that produces the price of complex securities such as stock options, warrants, and other so-called derivative securities (securities whose payoffs depend on or derive from those of other securities). For example, a call option on IBM stock gives the option owner the right to buy IBM at a prespecified price on or before the option's expiration date. The value of the IBM call option derives its price from the price of IBM's stock, and when the price of IBM's stock goes up, so does the value of the call option. The options markets are organized exchanges where such options are traded, with standardized contracts. In 1973, Scholes and Fischer Black published their now-classic article on pricing options and other derivative securities, deriving one of the best-known formulas in all the social sciences. In that same year, Robert C. Merton, a colleague and a friendly rival, published an extension to the Black-Scholes model, adding to the derivatives tool kit. Together, their contributions are often recognized collectively as the Black-Scholes/Merton option-pricing formula.

But there's much more to Scholes than just his formula. An early pioneer in the field of empirical finance, he applied careful statistical methods to measure the performance of mutual fund managers and test financial theories such as the capital asset pricing model (CAPM; see chapter 3). Not satisfied by academic achievements alone, unlike most academics who study investments without actually investing, he has also been involved in a number of commercial ventures putting his theories into practice, which gave him a deep understanding of market practicalities. As such, Scholes is ideally suited to help us formulate the Perfect Portfolio.

The Great White North

Myron Scholes was born in Timmins, Ontario, on Canada Day, July 1, 1941.[1] Timmins is a small gold mining town in northern Ontario with a population of fewer than twenty-nine thousand people when Scholes was born, peaking at around forty-eight thousand in the 1990s. The prosperity of the region attracted his father to practice dentistry there during the Great Depression, while his mother and uncle established a chain of department stores in the region. Like most young Canadians, Scholes learned to skate and played some hockey.[2] While he never made it to the big leagues, many others from his hometown did: Timmins was the birthplace of over two dozen National Hockey League players including Bill Barilko, who scored a classic overtime goal to help the Toronto Maple Leafs defeat their longtime rival, the Montreal Canadiens, in Game 5 of the 1951 Stanley Cup finals that led to Toronto's Stanley Cup victory.[3] Timmins is more than just the birthplace of famous hockey players, however.[4] The best-selling country singer and songwriter Shania Twain grew up in Timmins from the age of two. Scholes once quipped, "Shania Twain's economics was as good as my country singing."[5]

When he was ten years old, the Scholes family moved five hundred miles south to Hamilton, Ontario, a manufacturing city of over half a million people. The longtime home of steel manufacturers Stelco and Dofasco, Hamilton was known as the Steel Capital of Canada. Tragically, Scholes's mother developed cancer shortly after the family's arrival in Hamilton and died just after he turned sixteen. Around that time, he also developed scar tissue on each of his corneas that impaired his eyesight until he underwent a successful cornea transplant ten years later. In the meantime given his difficulty reading, he learned to think abstractly and become a good listener.

Scholes became interested in economics and finance through his mother and uncle's business. He was exposed to important economic topics such as principal-agency conflicts and contracting issues when the death of his uncle resulted in a family dispute over the department store. In school, Scholes became the treasurer of various clubs. He gambled in order to understand probabilities and risks, and he invested in the stock market in high school and at university.

Scholes was fascinated by what drove stock prices. He recounted, "There were many mining companies in northern Canada—silver mining companies and gold mining companies—and my parents and my aunts and uncles who lived nearby always were looking for the next strike either in gold or in silver, which would make a large amount of money. So, they would be attracted to buying stocks that were maybe a few pennies, with the expectation that they might jump to multiple dollars."[6] He would watch his family members doing this, although they were never particularly successful at it. "Partially what attracted me was to say: '[Are] there different methods or different ways than just trying to find a rumor and act on the rumor of possible findings of gold or silver?'"[7] The young Scholes would read reports and investing books, searching in vain for that secret of investing success.

Scholes decided to remain in Hamilton for his undergraduate studies, attending McMaster University. He mainly took courses in the liberal arts and graduated in 1962, majoring in economics. One of his professors, a graduate in economics from the University of Chicago, directed him to the work of the future Nobel winners George Stigler and Milton Friedman. Scholes was impressed. "That led me to really want to broaden my mathematics and other skills, in conjunction with economics, because I thought it was a wonderful area and a science that was really attractive to me."[8] Then as now, he was passionate about the importance of having a strong foundation in the field. "I think to be creative in any area . . . [,] to understand the area, to understand what the underlying theory is and what is the basic foundations of a science, gives one an ability to create because you have to go back to first principles to create. To have the correct foundation is the way in which you can really add value. So, to do things only from a technical aspect could leave a lot [of ideas] on the table. . . . And I think everything in science is inductive in that you gather data . . . [;] you are inductive, and then you stop at a moment in time and you become deductive. You have to deduce. And so, it is integration and differentiation—integration is adding things up and differentiation is deciding what is relevant to throw away and what is relevant to keep."[9] While Scholes had considered attending law school, he decided to pursue an MBA degree at the University of Chicago instead.

My Kind of Town

The University of Chicago attracted Scholes for its reputation as a place where he could learn from the best in order to bring out his best.[10] He would receive his MBA degree there in 1964 and his PhD in 1969. It was an auspicious time, as Scholes would become a member of what Eugene Fama referred to as the "once-in-a-lifetime cohort of PhD students that came to Chicago soon after [he] joined the faculty in 1963."[11] Besides Scholes, this cohort included Michael Jensen, Richard Roll, Ray Ball, Marshall Blume, James MacBeth, and Ross Watts. To the best of Scholes's recollection Fama was chair of all of their theses, and Jensen and Roll were to become lifelong friends of Scholes.

While Scholes had initially planned to follow his mother's wishes to join his uncle in his book publishing business after obtaining his MBA degree, his first summer at Chicago changed his career path. As a foreign (that is, Canadian) student, he had limited work opportunities in the United States, and he needed to secure a job on campus.[12] Although Scholes had never been involved in computer programming, he secured a position as a junior programmer through Dean Robert (Bob) Graves, the head of computing and a professor of management sciences. Immediately, several professors asked for programming assistance on their research projects. Scholes tried to excuse himself, citing his lack of experience and suggesting that senior programmers would be better suited to fill their needs. "Bob had said I was the number 7th person there, so don't worry about it. So, I would say, I'm [only] number 7 here, and you'll have to wait for more experienced people to come in. After a few days I went back to Bob and said that no one showed up other than me. [He said] well, no one other than you is there."[13] In his spare time, Scholes devoted himself to learning programming. He soon fell in love with computers and became a computer whiz.

In addition to his love of computers, however, Scholes also fell in love with economics and economic research. He saw how his programming clients—the professors—were able to create and address their own research programs. He would occasionally ask them to explain their research, and he even ventured to suggest design improvements. Besides Fama, another of Scholes's programming clients would go on to win a Nobel Prize in the economic sciences: Merton Miller, a professor of financial economics. Scholes was never sure whether it was because of his scholastic qualities or because Miller didn't want to lose a programmer, but Miller suggested that he enter the PhD program. Amazingly, he never even had to apply. He was simply told "Yeah, come on in to the PhD program."[14]

At that time, financial economics was still an emerging branch of economics, and Chicago was at the center of this new growth. Scholes became interested in relative asset pricing and the extent to which arbitrage—that is, attempting to make a riskless profit—prevented investors from earning abnormal profits. In his ninety-three-page PhD dissertation titled "A Test of the Competitive Market Hypothesis: The Market for New Issues and Secondary Offerings," he set himself the task of determining the shape of the demand curve for traded securities. The dissertation has been described as "an original and powerful piece of theoretical and empirical research that supported the efficient market hypothesis."[15]

A little background is necessary to show the originality in Scholes's dissertation. He began by focusing on risk and return relationships not only in individual securities but also in portfolios, attempting to understand such relationships in "frictionless" settings (i.e., without any transaction costs) and "friction-filled" settings.[16] Scholes observed that securities could be distinguished from one another by their risk and return characteristics.

What determines the price of a security? In economics, it's an axiom that prices are determined by supply and demand. Supply and demand curves show an expected relationship between prices (on the vertical axis of the traditional graph) and quantities of goods (on the horizontal axis). Supply curves tend to be upward sloping: suppliers are prepared to sell more goods if prices are higher. Conversely, demand curves tend to be downward sloping: consumers will typically reduce demand if prices are higher.

Rather than simply examining supply and demand for securities, however, Scholes reasoned that prices would change based on new information that was received by market participants. That information would include signals by large investors that were "informed" or aware of the true underlying circumstances of a security, perhaps due to pending bad news. In other words, rather than simply moving up or down the demand curve, such new information could cause the entire demand curve to shift its position on the price-quantity axes. According to Scholes, "This was the first statement in finance of a rational expectations approach to understanding economic activity. That is, only new information could change the demand for securities, not whether an individual wanted to sell more or less of a particular security."[17]

The empirical investigation in Scholes's dissertation validated the theory that he himself created. After this accomplishment, he went on to work with Miller on measures of risk and the effect of differences in risk on security returns.

Black Meets Scholes

In 1968, after Scholes had essentially finished his dissertation but before he had officially defended it, he considered his next step. He had two job offers. One was a teaching position at the University of Texas at

Austin at a salary of $17,000, with attractive consulting opportunities with local millionaires. The other was a teaching position at the Massachusetts Institute of Technology for $11,500 and no hint of consulting opportunities.[18]

Scholes decided to move to Boston anyway, where he became an assistant professor of finance at the Sloan School of Management at the Massachusetts Institute of Technology (MIT). Paul Cootner, the future Nobel laureate Franco Modigliani, and Stewart Myers were among his colleagues.[19] Behind the scenes, it turned out that Miller and Fama had recommended to Modigliani that Scholes should receive an offer from MIT. Scholes later joked, "What happened was that I thought that I was to be outsourced in the sense that I had to go to the farm team. At Chicago at the time, they didn't want to hire back any of their own people."[20]

It was during his first year at Sloan that Scholes met Fischer Black, who was at that time a consultant at Arthur D. Little in Cambridge. Scholes met Black through his Chicago classmate, Jensen, who had written his doctoral dissertation on the performance of mutual funds.[21] Black had been commissioned to do a study on mutual funds for one of his clients, and had contacted Jensen to get a copy of his work in that area. Jensen in turn mentioned to Scholes that once he was at MIT, if he wanted to meet someone interesting he should contact Black. Once Scholes had settled in to life in Massachusetts, he gave Black a call, and the two men had lunch together at the Arthur D. Little in-house restaurant.

The earliest collaboration between Scholes and Black occurred with Jensen and was closely tied to the development of the first index fund.[22] Before his move to MIT, Scholes had a consulting project with Wells Fargo Bank, headquartered in San Francisco. He was consulting for John "Mac" McQuown, who had been hired in 1964 as the head of Wells Fargo's management sciences division, which involved using computers to try to break the investment process into parts, evaluating those parts, and developing a reliable model for predicting the performance of those investments. McQuown had been entrusted with an "Investment Decision Making" project by the bank to take better advantage of its computing resources. McQuown had become intrigued with the possibility of applying analytics to finance. Inspired by a presentation given by

University of Chicago finance professors James Lorie and Lawrence Fisher to a group of Merrill Lynch executives, McQuown arranged to visit Chicago himself, where he was introduced to Fama and Miller. This life-changing moment exposed McQuown to researchers who were actively collecting data and investigating what was driving stock prices. He took this experience back to Wells Fargo.

In the summer of 1968, Scholes spent three weeks working with McQuown as a consultant and was given the task of evaluating the investment management process in the management science group and reporting his findings.[23] He later recalled, "My report said, in effect, that they had built very good technology on how to use analyst inputs and [how to] build portfolio models as management science people would do. But I said [they] didn't have any inputs to put into the model. I also I thought that [it] was somewhat of a dead end. And since we were trying to do something new, that maybe [they] should go the opposite way and study how to use passive investments as part of the investment milieu as opposed to active investment."[24]

Six months later McQuown contacted Scholes, indicating that Wells Fargo liked his ideas about passive investment and wanted to sponsor further research. Scholes recalled McQuown reasoning out loud that "no one had ever talked about passive management before."[25] What did he think of such a project? "Passive meant, to me . . . just thinking about, at the time, replicating, or being close to replicating an index. But as the index composition changed, you trade off the basis cost [lower return] associated with not having a perfectly correlated structure with the transaction cost of having to make the adjustment instantaneously or make the adjustments more slowly over time."[26] Scholes recounted his reply to McQuown: "I said I was a young assistant professor and was stuck in Boston teaching, but I had met this person who I thought was very smart and energetic, Fischer Black. He had talked about the possibilities of leaving Arthur D. Little and starting his own firm. So, I said, 'let me call him.' So, I talked to Fischer about the possibility of doing consulting, and that would be the spur that would make him jump from Arthur D. Little to his own firm,"[27] which Black did, eventually calling it Associates in Finance. Wells Fargo was interested in research examining the trade-off between risk and return, the topic Black had discussed with Jensen. As a result, Black and Scholes contacted Jensen, and the three of them ended up collaborating.

The fruit of this collaboration was the article "The Capital Asset Pricing Model: Some Empirical Tests."[28] Contrary to what was predicted by the traditional form of the CAPM as developed by Sharpe and others, the expected returns on securities (in excess of the return on Treasury bills) were not strictly proportional to a stock's beta, the sensitivity of a stock's return relative to the overall market, which was a surprising result. Nevertheless, they found that beta was still an important determinant of average stock returns.

This article also provided a way to address the "measurement error" problem. Any estimates of beta will be biased since the true value of beta cannot be directly observed, hence the problem. Their solution, a major contribution to later empirical studies and a standard practice today, was to reduce any such bias by investigating portfolios of stocks rather than individual stocks.

While Scholes was collaborating with Black and Jensen, another chance event would take place. In 1969, Robert C. Merton (featured in chapter 7) would join the finance group at the MIT Sloan School of Management. His encounters and shared interests with Scholes would ultimately lead the two to receive the 1997 Nobel Prize in Economics for discoveries related to the famous formula mentioned at the beginning of this chapter. If not for his untimely death in 1995, Fischer Black would in all likelihood have been part of this esteemed group.

The Formula

Known everywhere simply as Black-Scholes, the Black-Scholes/Merton option pricing formula has been described by mathematician-author Ian Stewart as one of "17 equations that changed the world."[29] But what does the Black-Scholes formula actually tell us? This world-changing namesake formula describes the correct price of a call option, under certain assumptions. However, to fully understand this accomplishment, a little more explanation is needed.

Just as stocks are securities—tradable financial instruments with monetary value—options are also securities. Options are a type of security whose prices are derived from the price of another underlying security. As a result, they have the generic name of derivatives. An option is a specific type of derivative based on a stock. For example, a bullish speculator who doesn't own a stock can still enjoy the upside of ownership through the purchase of a "call" option. An investor might buy shares in Apple stock, gaining or losing dollar for dollar as Apple's stock price changes. But what investor wants to lose money, especially dollar for dollar? The solution is the call option, a derivative that provides the upside of a rising stock price with a relatively small investment, usually a small fraction of the stock's current value, with a limit on the downside.

How does this work? A buyer of a call option has the right, but not the obligation, to buy shares in a stock such as Apple at a predetermined price, called the exercise price and also the strike price, within a particular time period, typically within the following year. If Apple is selling for $100 per share, a call option might have an exercise price of $105 and an expiry date three months hence. If at any time within the next three months Apple's stock price rises above $105, the holder of the call option can exercise the right to buy the stock for $105. If Apple's price rose to, say, $108, then the call option holder could exercise the right to buy at $105 and then sell at $108, receiving $3, the difference between the $108 price on that day and the exercise price of $105. Conversely, if Apple's stock price never rises above $105 over the next three months, then the call option won't be exercised, in which case the buyer is simply out the amount of money originally paid for the call option.

But what should that amount of money be? Options in various forms have been around for hundreds of years, from ancient Greece to trading on the Amsterdam Stock Exchange in the late seventeenth century (see chapter 1). However, no one had ever been able to calculate the theoretical price of a call option using robust assumptions. As fate would have it, both Black and Scholes were independently looking for a solution at the same time.

Fischer Black wrote that his background research in option pricing dated to 1965, when he started to work at Arthur D. Little.[30] His colleague there was Jack Treynor, who had independently developed a version of the CAPM, as discussed in chapter 3. Treynor had sparked Black's interest in the theory of finance, and Black spent further time examining financial models. "The notion of equilibrium in the market for risky assets had a great beauty for me," he wrote. "It implies that riskier securities must have higher expected returns, or investors will not hold them—except that investors do not count the part of risk that they can diversify away."[31]

Black started trying to apply asset pricing models to assets other than stocks. Some of Treynor's research was related to valuing cash flows within a company, and Treynor had devised a differential equation to solve that particular problem. A differential equation, simply stated, is a mathematical equation that relates the rate of change in one variable (or more) to another variable (or more). Some differential equations have been studied extensively, and solutions for them have been found; others can be extremely difficult to solve. Black reviewed Treynor's work and found an error in Treynor's differential equation, but between the two of them they figured out a correction.

With that as background, sometime around 1968 Black started to work on deriving a formula to value a warrant. A warrant is generally issued by a company that's trying to raise money. In principle, it works much like a special type of option. A warrant gives the holder the right, but not the obligation, to buy further shares in the company at a predetermined price within a particular time frame. In 1968, these warrants were usually traded in the over-the-counter market (sometimes involving a literal counter).

Black made some progress on the problem. He found that the value of the warrant was a function of the stock price and other factors. He simplified the problem further by assuming that complications such as trading costs did not exist. Even though Black had a PhD in applied mathematics, he had not spent much time working with differential equations and was unsure about the correct approach. Black also had an undergraduate degree in physics, but he did not realize at the time that the equation he had derived was a version of the well-known heat equation from thermodynamics, one that had a known solution. Unable to come up with a solution himself, he put the problem aside.

Around this time, Scholes was supervising MIT students who were required to do a thesis for their master's degree.[32] Some of these students were interested in call options and had obtained option pricing data from over-the-counter dealer books. In addition, Scholes's colleague Paul Cootner had also collected some options data that was available at MIT. These students were trying to apply the CAPM to discount the expiry date value of the options to the present value. It was hardly the worst idea in the world, but Scholes immediately saw that it was inadequate. According to Scholes, "I kept looking at the results, and it was kind of silly, especially since I could see that the discount rate was changing . . . that the underlying risk of the option was not constant. So, I started to work on creating a zero-beta portfolio, the idea of a hedge portfolio. But I didn't have the dynamics correct. . . . I was working on the dynamics. So, in one of my afternoon conversations with Fischer, we were talking about index funds and what we can do with our Wells Fargo research, you know the Black-Jensen-Scholes research, our dividend paper, and other papers that came because of that work together. I mentioned options and where I had gotten to and then Fischer said he had been working on options as well. So, I showed him what I had done, and he started showing me what he had done. He was stuck, and I was stuck. So, we started combining our thinking together, and that's how it came to be."[33]

As Black described his intuition,[34] suppose you're looking for a formula that calculates the value of a call option. You believe that the formula depends on the price of the underlying stock, the exercise price of the option, the maturity date of the option, and the interest rate. This formula will indicate how much the option value changes relative to a small change in the stock price.

Here is Black's insight. If the option value goes up (or down) by $1.00 when the stock is up (or down) by $2.00, then you can hedge your position by buying one share of stock and at the same time going short two call options. (Shorting is the opposite of buying or going long. In shorting, you gain when the value of a security declines and lose when the value increases.) This overall "hedging position" or "replicating portfolio" of being short two call options and long one share of stock is virtually riskless. If that's the case, however, the return should be equal to that of the short-term interest rate, the return on the risk-free security. As Black stated, "This one principle gives us the option formula. It turns out that there is only one formula for the value of an option that has the property that the return on a hedged position of option and stock is always equal to the short-term interest rate."[35]

Black noted that this was a joint breakthrough. "We started working together on the option problem, and we made rapid progress."[36] As Black recalled, he and Scholes focused on the dependence of the option formula on the underlying stock's volatility rather than its expected return. This allowed them to assume any expected return for the stock, such as a risk-free T-bill interest rate. They found a 1961 article by Case Sprenkle, a recent PhD graduate from Yale's economics program, that presented a formula for the expected expiry date value of an option.[37] With this, they could use the interest rate to discount the option's expected value at expiration to the present time and apply it to Sprenkle's formula. They then mapped the formula against the known heat equation. This had an easy solution, and Black and Scholes immediately knew they had the option pricing formula right.

Scholes recalled the breakthrough somewhat differently than Black—not in terms of credit but instead in terms of insight and inspiration. "We had all these tools. I remembered [Paul] Cootner's book,[38] and I read some of the articles in Cootner's book about option pricing. I saw the paper by [A. James] Boness,[39] which had the expected terminal value of the option. Then I said, 'Okay Fischer, why don't we try putting in the riskless rate because that came in a differential equation. Differentiate that, which is the closed form solution, and then we'll see what it looks like.' So, we differentiate it. We put it into our differential equation, and . . . voila, there it was. So that's when we realized for the first time what the implications were of the riskless rate. Because it said we could assume as if the underlying asset had an expected return equal to the riskless rate and then be able to discount at the riskless rate."[40]

Here is the formula as it eventually appeared in publication, in all its beauty:

$$w(x,t) = xN(d_1) - ce^{r(t-t^*)}N(d_2)$$

$$d_1 = \frac{\ln x/c + \left(r + \frac{1}{2}v^2\right)\left(t^* - t\right)}{v\sqrt{t^* - t}}$$

$$d_2 = \frac{\ln x/c + \left(r - \frac{1}{2}v^2\right)\left(t^* - t\right)}{v\sqrt{t^* - t}}$$

This may seem like hieroglyphics to the uninitiated, but here is a Rosetta Stone that may be of use. In this formula, *w* is the price of the call option. The notation *w(x,t)* is meant to show that the option price is a function of both *x* and *t*, where the current stock price is *x* and the current date is *t*. The expiration or maturity date of the call option is t^* (usually pronounced "t-star"), the exercise price is *c*, the short-term risk-free interest rate is *r*, the variance of the return on the underlying stock is v^2, and thus *v* is the standard deviation of the underlying stock return, which is also the volatility. Finally, *e* is a mathematical constant (2.71828 . . .) that's the base of the natural logarithms (and one of the fundamental constants of the mathematical universe), and *N(d)* represents the cumulative normal density function, very similar to the percentiles on a standardized test.

The notation *w(x,t)* is meant to show that the option price is a function of both the stock price and time, but in fact we can see that *w* depends on three other variables as well: the exercise or strike price, *c*; the risk-free rate, *r*; and the volatility of the underlying stock return, *v*. If you know these five factors, then you can determine the value of any call option. All of these factors, except the volatility of the underlying stock return, are readily available. The challenge to the implementation of Black-Scholes was a good estimate of volatility.

Let's unpack how the Black-Scholes formula works for pricing a call option. Suppose that IBM is trading for $130 and you could buy a call option on the stock, allowing you to buy it sometime in the next three months for $132—the strike price. Checking the financial websites, you see that Treasury bills are yielding 2.5 percent, the risk-free rate. The most difficult part is the volatility, but you estimate it using the standard deviation of the stock's returns and come up with a value of 30 percent. Using those inputs, the formula shows precisely what the call option should be worth—in this case $7.17. Most obviously, if the strike price were lower—say, $125—then this call option would be worth more. Similarly, the price of this call option will go up when IBM's stock price goes up, when there is more time remaining to exercise the option, when interest rates are higher, or when the volatility of IBM's stock price is higher.

Scholes recently reflected on option pricing and his contribution with Black and Merton to its development. "There's two aspects of the option pricing: One is the technology itself, and the other is the model."[41] Scholes here makes an important distinction between the technology and the model. A Black-Scholes–type model focuses on the solution of a particular pricing issue, such as the value of a call option, and requires specific assumptions, such as constant volatility of the underlying security and a constant interest rate, in order for it to be solved. The Black-Scholes model makes these assumptions in order to solve the pricing puzzle in "closed form" by applying mathematical equations. Thus, a model is an abstraction from reality, and a model's estimates are measured with error, for example, the predicted value of call options. The performance of a model depends on the quality of its assumptions—if the volatility or interest rates change, for example, then the model's predicted price of a call option will not be exact.

Scholes explains that "a model . . . by definition has an error to it. So, people say the Black-Scholes model doesn't work, but it depends on the assumptions and how good the assumptions are."[42] Derivatives technology, in contrast to the model, applies mathematical concepts in order to understand hypothetical relationships. For example, the technology can examine what happens to portfolio risk when an investor who owns both stocks and options on the stocks is able to buy and sell instantaneously and without transaction costs. It's the development of the technology—knowing that if A happens then B will result—that can help create a model. Both the technology and the model are important for the development of derivatives products such as traded options.

Scholes continued: "The technology that Fischer Black and I, and Bob Merton, developed was really trying to think about how to create a replicating portfolio. . . . The technology allowed us to have—every period of time—changing risk, or changing volatility, and a changing interest rate and to be able to think about how that hedging portfolio could be established each period of time and how it would evolve over time. What we developed was a differential equation, which described how the option changed with regard to changes in the time and the interest rate, and volatility, and the expected return fell away because we had a hedging portfolio, or a replicating portfolio. . . . We assumed that the volatility was constant, and we got a nice model. Even though we knew that was false, we got a model. . . . I think that the whole development of, or use of, derivative technology allowed for us to change the whole nature of finance."[43]

The Road to Publication

Much like Bill Sharpe's experience, there was no easy path to publication for Black and Scholes, despite an article that would receive an incredible forty thousand-plus citations by 2021,[44] according to Google Scholar, making it one of the most cited finance papers of all time. Black and Scholes initially thought they should try to publish a paper that simply described the formula.

Their next idea was to apply their formula in a corporate setting. Consider the typical balance sheet of a firm. It owns assets, and those assets are financed by a combination of debts, such as bonds, and common shares or equity, through share issues and retained earnings. Suppose all of the debts of a firm were "pure discount" bonds that matured at the same time (say, ten years), with no interim coupon payments. There is also a chance that the debt may default. Black and Scholes had the insight that stockholders then effectively held an option on the firm's assets. It was as though the bondholders owned the firm but had given the stockholders the option to buy back the assets. In ten years, the common shares would be worth the value of the assets minus the value of the bonds or zero, whichever was greater.

While Black and Scholes were working on their option pricing formula and applying its technology to corporate finance, Merton and Samuelson were also looking to extend and apply the option pricing technology. It was a friendly competition, but it was a competition nonetheless. Scholes recently reflected, "Fischer and I were secretly working in our boiler room," trying to determine whether they had an edge or whether Merton and Samuelson did, "and we didn't really talk to Merton or Samuelson until we got as far as we could."[45]

In the summer of 1970, Black and Scholes gave a presentation of an early version of their paper at a Wells Fargo conference on capital market theory and talked about the corporate finance application of options. Merton also attended the conference, but he overslept on the morning of their talk and only found out later that they were working on a similar application. Subsequently, as Merton became aware of the work they were doing he spent hours in discussions with Scholes, as academics tend to do, in the spirit of both intellectual rivalry and cooperation. According to Scholes, "A couple of weeks later [Merton] came into my office and said, 'I heard you had a proof, or so-called proof of the option model that was different [from what Merton was working on].' . . . We actually argued about it."[46]

By October 1970, Black and Scholes had a draft of their paper titled "A Theoretical Valuation Formula for Options, Warrants, and Other Securities." Black sent the paper to one of the oldest and most prestigious economics journals, *Journal of Political Economy*, which began publication in 1892 and is published by the University of Chicago Press. Scholes recalled, "We submitted the paper to the *Journal of Political Economy* first because of our association with the University of Chicago. We didn't submit it to a finance journal because we thought this would have a broader application."[47] Shortly after the submission, Black received what is known as a desk reject, a decision by the editor of the journal to reject a submission outright rather than soliciting the views of "blind" referees. The letter indicated that their paper was too specialized for the journal and would be better suited for the *Journal of Finance*, where Markowitz and Sharpe had published their seminal papers. Black then sent the paper to another prestigious economics journal, the

Review of Economics and Statistics, founded in 1919 and published by MIT Press, and again received a prompt rejection letter.

Black suspected that at least part of the reason for the prompt rejections was because it was clear from Black's return address that he wasn't at an academic institution, and thus the paper wasn't taken seriously. Black and Scholes then "rewrote the paper to emphasize the economics behind the formula's derivation"[48] and gave it a new title in January 1971, "Capital Market Equilibrium and the Pricing of Corporate Liabilities." Miller and Fama took an interest in the paper and gave Black and Scholes extensive comments. Miller and Fama also suggested to the editors of *Journal of Political Economy* that perhaps they should more seriously consider the paper, so Black and Scholes tried once again with that journal. Not long afterward in August 1971, they received a conditional acceptance of the paper, subject to further revisions suggested by the referees.

Black and Scholes completed the revisions by May 1972, with a revised and final title for the paper, "The Pricing of Options and Corporate Liabilities." The article finally appeared in the May–June 1973 issue of *Journal of Political Economy*.[49] In the meantime they had written a follow-up paper with results of empirical tests of the model, which appeared in the May 1972 issue of the *Journal of Finance*, before the article on their theoretical model appeared in print.[50]

Back to the Windy City, Then California Dreamin'

In 1973, Scholes returned to the University of Chicago, this time as a faculty member rather than a student.[51] There he joined Black, who received his first academic appointment at the University of Chicago in 1972[52] (before leaving for MIT in 1974) and was able to interact with colleagues such as Fama and Miller. Scholes's research interests expanded to include taxation and asset pricing tests. He wrote papers with Black and Miller, looking at the effect of a tax on dividends on security prices, as well as with Robert Hamada, examining the effect of taxes on capital structure, and with George Constantinides, examining the effect of taxes on the optimal liquidation of assets.

Scholes was actively involved with the Center for Research in Security Prices (CRSP), which was launched in 1960 with a grant from Merrill Lynch for the construction of a historical database of monthly stock prices.[53] In 1974, Scholes succeeded its cofounder James Lorie as its executive director, a position Scholes held until 1980. (The other cofounder of CRSP was Lawrence Fisher.) Scholes's involvement at CRSP led to the development of large files of daily data, and his research with Joe Williams on beta estimates using nonsynchronous data is now immortalized in the form of the Scholes-Williams beta.[54]

In 1981, Scholes visited Stanford University, where he became a permanent faculty member at the Business School and the Law School in 1983. His close colleagues were veterans Bill Sharpe and James Van Horne as well as up-and-comers such as Jeremy Bulow, Anat Admati, Paul Pfleiderer, and Michael Gibbons. There, Scholes collaborated with his close friend Mark Wolfson on research on investment banking and incentives to develop a theory on tax planning, later published in a book, currently in its sixth edition.[55]

Scholes is the rare financial economist who has made major contributions in both the theoretical modeling and the empirical testing of models. "I think that one of the things all of science is trying to do, and all of business is trying to do, is to see how we can have theory on the one hand and experience on the other hand and bring experience and theory closer and closer together. Because we always think you need theory, first, then you get experience, second. . . . Without theory, experience is meaningless. And without experience, theory is meaningless."[56] Scholes reflected on his involvement with the CRSP database. "To do the empirical work that I did, there was no data. We had to develop the data. And I worked very hard to make sure that we did develop the data. And then, as we developed the data, we made that data available to the community at large. And the community at large was then able to do empirical research, which then fed back on the theory. The theory became richer. And the two of them together were hand in glove. Some things were rejected. Some new things were born. Puzzles came about into the profession. And as a result of that, it builds a much richer science."[57]

In 1990, Scholes's interests shifted to the role of derivatives in financial intermediation. Financial intermediaries such as investment banks often act as matchmakers between buyers and sellers of securities. Scholes served as a consultant to the investment bank Salomon Brothers and became its managing director and cohead of the fixed-income derivatives sales and trading group while still at Stanford (where he has remained as professor emeritus since 1996). In 1994, Scholes joined several former Salomon Brothers colleagues to cofound Long-Term Capital Management, a hedge fund focused on applying financial technology to practice. The fund was extremely successful for several years before requiring a historically major recapitalization in 1998 (an event that will be considered in more detail in chapter 7).[58]

In 1997, for his accomplishments, Scholes was awarded the Nobel Prize in Economics, along with Robert C. Merton. The Nobel presentation speech praised Scholes: "Your methodology has paved the way for economic valuations in many areas. It has also generated new financial instruments and facilitated more effective risk management in society."[59] More than that, however, understanding the value of a financial option helped society understand the economic value of flexibility in general—the technology versus the model, once again.

Derivatives Markets and Information

While neither Scholes nor Black nor Merton invented the concept of derivatives, their contributions to option pricing led to an increase in efficiency that powered the explosive growth in the use of derivatives.[60] The world of derivatives was dramatically different before and after their 1973 publication containing the Black-Scholes formula. While options on stocks existed in the seventeenth century, before the 1970s, purchasing options in the public mind was considered to be basically the same as gambling and prone to market manipulation, often through the spreading of false rumors or fake news. One SEC official commented that he had never seen a market manipulation in which options weren't involved. At times in the eighteenth and nineteenth centuries, options were banned in Britain, France, and various U.S. states. Following the stock market crash of 1929, an outright federal ban on stock option trading was only narrowly averted. Even in 1970, trading in many derivatives such as S&P 500 futures was still illegal.

In the late 1960s, the two major futures exchanges, the Chicago Board of Trade and the Chicago Mercantile Exchange, usually saw little trading activity, with traders sitting on the steps of the soybean pit reading newspapers. However, exchanges were starting to look beyond trading in pork bellies, shrimp, and plywood and into financial futures, with derivatives related to stock market indices rather than physical products. With superb timing, the Black-Scholes paper was published in 1973, the same year that the Chicago Board of Options Exchange (CBOE) was founded as the first marketplace for the trading of listed options. Before the founding of the CBOE and its promotion of standardized option contracts, options were traded in a much less organized fashion in the so-called over-the-counter market, or direct trading between two parties, often through a network of dealers. The CBOE did not have an auspicious start. For most of the first day of trading the traders sat around playing backgammon and chess, but the Black-Scholes/Merton option pricing formula catalyzed an explosion in the use of financial derivatives. By 1984, the CBOE was second only to the New York Stock Exchange in terms of the trading value of financial assets.[61] Today the CBOE is the largest U.S. options exchange, offering options on individual equities as well as indexes such as the S&P 500, the most active U.S. index option.[62]

Many of the assumptions in the Black-Scholes model, such as zero trading costs and no restrictions on short selling, were originally unrealistic, but the world was starting to change, and commissions were soon about to dramatically fall. The Black-Scholes model had an almost immediate impact, hitting the emerging options market in its technological sweet spot. The model helped the exchange to overcome the stigma of options trading as gambling by legitimizing the practice as one related to efficient pricing and hedging. Even in the CBOE's early days, traders incorporated the formula into their trading strategies. One firm, Donaldson, Lufkin & Jenrette Securities, contracted Scholes and Merton to provide them with theoretical prices and found that some call options were overvalued by 30–40 percent.

As early as 1974, Texas Instruments marketed a handheld calculator with the Black-Scholes model and "hedge ratios" to calculate the number of securities to go long versus short in a hedging portfolio. Scholes lamented, "When I asked [Texas Instruments] for royalties, they replied that our work was in the public domain; when I asked, at least, for a calculator, they suggested I buy one. I never did."[63] But since calculators were slow to use for real-time trading, Black (and others) created and sold paper tables of options prices that traders carried around and relied on. Some competing traders cajoled those using the sheets to throw them away and "trade like a man." Eventually option prices began to converge to the theoretical option prices, creating a new reality, and the options exchanges thrived.[64] The increasing respectability of options made the formula more respectable and vice versa—part of important economics, not just a new trading scheme for gamblers. According to a 2020 report by the Bank of International Settlements,[65] the notional amount of over-the-counter derivatives worldwide was $559 trillion (the notional amount is the face value of the underlying securities of the derivatives). The market value of outstanding contracts was $11.6 trillion.

Derivatives, especially those related to an overall market such as the S&P 500, are important for another reason: they contain vital information. Every time a stock price or an option price changes, this sends a signal as to what that stock or option is worth. But because of important differences in how stocks and options are priced, the signals can be interpreted differently.

What information is contained in derivatives? Let's return to the key inputs of the Black-Scholes model. Again suppose we're interested in a call option, this time on the S&P 500 index. The call option depends on five factors: the price of the underlying security (here, the price level of the S&P 500 index), the exercise price, the time to maturity or expiration of the option (again, we'll assume three months), the risk-free interest rate (the three-month Treasury bill rate), and the volatility of the underlying security or, in this case, the volatility of a proxy for the U.S. equity market. We can readily obtain the first four factors. The only one not directly observable is the volatility.

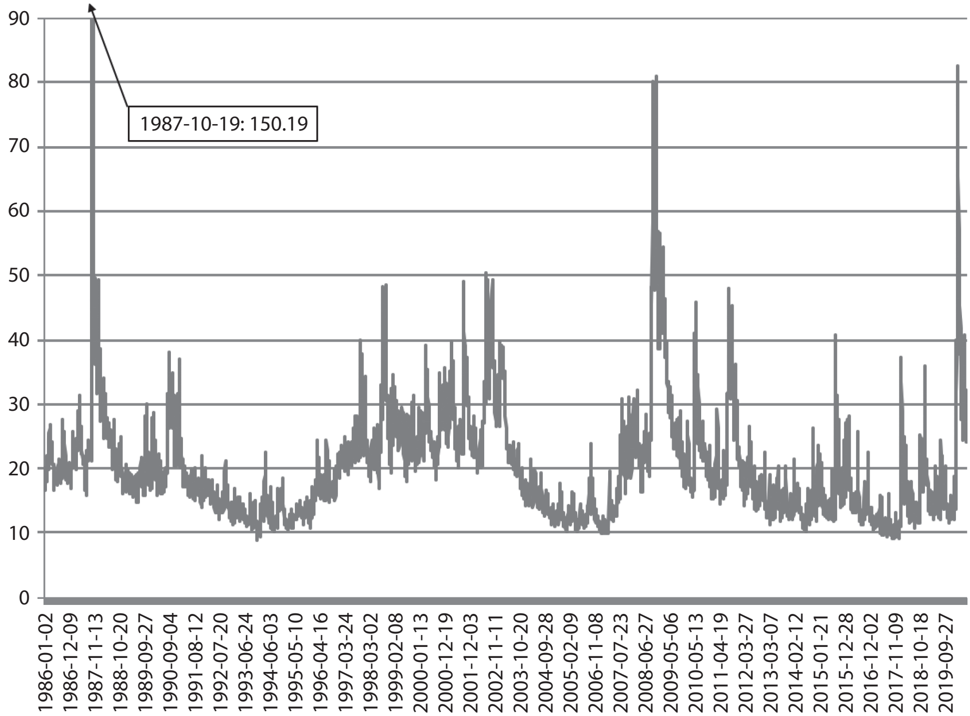

FIGURE 6.1: The CBOE Volatility Index, or VIX, January 1986 to July 2020 (back-tested prior to 2004). Source: "VIX Index Historical Data," CBOE, http://www.cboe.com/products/vix-index-volatility/vix-options-and-futures/vix-index/vix-historical-data.

Let's assume that traders have properly priced this particular option. If that's the case, then we can back out the implied volatility of the market, since we know the other four factors and the price. In other words, we can back-calculate how risky investors think the stock market will be over the next three months. In fact, the CBOE has created an index based on this process: the Volatility Index (VIX), usually expressed in percentage of the standard deviation of returns. Historical levels of the VIX are depicted in figure 6.1.[66]

The VIX has also been called the Fear Index, as a gauge of investor fear: the more uncertain investors are about future stock market values, the higher the VIX. But to describe the VIX narrowly as the Fear Index does it a disservice. The VIX provides the markets with the socially useful function of an insurance mechanism. Through the VIX, not only can you speculate on volatility, but you can also insure yourself against adverse changes in volatility.

Scholes recently noted, "Market pricing of options conveys much more information than [do] the spot markets. You had that in the '87 crash. . . . The market gives us tremendous amounts of information about how risks are changing in the market."[67] A check of the record bears out his comments. In 1987, between Monday, October 12, and Friday, October 16, stocks declined by 8.6 percent, but the VIX rose by a whopping 48 percent. On Monday, October 19, U.S. stocks saw the largest one-day drop on record, on average by over 20 percent.

Scholes contrasts the difference between the information in stock prices versus the information in the options market. "When we look at a stock, the information in the stock price is rich. But it has two components to it. It has changes in risk and expectations of changes in the risk, and it also has expectation of growth of cash flows. If it has two things [and] you have one number, it's hard to separate [them]. While the option market, and the beauty of the Black-Scholes technology and Merton follow-on is, essentially, it decomposes and tells you what the risk is."[68] In other words, stock prices can go up or down because either the stock's anticipated cash flow growth changes or its perceived risk changes. However, the change in the price of an option is unambiguously tied to changes in risk, and it's that assessment of risk that is quantified by the market.

Scholes gave the example of election prediction markets, such as the University of Iowa's Iowa Electronic Markets, in which futures market contract payoffs are based on political outcomes. "Who's going to win the election? We have election markets. People say, 'How can a market know anything about elections?' It comes up once every four years, or so. . . . The market is amazing, how accurate it is, relative to the pundits."[69]

Derivatives as Financial Weapons of Mass Destruction?

In 1998, the famous holding company Berkshire Hathaway acquired General Reinsurance Corporation, a reinsurance company. As with most major insurance companies, General Re used derivative securities, in part to hedge long-term risk exposure. In one of his highly anticipated letters to shareholders, Berkshire Hathaway chair and investment sage Warren Buffett felt compelled to comment on General Re's large reported loss in 2002, which he attributed in part to accounting conventions and the pricing of derivatives. However, Buffett also used the occasion as a springboard to share his broader views on derivatives. In his letter Buffett wrote, "The derivatives genie is now well out of the bottle, and these instruments will almost certainly multiply in variety and number until some event makes their toxicity clear. Central banks and governments have so far found no effective way to control, or even monitor, the risks posed by these contracts. In my view, derivatives are financial weapons of mass destruction, carrying dangers that, while now latent, are potentially lethal."[70]

This wasn't a onetime opinion for Buffett. In his 2008 letter, he commented specifically on the Black-Scholes/Merton option pricing model. "The Black-Scholes formula has approached the status of holy writ in finance. . . . If the formula is applied to extended time periods, however, it can produce absurd results. In fairness, Black and Scholes almost certainly understood this point well. But their devoted followers may be ignoring whatever caveats the two men attached when they first unveiled the formula."[71]

As late as 2015, Buffett reaffirmed his 2002 view of derivatives. He indicated that "at some point they are likely to cause big trouble. . . . Derivatives lend themselves to huge amounts of speculation."[72] Buffett used the example of very long-dated contracts in many derivatives, compared to the typical three-day settlement period for the purchase of stocks, noting that when the markets are closed for long periods, such as after the September 11 attacks and during World War I, huge market uncertainty is created, and almost anything can happen when markets reopen. However, Buffett also emphasized the important role for derivatives when used intelligently.

What does Scholes, as cocreator of the formula, think of Buffett's talk of derivatives as weapons of mass destruction? "Well, the interesting part is that I think that what [Buffett] was referring to was at the time he acquired General Reinsurance, there were many, many long-dated option contracts in the portfolio—twenty-year, thirty-year contracts. And that when he bought the company, he realized that the liability was much larger than he had thought than when he had actually acquired the company, because the value of the payoffs in the option were much larger than he had anticipated. I think that's what led him to say these longer dated options were weapons of mass destruction."[73] To put the issue in context, as is the case with many long-dated securities, including hundred-year or century bonds, a small change in key factors such as interest rates can have a large impact on today's price.

Scholes continued: "But I do believe that the statement that options are weapons of mass destruction has to do with the ability to lever options, or use leverage in options, and we also have myriad other ways to use options or derivatives for leverage or other things, other ways in the economy. But they do have that leverage component. Again, it's sort of survival of the fittest. One of the interesting things about a derivative or option, there's one buyer and one seller. It's a zero-sum game in that sense. And so, if I have a buyer and the buyer overpays for the option, a seller is willing to come in and right that option and basically protect the person against mispricing. And I think that's forgotten a lot about this. When market prices fall and derivatives fall in value, then other instruments also fall in value."[74]

There is a further benefit to buying and selling derivatives such as options. Options allow the investor to completely tailor the distribution of returns. For example, an investor who owns a stock that has increased in value and wants to hold the stock but is concerned about the potential losses from doing so can insure against this risk through an option purchase, specifically through buying what is called a "put" option—the option to sell an underlying security at a given price. Buying put options can be good insurance if an investor can't take losses, although often at a hefty premium. (Conversely, selling put options can be good underwriting if an investor *can* take losses.) Scholes continued: "But I think that the fundamental question is, 'Are the prices the best or accurate, in the sense of the best estimate? And does the market get really out of hand?' And I think, no, that's not been true. You don't see that over time. Market pricing of options conveys much more information than [do] the spot markets. You had that in the '87 crash—the futures market had much better pricing than the spot market. The spot market wasn't even trading, whereas the option markets on the portfolios were giving much richer information to what was happening in the marketplace. It's true that some people will lose money, some people will make money in options, if they've misused them, in just the same way as people who put all their money into a Valeant drug stock[75] and it collapses in value, lose money as well. I think that the reason options or derivatives have had a misnomer, or [were] misnamed, is simply because they're the newest ones on the block."[76]

What role does Scholes think derivatives played in the 2007–2009 financial crisis? Scholes admitted that "derivatives have huge implications for our society."[77] However, regarding their role in the financial crisis itself, he was skeptical. "If you look at the extent at which derivatives are still involved and have even grown dramatically since the [2007–2009] crisis, then one would be amazed to say if these are such awful things, why are they still being used so dramatically? [George] Stigler once said that survivorship is a very good method of determining value, and these survive and they flourish, and they grow. It's true that certain things in the [2007–2009] crisis came to the fore, mainly that AIG [American International Group, Inc.] had mispriced contracts. But that was an internal control problem within AIG, not the derivatives themselves. People want to write derivatives, even if they're fairly priced. . . . One of the interesting things about writing these options, even on AAA [credit rating] structures, is that you're going to make a little money a lot of the time, and occasionally you take a big loss. There's nothing guaranteed that you're going to do that. So, it's the risk management issue within the firm, a governance issue, that accounts more so than using these instruments."[78]

Scholes's Perfect Portfolio

Scholes has a different way of thinking about the Perfect Portfolio compared to Markowitz, Sharpe, and others.[79] While they focus on the composition of the Perfect Portfolio, for Scholes the Perfect Portfolio is all about risk management. If we pay closer attention to what markets are telling us, Scholes believes, particularly to the derivatives market, we can adjust our risk exposure, avoiding the downside "tail risks" and "drawdowns," such as those that occurred during the financial crisis, while capitalizing on the positive "tail gains" and thus better achieve our goals. In order to understand Scholes's logic, however, we need to understand what investors really care about and how to measure compound returns and the growth of wealth.

Scholes started by observing what investors are trying to achieve and extrapolating what should matter to them from those observations. "Investors are interested, in my view, [in] terminal wealth. They're interested in compound return. And they're interested in drawdown. So, they would like to, for a level of drawdown, have the best experience they possibly can." Let's examine in detail what Scholes means by terminal wealth, compound return, and drawdown.

First, let's begin with terminal wealth. Investors have certain goals, such as the kind of lifestyle they desire to lead in retirement. Once investors determine their desired lifestyle in retirement—say, buying a cottage or traveling—they can determine the wealth they will need at that "terminal" date in order to provide for that desired lifestyle. This terminal wealth will depend on their investments—for example, through annual contributions to a 401(k) plan—and the year-by-year return on those investments.

Next, let's spell out compound returns. Scholes noted that investors should care about the compound return (sometimes called the geometric return) rather than the average return (sometimes called the mean return). The former considers the change between your starting wealth and your terminal wealth. The latter takes a simple average of the one-year changes in wealth.

Compound returns will always be lower than mean returns, and the more volatile returns are, the greater their impact on the compound returns. This is what Scholes calls convexity risk, also known as volatility drag. Scholes explained, "If you have a choice, and let's say your portfolio would have fluctuation plus-20 percent, minus-20 percent. On average, it's zero percent [the mean return]. That plus-20 percent, minus-20 percent is not a very good result, because if you make 20 percent and then lose 20 percent, you're down at $96 for a $100 [initial] investment.[80] If it goes to $80 [after the first year, losing 20 percent], it only recovers back to $96 [after the second year, gaining 20 percent on the $80]. So, the convexity cost is 4 percent in this case. And we know that the greater the volatility, you're going to have that convexity cost. . . . The more excess volatility you take, the more you have lost compound return." While the concept of volatility drag is well known among academics and more sophisticated investors, it's less well known that changing volatility itself has a negative effect on compound return.

According to Scholes, the key to compound returns is to manage the risk of your portfolio at a target level. If you have an investment horizon of ten years, then what happens each year matters "because compound returns multiply, they don't average." Furthermore, avoid the use of average returns. "The average [arithmetic] return is a flawed measure. It might be able to evaluate whether a manager is outperforming, on average, but it doesn't talk about the ideal portfolio in investing. In other words, the problem is, when someone is thinking about crossing a river, you don't tell the person, if they can't swim, that, on average, this river is only a half a foot deep." We only have one life to live, and we're only crossing the river once. "If you cross the river at the twenty-foot part of the river and you can't swim, you drown. You don't get back again."

Finally, let's understand what Scholes meant by drawdown and the impact of tails. Drawdown refers to the peak-to-trough decline in the value of a portfolio. In other words, drawdown is another way to think about risk or volatility. According to Scholes, "Why is drawdown important? Because, if you can reduce the drawdown, then basically one can achieve a higher terminal value for their portfolio. And it's really the tails that have the most important effect." Scholes is referring to outlier events, particularly negative ones such as the one-day drop in U.S. stock prices of over 20 percent on October 19, 1987. If investors can avoid these tails, these really bad unusual events, then their projected terminal wealth will be better protected.

There are two kinds of tails, however: negative ones and positive ones. According to Scholes, for the Perfect Portfolio, investors want to not only avoid the negative tail risk but also take advantage of tail gain. Working with colleagues at Janus Henderson Investors, where he is the chief investment strategist, Scholes helps to interpret information from the options market to build distributions of expected returns on individual securities such as Microsoft along with those of asset classes, commodities, and bonds, using them to construct portfolios that maximize expected tail gain and minimize expected tail loss. “It’s not the middle of the distribution, it’s not your volatility that has the biggest impact on your terminal wealth; it’s the tail of the distribution. Tails are so much more important than the middle. If you want to talk about the Perfect Portfolio, you concentrate on tails. . . . All the other stuff doesn’t matter. . . . If you can risk-manage your portfolio and cut your tail losses, you’ll be so much better off. But risk management, it’s not only to avoid the tail loss, but it’s participating in tail gains. It’s symmetric. You don’t want to just have low risk.”

While a focus on compound returns, maximizing terminal wealth, and avoiding drawdown seems straightforward enough, Scholes laments that the investment profession has paid too much attention to relative returns rather than absolute returns. “How we are doing relative to a benchmark; so, are we doing better than the Standard & Poor’s 500?” Scholes believes that the focus on relative returns “is really ignoring the most important part of investment, and that’s the absolute return. And the interesting part about investing that’s being ignored—so moving to what I think the ideal portfolio should be, which is concentrating on absolute return and not relative return—is that relative return ignores the benchmark itself, ignores the risk of the benchmark itself.”

With a major shift to passive investing and a general embrace of index funds, it’s startling and sobering to reflect on the inherent risks to such strategies. As Scholes notes, “If you have an index fund, such as the S&P 500, there’s no way the risk of the S&P 500 can be constant over time. The composition is changing. Sometimes technology has a larger weight. Sometimes utility companies have a larger weight. So, the volatility, or risk, has to be changing that index.” Even a broad-based index has composition risk.[81] That changing volatility hurts compound returns.

There is yet another problem with index funds, according to Scholes. The extent to which prices of individual stocks in the index change relative to one another, the correlation structure, can change over time. For example, during the financial crisis of 2007–2009, stocks tended to go down together, and in the following period a few years later, stocks tended to go up together. "And so, the diversification is not there at times, when the correlation structure changes. And so, thinking about the assumption of constant correlation, thinking about the assumptions of having constant means and constant returns are fine from a theoretical point of view. But [the CAPM, the basis for passive investing, is] a one-period model. It's not a multiperiod model." Even in a multiperiod model, however, it can take a long time to recover from major losses. Scholes emphasizes that with compound returns, every period matters.

In pursuing the Perfect Portfolio, Scholes claims that the investor needs to address two basic questions. First, "Every investor has to ask, in a global sense, what the asset constraints are. Am I limiting myself to invest in a more limited set of assets?" In other words, in addition to a particular goal of terminal wealth, investors need to consider their set of assets (e.g., stocks, bonds, real estate, etc.) and the constraints within each of those asset classes, such as avoiding bank stocks if an investor was already employed in the banking industry. Second, investors have to consider how to manage risk through a combination of active and passive strategies. "The portfolio can be formed optimally to manage the risk over time . . . using either active portfolios or a combination of active portfolios and passive investments. And then . . . the investor would have to determine the level of risk they want that portfolio to be run at."

Unlike Markowitz and Sharpe, Scholes sees a significant role for active management in the Perfect Portfolio. This is somewhat ironic, given how instrumental Scholes was in the development of the first index fund. "I don't think that necessarily a buy-and-hold portfolio or an asset allocation such as a 60/40 [60 percent equity and 40 percent bonds] allocation is the optimal allocation, because the risk of, say, an index fund is changing all the time." Scholes emphasizes the importance of risk over a lifetime. "So, the ideal portfolio has to start talking about time, because we only have one run of time. And time is very important. And I want us to refocus on thinking about time. And how you'd run your portfolio depends on how your risk is and how you want to manage your risk over time." While products such as target-date funds exist, which automatically change the proportion of stocks and bonds based on one's age (the older an investor, the smaller the proportion invested in risky stocks versus safer bonds), Scholes isn't a fan of such products. "The ideal portfolio should take account of risk, not bonds versus stock. And the target-date funds, which say 'When you're young, you should invest in stocks; when you're old, you should invest in bonds' is not the correct model."

How, then, should investors manage their portfolio? "The correct model is risk. When you're young, what risk do you want to take? And what is the risk as a function of your realized return? What is the risk you want to take [relative to] your human capital, other parts of your wealth structure? And so, the target-date funds, which are stylized ways . . . of thinking of numerical asset allocation, are not taking account of what we should be accounting for [in terms of risks]. What's the risk? And how is the risk changing? And what [are] the dynamics of risk? . . . A new target-date fund of the future will be a risk-managed fund." Scholes describes an approach whereby investors first determine the maximum drawdown they feel comfortable with, then change their asset allocation (perhaps between stocks and bonds) as the anticipated risks in the asset classes change.

How can an investor anticipate a change in risk? According to Scholes, the way to do that is to listen to the options markets. Ultimately, Scholes would like "to see . . . those who have skills or managers start defining the portfolio that [he's] describing and offer that to investors as a way to think about [managing risk in a more active fashion]. Then the investors can choose different levels of risk, different levels of drawdown that they can have, and then have that as the way to run a portfolio. . . . It has to be dynamic."

Scholes would like portfolio risk to be managed by incorporating the information about risk that's provided by the market for different asset classes. For example, for U.S. equities, we can look at the information provided by derivatives related to the S&P 500, such as the VIX. The VIX gives us a market-based estimate of expected market volatility. To focus on the expected tails of the distribution, we could look at deeply out-of-the-money options that only pay if there is an extreme change in the market. The prices of these types of options provide valuable information about tail risk.

"Using this information to construct the ideal portfolio, one can change the composition of the portfolio based on risk and how risk is changing. If one can keep the risk of their portfolio constant, you reduce a huge amount of the convexity costs that will occur because you allow your portfolio to fluctuate. . . . If the ideal portfolio doesn't use information in the market to do it, it's not an ideal portfolio. And so, you need to look at the prices and how the market is telling us information. So, derivative markets are telling us information. The spot markets are telling us information. The forward markets and other ways are telling us huge amounts of information. And, I think, it's better to use the consensus or the wisdom of crowds, millions of people making decisions." Having helped create modern derivative markets, Scholes now wants investors to listen to those markets in order to form the Perfect Portfolio, thus coming full circle.

7

Robert Merton, from Derivatives to Retirement

IMAGINE BEING the son of Robert K. Merton, the distinguished Columbia University professor; founder of modern sociology; originator of such familiar concepts as "unintended consequences," "role model," "focus group," and "self-fulfilling prophecy"; and the 1994 recipient of the prestigious National Medal of Science, an honor bestowed by the president of the United States. Imagine sharing his first name. No matter how prominent you might become in your own chosen field (such as financial economics), you would have a lot to live up to.

What did Robert C. (Bob) Merton do to avoid confusion as to which prominent Robert Merton in academia he was, out of respect for his father? He would often sign his letters as the "son of the sociologist."[1] Now, imagine being the proud father of a son who is a recipient of the highest achievement in his field, the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel (also known as the Nobel Prize in Economics), and also sharing his first name. What would you do to avoid confusion? Well, Robert K. Merton would sign his letters "father of the economist."

As described in chapter 6, Robert C. Merton was working on an option pricing formula at the same time and along the same lines as Myron Scholes and Fischer Black. Black would reflect on the "long discussions" with Merton, his numerous suggestions that improved their famous option pricing paper, and the "mixture of rivalry and cooperation" between them.[2] It was, therefore, entirely fitting that in 1997, Scholes and Merton were together awarded the Nobel Prize in Economics.

Much like Scholes, Merton has also been involved in a number of commercial ventures, including patenting an approach to retirement planning. He has devoted a lot of thought to formulating the Perfect Portfolio.

The Young Trader

Robert C. Merton (son of the sociologist) was born in New York, New York, on July 31, 1944, and grew up in the New York suburb of Hastings-on-Hudson, where his younger sister and her family now live.[3] His father, who passed away in 2003, was born Meyer R. Schkolnick in 1910 in Philadelphia. As a teenager he performed magic tricks, using Robert Merlin as a stage name, which he eventually modified to Merton.[4] Robert C. Merton's mother, Suzanne Carhart, who passed away in 1992, was a stay-at-home mom from a New Jersey Methodist and Quaker family. Suzanne's mother lived in their household.

In public high school, Merton took courses in mathematics and the sciences, including a Massachusetts Institute of Technology (MIT)–designed physics course. He was a solid student but wasn't at the top of his class. "When I was a kid growing up, one skill I had was I was able to take long lists of numbers and add them up pretty quickly. And so that's why [vocational tests] that you took in high school said I was going to be an accountant or an engineer, because they asked whether you would rather take a dog out for a walk or add up a large column of numbers, and I said a large column of numbers."[5]

Merton played varsity football and ran track, but he wasn't a standout in either. His classmates included the sons of James Rainwater and Jack Steinberger, both physicists at Columbia University at the time, each of whom would go on to receive the Nobel Prize in Physics (in 1975 and 1988, respectively). Another local laureate was Max Theiler, who received the Nobel Prize in Physiology or Medicine in 1951 for developing a vaccine against yellow fever. Yet another resident was William Vickrey, a Columbia University economist who was awarded the Nobel Prize in

Economics in 1996, the year before Merton himself received the award (although Vickrey tragically died just three days after the award was announced).

Merton's father introduced him to baseball, magic, and the stock market. He later reflected on his childhood: "I think as a child I did the minimum amount of work I had to do in school; with the exception really of math—I enjoyed really. I liked baseball and other things. At the same time, when I was a pretty young age, I used to create fictitious companies, including a fictitious bank. I think it was called the RCM Dollars and Savings Company, of which I went and tried to get deposits and make investments. And at a relatively early age, ten or so, I invested my first share of stock. And I used to follow, look at companies and so forth. But throughout the whole period, and indeed right through my college years, while I was involved in the stock market, always interested in finance, I never thought of it as a full-time job. You know I always thought that was something for after hours. And it was really fairly late in my graduate study that I decided actually to move into economics."[6]

It was also an epic time for a New York boy to follow baseball. Merton cheered for the Brooklyn Dodgers, one of the three New York teams at the time, the other two being the New York Giants (also in the National League) and the New York Yankees (in the American League). Merton knew all the batting averages and pitching records of the players. The Dodgers won National League pennants in 1941, 1947, 1949, 1952, and 1953 but each time lost in the World Series to the crosstown rival Yankees. In 1951, the Dodgers suffered one of the sport's all-time major collapses, having led their National League rivals the Giants by thirteen and a half games in the standings. The Giants went on a tear and won their last seven straight games to force a three-game tiebreaker series. In the final game of the series, the first baseball game to be televised nationally, with the teams tied at one win each, the Dodgers were leading 4–2 in the bottom of the ninth inning when the Giants' Bobby Thomas hit a three-run homer in what became known as the "Shot Heard 'Round the World." Finally, in 1955 the Dodgers prevailed over the Yankees in seven games to win their first and only World Series in New York. In what must have been a blow to Merton, after the 1957 season both the Dodgers and the Giants moved their teams to California, where the rivalry continues between the Los Angeles Dodgers and the San Francisco Giants.

Around the time the Dodgers won the World Series, Merton began turning his passion to cars. In fact, it was no coincidence that his first stock investment was in General Motors at age ten.[7] The next year, he completed a risk-arbitrage trade (buying shares in a target company and selling those in the acquirer) on a takeover by the Singer Corporation, the sewing machine maker.[8] Also at age eleven he started counting the number of days until he could get his driver's license, at the minimum age of sixteen. He learned the horsepower and engine size of almost every recently built car, attending auto shows and stock car races, until at age fifteen he bought and rebuilt his first car. Merton went on to build and race hot rods and eventually spent two summers working for the Ford company in Dearborn, Michigan, one as an engineer in advanced vehicle design. "I love solving problems, and I like engineering-type things. I thought I was going to be an auto engineer."[9]

Just before turning seventeen, Merton went on a blind date with June Rose, a television actress who appeared on soap operas. They were married in 1966, just after he graduated from Columbia. They had three children, a girl and two boys. In 1996, Merton and June separated.

In 1962, Merton joined Columbia College, the undergraduate college at Columbia University. A day after entering he switched to the Engineering School at Columbia, where he took numerous pure and applied mathematics courses. He particularly enjoyed learning about partial differential equations and calculus. He also took an introductory economics course that used Paul Samuelson's classic book, night classes in accounting and stock market investments, and an English literature course. Although Merton received a low grade in his sophomore English course, it did lead to his first publication: "The 'Motionless' Motion of Swift's Flying Island," published in *Journal of the History of Ideas*.[10] Merton questioned how Jonathan Swift's fictitious flying island of Laputa in *Gulliver's Travels* was able to remain stationary when, based on Swift's description of opposing upward and downward forces, the island should actually have been rotating.

Upon graduating in 1966, Merton went to the California Institute of Technology to pursue a PhD in applied mathematics. He enjoyed learning more mathematics and was especially pleased that students were encouraged to be actively involved in their research rather than just passively learning the material. "I always loved mathematics, but I always loved mathematics for its applications, not pure math."[11] While at Caltech, he continued his investment trading. "That's when I first learned about convertible bonds. I would trade at 6:30 a.m. at Caltech. I traded over-the-counter options, especially warrants, and convertibles, even though I didn't know what I was doing."[12]

After a year at Caltech, however, Merton began looking for something more. As he prepared for his dissertation in mathematics, he reflected on the crossroads he felt he was facing. He noted that there were two things happening in his life. "One: I was following the stock market and doing things before hours—not interfering with my studies but doing that. And the other is I started to look at the range of problems that people were working on, using mathematics and the applied fields, and it ranged from plasma physics problems to water waves in a tank and fluid mechanics. And none of those really excited me too much."[13]

This was in the mid-1960s, when Lyndon B. Johnson was president. "Walter Heller, who was the head of the Council of Economic Advisors, made some announcements to say we had really solved the big macro problems . . . of hyperinflation . . . and deep unemployment. . . . And I thought about it and I said, 'That's amazing. Imagine if you could do just a little something in that area, you affect the lives of millions of people in a favorable way.' And that's kind of a kick."[14] Since he knew very little about economics in a formal sense at the time, he decided to investigate further by going to the Caltech bookstore. "I bought a book on mathematical economics. . . . It turned out to be a pretty awful book, but I didn't know that. But it was important, I think, that it was an awful book, because here this kid read it and said, 'Hmm, maybe I can do something.'"[15] Merton decided to leave Caltech to pursue a PhD in economics. He applied to six universities with good economics programs, but only one accepted him and also gave him a full scholarship. That university was MIT.

MIT: From Student to Professor

Harold Freeman spent most of his academic career at MIT. As an undergraduate he majored in mathematics and graduated with a bachelor of science degree in 1931.[16] He became an instructor in economics before studying at Harvard University from 1936 to 1938. He returned to MIT as an assistant professor in 1939 and was promoted to associate professor in 1944 and then to full professor in 1950. During World War II, Freeman was a member of the Statistical Research Group at Columbia University, devising methods of sampling for quality control in wartime industries.

In 1967, when Merton applied to MIT, Freeman was a statistician and a member of the MIT economics department. Freeman reviewed Merton's application and recognized the names of the mathematicians who had written his letters of recommendation. Freeman convinced the department to take a chance on Merton, who was accepted into the PhD program.

According to Merton, Freeman—who at the time was advising first-year students—examined his proposed course plan and commented, "You follow that and you'll leave here by the end of the term out of boredom. . . . Go take Paul Samuelson's mathematical economics course."[17] In this class, Merton was able to interact not only with Samuelson but also other interesting students, including Stanley Fischer (who would go on to become a prominent economist, author of a well-known economics textbook, governor of the Bank of Israel, and vice chairman of the U.S. Federal Reserve); learn economics from Samuelson's *Foundations* book; and write a term paper on the optimal economic growth rate after a change in population growth, which was published in 1969 (and eventually became a chapter in his dissertation)[18]—all thanks to Freeman's simple advice.

Beyond taking his course, Merton's relationship with Samuelson really blossomed when Samuelson approached Merton for a favor. "Paul came to me with some tattered yellow sheets of paper. He was writing something on Hamiltonian mathematics applied to growth theory and said would I read it over, not for the economics of course. But would I just check it over? So, as much as a twenty-something graduate student could do with Paul Samuelson, I didn't say, 'You're crazy.' I said, 'Of course.' And then I nonchalantly left, and I went home and, as you can do when you're in your twenties, pulled an all-nighter going through over and over and over again, and went in the next day as nonchalant as I could, and of course, not at all letting him know that I was up all night. And said, 'Well, Professor Samuelson, here it is.'"[19] During the all-nighter, Merton had uncovered some mistakes in Samuelson's draft. "And then the next time I came to class he offered me a job."[20]

While working as Samuelson's research assistant, Merton discovered that they shared a common interest and background in derivative securities such as warrants and convertibles. If you'll recall from chapter 6, warrants are securities issued by companies that want to raise money. They allow existing shareholders the option to purchase additional shares at a particular price by a specific date. Convertibles are somewhat similar. A convertible is a company-issued security that's initially a bond but one that can be converted to stocks once stock prices increase beyond a certain price level. These features make both types of securities behave much like traded call options.

Merton was delighted to find that his dabbling in trading warrants and convertibles could be a legitimate research endeavor. In 1968, he started working jointly with Samuelson to extend Samuelson's earlier research into the pricing of warrants, resulting in another publication (and another dissertation chapter) in 1969.[21] In the fall of 1968, Merton gave his first academic seminar presentation at the inaugural MIT-Harvard Mathematical Economics seminar. The audience included future economics Nobel laureates Kenneth Arrow (who would win the prize in 1972) and Wassily Leontief (who would win in 1973).

Merton continued his publication success even before completing his dissertation. In one paper, he tackled the important issue of the decision faced by every investor, known formally as the "portfolio selection problem": deciding how much to consume today versus saving for tomorrow and allocating those savings between risky and risk-free investments (for example, buying Treasury bills), all the while trying to maximize lifetime utility or satisfaction.[22] In another paper, published just after completing his dissertation, he examined the same problem using a more realistic "continuous-time" framework, in which prices are constantly changing.[23]

Merton's experience and knowledge of the financial markets inspired many of the assumptions that were incorporated into his models: "Because I traded markets, I knew something about the idea that even if you were watching the [ticker] tape very, very close to it, it's still the case that you couldn't predict the next price. So, if AT&T was trading, its next trade could be the same. It could be down or up. That was very hard to forecast, no matter how short the interval. And anything I did had to capture that."[24] His pathbreaking work on continuous-time stochastic processes would eventually culminate in a highly regarded book, *Continuous-Time Finance*.[25] As his eventual student Robert Jarrow noted years later, "I consider Bob the father of mathematical finance. . . . Bob invented continuous-time finance. And, continuous-time finance is the heart of mathematical finance. . . . Nowhere else in business is the flow of ideas between industry and academics as fluid as it is in mathematical finance."[26]

In the final chapter of his dissertation, Merton performed an empirical investigation of Samuelson's warrant pricing model.[27] He looked at three "perpetual" warrants that lacked a maturity date to purchase more shares, issued by the companies Tri-Continental, Allegheny, and Atlas, and found that the Samuelson model generally performed better than some of the proposed alternatives. In his concluding section, Merton mentioned that he planned future studies to develop a better pricing theory, particularly for finite-lived warrants such as the call option.

The publication productivity of Merton's dissertation can't be overstated. To have even one article follow from an economics dissertation is quite a feat, let alone four, but that was far from all. While he was completing his dissertation, he was already hard at work laying the foundation for three important studies that would all be presented at major academic conferences or published in 1973. In these three papers, he extended Sharpe's capital asset pricing model (CAPM) to many periods rather than one,[28] extended the use of option-pricing models to determine the price of debt,[29] and solved the option-pricing problem (as did Black and Scholes).[30]

Merton's extension of the CAPM to many periods was an important contribution to Sharpe's original model, which was intuitive but limited. Sharpe's model was a one-period model and did not mesh well with expected utility theory, a cornerstone of modern microeconomics, while Merton's model covered multiple periods and was tied directly to utility theory. "I was able to take a more realistic model, a more general model, and show that the outcomes were interesting."[31]

Around 1969, as Merton neared the completion of his dissertation, Samuelson nominated him to be a junior fellow at Harvard. However, Merton was rejected for that position, so he continued on to the regular academic job market, interviewing at numerous economics departments. Merton was able to get a job at MIT, not in the economics department but rather at the Sloan School of Management. Future economics Nobel winner Franco Modigliani, who had cross-appointments in both the economics department and at Sloan, made the invitation and convinced Merton that he could teach at Sloan even though he had no formal finance training. "Things were going very well," Merton recalled from his office at MIT Sloan more than four decades later. "I already had several published papers and more on the way. Why move from such a productive environment? I was perfectly comfortable, so I happily accepted the offer."[32] During the Sloan interview process Merton first met Myron Scholes, who had recently arrived from the University of Chicago.

Merton's Options Insight

What was trading options like prior to Black, Merton, and Scholes? According to Merton, "In the old options market, dealers ran ads in the newspaper with teasers, with posted prices for something that should change value by the minute. Can you imagine posting prices in the newspaper? It's just bizarre. There were the damnedest kinds of things being used to price options—cube-root rules and stuff that came out of thin air."[33]

In the late 1960s, Black and Scholes together, and Merton separately, were working on the development of a formula for the price of a call option. As Merton noted, "We were in a rivalry. As Myron said, 'We don't tell Merton everything, because he's a competitor.' Who gets it right wins, period. At the same time, it's cooperative. You all have an interest in figuring out how it works. That's a tension that always exists within research. It was a healthy competition, one of mutual respect."[34]

One of Black and Scholes's critical insights was that the act of hedging, such as shorting call options while holding a long position in a stock, removes *systematic* or market risk, as captured by beta in Sharpe's CAPM, and thus provides returns that were insulated from the ups and downs of the overall market return. Precisely the right combination of options and stocks could provide returns independent of the overall market return. In other words, with the right combination, an investor would be able to create a portfolio that didn't have any market risk—or, to use the terminology popularized by Sharpe's CAPM, the beta was zero. "What they had as an insight was that if they traded dynamically, frequently, they could manage a portfolio that kind of hedged that option. But hedging was used in the sense that you get rid of the systematic or beta risk. And that was a very common way of doing empirical work back then—you take the beta out,"[35] Merton recounted.

As they shared this insight, however, Merton was skeptical and thought that their hedging idea was impossible. "I said to [Scholes], 'I don't think that's going to work.' And then I said, 'But I'll take a look at it.' And so, I then took it. And of course, because of this work on developing dynamic portfolio theory, . . . I put it in a continuous-time context. All my work had been done that way. And so, I did the dynamics of what they did. And what they did was take out beta; the resulting hedge portfolio for beta has to have an expected return, the risk-free rate, according to CAPM. . . . So, I looked at it and I said, 'Wait a minute. If you do this with continuous trading, it's true. There's no beta but actually there's no sigma,'"[36] with sigma referring to all the risk of the portfolio, not just the beta or market risk. To his astonishment, Merton discovered that not only was it true there was no beta but also that there was no risk or volatility at all with such a hedging strategy.

Merton called Scholes one Saturday afternoon on the phone to exclaim that they were right.[37] He told Scholes, "You guys are absolutely right, but for the wrong reason."[38] Hedging not only removed systematic or market risk, it removed *all* risk! Quite astonishingly, combining two risky securities in a precise combination resulted in a payoff identical to buying a riskless security, such as a Treasury bill. This was the key to unlocking the secret to pricing a call option that had eluded other researchers.

How did Merton figure this out? He later explained, "In addition to naming it the Black-Scholes model,[39] my most significant contribution to the model was to show that if you go to shorter and shorter trading intervals, their same dynamic strategy rules will eliminate all the risk, which has the implication that you have a way to synthesize the option, even if the option doesn't exist. By following a set of rules for trading the stock and the risk-free asset, I could create a portfolio that produced exactly the same payoff as the option."[40] Simply relying on the assumption of "no arbitrage," or no riskless profits, one could derive the price of a call option.

This model is often referred to as the Black-Scholes model. According to Fischer Black, however, Merton contributed in a significant manner to the development of "their" option-pricing model. "Bob has contributed as much to other people's papers as he has to his own. For example, a key part of the option paper that I wrote with Myron Scholes was the arbitrage argument for deriving the formula. Bob gave us that argument. It should probably be called 'The Black-Merton-Scholes' paper."[41]

After Merton had completed and polished his working paper, "Theory of Rational Option Pricing,"[42] he searched for a possible outlet for its publication.[43] His colleague Paul MacAvoy had recently become editor of a relatively new journal, *Bell Journal of Economics and Management Science*, published by Bell Laboratories. MacAvoy expressed interest in publishing the work, despite its length, and even offered $500 for the manuscript—quite tempting, as his yearly salary at the time was only $11,500. Merton graciously asked MacAvoy to delay its publication until Black and Scholes's paper appeared, since his paper referred to theirs. Consequently, even though Merton's final version is dated August 1972, both papers appeared in print almost simultaneously in the spring of

1973 and had an immediate impact, since their publication coincided with the opening of the Chicago Board of Options Exchange.

The impact of the Black-Scholes and Merton publications was, in part, due to that fortuitous timing. As Merton noted, "Could we have predicted at the time how big this would get? No, of course not. Had we done this work in 1960–62, it would have probably gotten published and had no immediate impact on practice. But it was the 1970s. The stock market fell by 50 percent in real terms between mid-1973 and the end of 1974. Treasury interest rates were in double digits, peaking at over 20 percent in 1981. Inflation rates achieved levels not seen since the Civil War, with some price controls introduced and then abandoned. Suddenly the Bretton Woods agreement fixing global currencies was abandoned and world currencies started fluctuating for the first time in nearly 30 years. The first oil crisis occurred, with the price of oil going from $2.50 a barrel to $13. And all of this was happening in an environment of high unemployment. There was an explosion of new risks flowing throughout the system from everywhere."[44]

Today, the Black-Scholes/Merton formula is ubiquitous and used well beyond the pricing of call options. For example, if you have a mortgage, your right to repay is an option, and your right to default is an option as well. As Merton recently noted, "Several hundred trillion dollars of this stuff is sloshing around the earth."[45]

The Merton Model

Black-Scholes and Merton each recognized that option pricing would have important consequences for corporate finance and once again separately developed one of the first applications of option pricing. As mentioned in chapter 6, when Black and Scholes presented their insights at a Wells Fargo conference in the summer of 1970, Merton famously overslept and missed their talk and thus didn't find out until later that they had similar ideas.

Merton recently described his contribution in general as providing a systematic approach for a new world of derivative securities well beyond call options. "If I can actually trade the stock in cash, or whatever the asset is, and through the rules that we derive—it's like a production function, it just says mix 3 eggs, beat it for 45 seconds—it's just a prescription. If you follow all these rules, you make no mistakes, and you can trade frictionlessly, what comes out at the other end is exactly the payoff. Which means, I could synthesize. . . . I can do that for any derivative security."[46] Merton developed a concept that later became known as the Merton Model, based on his 1974 publication describing the idea.[47]

Consider a firm that has equity and a single class of debt, such as bonds. The value of the overall firm, or its assets, will be equal to the sum of the market value of its equity and debt, and both equity holders and debt holders will share in whatever happens to the assets over time. To keep the example simple, let's assume the bonds don't pay coupons, and the bonds mature in five years. What will the value of equity be in five years?

It turns out that the payoff structure of this situation is identical to that of a call option on the entire firm, with the exercise price equal to the face value of the bonds. In other words, the more the assets are worth, the greater is the value of equity. But if the assets are worth less than the face value of the bonds in five years, then the equity holders "walk away" (that is, they don't exercise their option), and the bondholders are left—in bankruptcy—with the remaining value of the assets. Thus, the value of the debt is the value of the assets less the value of the equity, and the riskiness of the debt can be determined through option pricing.

Unlike his earlier option pricing research, the Merton Model took longer to catch on. As Merton later commented, "The [1974] paper didn't exactly take the world by storm."[48] He noted that some investment banks used the model for pricing so-called junk bonds until a risk management firm called KMV used the model, altering it to assume that default could occur at any time, not only at maturity.[49] Despite this change, KMV continued to refer to the altered model as the Merton Model. Around 1999, several large banks and investment firms, including JP Morgan, Goldman Sachs, Deutsche Bank, and Credit Suisse First Boston, which had been using proprietary versions of the model, attempted to establish a standard version. (KMV was eventually acquired by the credit rating firm Moody's.)

At that time, there was an increased need for models such as Merton's in order to understand what was happening to the bonds of household names such as Xerox, which were falling into junk- or noninvestment-grade status. While traditional models were not able to sense their fall, the Merton Model was able to signal a pending drop in the value of their debt. In addition, credit derivatives were gaining in popularity. These types of derivatives were instruments designed to separate the risk of default—the credit risk—from the lender, and transfer it to another party who was willing to take it on. According to Merton, this new class of models was important, because "it does more than give a price—it also gives a risk structure for understanding how the risk is changing, how you might try to hedge the risk with other instruments."[50] Unlike less sophisticated approaches, which looked at valuing equity and debt separately, Merton showed that the value of debt was inherently linked to the value of the assets of the firm. The Merton Model provided a unifying theory for the price of debt securities.

The Merton Model can be applied to more than corporate bonds, however. At a broader level, the debt of individual firms can be examined in aggregate, along with government borrowing, then combined with the role of intermediaries such as financial institutions and central banks to form an overall model of the financial system within a country or even globally. Merton noted the importance of models of financial systems inspired by the Merton Model and other research he has conducted: "Today there's no major financial institution in the world, and that includes all the central banks and Federal Reserve, that can function without the use of computer mathematical models of the financial system and the merits of derivative securities, which are used both to transfer risks and to extract information from their prices about the risks."[51]

From Theory to Practice

Merton is both a scientist and an engineer—in fact, he has been called the First Financial Engineer.[52] Scientists tend to be theoretical, to observe the world and want to understand things; engineers tend to be more practical, to seek to change the world and want to build things.

One of the authors (Lo) has argued that a body of knowledge becomes a science only when a corresponding field of engineering emerges from it.[53] As such, financial science had its beginnings with Harry Markowitz in 1952 but didn't become a real science until Barr Rosenberg took Markowitz's theoretical ideas and showed how to construct real live portfolios through them, when he introduced the BARRA model of risk factors to the investment industry in the 1970s. Merton was acknowledged as a scientist by his PhD dissertation supervisor and collaborator, Paul Samuelson, who called Merton "the Isaac Newton of finance."

Like his Nobel corecipient, Scholes, Merton has had one foot in the academic world and the other in the investment world, and each world has benefited. He once relayed a story about a trade in Hong Kong with Scholes. They were trading an option with a stock price that had fallen below a certain level, at which point the option was cancelled—a so-called down-and-out option. They found a way to solve the pricing of this option by determining the appropriate boundary conditions mathematically. "Now later on when I wrote my paper on option pricing. . . . I was trying to illustrate how you could use the technology for a lot of different things. So [one of the items] I put in there was the down-and-out option. Now it turned out later on there's a whole industry called exotic options that's evolved, of which the down-and-out is . . . the prototype. I never would have even been aware of its existence let alone been able to solve the problem and write it up if I hadn't been involved in practice."[54]

Merton's first consulting experience was in 1969, with a California bank interested in the pricing of warrants.[55] He joined with Scholes in numerous consulting projects, including a 1972 project for the investment bank of Donaldson, Lufkin & Jenrette to develop option pricing strategies and hedging models. In 1976, Merton and Scholes created the first options-based mutual fund, which provided investors with exposure to the stock market but with downside protection, a precursor to the portfolio insurance products that were popular in the 1980s.

In 1988, Merton joined Salomon Brothers, the global investment bank then led by John Gutfreund, as a special consultant to the Office of the Chairman. John Meriwether was the head of the domestic fixed-income arbitrage group and had attracted many of Merton's former students, most of whom had PhDs.[56] Meriwether left Salomon Brothers in 1991, and in 1993 he had the idea to start a new firm. This would be a hedge fund named Long-Term Capital Management (LTCM), founded to undertake global fixed-income arbitrage on, for example, price discrepancies between similar bonds trading in different markets. Merton and Scholes were among its eleven founders, seven of whom had strong connections to MIT, Harvard Business School, or both. Over $1 billion was raised from its investors, a very large investment for its time.

LTCM used several related strategies in its operation. The main strategy behind LTCM was to look for discrepancies in prices between two similar assets, buying the underpriced one and selling short the overpriced one, thereby making money when the asset prices converged. These were known as convergence trades.[57] For example, based on quantitative models related to option pricing, traders might detect a discrepancy between the price of long-term Treasury bonds and the price of a related type of derivative security known as an interest rate swap, buying the former and selling the latter. Another was known as a relative value strategy and worked in a similar manner. Here, however, while convergence in prices was expected, it wasn't guaranteed except perhaps over a long period of time. Besides these two main strategies, LTCM initially included a smaller number of directional trades, but such unhedged positions were much riskier.

LTCM's returns were impressive. Between February 24 and December 31, 1994, the fund's return after fees was 19.9 percent, while the broad market S&P 500 index declined. In 1995 and 1996, returns were 42.8 percent and 40.8 percent, respectively, far outpacing market returns. In 1997 through August, the fund was up an additional 11.1 percent, although the 1997 return was below the market return. By September, LTCM's capital had grown from $1 billion to $6.7 billion—and given the leveraged structure of the derivatives, over $126 billion of assets were controlled by LTCM. At that point, the founders considered returning capital to most of its outside investors. By the end of the year, when its capital had increased further to $7.5 billion and net returns were 17.1 percent, LTCM returned $2.7 billion to outside investors, leaving it with $4.8 billion in capital of which $1.9 billion was held by principals and employees.

LTCM's run did not last, however, and by August 1998 the fund had dropped by over 40 percent for the year. Unexpectedly, Russia surprised markets by defaulting on its government debt. Some of LTCM's key positions in swaps turned against them, with spreads between positions widening dangerously instead of narrowing as expected. At the end of August, the Dow Jones Industrial Average had one of its worst one-day point drops. For the year to date, the fund was down 52 percent and losing capital. Given its highly leveraged position, LTCM was on the brink of collapse. Because of LTCM's reach in trading with financial institutions, the Federal Reserve worried about the effects of contagion from a collapse and supervised a rescue bailout in which many large financial institutions provided $3.6 billion in additional capital to LTCM in exchange for 90 percent of the company. Almost two-thirds of its losses in 1998 were related to swaps and equity volatility.[58]

Merton, reflecting on LTCM, later said, "Errors were made and unforeseeable things happened in financial markets. But the crisis was not precipitated by an error in the models or a mistake of this kind. . . . A series of bets and a series of circumstances in the markets that precipitated the events [was the cause of the losses]."[59] Indeed, many of the bets made by LTCM did eventually converge as expected but not quickly enough for the survival of the fund.

In 2003, Merton became a member of the board of directors of Dimensional Fund Advisors (DFA), where Eugene Fama also had a position. While DFA's initial focus was on investing in small capitalization firms, based on the academic research suggesting that small cap firms outperformed large cap firms, its later strategic focus was to turn academic investment ideas into financial products. In 2009, Merton became the resident scientist at DFA after its acquisition of the retirement planning software system SmartNest, which Merton had helped to develop.

The Derivatives World

Many developments have occurred in financial economics since Merton's initial work on options in the early 1970s. These include a number of enhancements to the Black-Scholes/Merton option-pricing model.

But Merton himself is careful to point out the limitations of financial models. "If you look at finance as a field . . . it's the only area where, when I say I have a model, it's a model of what should happen or what is expected to happen. And the model has an error term. It shouldn't be there, but since no model is complete, you always have an error. In a certain way, finance is all about the error term. If there were no uncertainty, finance would be a very boring field."[60] In other words, models can help us to understand key elements such as risk, but models are never able to explain everything. You always have an error.

In 1997, Merton commented on the many applications that had occurred in the twenty-five years after the development of option pricing theory. "Along with the vast over-the-counter derivatives market, these exchange markets trade options and futures on individual stocks, stock-index and mutual fund portfolios, on bonds and other fixed-income securities of every maturity, on currencies, and on commodities including agricultural products, metals, crude oil and refined products, natural gas, and even electricity."[61] Merton went on to mention other applications, related to the purchase of real estate, the acquisition of movie rights, employee stock options, insurance contracts, licenses, and offshore drilling rights. In his tribute to Black, Scholes, and Merton, the finance scholar Darrell Duffie at Stanford University described the further use of derivatives in the modern financial world: "Investment banks routinely sell securities with embedded options of essentially any variety requested by their customers, and then cover the combined risk associated with their net position by adopting dynamic hedging strategies,"[62] including those first suggested by Merton.

Similarly, the finance scholar Robert Jarrow at Cornell University, himself a former student of Merton's, paid tribute to these contributions in his article "In Honor of the Nobel Laureates Robert C. Merton and Myron S. Scholes: A Partial Differential Equation That Changed the World."[63] Jarrow observed that options (when properly priced) are a useful vehicle for both insurance and speculation. He emphasized that the Black-Scholes/Merton option pricing technology "was the equivalent of applying a miracle-growing fertilizer to a sparse and relatively infertile field within finance," raising an entirely new harvest of derivatives. Jarrow concluded, "The Black-Merton-Scholes option pricing theory is believed by many scholars, myself included, to be one of the most successful applications of economic theory in the history of economics."

For Merton, financial tools such as derivatives are a key to progress because of their ability to link different financial systems around the world. "Instruments such as derivatives have taught us how we can decompose different things into different parts and reassemble them to do their jobs more efficiently. For example, you can now buy stocks, invest in futures, swaps and life insurance in a number of different ways. These instruments have had a profound effect on how the financial system has evolved and will evolve. In our theory we can use markets and instruments as more efficient ways of performing the central functions of finance."[64]

Merton has often been asked whether the development of the derivatives market has led to an increase or decrease in overall market risk. He replied, "Our capacity to measure and manage risk has increased considerably, but this does not necessarily mean that we are more secure."[65] He expands, "Let me give you this analogy. If you're driving in inclement weather, you'd say that a four-wheel-drive car is safer than a two-wheel-drive car. Now suppose that we observed that over the last 15 years, the number of passenger accidents per passenger-mile driven hadn't changed at all. And someone says, now wait a minute: Has four-wheel drive made us safer? And the answer would be, technically, no, because we're having just the same number of accidents we used to have. So, was this all a waste, or were we wrong? I think you know the answer, as I do. What really happened is that people get something that will unambiguously make you safer if you behave the same way you did before. That's the key element to understand first. The amount of risk we take personally, individually, or collectively is not a physical given constant. We choose it. What happens is, we look at some new, safer instrument and we say, yes, we could be safer doing the same thing. Or, we could take the same amount of risk and do things that were too risky to do before. So, with a four-wheel-drive car, you look out the window and see six inches of snow, and you say, that's okay: I'm going to go over and visit my family. So, the question to ask is not, Are we safer? The question to ask is, Are we better off?"[66] Merton argues that we're better off: we have a much better financial system than in the past, with better tools at our disposal, with greater transparency, although the financial system is also more complex.

Merton's Perfect Portfolio

Merton is still active in research and teaching with no imminent plans to retire, so it's ironic that his latest focus both as an academic and a practitioner has been in the retirement area—which is also the backdrop for his thoughts on the Perfect Portfolio. His starting point is Markowitz's groundbreaking work on returns versus risk, the mean-variance framework: we want to earn enough during our working years to live comfortably in retirement through what we save and how those savings are invested. Since we generally invest some or most of our savings in risky assets, our desired return may not be realized.

Merton notes that the central objective of the mean-variance framework—attempting to maximize returns for a given level of risk—has been useful, but today "the time has come to extend the models by trying to capture the myriad of risk dimensions in a real-world lifetime financial plan. The three main approaches to risk control or risk management are hedging, diversification, and insuring. Most of the advisory engines in current practice for households, however, focus only on diversification. . . . We need to expand our toolkit."[67] As an example, he suggests that we should target expenditures such as anticipated college education expenses. For these expenditures, advisers would sensibly offer products targeted and indexed to the cost of college education.

Merton elaborated that in order to better understand what risk is, we first need to better understand what it means to be risk-free. "People don't stop and realize that the risk-free asset is very important. . . . It tells us what's risky. . . . A risk-free asset is . . . the asset that makes the payments in your goal be achieved for sure, whatever your goals. So, you write down all of your goals. . . . If I could buy an asset that would pay every one of those things in my goal . . . that's the risk-free asset for me.

But if you have a different goal, that's not a risk-free asset for you. . . . But what's important about the insight is recognizing that until you've carefully defined the risk-free asset . . . you really don't know what risk is. And if you don't know what risk is, then you're in a lot of trouble trying to make any decisions about investing."[68]

In other words, the Perfect Portfolio would be one in which each investor could invest in her or his own risk-free asset without having to take on any risk. Suppose an individual had retirement assets of $1 million. If she was planning to retire in five years and needed the inflation-adjusted equivalent of $1 million in five years in order to buy an annuity that would provide a lifetime income, allowing her to live comfortably in her preferred manner for the rest of her life, she could invest that $1 million in Treasury Inflation-Protected Securities (TIPS). These government securities are risk-free and indexed to inflation, with par values and coupon payments tied to the Consumer Price Index. However, if she had less than $1 million, then she would need to invest some of her money in riskier assets in order to be able to achieve her goals.

We can see how Merton believes this might work in practice by checking the U.S. Patent and Trademark Office. In 2005, he patented a method for retirement income planning with investment industry experts Roberto Mendoza and Peter Hancock, and Boston University's Zvi Bodie, filed under patent number 20070061238.[69] It's officially described as follows: "Embodiments of the invention generally provide a method and apparatus for retirement income planning. One embodiment of a method for planning an income stream includes receiving personal data relating to an individual, where the personal data includes the value of the individual's projected income and the value of the individual's projected expenses. The difference between the projected expenses and the projected income is then calculated, and an annuity is purchased in substantially real time from among a plurality of annuities presented in an auction-style format, where the annuity provides a sum to offset the calculated difference." The patent was later acquired by DFA, the same firm where Merton is the resident scientist.

Ever the car enthusiast, Merton uses an automotive analogy to indicate what the Perfect Portfolio is without describing it directly. "It happens under the hood. . . . And that's the whole trick, how to make it really simple for the consumer . . . like your car. You don't have to know how the engine works. You don't need to know how in cubic inches or anything else. You just get in your car, you turn the key, and you ask questions, 'Does it stop right? Is it comfortable?' That's what we're trying to do."[70] Your Perfect Portfolio would be created by professional managers who might use a dynamic trading strategy. But why leave it to professionals? "The challenge of doing it yourself is enormous. . . . If you had to trade continuously yourself, you would do nothing else with your life." The other reason has to do with investment knowledge: "This is not about education. It's about the same things of division of labor. People get paid millions of dollars to work full-time to try to figure out which manager is going to do better in the future."

What's the solution? According to Merton, "Only give people meaningful choices and meaningful information. And meaningful is different than important."[71] He explained the distinction between "meaningful" and "important" with another car analogy. Suppose you're looking at two cars, trying to decide which one to buy. You're told that one car's engine has a compression ratio of 9 to 1, while the other has a ratio of 9.3 to 1. "I can tell you with authority that compression ratio is very important to gas mileage, acceleration, reliability, and the kind of gasoline you have to use. So, it's an important piece of information; it was just totally meaningless to you. So, the parallel in investing is, we all know asset allocation is very important to the outcome. So, it's important. You tell me do I want 65/35 [percentage equity to bonds in a portfolio] or 70/30? That's meaningless. What I want to know is how likely am I going to be able to sustain my standard of living in retirement? And what could happen to me if I follow this path?"[72]

Merton is critical of the current regulations for defined contribution (DC) plans. Employers are required to disclose information about funds offered in 401(k) retirement plans such as past performance, but individuals have no idea how they might use that information to decide which funds to choose. Merton's proposed solution: "I take away from you every decision for which, like the compression ratio, you have no idea" and instead, work backwards from your goal with professional assistance. "I could promise you that you will be able to live in the standard of living you've become accustomed to in the latter part of your work life for the rest of your life. . . . If you agree with that, now you say, 'How do we get there?' Well, what happens is there are people who spend their whole career estimating what it would take to be able to sustain the standard of living for that person at that age and given wherever they are. . . . That's something that's done by professionals."[73] Merton explains that some information required would be your age, your desired retirement age, your income, your anticipated Social Security benefits, and the minimum income you would like to have in retirement to meet your desired standard of living. With that information, the professionals would take over, and the program would calculate your odds of reaching that goal.[74]

There is one other factor that's often overlooked for those who are involved with a retirement plan: "The biggest asset of most of your work life is going to be your future contributions. . . . When you're a young person, and I mean under forty, most of your assets for retirement are future contributions. They're very safe," in particular relative to one's desired standard of living.[75] Merton gives an example of the importance of these assets. Suppose two people had 100 percent of their retirement assets in equities in August 2007, just before the Great Recession, accompanied by a large decline in stock prices. By March 2009, the value of each person's retirement plan will have declined by 40 percent, a devastating result. But suppose one person was much younger than the other. For the younger person, it may be that only 10 percent of his total retirement assets were in the DC plan, while the other 90 percent were in the form of future contributions. He would have lost only 4 percent of his total retirement assets. However, the older person may have had 90 percent of her retirement assets in her DC plan, resulting in a total loss of 36 percent, a disaster. "Unless you take account of these other assets, how can I possibly make a good decision on your DC plan? You both have the same allocation, the outcomes are entirely different."[76] Merton makes the point that age alone is not the best proxy for risk, which traditional "target date" or "glide-path" funds that arbitrarily adjust one's asset allocation based on age assume. "It has to do with that the assets you're holding are a different risk character, the big asset being your future contributions."[77]

Merton believes that the best approach is to give individuals information about the effort needed to reach their retirement goals and then provide them with some simple options. For example, suppose you had a goal of 100 percent and you were currently at 70 percent. "What I say to you is, 'Okay. You would like to get yourself to a better place in terms of where you are, in terms of getting to a good retirement. There are really only three ways that you can improve your chances of getting to that goal: save more, work longer, or take more risk.' That's it. Now, I then say to you 'Okay, what if I saved 1 percent more?' So that's increase in saving, which means reducing consumption. You get feedback, 'Well, if you do that, your funded ratio will go from 70 to 81.' You say, 'Oh, that's an improvement.' Then you say, 'Wait a minute! If I fund that 1 percent, my paycheck next month [is] going to be smaller. Can I handle that?' . . . Okay, how about if you were willing to work an extra year? . . . Well, then the only other choice you have is take more risk. And how do I convey that to you? Well, the key is to be able to convey in a meaningful way."[78]

The software Merton helped to develop uses visual sliders to give people immediate feedback about the effects that changes in their savings rates, length of working career, or levels of risk taking have on their retirement goals. He dryly notes that if you don't want to save more, work longer, or take on more risk, "Then the only thing you can do is adjust your goal."[79] His software has been used at companies since 2005, and the technology is constantly evolving.

Applying this technology at DFA, Merton led the Managed DC program, which later transformed into the Target Retirement Solution[80] for DC plans and subsequently into Target Date Retirement Income Funds[81] for individual investors, strategies that essentially attempt to create a tailored and dynamic Perfect Portfolio for the investor. Instead of a typical plan with, for example, fixed allocations of 70 percent to equities and 30 percent to fixed income, these products focus on dynamically updating the investor's allocations to achieve a desired income in retirement. The communication and focus are on retirement income, the amount of an inflation-protected annuity an investor is able to purchase, rather than the current account balance. As Merton stated, "The secret sauce of Managed DC is that if you are willing to agree on a goal, say, for example, $58,000 per year, protected against inflation in retirement, and my competitors and I start with the same Sharpe ratio, but I use dynamic strategies based on the goal versus a 70:30 portfolio, then I promise you I'll beat them. Focusing on the goal is like having 20 percent more assets."[82]

Merton notes that if the typical individual in the past worked for forty years, retired at age sixty-five, and lived until seventy-five, he or she had to support fifty years of consumption on forty years of work, thus needing to save roughly 25 percent of his or her income.[83] However, if that worker today lives for twenty years past retirement until age eighty-five, in order to support sixty years of consumption on forty years of work, the individual needs to save roughly 33 percent of his or her income. Yet the typical individual is simply not saving enough. Furthermore, the amount we need to save depends on our desired lifestyle at retirement. "By the time you retire, you've gotten used to how you want to live. The goal is sufficient funding to sustain the standard of living you've enjoyed in the latter part of your work life. Jane Austen didn't say Mr. Darcy [a central character in her novel, *Pride and Prejudice*] was worth £10,000, but £10,000 a year."[84]

With that in mind, let's take a peek at what's under the hood. The DFA DC retirement products are connected to three simple portfolios: a global stock index and two inflation-protected (TIPS) bond portfolios with different durations, intermediate and long.[85] The DFA Target Date Retirement Income Funds are similar, with a global portfolio primarily in stocks (although including some bonds), combined with inflation-protection investments. For example, the 2030 Target Date Retirement Income Funds, targeted to investors planning to retire around 2030, are invested about 37 percent in U.S. equities, 22 percent in international equities (including some emerging market equities), 14 percent in global bonds (government and good-quality corporate bonds), and 27 percent in inflation-protected bonds.[86]

What's in Merton's own portfolio? "In my retirement account I am in TIPS, and I have a global index fund. . . . I have one hedge fund that gives me some exposure to unusual areas. . . . Also, of course, I own residential real estate."[87] Merton observed, "Probably the best hedge of your standard of living is a life annuity based on TIPS combined with ownership of your own home in a place where you plan to live for the indefinite future."[88]

Merton's final observation is on the broad issue of retirement planning preparedness—or lack of preparedness—and what the tools he has helped to create can do about it. "The message I would give is the retirement problem, which is a global challenge, is an engineering problem. It's not a science problem. There is a way to solve it, to create a sustainable system. We have the tools to do that and we could do that, but it's a very complicated engineering problem to execute. So, yes, you're going to be able to do more [sophisticated retirement planning] in the future."[89] The pursuit of the Perfect Portfolio continues.

8

Martin Leibowitz, from Bond Guru to Investment Strategist

MARTIN "MARTY" Leibowitz has often been called the Bond Guru. Whether one followed his extensive research or not, however, few could deny he was one of the first people on Wall Street to change the way investors thought about bonds and other fixed-income products, transforming them from stodgy and boring buy-and-hold assets to a dynamic and exciting investment.

But Leibowitz has contributed far more to the investment profession than bonds. Back in 1992, Bill Sharpe commented that Leibowitz's collected works "constitute a true tour de force" of investment analysis.[1] Leibowitz is one of the all-time most prolific authors in the Chartered Financial Analyst (CFA) Institute's flagship publication, *Financial Analysts Journal*—forty-two publications between 1974 and 2019, or almost one per year. He is also one of the all-time most prolific authors in *Journal of Portfolio Management*, with twenty-five publications between 1974 and 2019. Through his numerous books he is known as a founder of liability-driven investment, an investment approach that takes into account the cash flow needs of either individuals or pension funds.

But that's not all. Leibowitz is one of the few people to have received three of the highest awards presented by the CFA Institute: the Nicholas Molodovsky Award in 1995, for outstanding contributions that change the direction of the profession and raise it to higher standards of accomplishment; the James R. Vertin Award in 1998, to recognize individuals who have produced a body of research notable for its relevance and enduring value to investment professionals; and the Award for Professional Excellence in 2005, to honor a member of the investment profession whose exemplary achievement, excellence of practice, and true leadership have inspired and reflected honor on the profession. In 1995, he was the first inductee into the Fixed Income Analysts Society's Hall of Fame. And in 2014, the International Association for Quantitative Finance named Leibowitz "Financial Engineer of the Year."

Leibowitz is the rare practitioner whose research and leadership have been more prolific than even the most elite academics. As such, he is well suited to provide insights into the Perfect Portfolio.

From Rugs to Riches

Leibowitz was born in 1936 in York, Pennsylvania, once known as the White Rose City.[2] York was then a small factory town surrounded by Amish farms. The famous York Peppermint Pattie was created in York in 1940 by the York Cone Company (and now produced by the Hershey Company).[3] His parents ran a clothing store, the first retailer in the region to introduce an installment purchase plan. "We lived in modest circumstances," he recalled. "And one thing that was very pervasive, is the attitude that you didn't waste anything. You didn't waste food, you didn't waste your effort, you didn't waste people's time, you didn't waste money. And, so that kind of frugal economical background I think played a role in my being interested in trying to find ways to make things efficient, and make them more economic in the efficiency sense of the word."[4]

After Leibowitz's father passed away in 1940, the family moved to Los Angeles, then to Baltimore, and then to Oak Ridge, Tennessee, where his older sister gained employment at the Atomic Energy Commission as a physicist. Leibowitz attended high school in Oak Ridge, and in 1950, he won the Junior Chess Championship of Tennessee. The next year, at age fifteen, he won a prestigious Ford Foundation scholarship to the University of Chicago.

At the University of Chicago, Leibowitz studied physics as well as the liberal arts, obtaining his bachelor of arts in 1955 and his master of science in physics the next year, at the young age of twenty. One of his physics classmates was Carl Sagan, who became a Pulitzer Prize–winning science popularizer and planetary scientist and whose *Cosmos* series became the most-watched show in public television history.[5] Although not a student in business or economics, Leibowitz became friends with business school professor James Lorie, who would go on to establish the Center for Research in Security Prices. One of Leibowitz's influential physics instructors, Lawrence Friedman, left Chicago for the Case Institute of Technology in Cleveland to study an emerging field known as operations research, which employed mathematical techniques to improve business and military operations. Leibowitz's fascination with the practical nature of these problems would later prompt him to leave the study of physics. "I'd always been interested in mathematics, and particularly in applying mathematics to kind of the problems around me."[6]

With his newfound interest in operations research, Leibowitz headed to San Diego, where he obtained a job at General Dynamics in its newly created operations research department. In 1958, he took a position at the Stanford Research Institute, an independent nonprofit research center established in 1946 as an offshoot of Stanford University that focused on taking research and development from laboratories to markets.[7] In 1958, he published a note with the title "Metaphysical Considerations Involved in Choosing a Measure of Effectiveness" in *Journal of the Operations Research Society of America*. And then in the same journal in 1960, he published his first professional paper (coauthored with Stanford University Professor Gerald Lieberman), "Optimal Composition and Deployment of a Heterogeneous Local Air-Defense System," which examined the optimal defense against an enemy aircraft attack.[8]

In 1959, Leibowitz decided to move to New York City, since he felt that every young person should spend at least a year there. He got a job at Systems Research Group, a computer simulation laboratory, where he crossed paths with Harry Markowitz, who was working at a competing firm developing a programming language called SIMSCRIPT.

In 1964, Leibowitz took a job at Commercial Affiliates, a corporate umbrella for three carpet manufacturing and distribution companies. Its founder was Jim Marcus, the father of one of his friends, who became known during his seven decades in the industry as a visionary who made groundbreaking contributions that changed the face of the business.[9] Marcus had successfully developed a new process for nylon carpeting. Working for Marcus provided Leibowitz with invaluable lessons in business management. "I learned more about business than I ever could have learned in business school."[10] He was given increased responsibility within the company involving a variety of operational issues such as negotiating new factory sites, designing warehouse systems, and setting up computerized sales analysis systems. "It was very, very satisfying because you could actually make tangible products," Leibowitz recounted, and "you could send these real products out to customers. You could see these products being installed and see, in many cases, the functionality and beauty that they generated."[11] Along the way, he earned two patents in material handling.

Leibowitz had initially chosen to forgo the typical PhD route followed by many of his colleagues. While working full-time, however, he relented and took night courses at New York University's prestigious Courant Institute of Mathematical Science. After several years of this arduous schedule, in 1969, he earned a PhD in mathematics (within the subfield of probability and statistics). During his time at New York University he met and fell in love with Sarah Fryer, and they were married in 1966. Since her father had passed away several years earlier, the bride was given away by her uncle, Sidney Homer, who would have a huge impact on Leibowitz's career path. "Sidney was a brilliant man. He went through Harvard in very short order as a young man. And then disappointed his artistic and musical family by having to take a job on Wall Street . . . where he worked his way up to being called by many the 'Bard of the Bond Market.'"[12]

As the carpet firm flourished in the late 1960s, Leibowitz was asked to develop an appropriate financial structure for this growing business. He tried to convince Marcus that it was time to consider going public. As it happened, his uncle-in-law, Homer, was in a senior position at the legendary Wall Street firm Salomon Brothers & Hutzler, which was then primarily involved with bond trading. The brothers Percy, Arthur, and Herbert Salomon started the firm in 1910, while Morton Hutzler was a broker who had a seat on the New York Stock Exchange (his name was dropped in 1970, as the firm became known as Salomon Brothers, or sometimes "Sally B" for short).[13] Homer was a general partner in charge of its bond market research department.[14] At a social gathering in 1968, Leibowitz asked Homer about the initial public offering process and if he might provide assistance, but Homer noted that this was an area of corporate finance in which Salomon was only just beginning.

Meanwhile, Homer had questions for Leibowitz. Homer "had written this fantastic history of interest rates. He did it really as an avocation, not knowing how important it would ultimately become. But that garnered him great respect among many participants in the bond market at that time and eventually landed him at Salomon Brothers."[15] Homer asked Leibowitz how much he knew about bonds, to which he replied that he didn't know very much (perhaps the last time this could be said). Homer explained that he had asked because he knew that Leibowitz was a mathematician and confided to him that he was trying to write a book tentatively titled "The Mathematics of Bonds"—he had about fifty handwritten pages—but his calculations were not working out. In particular, the conventional wisdom about the price behavior of bonds with different coupons and maturities was inconsistent with Homer's actual mathematical calculations. He hoped that Leibowitz could find and correct the errors. "And so, I said, 'Well, where do these bond yields come from?' And he handed me this fat book of tables, and that really didn't help me much, but there was in the introduction a description of how bond yields were calculated."[16]

Leibowitz quickly came to grips with the math that led to a bond's yield and then did some reverse engineering to understand the source of the problem. Homer was impressed and appreciated the work.

But Leibowitz was puzzled. He questioned why Homer had come to *him* with the problem. "'But this is strange—surely you must have a house mathematician down there at Salomon Brothers?' But Sidney said, 'Oh no, no, there's no one like that at all.' And so, then I got the idea (as when little lights go on), they really do need a mathematician."[17] At that point, Leibowitz was hooked. He wanted a career on Wall Street and specifically at Salomon Brothers. He wanted to create a new position: the in-house mathematician.

The Inside Story

When Homer began his career in the mid-1920s, good-quality long-term bond yields were incredibly stable at around 4¼ percent, and there was very little speculation on interest rates.[18] When yields increased substantially to around 5½ percent by 1930, bond prices declined accordingly due to the classic inverse relationship between yields and bond prices. As the bond business developed, bonds were underwritten and then distributed both to private investors and institutional investors such as banks, pension funds, and insurance companies. While some bonds were listed and traded on exchanges, institutional investors increasingly traded off-exchange in the so-called over-the-counter market, where they could more readily trade in large round lots of thousands of bonds, each with a face value of $1,000.

During the Great Depression, lower-quality bond yields soared to as high as 15 percent, while good-quality bond yields dropped to as low as 2¾ percent. The corporate bond market became almost exclusively an institutional business. The bond market stabilized in the 1940s and 1950s, with yields once again in the 4–5 percent range. By the 1960s, investors ignored corporate bonds and focused on government bonds. Underwriting of new issues was massive, and secondary markets were quite active. However, by the late 1960s, as inflation started to pick up, bond yields soared again to over 9 percent.

In 1969, Leibowitz secured an interview at Salomon Brothers through Homer and joined Salomon Brothers (taking a cut in pay). Once there, Leibowitz observed that the traders at Salomon were frequently frustrated as they tried to arrange "bond swaps" that exchanged old portfolio bonds for new higher-yielding bonds. The institutions were willing to incur tax losses if they could gain improved income over the initial bond's remaining life. However, all too often the institution's calculation seemed

Bond yield table

7% Coupon Rate	Years and months							
Yield	10-6	11-0	11-6	12-0	12-6	13-0	13-6	14-0
4.00	125.52	126.49	127.44	128.37	129.29	130.18	131.06	131.92
4.20	123.58	124.46	125.33	126.18	127.01	127.83	128.63	129.41
4.40	121.68	122.48	123.27	124.04	124.79	125.53	126.26	126.96
4.60	119.81	120.54	121.25	121.94	122.62	123.29	123.94	124.57
4.80	117.98	118.63	119.27	119.89	120.50	121.09	121.67	122.24
5.00	116.18	116.77	117.33	117.88	118.42	118.95	119.46	119.96
5.20	114.42	114.94	115.43	115.92	116.39	116.86	117.31	117.74
5.40	112.70	113.14	113.57	114.00	114.41	114.81	115.20	115.58
5.60	111.00	111.38	111.75	112.11	112.47	112.81	113.14	113.46
5.80	109.34	109.66	109.97	110.27	110.57	110.85	111.13	111.40
6.00	107.71	107.97	108.22	108.47	108.71	108.94	109.16	109.38
6.20	106.11	106.31	106.51	106.70	106.89	107.07	107.24	107.41
6.40	104.54	104.69	104.83	104.97	105.11	105.24	105.37	105.49
6.60	103.00	103.09	103.19	103.28	103.37	103.46	103.54	103.62
6.80	101.48	101.53	101.58	101.62	101.67	101.71	101.75	101.79
7.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
7.20	98.54	98.50	98.45	98.41	98.37	98.33	98.29	98.25
7.40	97.12	97.03	96.94	96.85	96.77	96.70	96.62	96.55
7.60	95.71	95.58	95.45	95.33	95.21	95.10	94.99	94.88
7.80	94.34	94.16	94.00	93.84	93.68	93.54	93.39	93.26

FIGURE 8.1: Bond yield table (created by authors).

to suggest that such yield improvement would not really lead to the needed income improvement. Leibowitz couldn't resist the challenge.

To get a sense of the state of the art of bond pricing in the late 1960s, let's look at an article in 1969 that appeared in *Financial Analysts Journal* that begins with "Virtually everyone in the investment community knows how to find the dollar price of a specific bond—after obtaining certain essential information (coupon, maturity and yield), look the price up in the *Yield Book*."[19] The standard *Yield Book* was published by the Financial Publishing Company. You didn't need to understand the relationship between bond prices and yields; you only needed to know how to look it up in a thick book of tables, with charts like that in figure 8.1. The main point of the article was to show readers that the price of any bond was the present value of the future stream of coupons, plus the present value of the face value of the bond to be received at maturity, discounted at the yield to maturity—in other words, a very basic bond pricing formula.

In the late 1960s, financial markets were facing tumultuous times, and the tables in the standard *Yield Book* were becoming less and less useful. As interest rates rose, long-term government bond prices had fallen each year between 1967 and 1969, and the Dow Jones Industrial Average fell by over 15 percent in 1969. The timing was right for Homer to once again return to the writing of his more advanced book on bond prices, and soon Leibowitz was writing with him.

How their collaboration came to be was a blend of perfect timing and a perfect match between Homer's earlier musings about a book idea and Leibowitz's new job. When Leibowitz joined Salomon Brothers' 60 Wall Street office, it consisted mainly of a crowded trading floor with few sizable offices except for Homer's. Leibowitz recalls, "There was a paper ticker tape going all around this huge room. And every once in a while, the ticker tape would break and people would panic, and they'd run with scotch tape to fix the ticker tape. They didn't have screens. They were screaming to one another, and they didn't have any computers. They didn't even have calculators. And so, they had these big tables they would go through [in the *Yield Book*] trying to find out what the price would be for a given yield, what the yield would be for a given price. It was a pretty wild scene. I couldn't quite believe that this was *the* bond house that traded more government bonds, U.S. government bonds, than any place else in the world by far."[20]

Leibowitz initially had a small desk next to the corporate trading area, right on the frantic trading floor, but he did gain access to a time-share IBM computer, which allowed numerous users to run programs without the need for expensive (for the time) individual computing devices.[21] With this time-share access, he was able to solve problems that others had long grappled with. His intuition about the firm's need for an in-house mathematician was correct. Senior partners were lining up at his desk seeking solutions.

Then when bond yields climbed above 8 percent, Leibowitz became an even more valuable resource—because the *Yield Book* only went as high as 8 percent. "I had the only yield calculator in town—maybe in the world.

Now they really needed me. With the senior partners fighting with each other to be at the head of the line, I became discovered! I had gained a little footing at Salomon Brothers." He soon became head of a small group of analysts and was given the title director of investment systems.

Shortly after Leibowitz joined Salomon Brothers, he was given a copy of a paper written by Peter Williamson at Dartmouth titled "Computerized Approaches to Bond Switching."[22] Given his new position, Leibowitz was very intrigued with the paper and studied it carefully. The paper posed a problem for the "bond man" who owns two bonds, for instance, a high-grade utility bond and a government bond, and expects the yield spread between them to narrow. What yield change will make it profitable to sell government bonds and buy more utility bonds? The paper provided some excerpts from a Fortran program code to address this problem, developed by Williamson and a team of four graduate students. "Peter didn't quite have it," Leibowitz recalled, "but putting it together with what was my recent understanding of the nature of the yield calculation that was embedded in the *Yield Book*, it became clear that there was a fundamental problem in how institutions went about comparing two bonds with different yields."

Leibowitz made it clear that Williamson wasn't *totally* wrong in the assumptions he made about the market environment, but Williamson did gloss over the importance of the rate at which coupons from bonds, typically paid every six months, could be reinvested. Leibowitz eventually wrote a computer program to explore the implications of a common reinvestment rate on various types of bonds with different maturities (i.e., when the lender got her or his money back) and different coupons (i.e., the biannual interest that the lender received). For example, if a bond initially yielded 9 percent but then yields dropped to 7 percent, the actual return for holding the bond to maturity would be lower because of the lower returns on the reinvested coupons. "And I showed it to some of the people on the trading floor, and they said, 'Oh it can't be right,' because they were so imbued with the idea that yields were yields and that was it. So, it got around on the trading floor, and then Sidney got ahold of it, and he said, 'Well, this is actually very interesting.' So that led to his idea of writing a series of papers on using this analysis."[23] Homer's initial book project was about to transform from a book on bond mathematics into something much greater, including five papers written by Homer and Leibowitz. Homer labeled the series of papers for Salomon clients as "Memorandum to Portfolio Managers," what are now typically referred to as research reports.[24]

To appreciate what Leibowitz and Homer had discovered, it's worthwhile to step back in order to grasp some fundamental concepts about bonds. A bond is issued by the government or by a corporation that needs to borrow money, and each bond is typically denominated in increments of $1,000, which is known as the face value, or the par value, of the bond. In this example, we assume for the sake of simplicity that the lender issues the smallest typical value, $1,000. The lender agrees to repay the borrowed amount in a set time known as the maturity date, for example, five years from now. The lender also agrees to pay interest at a set percentage of the face value, known as the coupon rate, say 4 percent. Interest is in the form of coupon payments, paid on a semiannual basis. We can calculate that in this example, coupons will be $20 every six months for a total of $40 each year, 4 percent of $1,000. The yield of the bond, also known as the yield to maturity or the "promised" yield, is the interest rate that equates the purchase price of the bond with the discounted value of the future cash flows—that is, the coupon payments and the face value at maturity. When a bond is issued and sold at par, the yield of the bond is identical to the coupon rate.

An important assumption in this calculation is that any coupon received is reinvested at a rate identical to the yield. However, that's a special case. While a bond could be held to maturity, there is often an active secondary market in which the bond can be traded. The question is, what is a fair price for that bond? The answer is that it depends on the time to maturity, the coupon payments, and, most importantly, the prevailing interest rates.

Going back to the example above, suppose interest rates or yields suddenly dropped to 3.5 percent. For instance, suppose investors decided that inflation was going to be much lower than previously thought. Now, what would be a fair price for the bond? Well, if the lender was issuing a new bond today (borrowing again), the new bond could be issued at par, also with five years to maturity but with a coupon rate of only 3.5 percent. A new investor would have the choice whether to buy the new bond for $1,000 and only receive $35 of coupons each year, and hence a yield of only 3.5 percent, or buy the old bond with a 4 percent coupon rate.

It turns out that given the more attractive coupons of the old bond, the investor would be prepared to pay more than the old bond's face value of $1,000. In fact, based on time value of money calculations, the investor would be willing to pay $1,022.75. At that price, the yield on the old bond would be identical to the yield on the new bond, 3.5 percent. This is the inverse relationship between bond prices and yields: as yields go down, bond prices go up and vice versa. However, the initial investor or lender who bought the 4 percent coupon bond when it was issued won't have a *realized* return of 4 percent over the lifetime of the bond if he or she holds it to maturity, because the initial investor can only reinvest the coupons at 3.5 percent instead of 4 percent.

This was Leibowitz and Homer's important insight, made in their first memorandum, published on October 5, 1970, titled "Interest on Interest." Unlike earlier decades with very stable yields, there was considerable uncertainty at the beginning of the 1970s as to whether yields would remain high. Homer and Leibowitz therefore wanted to emphasize the importance of interest on interest and the reinvestment of coupons. For the typical bond, they noted that over half of the total compound return was attributable to the interest on the reinvested coupons rather than the coupons themselves. Their first table examined a typical bond at the time, one with an 8 percent coupon that matured in twenty years. According to the *Yield Book*, the total coupon income would be $1,600 ($80 per year times 20 years). Assuming all coupons were reinvested at the coupon rate of 8 percent, the interest on interest would be $2,201. Thus, the total compounded return would be $3,801, the interest on interest would be 58 percent of this total return, and the total realized compound yield would be 8 percent. According to the *Yield Book*'s conventional wisdom, that should have been the end of the story.

But Homer and Leibowitz extended the story, showing what would happen if reinvestment rates suddenly dropped or increased. With a drop to 6 percent, the reinvestment interest on interest would be $1,416, for a total return of only $3,016, and the interest on interest would be only 47 percent of the total return, for a total realized compound yield of 7.07 percent. Conversely, with an increase in rates to 10 percent, the reinvestment interest on interest would be $3,232, giving a total return of $4,832. The interest on interest would be 67 percent of total return, with a total realized compound yield on the bond of 9.01 percent.

Investors were by no means assured of the so-called promised 8 percent return. Leibowitz later reflected that these results were "viewed by many readers as an attack on the sanctity of the standard yield measure. There was considerable outrage among many of the crustier members of the bond community (and there were lots of crusty members!)."[25]

After the memorandum's release, Homer received numerous outraged letters and calls from friends and customers alike. "The yield was so embedded in their thinking, in the way they looked at things, that they couldn't conceive that there was anything wrong with it or that what I had shown, or what I tried to show, was correct. But it was pretty [incontrovertible]."[26] Leibowitz was then given the job of responding to each complaining client and somehow convincing them that he and Homer were right. It gave Leibowitz an opportunity to interact with the leaders of the bond community. "Some were soothed by my written explanations, but many were not, which resulted in some pretty nervous grumbling [within Salomon]. Eventually virtually everyone accepted my arguments, and Salomon's sterling reputation was maintained—and perhaps even enhanced!"[27] It didn't take long before Leibowitz's insights became the new conventional wisdom.

The clarity that Homer and Leibowitz brought to the assessment of bond returns had a real and profound impact on many large investors. At a time of relatively high interest rates, "just about all bond portfolios were selling underwater at a deep discount. And [Salomon Brothers] was having trouble getting insurance companies and pension funds to consider trading those locked-up bonds because they had to take losses, and they felt that they would not be able to recover those losses. And they had various incorrect formulas for ascertaining whether they would recover those losses. And so, a huge amount of the outstanding bonds were just locked up for artificial reasons. So, it turned out that when you start looking at these calculations in terms of the proper accounting for reinvestment rates . . . many of these losses could indeed be recovered, and that made an argument for unlocking some of those portfolios. And aside from hopefully doing some good, that also enamored me to the senior partnership of the firm."[28]

Homer and Leibowitz's next two memoranda focused on price volatility: What happens to the price of a bond when yields or interest rates change? These memoranda were less contentious and were generally well received. While the conventional wisdom suggested that bonds with longer maturities were more volatile than those with shorter maturities, Homer and Leibowitz showed that, surprisingly, this wasn't necessarily the case. In fact, some bonds with lower coupons could be more volatile, even with shorter maturities. Another memorandum examined how the price of a bond without any coupon would react to yield changes, an important insight that predated the issuance of zero-coupon bonds.

It was Homer and Leibowitz's last memorandum, however, that had the most impact. This memorandum dealt with the topic of bond swaps, an important area in the practice of bond portfolio management.[29]

A bond swap is simply buying one bond and simultaneously selling another one. At that time, no distinction was made about the purpose of the swap. Homer and Leibowitz were the first to systematically categorize different types of swaps and show how rate changes might impact their profitability. The first category was the substitution swap, swaps between bonds that had essentially the same characteristics such as coupon, maturity, quality, and liquidity but different yields. The second category was the intermarket spread swap, swaps between two bonds in different sectors when the spread differential appeared either too narrow or too wide. The third category was the rate anticipation swap, intended to anticipate a change in interest rates that affected one of the bond's prices more favorably. The final category was the pure yield pickup swap, a swap with no anticipation of interest rate changes but purely selling a lower-yield bond in return for a higher-yield one. This fifth and final memorandum was to create a whole new vocabulary for the bond industry.

These memoranda were widely distributed, both in the United States and internationally, and soon were translated into Japanese and German. They even made their way into the training programs of Salomon Brothers' competitors. Urged by the New York Institute of Finance and Prentice Hall to expand these papers into book form, Homer and Leibowitz added a few more chapters and a technical appendix that described the basics of time value of money calculations such as present value and yields, a section surprisingly most valued by many readers. Homer and Leibowitz completed their project in 1972, titling it *Inside the Yield Book: New Tools for Bond Market Strategy*.[30]

The Homer-Leibowitz collaboration became a classic. After the 1972 publication, the book went through twenty-five reprintings. Now in its third edition, the book was updated with Stanley Kogelman and Anthony Bova as coauthors.[31] Thanks to Homer and Leibowitz, active bond strategies would replace the boring buy-and-hold approach, and bond investing would never be the same.

The publication of this classic was also well timed technologically. By 1973, computers were beginning to play an increasingly central role in bond pricing. As the methods in Homer and Leibowitz's book became more accepted, the Bond Portfolio Analysis Group at Salomon Brothers was formed, the first fixed-income quantitative analysis group in the United States. As Leibowitz later reflected about Salomon Brothers' bond department, "It was really wonderful. A wonderful place to learn, and a wonderful place to grow."[32]

During the 1970s, Leibowitz's team developed computer programs for better performance measurement of active bond strategies.[33] In the late 1970s and 1980s, his team was involved in numerous innovations in the bond industry (some of which we discuss below), including financial applications of duration, a measure of a bond's volatility; the first bond performance index; the issuance of zero-coupon and strip bonds (repackaging Treasury coupons as stand-alone bonds); immunization strategies and matching assets with liabilities; and the analytical foundation that led to the growth of modern mortgage securities. Leibowitz himself became a general partner of Salomon Brothers in 1977, a managing director in 1981, and deputy director of the research department, reporting to Henry Kaufman, in 1986. In 1991, Leibowitz became Salomon Brothers' director of the research department, covering both fixed income and equities, and a member of the firm's executive committee.

Dedicated to Immunization

Leibowitz has sometimes been called the founder of asset-liability management, or liability-driven investing. He helped to articulate the concepts of bond duration and immunization, and he is probably the most prolific author on what is also known as dedicated portfolio theory. Let's step back a little to understand what these concepts mean.

In a stock portfolio, we saw that Sharpe's beta captures the riskiness of a stock relative to the market as a whole. Similarly, the bond duration (measured in years) captures the riskiness of a bond. The bond duration is the average time that a bond investor needs to wait to receive all the bond's cash flows, weighted by present value. The duration reflects the bond's price sensitivity to interest rate changes. The longer the investor needs to wait to receive cash flows, the riskier is the bond. For example, a ten-year bond with a 5 percent coupon rate would have a duration of around eight years. If interest rates go up by one percentage point, the price of that bond will drop by about 8 percent. A bond's duration should not be confused with a bond's term or time to maturity, which is the time until repayment of the bond's principal is due.

Immunization is a strategy meant to match an investor's time horizon with a portfolio's duration in order to minimize any potential effects of interest rate changes. In an award-winning article that appeared in *Financial Analysts Journal* in 1986, Leibowitz was able to extend the concept of duration beyond bonds, applying it to a total portfolio that included stocks as well.[34] We now begin to see how his ideas fit together. Dedicated portfolio theory describes a process for creating a portfolio with predictable cash inflows that precisely match the amount and timing of cash outflows or liabilities. In another award-winning article that appeared in *Financial Analysts Journal* in 1987, Leibowitz highlighted the impact of changing interest rates on both assets and liabilities, stressing the importance for pension fund managers of focusing on the difference between assets and liabilities, or the surplus.[35]

Asset-liability management, or liability-driven investment, broadens the investing perspective. Instead of focusing only on investments and returns, the investor or fund manager also necessarily has an eye on liabilities, putting this all together into a whole. Let us see how Leibowitz earned his spurs in the area of asset-liability management.

In the 1980s, actuaries played a particularly important role in pension fund management because they were responsible for estimating the value of future promised payouts to current and retired employees. The role of pension managers was to ensure that their assets exceeded the estimated value of these liabilities. To estimate such values, a standard practice was to use a discount rate of around 4 percent to calculate the present value of future cash outflows. However, in the early 1980s, when inflation was a major concern, the Federal Reserve, led by Paul Volcker, tightened monetary policy and raised interest rates to over 10 percent. Based on the time value of money, if the anticipated cash outflows were discounted at those much higher rates, then the liabilities would decrease dramatically. Company pensions would be in much better shape, and the companies themselves would be more valuable.

Leibowitz looked at another approach. "I started doing some of the math on what immunization would amount to, by essentially immunizing those liabilities—putting together a portfolio which could, without any argument, take care of those liabilities and doing it for a fraction of what the actuaries had required as a liability accounting value."[36] In solving these problems for clients, he and his colleagues were able to make lasting contributions in bond portfolio management. One contribution involved a refinement of the concept of duration, which became known as duration targeting. "Duration targeting is a term that Stan Kogelman and I coined in the early 1990s along with my colleague Terry Langetieg.[37] We found that, as bond managers became more performance-oriented, they tended to rebalance toward a duration target, instead of holding to maturity as they had done in the past."[38] The idea behind duration targeting was to maintain a balance between return and risk. Leibowitz and his colleagues were able to show that realized return from a duration-targeting process, over an investment horizon that was roughly twice the duration, would closely approximate the initial yield level—*regardless* of whether yields rose or fell!

While asset-liability management is most applicable to a defined-benefit pension plan, Leibowitz showed that the principles apply to individuals as well, although answers aren't always straightforward. To take one of his examples, suppose you're facing retirement and currently you can only fund 80 to 90 percent of your desired lifestyle. "Do you take risks and how much risk? Well, if you're at 90 percent, at least it's viable and you have some degrees of freedom, I would think. If you found yourself deteriorating down to 80 percent, it's extraordinarily painful. So yes, you may want to de-risk at that 90 percent point. On the other hand, if you find that you're at 90 percent funding ratio of what's a fairly comfortable lifestyle and you feel that you have some degrees of lifestyle freedom, and a future surplus would be nice, then you may want to remain in risky assets to garner more return."[39]

How did Leibowitz come up with so many ideas that became so widely accepted and put into practice? "In the years at Salomon Brothers, I learned greatly from talking to clients," he recalled. "Actually, the whole issue of immunizing corporate pension funds was sparked by a client named Len Wissner who realized that the market environment at the time just begged for a solution that immunization could provide."[40]

Asset Allocation

In 1995, Leibowitz received a call from John Biggs, the chairman of TIAA-CREF, the Teachers Insurance and Annuity Association–College Retirement Equities Fund, a fund with assets of over $300 billion. Leibowitz was offered a position as the fund's vice chairman and chief investment officer, overseeing its equities portfolio. Since he was enjoying his time at Salomon Brothers, he considered turning down the offer. However, in addition to having his arm twisted by TIAA-CREF trustees such as Bob Merton and Steve Ross, Leibowitz's wife, Sarah, helped him to decide to make a change. Sarah was a neuroscientist at Rockefeller University and a member of a TIAA plan. Leibowitz had seen her monthly reports and admired them. To clarify his thinking, Sarah asked him, "Well, where would you go after Salomon?" And he admitted it would be a place like TIAA-CREF. She then asked, "How many places are there like that?" It was then he realized that there weren't many others, if any.[41]

After twenty-six years at Salomon Brothers, Leibowitz took the plunge to a new institution. Soon after, he became the chief investment officer for all of TIAA-CREF's investments, including equities, bonds, and real estate. "I was into everything, with terrific people."[42] He was so valued that in 2001 when he reached age sixty-five, TIAA-CREF's normal retirement date, he was asked to stay on for an additional three years. After his stay at TIAA-CREF, Leibowitz, not one for retirement, jumped at an opportunity to join Morgan Stanley in 2004, which gave him an irresistible offer. "I was made Managing Director and given the freedom to pursue many different facets of financial theory and investment practice."[43]

With his broadened perspective, Leibowitz's research turned to issues beyond bonds. One major area of interest was asset allocation, or the mix of assets within a portfolio. Typically, pension funds and endowments tended to allocate 60 percent of their assets into equities and 40 percent into bonds, though some funds had been starting to diversify into "nontraditional" asset classes. Leibowitz joined forces with his Morgan Stanley colleague, Anthony Bova, on an article that would turn the traditional asset allocation problem on its head.[44]

Their unique approach was to reimagine the notion of beta. Before Leibowitz and Bova, beta had been used primarily in the context of equity, the risk of an individual stock relative to the overall stock market or a benchmark such as the S&P 500 index. Instead, they estimated betas for a wide variety of *asset classes* relative to U.S. equities: bonds, non-U.S. equity in international and emerging markets, nonpublic equity such as venture capital and private equity, commodities, real estate (both private and real estate investment trusts), absolute return (hedge funds), and cash and money market funds. Commodities had a negative beta, which was excellent for diversification purposes: when U.S. equities were going up, commodities tended to go down and vice versa. Not surprisingly, cash had a zero beta. All the other asset classes were treated as having positive betas, ranging from 0.07 for real estate to 0.96 for private equity.

Leibowitz and Bova then examined the overall *portfolio* beta for typical and atypical pension and endowment funds. The traditional 60/40 allocation resulted in a total beta of around 0.6, regardless of whether the 40 percent allocation was in U.S. bonds or cash. It was surprising, however, that seemingly very different portfolios had similar total beta values. For example, an effective beta sensitivity of 0.55–0.60 characterized even a highly diversified portfolio that was composed of 20 percent U.S. equity, 20 percent U.S. bonds, 15 percent international equity, 5 percent emerging market equity, and 10 percent each in absolute return, venture capital, private equity, and real estate. With another measure of risk, the standard deviation (which measures the overall volatility of a portfolio's returns), this diversified portfolio's volatility ranged between 10 percent and 11 percent, close to the volatility of the traditional 60/40 allocation. As Leibowitz noted, "Most institutional portfolios . . . have a beta of 0.6. . . . Some research we did at TIAA-CREF led me to find that most variants of real-world allocations consistently had equity betas near 0.6. We found that implicit equity risk dominates diversified portfolios, even in normal times, and that they basically have the beta sensitivity of a 60/40 portfolio, no matter their composition, which was astonishing to me and to a lot of investment professionals. It's not the dominance of equity risk that is so surprising, it's the fact that so many institutional portfolios—endowment, sovereign wealth, foundation, and pre-LDI [liability-driven investment] pension plan—all map into this basic 60/40 portfolio risk profile."[45]

Leibowitz further reflected, "We wrote a paper called 'Convergence of Risks,' where we looked at three types of risks that people would want to avoid: a within-one-year loss, an over-three-year decline below initial value, and a drawdown risk. And we assigned various probabilities and just took standard numbers and simple normal distributions. And it turned out that a lot of these different types of risks converged to being within shortfall bounds for 60/40 portfolios."[46]

Another surprising finding was that most of the total volatility of the portfolios—around 90 percent—could be explained simply by the total beta. Leibowitz commented on this finding: "Regardless of how diversified a fund is, just about every fund is dominated by equity volatility, with about 90 percent of the short-term risks related to equity movements. This is true for even the most diversified funds. A diversified fund has the same sensitivity to equity movements as a traditional 60/40 fund consisting of just fixed income and equity. Diversification does not help you reduce short-term volatility. When you have a very bad market like we did in 2008, in addition to the illiquidity problem, the correlation between these multiple asset portfolios can get worse. Ironically, in a very bad market, the degeneration in a diversified fund can be even worse than in a traditional 60/40 fund. On the other hand, diversified funds have had a much better return over a long period of time. And, for a fund that can afford to be truly long term, incremental return is the best defense against risk. But that means you have to be able to survive those downward spikes. That brings us back to the liquidity issues—you need to have sufficient liquidity to survive the bumps."[47]

Alpha Hunters and Beta Grazers

Leibowitz then tackled another issue at the heart of investing: the pursuit of superior risk-adjusted returns, the so-called alpha—or, as he describes it, "the holy grail of active investment."[48] If you recall, alpha (a term coined by Eugene Fama's student, Michael Jensen) refers to the excess return earned by an investor above and beyond the expected return predicted by its beta exposure in the capital asset pricing model (CAPM)—a holy grail indeed.

To celebrate the sixtieth anniversary of *Financial Analysts Journal,* a number of luminaries including Leibowitz were asked to contribute articles reflecting on the current state of investment theory and practice.[49] However, there was a catch: they were instructed to produce a readable paper without any numbers, tables, or equations, not an easy task for a mathematician such as Leibowitz. Nevertheless, he submitted a paper that observed these stringent guidelines but appeared next to one by Markowitz, which Leibowitz lamented was "a terrific, thought-provoking, deep study—but with lots of diagrams, numbers, and equations!"[50]

Leibowitz's paper was catchily titled "Alpha Hunters and Beta Grazers,"[51] a title for which he has received more compliments than anything else he has written. Leibowitz characterized beta grazers as investors who strongly believe in market efficiency and take passive positions such as investing in index funds. He later commented, "Beta grazing is a sort of passive approach to structuring a portfolio, accepting its main risks, which essentially were equity-type risks, and having an asset allocation which would be, to a large extent, maintained over time."[52]

Alpha hunters, on the other hand, are active investors in search of excess returns. Leibowitz made an important distinction between two broad types of alphas. The first, "allocation alphas," are broadly available to anyone moving their portfolio to a more balanced risk-return structure from, for example, a portfolio dominated by domestic equity to one with more global equity exposure. These alphas "are akin to the civilized sort of protein-seeking found by shopping at the local supermarket, with the selections determined by personal taste and dietary restrictions,"[53] in other words, a somewhat more sophisticated form of grazing.

In contrast, "truly active alphas" are much harder to exploit. They are captured by, as Leibowitz put it, "tracking down—and bagging—the fleeting and elusive opportunities that arise from market inefficiencies."[54] Some of these inefficiencies include investor reliance on past performance as an indication of future performance, herding behavior, stubbornness of investor views, price target revisions, inefficient rebalancing procedures, clustering in portfolio volatilities, and the home-market bias. He noted that many of these biases may create short-lived opportunities, possibly explaining why investors such as Warren Buffett and David Swensen (known for his stellar management of Yale's endowment fund) were able to consistently produce alpha and simultaneously explaining why there are so few such investors. Alpha hunting "could be viewed as a different kind of lifestyle, a different kind of culture, a different kind of risk taking."[55]

How might investors go about hunting for a different kind of alpha? Leibowitz has encouraged investors to "think outside the benchmark." One method would be to go beyond the constraints of "long-only" investing by considering using leverage and shorting, for example, with a

130/30 portfolio, shorting the equivalent of 30 percent of one's portfolio, with the shorting proceeds reinvested in more equities.[56] Another approach would be to uncover what he describes as a firm's "franchise value," its value-added growth component, and invest in those stocks that have underpriced franchises.[57]

The Endowment Model

Building on these earlier insights, Leibowitz teamed up with Bova and his former colleague at TIAA-CREF, Brett Hammond, to synthesize these ideas about asset allocation and diversification, and created a new framework for endowment funds, one that was also applicable to individual investors. "I always found the individual investors' problems more challenging," he admitted. "For instance, they don't have near-infinite time horizons like many institutional investors say they do, nor various degrees of sponsor backup if things go poorly. So, the first benefit that comes out of this research is a better understanding of how people might approach retirement. They have to, or most should, go toward lower-risk portfolios as they enter retirement. That idea has been around for many years and is widely applied in life-cycle funds. The prevalence of the 60/40 model means, of course, that equity market beta is indeed the dominant source of risk, just like the theory says. It also means that to the extent that you can find ways of generating returns which are uncorrelated with that portfolio, those are really good returns, those are the ultimate alphas. It was these findings that eventually led to the *Endowment Model of Investing: Return, Risk, and Diversification* book."[58]

This book starts with Markowitz's mean-variance framework as its foundation. Investors want to form diversified portfolios that maximize their expected return for a particular acceptable level of risk. Within this framework, Leibowitz, Bova, and Hammond built on the earlier Leibowitz-Bova model that measured asset class betas relative to U.S. equities. The asset class returns were then decomposed into equity beta and alpha components that provided returns beyond those from the beta level. Since equity risk dominated in the typical endowment and pension fund asset allocations (as described earlier in this chapter), their approach diverged from the typical means of reducing portfolio risk through simple portfolio diversification. Their novel suggestion was to reverse the standard asset allocation process of beginning with basic asset classes such as stocks and bonds, then incrementally adding nonstandard assets such as real estate and commodities. They inverted the process by placing nonstandard asset alpha at the core, subject to a fund's intrinsic constraints on the acceptable sizing of alpha-producing asset classes. Afterward, the traditional stock/bond assets were incorporated as "swing" assets to bring the portfolio to the desired level of beta risk.

What constraints were placed on the nontraditional asset classes? The answer depended on a different way of thinking about risk. Leibowitz reflected, "'Dragon risk' is a term I borrowed from Cliff Asness (with his permission!)—a term used historically to describe unknown parts of the world with maps having borders labeled 'here be dragons.'[59] I thought that this was a great term to define how much of an asset class people are comfortable using in their portfolios. This comfort level is a critical factor in determining asset allocation weights. Why not have 30 percent or 40 percent in real estate? Mean/variance optimization models with standard data input would, if unconstrained, have maybe zero fixed income, lots of real estate, lots of commodities, and lots of emerging market equity. End of story, and yet nobody does it."[60]

Nontraditional asset classes would be constrained according to the maximum amount of an investor's comfort with dragon risk. Leibowitz, Bova, and Hammond concluded that their endowment model wasn't really a technique for reducing short-term volatility but instead was a strategy for accumulating alpha to achieve long-term goals. Its emphasis was on enhancing returns rather than controlling risk. The key was to have a long-term focus and be able to ride out short-term setbacks and liquidity crises, such as those that occurred in 2007–2009.

Leibowitz's Perfect Portfolio

The endowment model dovetails with the notion of a Perfect Portfolio. This approach was developed for institutional investors, as with endowment funds and pension plans, but also can be used for individual investors. Instead of starting with traditional assets such as stocks and bonds, start with the nontraditional assets such as real estate, commodities, hedge funds, and private equity, asset classes that can potentially provide enhanced returns compared with the traditional asset classes. Once you've created the core to your component, you can add stocks and bonds to bring your portfolio to a desired risk level. "First of all, it's important to know how much risk you can take, and I think that's something which is easily said but not really well appreciated," Leibowitz begins. "Many institutional investors view themselves as being very long-term oriented, and yet, if you see how they fared during 2008 or even under more modest downturns, you find that their long-termism can come apart at pressure points. People go from being convinced that they're long-term to being less sure and then eventually getting to the panic point."[61]

What should investors do when markets go sour? "The usual standard answer is 'stay the course,' which is usually the right answer but not always. Aside from the emotional reaction of wanting to de-risk at the wrong time or de-risk in the face of bad times, there is a consideration especially more for individuals, but not just for individuals, where you get to a point where the risk level in the market relative to your ability to tolerate risk may essentially move you to say, 'Don't stay the course,' cut back some, sleep better at nights, or if you're sleeping at nights and you shouldn't be, get yourself to the point where you should be sleeping better at night."[62] Leibowitz's Perfect Portfolio is "definitely not buy and hold. Even though buy and hold may be a good advice for openers, it's not a good advice for ending, or for always getting all the way through the process."[63]

The risk an investor can bear has an impact on the asset types in which they can invest. Leibowitz compares it to the funding ratios in pension funds, the relative amount of investment assets compared to the discounted value of future liabilities. In other words, "How much do you have in terms of assets and assured future income, relative to your needs? And, if you have a high level of this 'generalized funding ratio,' you're in a comfortable position, and you can afford to take risks." In such a case, you could have a greater proportion of your portfolio in riskier assets such as traditional equities or in risky alternatives such as private equity or venture capital funds, if available.[64]

Leibowitz cautions against hard-and-fast rules. "Nothing in investments is absolute. So, having the ability to take more risk doesn't necessarily mean that you *should* take more risk. Suppose the market is riskier or more expensive and the reward-to-risk is well below what should be a reasonable level. It may then be that even though you enjoy a high generalized funding ratio so that you could take more risk, maybe you shouldn't. These are never easy decisions, but I think ones which, if you're an investor, you really have to be prepared to try to make those judgments, not continuously and not for just small things, but when the prospects are sufficiently out of line."[65]

Leibowitz mentioned another situation where, despite an investor's appetite for risk, investing in risky assets may not be appropriate. "Why take risk when you don't have to? Think of a situation where an individual has a modest lifestyle, has no heirs, is not particularly motivated to give to charities. He has things where he wants them. Why should he take more risk? . . . [I]ncremental return will not have a marginal value to him."[66] That investor could simply invest in safer assets.

Leibowitz reflected on individual investing versus institutional investing. "I think advising individuals is much more complex. This is due to the fact that the very specific situations that pertain to individual circumstances are far more complex. They involve other types of ingredients such as life events, contingency events, taxes, estate taxes, and so forth. There are also many more complicating factors, not the least of which is that you're dealing with multiple objectives almost all of the time, and you're dealing with objectives that shift in priority,"[67] for example, with both the asset level and the passage of time.

In terms of asset types for the individual investor, they should have both equities and bonds. Why include fixed income in a portfolio? In addition to reducing volatility and providing a relatively stable return, "fixed income is sometimes viewed as a hedge against disastrous equity markets."[68] It all comes back to the benefits of diversification that Markowitz uncovered. "Diversification, as Harry Markowitz so beautifully pointed out, is the cheapest source of reward." That's because it's not just about reducing risk. "It's also about reducing unintentional, unrewarded artificial risk."[69] In other words, "You don't want to take unintended risks, and to the extent you don't diversify, you are taking unintended, unrewarded risks. So, you want to take the risk level that you want to take; you want to have it be a risk that is basically determined by your chosen beta sensitivity."[70] As Markowitz points out, "Equity is far more volatile than, say, fixed income. So, that's why it is a dominant factor in almost all portfolios." In the extreme, holding only one stock isn't rational, unless you can adhere to Will Rogers's philosophy: "I only buy stocks if they go up. If they don't go up, I don't buy them."[71]

Leibowitz noted an important area in retirement planning that deserves more attention: inflation. "People today can have a reasonable expectation of spending a span of twenty or thirty years in retirement. Over such a long time, even a low level of inflation can be devastating for what might otherwise look like a nominally comfortable retirement. I think that issue is not very well reflected in financial discussions in this country."[72] To put the issue in perspective, with an inflation rate of 3 percent, $50,000 of annual expenses today would grow to over $121,000 in thirty years.

As for the asset allocation mix, target funds are becoming increasingly popular. These funds automatically shift their allocation from riskier equities to less risky bonds as an investor gets older. Leibowitz believes that "target date funds can be helpful for some investors, although I have concerns about the inherent rigidity in their typical rebalancing protocols."[73]

Leibowitz has a few parting comments about the pursuit of the Perfect Portfolio: it all comes back to two fundamental notions. "First, know what risk level you can really tolerate. Second, try to set up potential contingency plans in advance for foreseeable risks so that you have a course of action if these risks should actually eventuate. Remember that when talking about risk, you're talking about events that might actually happen. To the extent that you are prepared to deal with such adverse events, the associated financial distress can be mitigated, at least somewhat. One of the things we found from 2008 is that investors often exhibited dysfunctional responses to crisis situations. Many investors just became paralyzed and did not take any corrective action. Some rebalanced mechanically, often getting back into the market too early. Others actually sold their equities only because they found themselves in massive liquidity squeezes, some of which were predictable. So, as investors, you should have a plan for liquidity needs in the face of deep trouble. And you should have some plan, in advance, for how you're going to rebalance and move forward."[74] To create a Perfect Portfolio, you need to start with a plan.

9

Robert Shiller and Irrational Exuberance

ROBERT (BOB) SHILLER's most famous work was a challenge to the conventional wisdom that financial markets are efficient. Although the Nobel Prize committee would later call it the centerpiece of his work, many in the academic profession originally greeted it with harsh criticism. It wasn't easy for him to endure the attacks on his work. At the time, he had commented to a colleague, "I wish I had never written [the] paper."[1] Yet Shiller's sometimes controversial musings will give us insight into his ever-changing Perfect Portfolio.

Shiller is different. Most professionally successful economists often make their mark in a particular narrow area of research, using traditional techniques and building on the existing literature that's generally accepted in the profession, yet Shiller describes his research interests as both eclectic and eccentric. He is that relatively rare economist willing to violate professional norms, borrow ideas from other disciplines, and collect raw data through surveys—often dismissed in economics as "lowbrow" research—simply because something interests him. He also differs from most economists by devoting his time to journalism, writing extensively for publications such as *The Wall Street Journal* and *The New York Times*, while writing books for the masses instead of the academic elite. But it was his formative experiences in early life that were to contribute most to his later success.

The Origin of an Eclectic Economist

Shiller identifies himself as a Lithuanian American, as all four of his grandparents emigrated from Lithuania to America in the early 1900s.[2] He refers to them as "people with independent spirit, who invest in a new culture."[3] He also claims to be a product of the auto industry. "In 1914, Henry Ford announced he was paying $5 a day for assembly-line workers, which was twice the going rate. . . . [He] got a deluge of applications. So, one of my grandparents was living in Gardner, Massachusetts, working in a stove shop, and my other grandfather was a tailor, operating in Chicago. And they both responded and came to the same River Rouge plant, and both took jobs. If they hadn't converged in Detroit, my parents would never have met, and I would not exist."[4]

Shiller received a low grade in "citizenship" in elementary school because of his restlessness and uncontrollable talkativeness, and there were worries that he might fail the second grade. Even today, he is still easily distracted by reading material and will become very focused on something that catches his attention. His early talkativeness, however, has transformed into his current interest in giving interviews to reporters. An elementary school science teacher encouraged an admiration for science and "true" scientists—as opposed to social scientists such as economists—and he has an interest in details typically only reserved for specialists.

Shiller was inspired by Albert Einstein's 1930 *New York Times Magazine* article "Religion and Science." For Einstein, "cosmic religious feeling" was one of a number of impulses through which religious belief developed, belonging to everyone but knowing no dogma and "the strongest and noblest motive for scientific research." Einstein felt that a life devoted to understanding because of this cosmic religious feeling gives a person strength and that true scientists of all kinds are the ones who are religious people. For Shiller, "In some sense science became a sort of religion to me."[5]

Shiller's father was an entrepreneur who invented and patented a particular type of industrial oven, but he had difficulty establishing the business when he developed health issues. Shiller later reflected that the economics profession paid too little attention to invention. "There should be more articles offering trial-balloon ideas about how economic institutions and methods could be set on a completely different framework, even if the ideas are not fully developed."[6]

Shiller's interest in economics was piqued when he was eleven years old, after reading *The Affluent Society* by John Kenneth Galbraith.[7] That interest was strengthened in 1960 when, as a high school student at Southfield High School near Detroit, he borrowed and read his older brother John's college textbook on vacation, *Economics*, by Paul Samuelson. (Samuelson himself would be awarded the Nobel Prize in Economics in 1970 for his almost uncountable contributions to the field.)

Upon graduating from high school, Shiller won a National Science Foundation scholarship that would partially offset the cost of attending a top college, but the family was unable to afford its share.[8] In 1963, he chose to go to nearby Kalamazoo College, where he spent one year before transferring to the larger University of Michigan, where his brother attended. "My experience at K [Kalamazoo College] was great and helped set me on my path. I remember that it was my admiration of Bruce Timmons, an economics major at K, that got me into economics. It wasn't so much my experience taking economics at K, I only got a B+ in intro econ, as I recall, which I thought, momentarily, might mean that I just did not have talent in economics."[9]

There was a foreign-language requirement at the University of Michigan, and Shiller's was Russian. While other classmates went abroad in their junior year, however, he had nowhere to go. "I thought joining a big college newspaper staff [the *Michigan Daily*] would be great fun. More fun than staying behind when my whole class went abroad. So that is what I did."[10]

At the University of Michigan, Shiller started writing for the university newspaper, where he enjoyed the fact-finding aspect of reporting. He was inspired by two professors: Kenneth Boulding in the economics department, who promoted the idea of general systems that interconnected the sciences, and George Katona in the psychology department, who impressed upon Shiller the importance of psychology for economists, which eventually led him to the area of behavioral economics.

Shiller struggled with a choice of graduate programs and seriously considered both physics and medicine. While medicine in particular was an attraction, he simply could not see himself in the typical role of a doctor with a structured day of appointments, and as a result, partly by chance, he chose economics. "When I was young I thought everything sounded interesting, and I thought it was of great tragedy that I had to narrow down to one thing. Economics."[11]

Rational Beginnings

After completing his undergraduate degree in 1967, Shiller went directly to the PhD program at the Massachusetts Institute of Technology (MIT). One of his fellow students was lifelong friend Jeremy Siegel (featured in chapter 11), who went on to become a distinguished professor at the Wharton School and is now best known for his book *Stocks for the Long Run*. At MIT, Shiller connected with Samuelson in person and, after reading his textbook, considered it an honor to have Samuelson as a teacher and admired his approach to economics as a mathematical science.

Shiller's dissertation adviser was Franco Modigliani, who would receive the Nobel Prize in Economics in 1985. Modigliani's combination of economic theory with real-world application made him an attractive choice. At the time, Modigliani was working with Albert Ando at the University of Pennsylvania to create a large-scale macroeconometric model of the U.S. economy, known as the MIT-Penn-SSRC model. The model used large amounts of historical economic data to forecast economic activity. Shiller later stated that he did not embrace this particular branch of Modigliani's work, and skepticism of such models would lead him to question their underlying "rational expectations" assumptions. "I didn't really believe these models. They're always wrong. But I wanted to get at the insights from it, and I was thinking about that and thinking about how to quantify things."[12]

Shiller's initial graduate work had rational expectations as its linchpin. The theory of rational expectations suggests that individuals make rational decisions based on the available information. On average, the future state of the economy should be reflected in its current expectations. In other words, while rational expectations of what will happen in the economy may not always be accurate—for example, its expectations of interest rates a year from now—on average they are. Interestingly enough, in terms of his debates to come with Eugene Fama, rational expectations and market efficiency are essentially the same idea, although there are slight differences. Rational expectations are a consistency condition that expectations *in* the model should be expectations *of* the model, while market efficiency is closer to a descriptive statement about the world.

Shiller's completed dissertation in 1972 was titled "Rational Expectations and the Structure of Interest Rates."[13] Samuelson was a member of his dissertation committee, along with Robert Merton. Shiller's 182-page dissertation developed a model of the term structure of interest rates, or the yield curve, a series of rates at which businesses or the government can borrow money, depending on the maturity rate of the debt that was issued. His model was based on expectations of future interest rates. He found that the model, tested using corporate bond yields, worked quite well. By the time his dissertation was complete, Shiller had three publications in print or forthcoming, including one study for the Federal Reserve, one at the prestigious economics journal *Econometrica*, and a joint publication with Modigliani.

Shiller's first academic job was in 1972 as an assistant professor in economics at the University of Minnesota. His close colleagues were Thomas Sargent and Christopher Sims, both of whom would be awarded the Nobel in Economics in 2011. Sargent helped hire Shiller, later reflecting, "I thought he was wonderful, and he had some really important ideas, even in those days."[14] Sargent and Sims, together with 2004 Nobel laureate Edward Prescott and Neil Wallace, were known in the economics department as the Four Horsemen due to their innovative work in macroeconomics. Sargent and Sims won their Nobel Prize for their empirical work on cause and effect in the macroeconomy, which relied on rational expectations models. According to Shiller, "I gave up my faith in strict rational expectations models more definitively than they did, or sooner."[15]

In 1974, Shiller joined the department of economics at the University of Pennsylvania as an associate professor. Into the following year, he was also a visiting scholar at MIT and a research fellow at the National Bureau of Economic Research in Cambridge, Massachusetts. While at an MIT folk dance party, he met his wife-to-be, Ginny Faulstich. They married in 1976 and lived in Newark, Delaware, as Faulstich completed her PhD in clinical psychology at the University of Delaware. Faulstich regularly brought home psychology books and articles, while Shiller continued his habit of reading materials he found interesting. He was also exposed to the field through interactions with psychology faculty members and graduate students at parties that he and Faulstich attended. It wasn't until 2011, however, that husband and wife collaborated as coauthors on an article that called for economists to take a broader view and incorporate thinking from other disciplines.[16]

After eight years at the University of Pennsylvania, the last year of which included a cross-appointment at the Wharton School, in 1982, Shiller took a position as a professor of economics at Yale University, where he has remained ever since. His position at Yale overlapped for twenty years with that of James Tobin, the winner of the Nobel Prize in Economics in 1981 and an inspiration to Shiller, sharing his respect for what he refers to as "fact-oriented economic science."

Shiller's research is all about the data. As he puts it, empirical research and examining data is "considered something for lower-class economists to do—the real leaders are the theorists—but I like it."[17] For example, within days of the largest one-day stock market crash in the United States on October 19, 1987, he sent a questionnaire to individual and institutional investors about their economic attitudes and opinions. His former PhD student and longtime collaborator Harvard professor John Campbell recollected, "What is striking about Bob is that he will consider any idea, and he takes a richer view of that thought and human nature by collecting data. When the crash of '87 hit, he immediately surveyed people to get inside their heads. That informed his work on behavioral finance."[18]

According to Shiller, "Groupthink happens even in academia. But I think that's actually something about my personality. I always think the opposite of people around me. My wife complains about that. She said, 'You always have to take the other side.'"[19] It's no surprise that his biggest pet peeve is conventional thinking.[20]

Shiller's unconventional nature spills over to his view of life. "I've always been interested in people. When I go to sports events, which is rarely, I find myself watching the crowd rather than the game. I don't care who wins this. There's something missing in my motivational structure, but I'm just fascinated by people. . . . The crowd is so much more interesting. Why do they care? You can see their body language when someone's making a difficult move and they almost feel that they're doing it. It's empathy."[21] He further elaborated, "Here's one of my observations about people: they run in herds. People do the same. And in the short run that might even be the optimal strategy. If you're a young person trying to get ahead . . . you have to get immersed in what other people are doing. But I also think that people miss things."[22] The actions of individuals can be aggregated, and that aggregate can manifest in the motion of stock markets.

Excess Volatility

Shiller's most famous research article was published in 1981, with the inquisitive title "Do Stock Prices Move Too Much to Be Justified by Subsequent Changes in Dividends?"[23] It was controversial because it went against the prevailing wisdom that U.S. stock markets were efficient—that is, the notion that prices were determined by rational investors and fairly reflected underlying values. He used a simple model of the value of stock prices. The dividend discount model suggests that in an efficient market, the current price of a stock should equal the present value of all expected future dividends, assuming for the sake of simplicity that the investor has no intention of selling the stock. (The present value is sometimes called the discounted value, since the present value of an item is discounted from its value in the future.)

For example, suppose you were interested in buying a stock that pays $1 per share in dividends annually, and you expect the company to continue paying that amount each year forever. Further suppose that given the riskiness of the stock, you felt that a 10 percent expected return was reasonable. How much should the stock be worth? Since you're essentially buying a perpetuity, you can simply divide the annual dividend by the rate of return, giving a fair price for the stock of $10. (If you expect the dividend to grow at a constant rate, then you can apply a slightly modified formula for a growing perpetuity.) This same model can be applied to the market as a whole.

To understand the intuition behind Shiller's paper, consider the following sports analogy.[24] Suppose you're trying to predict the result of a basketball game. You predict that the Miami Heat will consistently beat the San Antonio Spurs by 10 points. Yet the results of actual games will show much more volatility: sometimes Miami will have huge wins and sometimes it will have nail-biters, while other times San Antonio might win. In this analogy, the actual basketball scores are the dividends that investors actually receive and should be quite variable, and the predicted scores are the stock prices which the market predicts and shouldn't have much variability.

Surprisingly, Shiller found that exactly the opposite was true in the stock market. Stock prices—the predictions of the market about future dividends—show considerable volatility, while the dividends—the actual results—didn't vary much, exactly the opposite of predictions versus actual scores in basketball. Another way to think about his results is that if stock prices reflected the steady increase in dividends, we would see a straight-line relationship of this exponential growth through time, but instead we see wild fluctuations around a trend line. Shiller's conclusion: the rational expectations model was wrong. Clearly, the level of stock market volatility couldn't be explained by the efficient markets model in which stock prices reflect today's value of expected dividends.

Shiller tested this idea by examining U.S. stock market data back to the 1870s. He assumed that investors had perfect foresight about the value of future dividends, then graphed those perfectly predicted prices (adjusted for inflation and a growth trendline) and compared them with the actual stock prices (figure 9.1). As he wrote about his discovery, "The striking fact is . . . the present value of dividends looks pretty much like a steady exponential growth line, while the stock market oscillates a

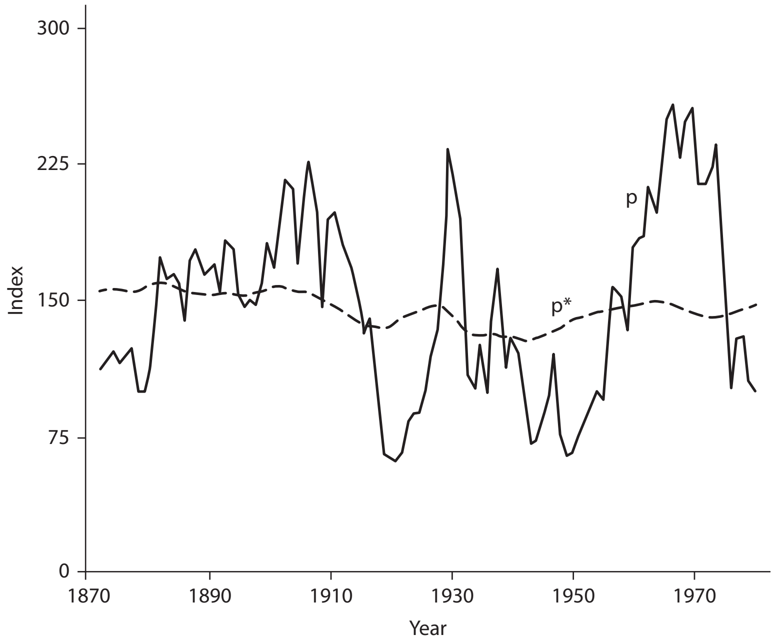

FIGURE 9.1: S&P index adjusted for inflation (solid line p) and ex post rational price (dotted line p*), 1871–1979, detrended by a long-run growth factor. This chart is reprinted from Robert Shiller, 1981, "Do Stock Prices Move Too Much to Be Justified by Subsequent Changes in Dividends?," *American Economic Review* 71: 422.

great deal around it. . . . [I]f, as efficient market theory asserts, the actual price is the optimal forecast as of any date of the present value as of that date, why is the stock market so volatile?"[25]

We can see in his graph the dramatic decline in the stock market between 1929 and 1932, yet this decline cannot easily be rationalized by subsequent dividends. Shiller performed tests using a number of statistical techniques, including "variance bounds" tests,[26] finding that stock price volatility was between five and thirteen times too high to be attributable to new information about future dividends. He concluded, "The failure of the efficient markets model is thus so dramatic that it would seem impossible to attribute the failure to such things as data errors, price index problems, or changes in tax laws."[27]

Interestingly enough, a paper by Stephen LeRoy and Richard Porter on this topic was published in the prestigious journal *Econometrica* in

May 1981, beating Shiller's publication by one month.[28] LeRoy and Porter are referred to in Shiller's 1981 article, where he notes that they "independently derived some restrictions on security price volatility implied by the efficient markets model and concluded that common stock prices are too volatile to accord with the model." Why didn't LeRoy and Porter get more attention? It may be, in part, because Shiller included a very compelling graph of this phenomenon in his paper (shown in figure 9.1) and a more attractive interpretation compared to LeRoy and Porter.

More than twenty years later, Shiller restated his main conclusion: "There is a clear sense that the level of volatility of the overall stock market cannot be well explained with any variant of the efficient markets model in which stock prices are formed by looking at the present discounted value of future returns."[29] In other words, the rational expectations model was wrong.

John Cochrane, author of the famous *Asset Pricing* text (a must-read for any researcher or student in the area of asset pricing) and financial economist at the University of Chicago, and, incidentally, Eugene Fama's son-in-law, recently explained the reaction around the presentation and publication of Shiller's paper. "This was a bombshell. It said to those of us watching at the time (I was just starting graduate school) that you Chicago guys are missing the boat. Sure, you can't forecast stock returns. But look at the wild fluctuations in prices! That can't possibly be efficient. It looks like a whole new category of test, an elephant in the room that the Fama crew somehow overlooked running little regressions. It looks like prices are incorporating information—and then a whole lot more! Shiller interpreted it as psychological and social dynamics, waves of optimism and pessimism."[30] For investors, Shiller's result implied that the buy-and-hold market portfolio strategy based on the work of Markowitz, Sharpe, Fama, and others wasn't necessarily optimal, as there might be times when the overall market was overvalued or undervalued. A fifteen-year investigation ensued, with a generation of scholars trying to explain the results, including Cochrane himself. Cochrane went on to comment, "You get famous in economics for inducing lots of people to follow you, and Shiller . . . is justly famous here by that measure."

According to Cochrane, the profession has now come to accept that the main reason stock prices are so volatile relative to dividends is because investors vary their expected returns, unlike the simple models that suggest investors have constant expectations. What is still up for debate, particularly between Shiller and Fama, is the nature of those time-varying expected returns. "To Fama, it is a business cycle–related risk premium. He (with Ken French again) notices that low prices and high expected returns come in bad macroeconomic times and vice versa. . . . To Shiller, no. The variation in risk premiums is too big, according to him, to be explained by variation in risk premiums across the business cycle. He sees irrational optimism and pessimism in [investors's] heads." The notion of "irrational optimism" (or exuberance) would play a major part in forever tying Shiller to the Federal Reserve's most famous chairman, Alan Greenspan.

The Whisper That Moved the Markets

Greenspan was sworn in as chairman of the Federal Reserve by Vice President George H. W. Bush on August 11, 1987, during a ceremony at the White House as President Ronald Reagan watched. Greenspan had big shoes to fill, both literally and figuratively, taking the reins of the Fed from the six-foot, seven-inch, Paul Volcker, who was known for his successful inflation-fighting record. Within weeks, Greenspan made his mark by raising the discount rate for the first time since 1984.

Greenspan would soon face a major crisis in October of that year. The Dow Jones Industrial Average had reached a new record high of 2,722 on August 25, 1987, two weeks after Greenspan's swearing-in ceremony. However, by Thursday, October 15, the Dow closed below 2,400, and then on Friday, October 16, it fell by over 100 points, to 2,246.74. Over the weekend, investors—and Greenspan—were waiting nervously to see what would happen next.

On Monday, October 19, now known as Black Monday, Greenspan decided to fulfill his previous obligation to speak to the American Bankers Association meeting in Dallas.[31] Before boarding his four-hour flight from Washington, D.C. (in the days when passengers had no communication with the outside world when flying), the Dow was already down a staggering 200 points, or over 8 percent. When he arrived, he asked the official greeting him, "How did the market close?" The reply was "Down five-oh-eight." He was momentarily relieved, thinking the market had rallied and ended the day down just 5.08 points. But he had the decimal points misplaced: the market had dropped 508 points, or almost 22 percent, the worst one-day loss in history.

Greenspan faced the crisis head-on. Having learned from the mistakes of the Great Depression, he took immediate steps to loosen credit. Markets in the United States fully recovered, and by 1990 the Dow had set a new record. By the middle of 1996, the Dow had doubled from its 1987 record high, thanks in particular to the advance of technology stocks.

On December 2, 1996, Shiller was part of a group having lunch with Greenspan in the Federal Reserve dining room in the Eccles Building in Washington, D.C., including his former student and coauthor, Campbell, and Goldman Sachs strategist Abby Joseph Cohen.[32] Cohen began her career as an economist at the Federal Reserve in Washington before moving to Wall Street to work as a vice president of investment strategy at Drexel Burnham Lambert, known for its dominance in the junk bond market before its downfall in 1990. She joined Goldman Sachs in 1990 and then in 1996 was named a managing director. Cohen was well known for predicting the 1990s bull run and was particularly keen on tech stocks. In addition, several Federal Reserve board members were at the lunch.

Over this elegant lunch, Shiller asked Greenspan when was the last time a Fed chairman warned the public that stock market prices were inflated. Shiller and Campbell argued that the stock market had risen to irrational levels. "John Campbell and I decided to describe what was going on as a bubble. . . . We told them, 'Hey, this isn't rational. This is psychology.'"[33] Greenspan listened but didn't offer his opinion. Three days later, however, he gave a dinner speech to the American Enterprise Institute for Public Policy Research in Washington, D.C., titled "The Challenge of Central Banking in a Democratic Society," highlighting the role of the central bank as the guardian of the purchasing power of money. He alluded to the impact that inflation might have on the level and distribution of wealth in society and provided some historical context for the creation of the Federal Reserve in 1913 following the Panic of 1907, the three-week financial crisis that saw stock prices fall almost 50 percent. He reviewed key economic events that followed the Great Depression and emphasized the Fed's mission of developing monetary policy.

Greenspan continued in his speech, stressing how sustained low inflation leads to less uncertainty and hence to investors demanding lower-risk premiums for owning stocks relative to government bonds. These lower-risk premiums in turn lead to justifiably higher price-earnings (P/E) ratios—for example, instead of paying 15 times Microsoft's expected earnings we might be willing to pay 16 times for the stock. There he paused and, perhaps unwittingly, dropped a bombshell on the market: "But how do we know when *irrational exuberance* has unduly escalated asset values, which then become subject to unexpected and prolonged contractions as they have in Japan over the past decade?"[34] Greenspan warned of complacency about rising stock prices and the interaction of the stock market with the real economy, concluding that monetary policy needed to take into account asset prices and that the Fed needed to adapt to changing circumstances in both financial markets and the economy. It was a rare display of a Fed chair questioning whether the stock market was overvalued and susceptible to a major decline.

The next morning, while driving his son to school in the family Volvo, Shiller heard on the radio that stock markets were plunging because Greenspan had questioned whether "irrational exuberance" was affecting markets. The Tokyo market, which was open for trading during Greenspan's televised speech on C-SPAN, fell sharply and closed down 3 percent for the day, as did the Hong Kong market. Later Frankfurt and London fell 4 percent, and the next morning the U.S. market fell 2 percent at the open of trade.[35] Shiller told his wife Ginny, "I may have just started a worldwide stock market crash."[36] She accused him of delusions of grandeur. But the incident was a rare high-profile questioning of market rationality and an indication of the mainstream acceptance of Shiller's work.

Who originated that memorable phrase "irrational exuberance"? Shiller doesn't remember using the phrase in his conversation with Greenspan. Shiller's friend Jeremy Siegel happened to find a 1959 *Fortune* magazine quotation in which Greenspan refers to the "over-exuberance" in the financial community, and it's most likely that Greenspan came up with the phrase on his own.[37] According to Greenspan, "The concept of irrational exuberance came to me in the bathtub one morning as I was writing a speech."[38] Whoever coined the phrase, the "irrational exuberance" speech was, for Greenspan, the perfect opportunity to speak up about the value of assets. Price stability was relevant not only for product prices such as clothing and food but also financial assets—not only for actual eggs but also for nest eggs. The price of income-earning equities and real estate mattered, and if those asset prices were inflated or unstable, then it was a matter of significant concern for the economy.

After the speech, Greenspan wondered what part of it might make news. By the next morning, he knew. The headline at *The Wall Street Journal* screamed "Fed Chairman Pops the Big Question: Is the Market Too High?," while the *Philadelphia Inquirer* claimed "Irrational Exuberance Denounced." As Greenspan ironically noted, "'Irrational Exuberance' was on its way to becoming a catchphrase of the boom."[39]

When asked more recently whether Fed chairs should ever express opinions about equity markets, Shiller commented, "I think there is a moral imperative for Fed leadership to express some opinion about the market. They have a staff of experts—a whole research army—to study these issues, and people look to the Fed as an authority. Believers in efficient markets would say that we shouldn't care about these opinions. . . . But I disagree. I think that the market is not smart about these sorts of things and that we do need leadership from people who study these questions. . . . One reason why the boom in the 1990s went on as long as it did is that Fed Chairman Alan Greenspan made very little of worries about the market."[40] When asked whether Greenspan deserves credit (or blame) for his policies and comments, Shiller observed, "I guess as a Fed chairman, you do have to have a little bit of a bias toward optimism. Because if you say anything vaguely pessimistic, it gets you in trouble. In fact the reason why the term [irrational exuberance] is famous is because when he uttered those words, the stock market crashed almost immediately. So that was the news story at the time. He just utters the words irrational exuberance, and that just causes a cascade."[41]

Bubbles versus "Bubbles" (or Shiller versus Fama)

How do markets develop frothiness? How are they brought cascading back to earth? And how often does this happen? The late economic historian and professor of international economics at MIT, Charles Kindleberger, wrote the definitive narrative on these questions, the 1978 classic *Manias, Panics, and Crashes: A History of Financial Crises*, followed by numerous updated editions.[42] In his last edition, Kindleberger chronicled thirty-eight major financial crises between 1618 and 1998. To describe the cause of these crises, he built upon a model developed by Hyman Minsky, an economics professor at Washington University in St. Louis.

According to Minsky, a financial crisis starts with some kind of exogenous shock or displacement to the macroeconomic system, such as a war, a major crop failure, or a new invention with pervasive effects. Opportunities for profits develop in some areas and close down in others. A boom gets under way, fed by bank credit expansion as investors borrow increasing amounts of money to take advantage of the new opportunity. Speculation and increased demand press against the existing capacity, leading to price increases, which gives rise to further opportunities. Profits are often overestimated during a stage of euphoria. Overtrading occurs, as investors use increasingly large amounts of leverage on their positions. Other investors adopt a "monkey see, monkey do" attitude, and prices rise further, leading to manias or bubbles. At some stage, a few insiders take their profits and sell out. Prices begin to level off. Financial distress emerges, as there is an increasing awareness that a rush for liquidity might occur. As the distress persists, there is also an increased awareness that prices will not continue to rise, and the race to the exits becomes a stampede. Prices decline, and bankruptcies ensue.

Liquidation may result in a panic, and the panic feeds on itself until prices are so low that investors are once again tempted back or until trade is cut off, such as with the closing of exchanges and trading floors, or until a lender of last resort such as the central bank convinces the market that sufficient liquidity is available.

Kindleberger notes that manias are associated with irrationality, while the term "bubble" is used to foreshadow bursting, and that some economists refer to a bubble as some kind of deviation from "fundamentals." Kindleberger has his own definition: "A bubble is an upward price movement over an extended range that then implodes."[43] Shiller's definition falls somewhere closer to the former than the latter: "I define a bubble as a social epidemic that involves extravagant expectations for the future."[44] Shiller also views bubbles as involving a feedback mechanism in which increasing prices attract investors who bid up the price even more, with the process continuing until prices are too high.[45] Emotions come into play: some investors will enter the market because they are envious of other investors who have already made money, and they regret not having participated earlier. Bubbles are justified by stories explaining why prices are at such high levels, and people believe the stories because they are confirmed by the increasing prices. But eventually the bubble bursts.[46]

Shiller notes that every bubble has a unique culture. "I named the 1990s bubble the Millennium Bubble, because I think it was affected by the sense of an impending new millennium. It was kind of a futuristic excitement about the birth of the Internet, and thinking that 'wow, it's going to be really something that is coming!' Then, the 2007 bubble was different. I call it the Ownership Society Bubble. That was a smaller one. But the current one, taking form from 2009 to the present [2015], is different. The stories change with each new bubble. I call this the New Normal Bubble. Or boom. Bubble or boom; I don't know with confidence which to call it, because it hasn't burst yet. It's less starry-eyed and it's more fear-driven, so it's a different story. Still, it's a story where people think that there's a good chance that prices will keep going up."[47]

According to Shiller, fear rather than excitement can lead to a bubble in the stock market. Investors worry, and "as a result of all of this anxiety, they want to save more. But given the lack of options to invest in at a high return, they end up bidding up the price of existing assets. That in turn creates disappointment, more concern, and perhaps the feeling that they might be too late because of how much the market has already risen. But they still invest because of their anxieties."[48] Shiller refers to this phenomenon as "the life preserver on the Titanic theory."[49] As he describes the behavior, "When a market is highly priced and when people don't trust the value of it, that becomes a hallmark of a bubble: People are buying it even though they think it's overvalued," noting that was the case in early 2015.[50]

How can you spot a bubble while it's occurring? Shiller relayed his technique from the mid-1990s. "I played a game with my wife when we went out to eat. I said, 'I'm not going to listen to other people's conversation.' But I have an ability to hear the word 'stock market' from adjacent tables. Every time we went out to eat, I would hear 'stock market.' It's uncanny how the spirit of the times changes and suddenly everyone's excited about something. So, I based [determining a bubble] on that kind of observation."[51] Then in the mid-2000s, he noticed indications of a real estate bubble. "I was visiting Phoenix, which was a little bit late to the bubble, but then prices were really soaring. And I mentioned to my cab driver from the airport, 'What's going on in home prices?' Boy did that set him off. He wanted to talk and talk and talk, point out different houses and what they sold for."[52]

During the mid-1990s, when Shiller made public his observation that the U.S. stock market appeared to be in a bubble, the reaction from his colleagues as well as investment industry professionals was strong. "There was enormous skepticism—like, 'You are embarrassing our academic community. We have solid econometric evidence that markets are efficient. What are you talking about?' That's the reaction. It was angry. And it was that there's a conventional wisdom, or received wisdom, on the efficiency of markets. But actually, if you look at the data, people have the impression that there's all this evidence supporting market efficiency, but you look at the [academic] literature—even the literature in 1996—there were lots of anomalies being reported."[53] These anomalies (to use the academic term) refer to empirical indications that markets aren't always efficient. In 1996, these included U.S. equities. For example, actual stock returns often differed from what was expected according to Sharpe's capital asset pricing model (CAPM).

Is a bubble in the eyes of the beholder? Where Shiller sees a bubble, Fama, who coined the term "efficient markets," does not. Many saw ironies in the awarding of the 2013 Nobel Prize in Economics to both Shiller and Fama (along with econometrician Lars Hansen). In the week surrounding the presentation of the award in Sweden, dubbed Nobel Week, Shiller and Fama engaged in many contentious debates. "When I said the word 'bubble,' I could see Eugene Fama squirming. He said he called it 'that nefarious term.' And he said it's never even been properly defined what it even is."[54] Shiller learned more about Fama's style of thought: "You know, the thing that struck me, first of all, I like the guy and I'm very impressed with him. But we don't really disagree much on the facts. It's all down into interpretation. You know he's famous for identifying anomalies! But he likes to come up with the idea that 'How do you know it's not rational?' For example, crazy dictators in history—are they rational? They look crazy to me. But, you know it's an act."[55] Shiller concluded, "There *are* bubbles. There are times of popular excitement. People see prices going up in some market, they get excited. Smart money stays out. And sometimes they short."[56]

A leading critique of the behavioralists' approach to bubbles is that it's storytelling after the fact. Fama once exasperatedly said, "The word 'bubble' drives me nuts."[57] Using the example of what is commonly called the "Internet bubble," Fama reminded his audience that if we went back in time, the Internet was viewed as an invention that would revolutionize business, leading to success for those firms involved with it. He gave the example of Microsoft as a revolutionary firm of a different era and estimated that it would only have taken about 1.4 Microsofts to justify the entire set of all Internet valuations. It's only with hindsight, he claimed, that we can see that not all of the business valuation we expected from the Internet came to fruition. The farthest that Fama would be willing to go about the existence of bubbles was to admit that it might be possible that a bubble existed in a single stock, but not in the market as a whole, or an entire sector.

In his Nobel lecture, Fama observed, "Available research provides no reliable evidence that stock market price declines are ever predictable."[58] While Fama's own research finds that stock returns for market portfolios are predictable using dividend yields and short-term Treasury bill rates, there's no evidence for significant negative expected returns. If bubbles existed, then there *should* be evidence of predictable price declines. Thus, any prescriptions and policies about reacting to bubbles are based on beliefs rather than reliable empirical evidence.

The keyword here is "reliable." Fama emphasizes the notion of *reliability* in empirical evidence. He points to the existence of "ex post selection bias." After a major stock market decline, attention is naturally focused on the few who happen to have predicted such a decline. But to conclude that these forecasters *reliably* predicted the decline, we would need to consider the forecasters' complete track records, including all of their incorrect past predictions, as well as the records of other forecasters we might have relied on instead of them.

Fama presents another argument against bubbles. He examines the five largest U.S. stock market declines since 1925 and considers each of these declines as "bubble"[59] candidates (his quotation marks), because each was preceded by large stock price increases. However, each "bubble" candidate is also associated with a recession. Fama thus concludes that large swings in prices are responses to large swings in real economic activity. Since stock prices reflect investor expectations, this evidence is consistent with what we would see in efficient markets.

Fama observes that "bubble" rhetoric usually involves stock market bubbles bursting as the result of a correction of irrational price increases. But he notes that historical market price declines tend to be followed by rather quick price increases, wiping out most of the preceding decline, if not all of it. For example, despite Shiller's 1996 warning to Alan Greenspan about bubbles that led to Greenspan's famous "irrational exuberance" speech, stock market prices in March 2003, which most people would argue was after the crash of the supposed bubble, were still above those in December 1996.[60]

Besides these verbal sparring matches with Shiller, Fama has also had well-known debates with his Chicago colleague, the behavioral economist Richard Thaler, 2017 winner of the Nobel Prize in Economics whom Fama personally helped to hire. While Fama feels that behavioral economists haven't really established anything in over twenty years of research, Thaler once quipped that Fama "is the only guy on earth who doesn't think there was a bubble in Nasdaq in 2000."[61] Fama recently described their relationship. "Thaler likes to always have these little, I call them, anecdotes about when the markets don't work. I said, 'Okay, but there are thousands of these papers where it seems to work very well.' All event studies. Those are the best, I think, studies of how well markets adjust to new information. . . . I've started to tease [Thaler] and say, 'I'm the most important person in behavioral finance, because without me, they have nobody to pick on.' . . . Twenty years ago I wrote a paper, 'Market Efficiency, Long-Term Returns, and Behavioral Finance,'[62] where I said, 'Look guys, you have to grow up. You can't just be complaining about market efficiency all your life. You have to come up with something that we can test and reject.'"[63] To this day, they haven't.

Fama was once asked to comment on the 1929 and 1987 stock market crashes in order to reconcile alleged herding behavior among investors with the notion of market efficiency. "Economists are arrogant people," he replied. "And because they can't explain something, it becomes irrational. The way I look at it, there were two crashes in the last century. One turned out to be too small, [and the other] too big."[64] In 1987, "People all of a sudden became very risk-averse and then you get a crash. They didn't like the look of the future, but then they changed their minds [and stock prices soon recovered]. In 1929 there was a crash and they didn't like the look of the future, but they were actually too optimistic and there was another crash."[65] His conclusion based on these two events: "One [1929] was an under-reaction; the other [1987] was an overreaction. That's exactly what you'd expect if the market's efficient."[66]

Regarding the concept of market efficiency and the 2007–2009 financial crisis and its associated stock market decline, Fama stated, "I think it did quite well in this episode. Stock prices typically decline prior to and in a state of recession. This was a particularly severe recession. Prices started to decline in advance of when people recognized that it was a recession and then continued to decline. There was nothing unusual about that. That was exactly what you would expect if markets were efficient."[67]

CAPEd Crusader

Shiller's interest in bubbles and the value of assets led to his development with Campbell of a metric known as the cyclically adjusted price-to-earnings (CAPE) ratio. CAPE is a measure of average stock prices divided by the average of ten years of earnings, adjusted for inflation.[68]

The P/E multiple of a stock, that is, the stock price divided by its most recent (annual) earnings per share, has traditionally been used by investors as a measure of valuation. The basic idea is that a stock should be worth several times what a company generated in recent earnings, since investors are entitled to those earnings and expect more in the future. These earnings should translate into a combination of dividend payments for investors and an increasing stock price. P/E multiples for individual stocks can be averaged together to create an overall stock market P/E.

However, Campbell and Shiller were concerned about the volatility of earnings as a firm goes through the good times and bad times of the business cycle. Using traditional P/E multiples to get a sense of market health might incorporate exceptionally high or low P/E ratios from the effects of business cycle fluctuations and resulting short-term earnings fluctuations. The idea behind CAPE is to minimize those short-term effects. By taking an average of earnings over a rolling ten-year period, Campbell and Shiller were able to remove that source of volatility.

Campbell and Shiller's work, using data going back more than a century, found that P/E multiples tend to revert to historical means over time. "In the last century, the CAPE has fluctuated greatly, yet it has consistently reverted to its historical mean—sometimes taking a while to do so. Periods of high valuation have tended to be followed eventually by stock-price declines."[69] Shiller further elaborated on this. "What [happens] when the [P/E] ratio gets high? What changes to bring it back? Is it that earnings go up or the prices go down? We found that, historically, it was that prices go down. So, it was a model of human psychology that just sometimes everything looks great; we're all excited. It's best to stay away from crowds that are overly excited about anything."[70]

On average, since 1881, U.S. stocks have sold for approximately seventeen times their annual earnings over the previous ten years. CAPE is interpreted as a measure of whether markets or individual stocks are expensive or cheap on a historical basis. When CAPE is exceptionally high, stock price declines tend to follow. According to Shiller, "We have found this ratio to be a good predictor of subsequent stock returns, especially over the long run."[71] While CAPE is a good long-term predictor of stock prices, the measure tends to be very imprecise for short-term market timing purposes.

The historical CAPE ratio is presented in figure 9.2, along with long-term government bond yields. In 2014, when the CAPE ratio had reached a multiple of 25.5, Shiller commented that it had only reached that level on three previous occasions in over 130 years, in 1929, 2000, and 2007, each followed by a crash. (In 2018, well after his comments, the CAPE ratio reached a multiple of over 33, even higher than the 2007 peak.) The CAPE ratio reached its all-time low in the United States in 1921, when it fell to under 6.[72] However, this is not meant to be a timing signal. According to Shiller, "The CAPE was never intended to indicate exactly when to buy and to sell. The market could remain at these valuations for years. But we should recognize that we are in an unusual period, and that it's time to ask some serious questions about it."[73]

Making a Market in MacroShares

Shiller's interest in market values and bubbles extends beyond stocks into real estate, once well out of the mainstream for economists, in part, given the lack of good housing price data. Thus, he decided to find the data. "One thing I did is create a home price index back to 1890. Nobody had one,"[74] he recounts.

In 1987, working with Karl Case, an economics professor at Wellesley College,[75] Shiller developed a housing price index. They continued their research together in this area, collecting data on the same property

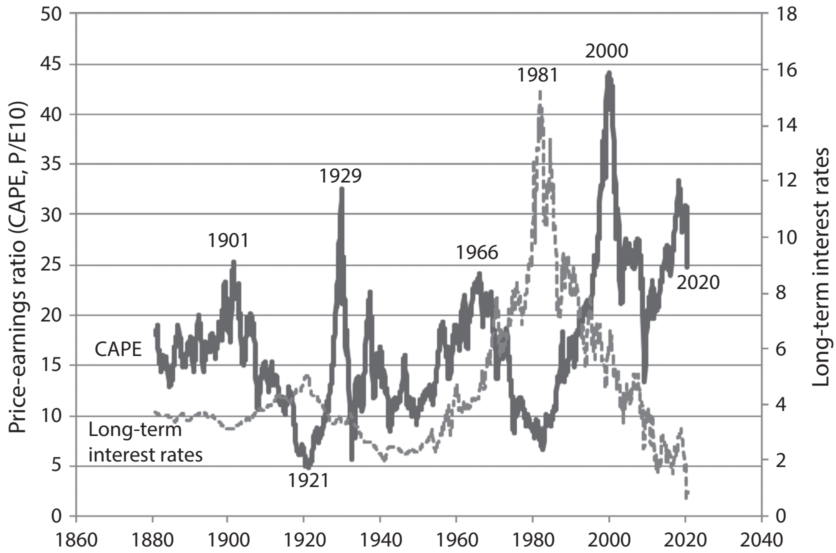

FIGURE 9.2: This chart is reprinted from "Online Data Robert Shiller," Yale University, http://www.econ.yale.edu/~shiller/data.htm.

through time as it was resold. Case "was more connected to the business world than most academics," Shiller recounts. "He also talked to people in the real world, like home appraisers, in order to isolate data for housing prices, which wasn't easy."[76] In 1991, the company Case Shiller Weiss, Inc. (CSW), was launched with former Yale student Allan Weiss in order to commercialize their house price models and produce a variety of home price indices.[77] In 2002, Fiserv, an information management company, bought the firm, later joining with Standard & Poor's to develop tradable indices based on their work. According to Harvard professor of economics Edward Glaeser, "What Case and Shiller put together is really the gold standard for price changes in the housing market. It has the beauty of being both transparent and reliable."[78]

In 2003, Case and Shiller surveyed homebuyers and analyzed house prices in selected U.S. cities in order to highlight the potential dangers of house price declines. "You just look at the picture [U.S. house prices adjusted for inflation, since 1890], and anyone I showed the picture said, 'Wow! Look what's happening right now.' It looked anomalous," he recalled. "Then the question is: what to make of it? Something is unusual. And is it interest rates? Or is it some policy of taxes? Or population growth? So, I worked with Karl Case on this, and we couldn't seem to find anything like that. There's nothing plausible except bubble."[79] Writing for a Brookings Institution publication, they focused on what was happening in individual markets compared to nationwide house prices and concluded that despite what they saw, while a bubble existed in some cities and price declines were to be expected, "a nationwide drop in real housing prices is unlikely, and the drops in different cities are not likely to be synchronous."[80] By 2005, however, Shiller was highlighted in *Barron's* magazine for his forecast that U.S. real estate prices might decline by 50 percent over the next decade adjusting for inflation, or 20–25 percent in nominal terms.[81] His prediction turned out to be spot on.

In 2005, in the second edition of his book, *Irrational Exuberance*, Shiller raised the possibility of a major real estate crisis. Around that time, he met with members of the quasi-government entities Freddie Mac and Fannie Mae. While these companies were government-sponsored enterprises, they were not actually part of the U.S. government. Founded in 1938 with a mandate to expand the secondary mortgage market, Fannie Mae became a public company in 1968.[82] Similarly, Freddie Mac was created by Congress in 1970 to ensure that financial institutions had mortgage money to lend, make houses more easily affordable for consumers, and stabilize the residential mortgage market in times of financial crisis.[83]

Shiller told the representatives of Fannie Mae and Freddie Mac that "they should be hedging their portfolio risks for the possibility of a decline in home prices." But according to Shiller, "We just never really got their attention. We told them they had a portfolio that was heavily exposed to real estate risk and that it would be sensible for them to take hedging positions that would offset that risk, especially given their public G.S.E. [government-sponsored enterprise] status. . . . Actually, what they typically said . . . is, 'Well, there isn't an established market for home-price risk. So, we couldn't hedge the risk.'"[84]

In these meetings, Shiller talked with Frank Nothaft, Freddie Mac's chief economist. "Frank Nothaft claimed that they had considered price

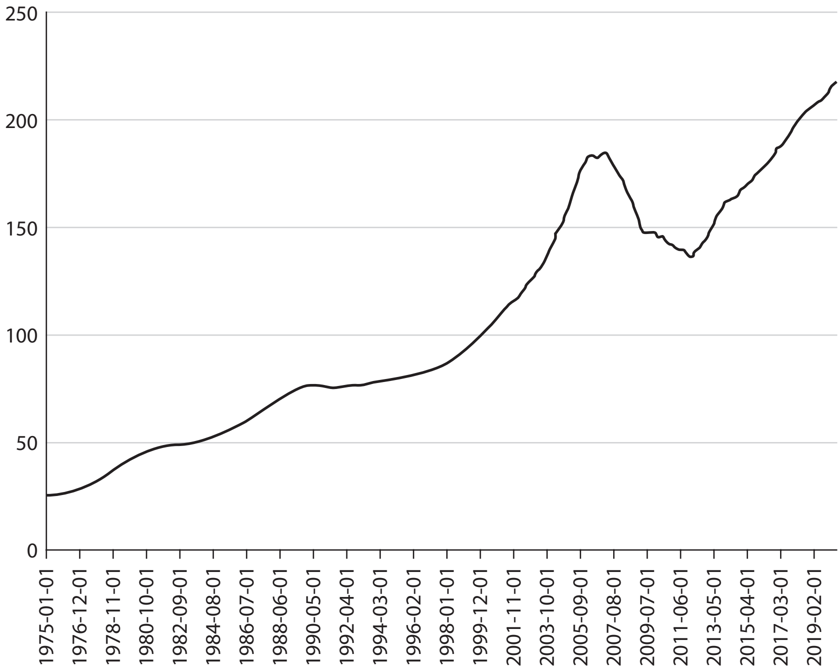

FIGURE 9.3: "S&P Dow Jones Indices LLC, S&P/Case-Shiller U.S. National Home Price Index©" [CSUSHPINSA], Federal Reserve Bank of St. Louis, https://fred.stlouisfed.org/series/CSUSHPINSA.

declines as much as 13.5 percent. And I said, 'What if it is worse than that?' And he said, 'It's never been worse than that.' And then he corrected himself. 'Except for the Depression.'"[85] A few months later, in March 2006, the S&P/Case-Shiller U.S. National Home Price Index, an index of single-family home prices, reached an all-time high of 184.36 (figure 9.3). By February 2012, the index had dropped to a level of 136.53, a decline of almost 26 percent, double the worst-case scenario that Nothaft had contemplated. (By late 2016, the index would hit a new high.)

However, this drop was consistent with Shiller's 2005 speculation in the pages of *Barron's*. He notes that he didn't predict the technology or housing bubble bursts, saying "I only said they were possible."[86]

When their company, CSW, was sold, Shiller and Weiss kept a patent that they had written for MacroShares, a product that paired long and short securities tied to a housing index. MacroShares could act as a hedging vehicle, or a speculation vehicle. A new company was formed to license the indices to Standard & Poor's, and they also worked with the Chicago Mercantile Exchange (CME) to create a futures contract in home prices.[87] Some wondered whether Shiller created MacroShares simply to make money, but not according to Case, who observed that Shiller "cares about making the world a better place."[88]

According to Shiller, MacroShares was about controlling risk. "The value of a house can fall. A hurricane might hit. . . . But we can create hedging markets that will offset these problems. We should be able to hedge everything from the rising costs of health care and education to national income risk and oil prices."[89] Unfortunately, the MacroShares products tied to residential housing prices, MacroShares Major Metro Housing Up and MacroShares Major Metro Housing Down, ceased trading on the New York Stock Exchange due to a low level of assets under management, less than $21 million. However, the CME Group, the world's leading derivatives marketplace, continues to offer futures contracts based on the S&P/Case-Shiller Home Price Index.

Shiller's Perfect Portfolio

What springs to Shiller's mind when he thinks about the Perfect Portfolio? He begins with the early takeaways from modern portfolio theory and quantitative models. "When you say a Perfect Portfolio, it brings me back to some mathematics, the capital asset pricing model. Some people would say that the Perfect Portfolio is the same as the market portfolio because if everybody is doing that, then it is the same. But I think that's where the capital asset pricing model is being overextended. Not everyone is doing that, so you have to make some sense. Not many people are very quantitative about it."[90] For example, in order to create Markowitz's efficient frontier of "the best" risky assets—those with the highest expected return for a given level of risk—you need abundant quantitative information, such as the expected returns and risk, and the expected correlation among assets. Then the mathematics kicks in. "You have to invert a matrix, that sort of thing. And we don't know [how to estimate expected returns, risk, and correlations]—the future is still a little fuzzy."[91]

Despite the daunting prospects of a purely mathematical approach, there are important general investment principles that follow from modern portfolio theory models such as the CAPM. Shiller explains, "It has to be a widely diversified portfolio. I think people are too afraid of investing abroad, generally, or across major asset classes. And also, I would say it has to deal with your own vulnerabilities. If you work in the automotive industry, you shouldn't put a lot in the automotive stocks. You might want to short them; hardly anyone does that."[92]

Shiller was asked what actions investors should take when many asset classes look expensive. "I'm not an investment adviser. But I would say that the main implication for most people is that they should save more because their portfolio probably won't do as well as they imagined. . . . People have learned about the power of compound interest. But what they don't understand is that if interest rates are zero, you don't get any compound interest. . . . As a general principle, I think people should diversify across assets and geographies because there is no way to predict what any one asset will do with accuracy. . . . I would invest something into U.S. stocks; I would just put a heavier contribution in stocks around the world, where CAPE ratios look lower. . . . And I would also own bonds, real estate, and commodities. Commodities are overlooked by many investors, but they are an important part of investing."[93] Commodities tend to have relatively low correlations with stocks.

In 2015 Shiller noted, "Another investment category to consider right now is inflation-indexed bonds. Last time I looked, 30-year TIPS were paying less than one percent. Not very inspiring at all, but at least they are guaranteed by the government and are inflation-proof. But they are not very inspiring, I have to admit."[94]

In terms of equity investments, Shiller has been a market timer. "In 1982, I was a real bull. I had 100 percent of my money in the stock market."[95] In 1998, and again around the financial crisis of 2008, he was virtually all out of equities, with one exception: Kmart stock.[96] "My mother gave me Kmart, so I didn't want to sell it."[97] By early 2015, he had about half of his portfolio in equities. "It's changing all the time. I still have a lot in fixed income, and then housing—I have two houses."[98] But he warns, "If you invest in real estate businesses, that is a sector of the economy that should be part of a diversified portfolio, but in proportion. If you invest in single homes by yourself, then you're buying something that you need to know more about."[99]

However, Shiller thinks that for many individuals, doing it yourself is not the best approach. "We don't really want people to get caught in [bubbles] and have their lives disrupted. So, what I often say is get a financial adviser and get one that good people recommend. They generally are helpful."[100]

The future of investments may look different from the past as new financial instruments and products are developed. "I think also that the Perfect Portfolio would involve some financial innovations. For example, I have been advocating for years now that governments issue GDP [gross domestic product]-linked bonds,"[101] an idea that he has had since the early 1990s. Shiller elaborated, "The simplest GDP-linked bond—my work with Mark Kamstra at York University—is what we call a trill. It's just a share in GDP. A trill is one-trillionth of the country's GDP. So, if the GDP of the U.S. is $18 trillion, then this year you get an $18 dividend on one share. And that just goes forever paid in local currency."[102] The trill would effectively be an equity stake in the economy, paying a fraction of its total "earnings"—in this case, of the U.S. economy as a whole. It would provide investors with growth opportunities while giving inflation protection such as with TIPS investments. Both the coupon payments and principal would move up or down in response to GDP changes. As a constant share of GDP, they would protect relative standards of living. While target-date funds currently invest heavily in equities when the individual investor is young and then more in bonds as time goes on, trills could be added to such portfolios in small proportions initially and then in larger proportions as the individual investor ages.

Shiller sees benefits in trills for both governments and investors. "Governments would be putting themselves into a less leveraged position. Instead of borrowing at a fixed rate, it's like equity. It would be borrowing in such a way that their tax revenues would correspond to their obligations. And for investors it would be a much more wide-diversifying move. The GDP is much bigger than corporate profits. It's typically ten times bigger for each country. And so, investing in GDP is a much broader diversification than investing in stocks."[103] According to Kamstra and Shiller, trills might provide returns similar to a broad equity market such as the S&P 500 but with only half of its volatility. In simulations, using Markowitz's mean-variance framework, they estimate that an optimal portfolio—our Perfect Portfolio—might be 28 percent in long-term bonds, 38 percent in U.S. equities, and 34 percent in trills.[104] They also estimate that trills might have a beta relative to the CAPM of around 0.25, well below the market's natural beta of 1.0 (and lower than Leibowitz's observations that pension plans tended to have overall betas of around 0.6). However, the development of the trill concept won't happen overnight. "These things happen slowly. The problem with investing innovation is that you don't see the outcome right away, and people are mistrustful of financial innovations."[105] Despite that, he has seen expressed interest in the trill concept from central bankers in Turkey and England. Countries such as Bulgaria, Bosnia, Costa Rica, Singapore, and Argentina have issued securities that are at least partially connected to GDP growth, although not precisely like trills.[106] There is even the possibility that trills could be privately issued, such as Shiller's MacroShares.

As an eclectic thinker who doesn't follow the herd, Shiller has one last take on what the best investment might be. He thinks that in order to progress, society should invest in something other than houses. "How about scientific research, medical research? What would be better, that people build big houses thinking that they'll make capital gains or that they send their children to medical school and they do research on curing diseases?"[107] Rather than thinking about your own portfolio, he suggests, think broadly. Think in terms of society as a whole, and think twice about what you're investing in and its purpose.

10

Charles Ellis and Winning at the Loser's Game

CHARLES (CHARLEY) ELLIS has been called the wisest man on Wall Street. After all, he is recognized as the first insider to publicly question the benefits of active investment management, in the mid-1970s.

Ellis is an exceptional pacesetter and thought leader. He developed a key consulting firm from scratch, through the simple method of carefully listening to decision makers of institutional financial service providers—banks, dealers, brokers, and investment managers—and then providing those clients with unbiased advice. His insightful and controversial article, "The Loser's Game," helped inspire the growth of index funds. His participation in one of the most innovative endowment funds, at Yale University, gave him the perspective to put investment management principles into practice. A prolific and colorful writer, he has been able to connect to a broad audience with a clear message. Ellis and his views have much to tell us about the Perfect Portfolio.

The Early Years: From WGBH to HBS

Ellis was born in 1937 in Boston in the municipality of Roxbury, one of the first towns of the Massachusetts Bay Colony, first settled in 1630. His father was an attorney who served in the U.S. Navy in World War II, but the most powerful teacher in Ellis's early life was his sixth-grade teacher, Miss Nellie Walsh at the Elbridge Gerry School in Marblehead, Massachusetts. As he recalls, Miss Walsh stood in front of the class and told them that while the class size was supposed to be around twenty-eight it was actually forty-two and that as she was only one person, they would work together to cover some interesting material.

Walsh was also the school principal, and one day Ellis was surprised to be called into her office. Walsh told him, "Charles, I'm very disappointed with you. Am I right that you were found fighting with Peter on the school playground during recess?" The young Ellis admitted that was the case, but he explained that Peter was picking on younger children and throwing snowballs at little kids, and he was trying to make Peter stop. Walsh replied, "Charles, I expect more of you than you would bring yourself to the likes of Peter. That will be all."[1] Ellis would later say that that was the best lesson he had learned from anyone.

Ellis was in about the seventh grade when his father advised him not to pursue a career in law. His father, in very lawyerly fashion, outlined three arguments to support his advice: Ellis wasn't cut out for a career in law because he was not, fundamentally, a scholar; a large number of talented recent war veterans, about ten years older than Ellis, were receiving scholarships from the Servicemen's Readjustment Act of 1944 (also known as the G.I. Bill) and were going into law, making it tough to advance; and law was changing from a profession to a business, so he should consider going directly into a business rather than something that was in a state of flux.[2] Ellis would take his father's advice.

For grades nine through twelve Ellis attended Phillips Exeter Academy, the famous boarding school in Exeter, New Hampshire, one of the oldest secondary schools in the United States. Early Exonians include U.S. senator and secretary of state Daniel Webster, U.S. president Franklin Pierce, Abraham Lincoln's son Robert, and Ulysses S. Grant Jr., while later Exonians included the great-grandsons of John D. Rockefeller, John Davison "Jay" Rockefeller IV and David Rockefeller Jr., and, of course, Ellis himself. Phillips Exeter employed the Harkness method of education, in which students seat themselves in a large oval to discuss ideas with minimal teacher intervention, similar to the Socratic method—a precursor to his later education at the Harvard Business School.

Upon graduation from Phillips Exeter Academy, Ellis entered Yale College, the undergraduate liberal arts college at Yale University, to study art history. For a time he was the chair of Yale's student news and talk radio station, WYBC. Although he successfully earned a BA in art history in 1959, his studies were not to lead to a career. "Unless you are really good at art history, there's no destination there," he later recounted. "At the top of the group it's quiet and lonely and I realized I'm a social guy and I didn't want to do that."[3]

After graduating from Yale, Ellis was briefly employed at WGBH, an FM radio station in Boston that first aired in 1951 and eventually became a charter member of National Public Radio. While at WGBH he became friends with a volunteer there, a "wonderful woman" his age who caught his eye that he wanted to get to know better, so he asked her to lunch. They talked frequently and soon started dating. One day she said to him, "You know, Charley, you should go to the B-School," to which he replied, "What's a B-School?" She informed him that it meant a business school. He then asked her if there was more than one business school. She replied that there were many but only one that he should attend, *the* business school, Harvard Business School (HBS). Ellis applied and was accepted.[4]

Ellis found his HBS education to be a transformative experience. "The School brings together some very bright people and challenges each and every one of them to think for themselves and to think about what the other person is saying. So, you learn to listen, and you learn to speak up and articulate your own views."[5] HBS's case study approach required students to work their way through problems that had no clear answers, unlike textbook learning. "You realize how complicated the world is and how important making good judgments can be, and how important having the right facts can be." The experience helped him to think creatively.

Nearing graduation from HBS in 1963, Ellis considered applying for a job at Goldman Sachs, since his father had told him that Goldman was the best firm on Wall Street. The starting salary was $4,800, but Ellis realized that that salary wouldn't work; he was getting married, and his wife had loans to repay to Wellesley College. He calculated that he needed to earn at least $5,000.[6]

After several interesting job interviews but no job offers, Ellis was having lunch with a classmate who shared that his father had a friend who was looking for an MBA graduate to work at Rockefeller. He asked if Ellis might be interested. Thinking he meant the Rockefeller Foundation, the global philanthropic private foundation, Ellis immediately expressed interest and soon met with Robert Strange, whom he found to be thoughtful and engaging. It soon became clear, however, that Strange didn't work for the Rockefeller Foundation but instead worked for Rockefeller Brothers, Inc., the Rockefeller family office that managed the investments and endowed the philanthropies. While investing was a field that Ellis knew nothing about, he was offered a job and readily accepted.

When Ellis excitedly told his wife the good news, he realized he forgot to ask what the starting salary was. It turned out to be the standard $6,000 rate that the Rockefeller bank, Chase Manhattan, paid first-year MBA graduates—and also what the Rockefeller family paid beginning domestic servants.[7] Fortunately, his wife was going to be a teacher, earning $7,000, so between the two of them they would be all right financially.[8]

Rockin' with the Rockefellers

At Rockefeller Brothers, Ellis's mentor was J. Richardson Dilworth, a senior financial adviser to the Rockefeller family. Dilworth was also a trustee, treasurer, and chairman of the finance and investment committee of the Rockefeller Institute for Medical Research (now Rockefeller University); a member of the Yale Corporation, Yale University's board of trustees; and a vice president of the Metropolitan Museum of Art.[9]

Ellis's initial job involved writing research reports on various stocks. His direct supervisor was Phil Bauer. When Ellis completed his first research report, on textile stocks, he submitted it to Bauer.[10] After reviewing the report, Bauer was not pleased and came to see him. Bauer sarcastically asked Ellis if he had learned *anything* about investing while studying at Harvard. Ellis admitted that there was only one investments course taught at Harvard, which he hadn't taken because it had a reputation as an extremely dull course given by a boring professor between the hours of 11:30 a.m. and 1:00 p.m. It was affectionately referred to as "Darkness at Noon."

As one can imagine, Bauer impressed upon Ellis the urgency of learning about investments. By the end of that day, Bauer had arranged for Ellis to join a training program at the Wall Street firm Wertheim & Company, join the New York Society of Security Analysts, and enroll in night courses on investment basics at New York University.

Ellis learned an important lesson while in the training program at Wertheim & Company. "One day the firm's senior partner, J. K. Klingenstein, was our guest speaker. As he was about to leave, one of the trainees blurted out, 'Mr. Klingenstein, you're rich. How can we become rich like you?' Everyone else was mortified, and J. K. was clearly not amused. But then his face softened, and you could see that he was taking the question very seriously, and trying to sum up everything he'd learned in a lifetime on Wall Street. The room was silent as a tomb, and finally Mr. Klingenstein said firmly, 'Don't lose.' Then he stood up and left. I've never forgotten that moment. That's what investors should really care about: Don't lose. Don't make mistakes. They cost too much."[11] Ellis went on to explain, "In investing, losing means taking decisive action at the worst possible times—being driven by your emotions precisely when you need to be the most rational. Trying too hard to win eventually means losing. To win the Indianapolis 500, you first have to finish the Indianapolis 500. If you try too hard on just one lap, you won't live to finish."

Encouraged to enroll in night courses on investment basics, Ellis went to register at New York University.[12] When he eventually made his way through the long line, the woman sitting at the registration table asked if he was a special or regular student. Not knowing the difference, he asked for clarification. The woman explained that special students were only taking one or two courses, while regular students were in the degree program. She asked Ellis what his latest school and degree were. When he replied "Harvard Business School, MBA," she said "Oh wow! Harvard Business School! That's really great! Well, since you already have your MBA, you should be in our PhD program!" Since it cost nothing more, he could drop out at any time, and no family members yet had a doctorate, he ended up in the PhD program at New York University.

After about seven years in the program, Ellis was starting his own firm, but he still hadn't completed his general exams or started on his dissertation. That's when he had a heart-to-heart chat with his son, Harold, while they were shoveling snow, which Ellis recounted: "'Harold, how's school?' And Harold said, 'I like school, Dad. Teachers are good, and I like the other kids. And we're learning a lot. How's school with you?' And I said, 'Well, Harold, you know, with the new firm, I'm working so hard, I think I'm going to have to stop.' 'Dad, you can't stop school till you finish.' So, the next day I went back to work, at school. And then kept on clunking away."[13] Ellis eventually graduated in 1979, fourteen years after starting.[14]

In 1964, Ellis published his first article in *Financial Analysts Journal*, titled "The Corporate Tax Cut."[15] The article examined the implications of the Revenue Act of 1964, enacted by President Lyndon Johnson, that reduced the corporate tax rate from 52 percent to 48 percent (reducing individual tax rates as well). One of the act's stated goals was to increase capital investments. In his article, Ellis argued that Johnson's declared benefits to the economy as a whole were not as simple as the president or investors expected and cautioned financial analysts to examine its impacts carefully. It was a theme to which Ellis would often return.

In 1966, Ellis's classmate at HBS, Charlie Williams, called him and suggested he visit his employer, the investment bank Donaldson, Lufkin & Jenrette (DLJ).[16] DLJ was founded in 1959 by William H. Donaldson, Richard Jenrette, and Dan Lufkin. Its nearly unique business model for the time was to provide quality independent corporate research to national investors. Around this time, other than DLJ and a few other new firms, "There was virtually no research being done."[17]

Ellis was offered a position at DLJ and accepted a salary more than double his current pay plus bonus, profit sharing, and eventual stock ownership. "Most securities firms did not have a research department. We were all about research. And [when most other firms] put out a report, it would be 2 pages long at the most. We were doing 50, 75, 100, 150-page reports. We were really making an effort to understand the companies very, very well."[18] While at DLJ, he was also given the opportunity to work with top investment managers at leading institutions, including those in the fast-growing areas of mutual funds and pension funds. The late 1960s were the "Go-Go Years" on Wall Street, the era of the popular Nifty Fifty, large capitalization stocks widely regarded for their growth potential. According to Jason Zweig of *The Wall Street Journal*, while at DLJ, Ellis "punctured 'Go-Go' stocks" with his sharp analysis.[19] Ellis reflected that his time at DLJ "was fabulous and fun. . . . We were involved in the front edge of research being important."[20]

While working at DLJ, Ellis was also studying to earn his Chartered Financial Analyst (CFA) designation, the gold standard of credentials in the investment industry. To obtain the designation, candidates need to pass three rigorous exams assessing a candidate's financial analysis and portfolio management skills, at that time only offered once per year on the first Saturday in June. By 1968, Ellis had successfully passed the first two levels but was considered too young to take level III and had to wait another year.

In June 1969, Ellis was shocked and delighted to see that the entire afternoon session was devoted to commenting on a recently published article in *Institutional Investing* that he himself wrote! Prophetically enough, it was titled "To Get Performance, You Have to Be Organized for It."[21] Not surprisingly, he obtained his CFA designation that year.

In his article, Ellis argued that a strategic overview was required for investment performance. Young research-oriented portfolio managers should be left alone by investment committees in order to maximize investor returns. He cited the apparent virtues of active investing, including taking advantage of short-term profitability, taking on risk when higher-potential profit is available, and avoiding price declines. However, only two years later, he recalled, "I began to see a few clouds on the performance horizon."[22]

In retrospect, the clouds also started to appear in his writing. In 1968, while still at DLJ, Ellis wrote an article published in *Financial Analysts Journal* on performance investing, which he defined as "an aggressive, eclectic, intensively managed effort to continuously maximize portfolio profits."[23] He described performance investing as an active strategy "somewhere between the extremes of tape reading traders [following short-term price movements] and very long-term holders." Success was to be had by combining the best of both types of traders. The key was to act quickly when factors indicated potential price changes based on the most current information available about a wide range of companies. He mused that success might spoil performance, particularly when too much money chased similar strategies, resulting in a lower return per invested dollar. He cautioned that performance investing might be "doomed to follow the typical phases of development, maturation, and decline."

In 1971, Ellis published an insightful article in *Financial Analysts Journal* titled "Portfolio Operations,"[24] part of a book he was writing on institutional investing. Well-managed portfolios were dynamic, he observed, since the stocks in them were constantly changing, the firms themselves were changing, and large capital inflows and outflows were always occurring. The challenge for the manager was to harness the "thrust" of these different dimensions to make portfolio operations more effective. However, moving toward efficiency would take time. "Another decade of exploring and testing will be needed before the work of fund management becomes sufficiently scientific or quantitative." Here, he emphasized the importance of minimizing the impact of failure and maximizing the impact of success. He also highlighted the importance of Harry Markowitz's work on diversification and the dangers of concentration. "The portfolio manager who opts to concentrate his portfolio must be satisfied that he can achieve higher returns thereby than following the policy of investing in a very broad list of volatile stocks. This is not easy." Ellis also stressed the expense of high turnover. Finally, he noted the usefulness of comparing a portfolio to the S&P index in order to "give the portfolio manager useful insights into his own organization's strengths and weaknesses in investment selection."

Greenwich Associates

Ellis's article on portfolio operations was to foreshadow the founding of his consulting company the following year. In 1972, he founded Greenwich Associates with $3,000 and an idea for a new kind of business research based on consulting to banks, large fund managers, and Wall Street firms.[25]

Ellis explained how he came up with the idea while working in equity research. "It was clear to me that I had no idea how well I was doing. I was working very, very hard; I knew that. I knew that I knew a lot about my individual clients . . . my institutional clients. And I also knew I didn't know very much about how they'd really thought about me. And I didn't know how they thought about any other firm. You know, if anybody could go out and find out what they really think, that would be tremendously valuable to everybody. And that was basically a light bulb."[26] He expanded, "The basic idea is there are a thousand or five hundred professional people who are the dominant buyers of a particular institutional service. They know exactly what's going on. They know who's good, what they're good at. They know how they've improved or not improved over the last year. They know what they would like to see more of. And if you would come and talk to them candidly, for an hour, in confidence, they would tell you."[27]

In the firm's inaugural year, Ellis visited ninety cities selling his vision of the importance of benchmarking data so firms knew how well they were serving their clients. His idea was to provide timely, unbiased, effective managerial information based on high-quality proprietary research, maintaining the relationship at a senior level. The primary added value of his company was getting good advice based on listening to a firm's clients, since it rarely provided feedback directly to the firms. Its business model was based on conducting thoughtful interviews with clients and analyzing the results. "It gave senior management undeniable information. So, if they said to anybody, 'Look, this is what the clients are saying about you,' that had to be accepted. There was no way you could say no."[28]

Although it took some time, Ellis was ultimately successful. "Going to bed at midnight, I set the alarm for 5:30 and then I would get up and get going again. When I flew into a city, I'd get into the taxicab at the airport, and I'd say to the driver: I'm fine. I have not had anything to drink, but I am exhausted. May I lie down on the back seat of your cab, and will you wake me up if I fall asleep?"[29] After two years, the firm ran out of cash, requiring him to borrow against securities that his brother owned, and after the October 1987 market crash the firm was forced to downsize by 10 percent, part of the general contraction of the financial services industry.

Despite these setbacks, Greenwich's client base would eventually grow from 28 clients in North America in its first year of business to over 250 clients in 130 financial markets across the globe. Greenwich recently had more than 250 employees, six global offices, and over 50,000 institutions and corporations participate in its research. In 2000, Woody Canaday succeeded Ellis as CEO of Greenwich Associates, and in 2009, Steve Busby followed Canaday.[30]

The Loser's Game

While he was busy finding new clients for Greenwich Associates, Ellis somehow found the time to write his influential article "The Loser's Game,"[31] published in 1975, which went on to win the CFA Institute's prestigious Graham and Dodd Award. Ellis would later follow up on the article with his best-selling book *Winning the Loser's Game*, published in 1998, selling over 650,000 copies through various editions.[32]

What exactly is "a loser's game"? The title of Ellis's article was inspired by a book by Simon Ramo, *Extraordinary Tennis for the Ordinary Tennis Player*. Ramo himself was a colorful individual who lived to the age of 103.[33] A former worker at Howard Hughes's aircraft company, he cofounded his own aerospace firm, the predecessor to TRW Inc., and was the chief architect of America's intercontinental ballistic missile system. At age 100, he became the oldest person at the time to receive a patent, for a computer-based learning invention. Ramo wrote or cowrote sixty-two books on diverse subjects, including a textbook on electromagnetic fields that sold over a million copies.[34]

According to Ellis, Ramo realized that "there are two games of tennis, and they used the same equipment, the same court, the same dress code, and they keep score the same way. But other than that, they're completely different. In professional tennis or expert tennis—and there are very few people that really play expert tennis—but there are people and we've all seen them, when you see the Williams sisters or some of the others. They are really good. And they don't make mistakes, but they force the other person to do just a little bit harder, to do a little bit harder, to do it . . . and sooner or later, a forced error is made. And they win points, most of the time."[35]

But Ellis's game of tennis—and the game that most of us play—is very different. "When I play tennis, I play for fun, and I lose points. And I hit at the net. The really good players never hit at the net. I double fault. Good players almost never double fault. I hit it out of the court. They don't hit it out of the court. They get close to the line, but they don't hit it out. And I give you layup, after layup, after layup, easy shots you can put away."[36] So, Ramo's message was simple: "You have to understand which game of tennis you're playing. And if you're a brilliant athlete, fabulous tennis player, you should play a winning strategy. But if you're not, you should play to not lose. You should be defensive. Keep the ball in play."[37] In other words, avoid unforced errors.

It struck Ellis that what Ramo was describing also applied to investment management. "There are people who are playing a winner's game. And they are doing something that is so beautifully done that you and I would be very confident they'll keep it up. Then there are a lot of people who are in there competing as best they can, but candidly, they make mistakes. They buy high and sell low, and they have their portfolio arranged the wrong way. And sooner or later they fall short of what they're trying to do."[38]

Ellis wrote that investment managers were failing to perform on a relative basis by not beating the market. "The investment management business is built upon a simple and basic belief: Professional money managers can beat the market. That premise appears to be false."[39]

Ellis came to a profound realization: Investors needed to realize that mistakes are extremely important; therefore, the key to success was to avoid making mistakes. The new null hypothesis was that investment managers couldn't beat the market, so the message should become "don't do anything [by way of active management] because when you try to do something, it is on average a mistake. And if you can't beat the market, you certainly should consider joining it." How? "An index fund is one way."[40]

The idea of investing in an index fund in 1975 was a radical notion. Ellis and his close friends were concerned that the reaction to his article was going to be a rough one and that his article would anger a lot of active investors. He was surprised by the reaction. "They all thought: 'Yeah, that's cute. Of course, it doesn't apply to me but you know, it applies to a lot of these other guys. But not to me, I'm really doing well.'"[41] Unfortunately for them, his arguments were sound.

Ellis showed the difficulty of the challenge for active managers to outperform the market through some simple mathematics. Suppose the average equity return is 9 percent, the annual portfolio turnover is 30 percent, the average spread and commission costs are 3 percent, the asset management and custody fees are 0.20 percent, and the goal of the manager is to outperform by 20 percent. On a gross return basis, by how much would the manager need to outperform in order to net 20 percent outperformance? The answer was to solve for "Y" in the following equation:

$$(Y \times 9\%) - [30\% \times (3\% + 3\%)] - (0.20\%) = (120\% \times 9\%).$$

It turns out that $Y = 142$ percent, or in other words, the manager would need to outperform by over 40 percent. Using the same equation, in order to perform as well as the market, such as the S&P 500—but no better—the manager would need to outperform the market by 22 percent!

Ellis's book, *Winning the Loser's Game*, expanded and updated from his original article, offered many nuggets of wisdom. Throughout the book, he built a strong case for index investing. For example, he wrote, "Since most investment managers will not beat the market, investors should at least consider investing in 'index funds' that replicate the market and so *never* get beaten by the market. Indexing may not be fun or exciting, but it works. The data from performance measurement firms show that index funds have outperformed most investment managers over long periods of time."[42]

According to Ellis, the real game is about setting goals and focusing on the long term, not trying to play a short-term game that you're bound to lose. "The one encouraging truth is that while most investors are doomed to lose if they play the loser's game of trying to beat the market, every investor can be a long-term winner. All you need to do to be a long-term winner is to concentrate on setting realistic goals and staying the course with sensible investment policies that will achieve your particular objectives *and* apply the self-discipline, patience, and fortitude required for persistent implementation."[43] Underscoring the importance of goal setting, he writes, "In reality, few investors have developed clear investment goals. That's why most investment managers operate without really knowing their clients' real objectives and without the discipline of explicit agreement on their mission as investment managers. *This is the investor's fault*."[44]

Is there any role for active management success in the long run? Ellis points out that, in theory, active management might be successful, including strategies such as timing the market, but he also notes that the chances for success by trying to implement such strategies are low. "Just as there are *old* pilots and there are *bold* pilots, but no old, bold pilots, there are almost *no* investors who have achieved recurring success in market timing."[45]

More recently, Ellis has commented on the quality of current active managers and the paradoxical impact that has had on the investment world. "You will not find in any other constituency a group of people who are smarter or harder working or better educated or better informed or have better devices and tools to be able to keep right at the frontier of knowledge than the investment managers of the active investment management community. . . . The net result of it is that they do such a good job, that there's no reason for anybody to pay a full fee to be able to compete and try to do better. It's much smarter to say, 'Yes, and I can get at a low fee access to all their talented work, and I'm going to do that.' That, to me, is the main thesis [for investing in index funds]."[46]

Ellis emphasizes "four wonderfully powerful truths about investing" that experienced and wise investors understand and follow. First, your chosen asset mix is the most important investment decision; second, there should be a purpose behind the chosen mix, such as a desire for growth, income, or safety, and an idea how income from the assets will be used; third, diversification within and between asset classes is critical, since bad things will happen; and fourth, be patient and persistent.[47] There is often too much emphasis on chasing returns without recognizing the other side of the equation. “Most investors and most investment managers and *all* advertisements about investments focus on only one side of investing: returns. There is another side,” he writes. “And for long-term success, that other side is important—even more important than returns: risk—particularly the risk of serious permanent loss.”[48] He describes some of the forms of risk, including frauds and scams, unexpected business troubles, individual behavioral biases, and an undiversified portfolio.

Stressing the importance of investing beyond one’s domestic market, Ellis remarks, “Most investors are surprised to learn that the best ‘plain vanilla’ or ‘null hypothesis’ index fund mix is half *international*.”[49] International diversification enhances the “free lunch” that comes with domestic diversification. By investing in all of the world’s major stock markets, investors are able to tap into all of these different economies.

Ellis also emphasizes the importance of truly matching an investor’s time horizon with an appropriate asset mix. He notes that if the horizon is five years, then a 60/40 equity to fixed income ratio is appropriate, but such a horizon is much too short for “most individual investors who want to provide financial security for their families.”[50] Ellis implies that if investors thought for the longer term, they would invest more heavily in equities, thus earning higher returns in the long run.

In addition to his four powerful truths summarized above, Ellis also developed ten “commandments” for individual investors as a guide for thinking about investment decisions:[51]

1. Save as much and as early as you can.
2. Don’t speculate in “hot tips” or individual stocks that everyone is talking about.
3. Don’t do anything in investing primarily for tax reasons. Consider an investment on its own benefits, and if there are also favorable tax implications from the investment, then treat them as icing on the cake.

4. Don't think of your home as an investment or treat it like a bank from which you can borrow.
5. Don't invest in commodities, since their prices can fluctuate widely.
6. Recognize that stockbrokers and mutual fund salespeople make money *from* you. Their job isn't to make money *for* you, so consider the fees they charge for various products and what their incentives are.
7. Don't invest in new or "interesting" investments for which you may not understand the associated risks.
8. Don't invest in bonds just because you've heard that they are conservative or safe. Understand the risks associated with them, particularly when interest rates are expected to rise.
9. Write out your long-term goals and investing and estate plans and review them regularly. Use them to guide you.
10. Distrust your feelings. Don't make investment decisions based on emotions.

So how does an investor avoid losing? "Winning the loser's game of beating the market isn't easy. *Don't play it.* Concentrate on the winner's game of defining and adhering faithfully to sound investment policies that are right for the market realities and right for your long-term goals and objectives."[52] Since everyone is different, his or her investment policies should be different as well.

The Yale Model

Ellis has been closely involved in Yale University's endowment fund, managed by David Swensen and his team in Yale's investment office. Ellis joined Yale's investment committee in 1992 and served as its chair between 1999 and 2008. As of 2020, its endowment assets were over $31 billion. Over the previous thirty years, Yale's investments have returned 12.4 percent annually, an unparalleled performance for a university endowment fund.[53] This success is evident daily, as the endowment supports a huge portion of Yale's operating costs. In honor of Ellis's longtime support, the dining hall at Yale's School of Management is named Charley's Place.

How can an endowment fund attempt to outperform its peers? It has two broad strategic decisions to make: choosing the "right" asset mix and then, within each asset class, choosing superior managers. Over the past thirty years, relative to the median endowment, Yale's asset allocation decisions—being in the right assets at the right time—have added 1.9 percent per year, while its superior manager selection has added 2.4 percent. The portfolio is constructed using a combination of academic theory, including Markowitz's mean-variance analysis, and informed judgment. In 1989, domestic marketable securities (i.e., U.S. stocks, bonds, and cash) represented almost 75 percent of the fund's assets. By 2020 that percentage had dropped to less than 10 percent, with the other 90 percent invested in foreign stocks, private equity, so-called absolute return strategies, and real assets such as real estate. The resulting change in the asset mix led to a portfolio with higher expected returns and lower volatility.[54]

According to Ellis, there is a key investment philosophy that's required if an endowment fund is trying to outperform through its asset mix and manager selection: taking the long-term view and sticking with one's convictions. "There's too much dating in the management of endowment funds. I confess: I was once married, once not married, and now I'm married forever. . . . All of us would be better off if we thought about the selection of managers and illiquid assets as marriages, not dates."[55]

Yale's endowment fund is synonymous with its longtime and highly regarded chief investment officer, David Swensen. Ellis and Swensen share a mutual regard for each other's skills. According to Swensen, "My colleagues and I eagerly anticipated his contributions to our meetings. We were never disappointed. Charley always advised gently, more often than not with superbly crafted stories (or Charley's parables, as we called them). Charley advanced Yale's interests in a manner that mattered immediately and resonated more deeply as time passed."[56] According to Ellis, "I've had the rare privilege of sitting in the front row and watching one of the most beautiful players of one of the most difficult games that there may ever have been. It's a little bit like being the copilot sitting right behind Charles Lindbergh as he flies across the Atlantic."[57] What is Swensen like? "He's a lot like my mother. My mother was one of the best cooks I ever knew, and she was very clear that in her kitchen the corner in between the stove and the sink was her corner. If you ever got in the way, you were volunteering to do the dishes. One of the most useful things that a committee can do is to stay out of the corner so that the person who's actually doing the work is free to do his job."[58]

As a consultant to endowment fund and pension fund managers, Ellis has encouraged the development of investment policy statements. These statements are meant to articulate expected return targets and acceptable risks, along with any investment constraints such as liquidity needs, time horizon, regulation, and taxes. An investment policy is "a written statement of what you believe as an investor and what you can hold on to even when everyone you know is either excited or scared to death of the market. . . . Investing is a continuous process too; it isn't supposed to be interesting. It's a responsibility. . . . Visualize yourself looking back when you're 80 years old, reviewing whether you invested your money wisely. Ask, 'What is it I can trust myself to do in good times and in bad?' Then write it down on one side of a single sheet of paper—when you'll put money in, how you'll manage it, when and why you'll take it out. The best plan, for most of us, is to commit to buying some index funds and do nothing else. Benign neglect is the secret to long-term investing success. If you change your investment policy, you are likely to be wrong; if you change it with a sense of urgency, you're guaranteed to be wrong."[59]

Ellis shared a number of lessons that one could learn from Swensen and his experience at Yale. "First, understand who you are and what you're trying to accomplish. Second, think comfortably about international activity. Third, you want to be diversified so that you aren't heavy in one kind of equity, but on several different kinds. So, you have different characteristics of behavior, so your aggregate portfolio will be more consistent in performing over time than it would be if it was in any one component part."[60]

Murder on the Orient Express

In 2012, Ellis wrote a provocative article in *Financial Analysts Journal* titled "Murder on the Orient Express: The Mystery of Underperformance."[61] The first part of the article's title refers to the classic Agatha Christie murder mystery (warning: spoiler alert). The Belgian detective, Hercule Poirot, is called upon to solve the mysterious murder of a fellow passenger on the Orient Express train from Istanbul to Western Europe. Poirot deduces that twelve fellow passengers had a motive in the killing and eventually correctly concludes that in fact *all* twelve were guilty of committing the murder.

Ellis cleverly uses a similar premise to investigate which party is guilty of underperformance, or not beating the market. Is it the investment managers? the consultants? the fund executives? the investment committees? He concludes that all four parties are guilty, and yet "none of the four guilty parties is ready to recognize its own role in the crime." He carefully reviews the evidence and the suspects.

The investment managers knew they were talented and hardworking, and in meetings they presented their performance records to make the best possible impression, often not showing their performance after deducting fees. They presented their decision-making process in oversimplified terms and implied that they had a competitive advantage over their peers.

The consultants were in the *business* of consulting and thus making profits for themselves rather than their clients. Their goal was to maintain relationships and retain existing clients. By recommending many fund managers to each client, they reduced the risk of having recommended only one underperforming manager and made clients more dependent on them to monitor all the managers.

The fund executives of each institution often insisted on having separate rather than pooled accounts, adding to costs. In addition, rather than *buying* investment managers, they usually *sold* them.

Finally, while the investment committees were well intentioned, often their objectives were poorly defined, and very little time was devoted in their meetings to the productive work of providing governance.

They often believed that their objective was to identify managers in the top quartile of performance, not recognizing that past performance is not a strong guide to future returns.

Ellis concludes his mystery on a cautionary note: Not realizing they themselves are the guilty party, these four groups will each continue to contribute to future underperformance.

Performance Investing Revisited

Ellis recently reflected on the rise and fall of performance investing.[62] He defines performance investing as actively seeking incremental returns above market indices—also known as seeking alpha—by managers for their clients. What has changed to cause this rise and fall over time? In his account, the focus of asset management has shifted from costs decades ago to, more recently, value. For example, pension assets were once managed by insurance firms and banks. Newer investment managers, however, realized they could charge much higher fees by promising superior performance. As the number of mutual funds and pension funds grew and fees increased, the investment *business* grew increasingly profitable. But what was good for the business wasn't necessarily good for the investors.

There was yet another major difference over time: the ability of managers to consistently obtain superior performance as the information environment changed. "The secret sauce of active investing has always been to get an advantage on information. Fifty years ago, that was easy. Guys like me would study and analyze information for 3–4 weeks and then go visit the company for 2–3 days and interview several executives, who would gladly answer all our questions so we would really know what was going on," Ellis recalled. "Today, that is long gone. The SEC [Securities Exchange Commission] requires all public companies to make sure that any useful information is distributed simultaneously to all investors at the same time. Poof, there goes the chance to get a competitive advantage on information. . . . While traders retire by 45 and investment bankers quit by 55, investment managers could continue into their 80s, so career competition was even greater."[63]

Higher fees and a declining information advantage translated into a destruction of value for investors. Ellis reviewed the consequences of higher fees and lower incremental performance in a mock question-and-answer period. "'Mathematically, how much higher return do you get from active management, incrementally, for that incremental fee of 100 basis points?' 'Well, the answer is, on average, it's a negative number. It's not a positive number. Active management actually deletes a little bit of return.' 'My goodness! You mean, the fee is something like 100 percent of the value added?' 'Well, that's one way of expressing it. Yes, it is . . . the incremental fee, 100 basis points, is equal to or greater than, typically greater than, the incremental return.'"[64]

In response, many investment managers took a different tack. Instead of active management per se, they sought strategies similar to an overall market capitalization-weighted benchmark such as the S&P 500 but ones that might provide a better return-to-risk ratio by using alternative weighting schemes, such as based on volatility measures or dividends, the so-called "smart beta" strategies. According to Ellis, "Smart beta is such a clever name—second only to the clever Scots who changed the name of death insurance to life insurance."[65]

Instead of these strategies, Ellis suggests that the better alternative is to focus on low-cost index funds and exchange-traded funds (ETFs). In addition, investment managers and advisers should concentrate on what he refers to as "value discovery," guiding their clients through important questions, the answers of which will determine an appropriate investment strategy for their particular long term, despite the inevitable ups and downs of the market.

The Revolution

Ellis is a strong advocate of passive investing in the low-cost, broad-based, market capitalization–weighted index fund. Index investing "eliminates or reduces all the 'little things' that, like termites, eat away at returns: high fees, taxes, errors in selection of managers and more."[66] In his recent book, *The Index Revolution*,[67] he begins with nine silly "reasons" not to index:

1. Indexing is for losers.
2. Passive investing is like giving up trying.
3. Indexing forces investors to buy overpriced stocks.
4. With indexing, some unknown administrators are selecting your stocks.
5. There isn't any urgency to switch to indexing—maybe next year.
6. At current stock market levels, this isn't the right time to switch to indexing.
7. "Smart beta" investing is better than a market capitalization index fund.
8. Active investing funds are making a comeback.
9. Since indexing did so well last year, active investing will surely do better soon.

He then proceeds to debunk these silly reasons. But where did these "reasons" come from?

According to Ellis, active managers have created three problems for themselves. "One problem is that they've defined their mission as beating the market. Second is allowing the value of their profession to be increasingly dominated by the economics of the business. That is, the metric of their success is: Are profits going up? That's a profound mistake made by investment managers, particularly active managers." Finally, the third problem is "not realizing that most investors can use help in designing investment programs that match their objectives."[68]

Ellis recalled some memorable words from the legendary value-investing guru, Benjamin Graham. In the 1970s, Ellis had organized a three-day discussion about investment practices for an audience of successful active managers and invited Graham—then in his eighties—to attend. The conference was organized with meetings in the morning and evening, and Graham would take a nap in between. It was clear to Ellis that Graham was the smartest person in the room. While Ellis was leaning toward index investing, he wasn't as clear-minded as Graham, who said at one of the meetings, "You know, it seems to me that everyone in this room would do better for their clients if they were indexing."[69]

Ellis identified four phases of active management since 1960.[70] In phase one, from 1960 to 1980, active managers were able to earn 2–3 percent above benchmark performance by competing principally against individuals and conservative mutual funds, while trust institutions and index funds received no attention. In phase two, from 1980 to 2000, active managers rode a strong bull market that provided strong returns and pleased clients, but costs and fees generally offset any incremental performance gains, and index funds received some attention. In phase three, from 2000 to 2010, active managers underperformed benchmarks after fees, and index funds were in higher demand. In phase four, since 2010, an increasing number of active managers underperformed in a market that was almost completely dominated by professionals, and demand for low-cost indexing accelerated.

According to Ellis, "Over 10 years, 83 percent of active funds in the U.S. fail to match their chosen benchmarks; 40 percent stumble so badly that they are terminated before the 10-year period is completed; and 64 percent of funds drift away from their originally declared style of investing. These seriously disappointing records would not be at all acceptable if produced by any other industry. And while these are U.S. statistics, since international institutions dominate all stock markets, they are all moving in a similar direction. The forces of change causing these shabby results for most active managers are numerous and undeniably powerful."[71]

Ellis's Perfect Portfolio

What does the Perfect Portfolio look like according to Ellis? Before you can get there, he instructs, you need to start with savings. He and his coauthor Burton Malkiel, author of the financial classic *A Random Walk Down Wall Street*, dispense key advice toward savings in *The Elements of Investing*.[72] Some might find it basic, but for others it will be an important foundation. It's important to stop dissaving (that is, spending more than earning) by taking on credit card debt. The time value of money shows that saving early can have a huge impact on later wealth through the magic of compound interest. And they note that it's never too late to start.

Once you have the savings, then come the investments. Of course, Ellis's Perfect Portfolio includes index funds. Although investors may be seduced into trying to find the next great stock pick, "suggesting a retail investor can invest in the next Apple is like suggesting that you can date a 19-year-old Elizabeth Taylor."[73] According to Ellis and Malkiel, only a few fund managers beat the market, but "nobody—repeat, nobody—has been able to figure out in advance which funds will do better."[74] They also note that funds that do outperform tend to do so by much less than funds that are beaten by the market underperform. As an alternative, with a low-cost index fund, "I can guarantee you that you'll be in the top 20 percent" of funds over a fifteen- to twenty-year period, based on history.[75] Ellis and Malkiel refer to the "one investment truism: Minimize your investment costs" through index investing.[76] They are proponents of many different kinds of index funds, including bond index funds and low-cost international funds that track the MSCI EAFE (Europe, Australasia, and Far East) index, which replicate broad markets of developed economies outside North America.

While bond investing is a key part of a diversified portfolio, Ellis strikes a cautionary note. In a low-interest rate environment, he said, "The best piece of advice I could give long-term investors today is don't own [domestic] bonds. And if you do own them, you probably ought to move out of them."[77] With long-term Treasury yields well below their historical average of around 5.5 percent, he notes that any reversion to the average trend will result in a substantial decrease in the bond's value. However, he adds that if that advice is too extreme, "You can diversify more. You could look at foreign bonds or dividend-paying stocks, though you will be taking on more market risk than you would with CDs [certificates of deposit]. Or you could perhaps stick with a short-term bond fund, which would fall less if rates were to rise. There's no simple answer."[78]

Ellis and Malkiel remind us that diversification is important not only across stocks but also across asset classes, across markets, and over time—not making all of your investments on a single day. They also argue that rebalancing to the desired long-term weights in different asset classes ensures that your portfolio will remain efficiently diversified.

Like the Loser's Game, an important key to success is to avoid blunders. In order to avoid blunders, however, one needs to be aware of the tendencies toward overconfidence we all share. For investors, the "timing penalty" comes into play when they rush to invest near a market peak and then flee the market near the trough.

But Ellis is adamant that there is no one Perfect Portfolio, because every investor is different. "Are you ninety-nine and you're basically at the end of your run, or are you nine and you've got a long way to go? Do you have others who are dependent on you, or are you an individual person? Do you have any friends that you're trying to help out? Have you studied investing? Have you had a wide acquaintance with people in the investment business, and do you chitchat with them all the time about everything that has to do with investing, and you just can't resist the temptation to talk to another guy, and another guy, and another guy? So, pretty soon you realize we're very, very different. And from an investing point of view, if you take age, income, spending, assets, knowledge of investing, comfort with risk, interest in spending more time on investing, access to information, access to judgment, all those characteristics, you know you're unique. And every investor is; whether they want to accept it that way or not, every investor is unique. So, what's right for one person may be close to right but isn't quite right. And then the adviser would try to come up with 'I don't know, are you the kind of guy who should be 60/40 or 70/30?' And you and that adviser would both be making one of the most obvious mistakes you could possibly make if you stood back from it. You're looking at the portfolio of securities. And that's all you're studying. And you're paying no attention to all the other variables that make a big difference. It takes a lot of disciplined thinking to get exact insight and exact understanding."[79]

Ellis emphasizes other important considerations. Factor in your total portfolio. What income are you earning? Capitalize that stream of future income so it fits into your total portfolio as the asset in reality. You will also need to take into account home ownership, and Social Security. After waving the red flag about the lack of savings preparedness for those approaching retirement in the United States for some time, Ellis offers three pieces of advice: first, enroll in any employer retirement plans and maximize your savings options, using index funds where possible; second, work until the age of seventy; and third, defer your Social Security benefits until the age of seventy.[80]

Another consideration is the bite of taxes. Ellis reminds us, "You have to pay attention to taxes. If you look at the actively managed mutual funds, their turnover is about 40 percent a year. That means that they're going to be incurring a lot of relatively short-term gains, when they do have gains. And those are taxable at ordinary income rates. . . . Index funds typically turn over about 5 percent a year, and a well-managed index fund will match gains and losses so that there actually is virtually no tax, and that's really worth paying attention to if you're a taxpayer."[81]

What about the investor who doesn't want to invest in an index fund? According to Ellis, "if you're going to opt for an actively managed fund, pick one in which you'd be comfortable doubling your investment whenever the manager has a dreadful two or three years," because inevitably, every good manager will have some dreadful years.[82]

Ellis offers three ways that an investor can succeed. "You can succeed intellectually, physically or emotionally. The intellectual way is how we would all like to succeed: being so smart that we understand things more clearly and see farther ahead than every other investor. The preeminent example, obviously, is Warren Buffett. But people like him are very, very, very rare. The physical way to succeed is simply to work harder, to start at dawn and grind away till midnight and carry home a heavy briefcase full of research and keep working right on through the weekend too. This way is the most popular on Wall Street, where nearly everyone seems to try it. I can't say I've met many people for whom this way actually works, but they must think it does, or they wouldn't keep trying so hard. The third way to succeed as an investor is difficult: emotionally. When that seductive fellow Mr. Market [an allegory created by the legendary Benjamin Graham] comes around, you have to pay absolutely no attention to him, no matter what happens. You have to control your emotions, and most of the time that means the best thing to do is nothing. If you can't control your emotions, being in the market is like walking into a heated area wearing a backpack full of explosives."[83]

Investors don't always go it alone. Seeking financial advice can be useful. However, Ellis stresses that the major problem with the typical adviser-client relationship is that we often don't share what we should with advisers. "Nobody ever says, 'Now I'm going to tell you the truth about who I am and what I care about from an investment point of view, and what I'm trying to accomplish.' That's not what we do. What we do is say, 'I want to have a good investment program that will do better than the market.'"[84]

"The most important single thought I can give is, contrary to the often-made statements, it's not about knowing the market and it's not about selecting the right manager. It is about you, your values, your history, your financial situation, and what will work best for you to accomplish the objectives you have in your life, and the most important variable is not the market, and it's not the clever investment manager. The most important variable and the prominent one or the opportunity to solve it is you, as an individual, get it right for you, and you'll be very, very happy. Get it not quite right for you, and you'll wish you had."[85] The Perfect Portfolio for you starts with knowing you.

11

Jeremy Siegel, the Wizard of Wharton

When most investors think of an investment portfolio today, the asset class that comes to mind is stocks. One of the most influential proponents of the importance of holding stocks in one's portfolio is Jeremy Siegel. He's often been called the Wizard of Wharton,[1] and with good reason. His classic book on investments, *Stocks for the Long Run*, first published in 1994 and now in its fifth edition, builds a compelling evidence-based case for why long-term investors should make stocks a big part of their portfolio.

Initially trained as an economist, Siegel always had a passion for investments. As one of the premier business educators in the country, his classes at Wharton were often standing room only, since so many MBA students—including ones who could not enroll in his classes because they were already full—would go to his morning briefings to hear his perspective on market dynamics. As such, Siegel is well positioned to provide us with his views on the Perfect Portfolio.

Paradoxical Beginnings

Siegel was born in Chicago in 1945, the son of Bernard Siegel and Gertrude Levite.[2] His family moved to the northern suburb of Highland Park when he was three years old. His father, a homebuilder, constructed a home next to Ravinia Park, the summer site of the Chicago

Symphony Orchestra, and Siegel still remembers hearing their concerts from his home in the evenings.[3] He attended Highland Park High School, where he was president of the math club. Siegel recalled, "I loved math and I was good at it. I worked all the integral problems in the calculus textbook by [George] Thomas, which was used by schools in the 1960s."[4] Siegel graduated second in his class from Highland Park High School in 1963.

As an undergraduate, Siegel attended Columbia University, where he obtained a BA in mathematics and economics in 1967, graduating summa cum laude and as a Phi Beta Kappa. It was at Columbia where he recalls he first became interested in economics and investments. "There was no economics taught in high school when I grew up. Being good with numbers, I was a math major. But I got disillusioned with math as it got more and more abstract. A friend said, 'Jeremy, try economics. You're kind of interested in the stock market. Maybe you'd like that.' But it wasn't until my junior year [that] I took my first economics class. After two weeks, I fell in love and knew I wanted to be an economist. And so, I finished up both the math major and economics major at Columbia."[5]

In 1967, Siegel received a fellowship from the Woodrow Wilson National Fellowship Foundation, founded in 1945 in response to a shortage of college faculty in order to offer talented students the opportunity to attend doctoral programs.[6] He also received a National Science Foundation Graduate Fellowship. These fellowships allowed him to pursue his doctoral studies in economics at the Massachusetts Institute of Technology (MIT). While pursuing his degree, he taught economics and was also a teaching assistant for a graduate course in monetary theory.

Why did Siegel pursue a PhD in economics rather than finance? "I always had an interest in financial markets, but in the 1960s a PhD in finance, it's not like it is today. There was almost no theory. I remember I sat in one course on IPOs [initial public offerings] and the professor laboriously only went through all the institutional details. I thought, 'This doesn't interest me.' My adviser said, 'Listen, Jeremy, you're interested in interest rates, macro, and markets. Go into economics, and then you can kind of move into finance and investments.' And that's what I did. If I had been born ten years later, I would have probably got my PhD in finance."[7]

Siegel's dissertation, completed in 1971, was titled "Stability of a Monetary Economy with Inflationary Expectations." His committee was a powerhouse of present and future Nobel laureates in economics: Robert Solow, his chair, and members Franco Modigliani and Paul Samuelson. Siegel also acknowledged his fellow students Robert Merton and Robert Shiller (featured in chapters 7 and 9, respectively), also future Nobel Prize winners, who provided encouragement and helped him with the formulation of a key component in his dissertation. Siegel noted that Samuelson in particular was a huge inspiration for him. "Wow. I mean, just being in Samuelson's presence and seeing how he thought about any topic in economics was, to me, an honor. How fast he thought through all the issues on any topic of economics. I regard him as the greatest theoretical economist of the twentieth century. However, I don't think he was the most influential one in terms of politics. I would say Keynes and then Friedman were more influential politically, but in terms of forwarding the field of economics, [Samuelson] had no equal. It just was inspiring to be both his student and to have him on my thesis committee."[8]

Siegel's 128-page dissertation explored the consequences to the macroeconomy when inflationary expectations change, building on work by well-known economists John Maynard Keynes, Don Patinkin, Phillip Cagan, and Milton Friedman. The dissertation even included computer simulations. Siegel explains the motivation behind his dissertation. "When I went through graduate school, that was a period of time when inflation and interest rates were over 10 percent and the economy was very unstable. The stability of an economy under inflationary expectations was not treated in the Keynesian model, and I wanted to explore it. It was built on Phil Cagan's work on hyperinflation but applied the concepts to a Keynesian-Patinkin economy. It was a theoretical piece, and it was a subject I much enjoyed working on."[9]

One of Siegel's first references in his dissertation was a 1969 quotation from Nobel laureate Milton Friedman. In fact, Siegel cited a total of fifteen papers by Friedman, who would later become a colleague and mentor. "When I was in Columbia I began to read [Friedman's] *Capitalism and Freedom*, and I discovered I had many of his libertarian tendencies. MIT was not libertarian; in fact, it was quite Keynesian and anti-Friedman. The profession was a battle between Keynesians and non-Keynesians, classicists and monetarists, which I found very exciting. I wanted to hear the other side of the story and go to Chicago."[10]

In 1972, Siegel published one of his first academic articles in the prestigious *Quarterly Journal of Economics* titled "Risk, Interest Rates and the Forward Exchange."[11] In this article, he examined the relationship between risk, the forward exchange rate (an agreement today to exchange one currency for another at a future time, for example, dollars for pounds in six months), and equilibrium interest rates for countries that engage in foreign trade. He showed that, depending on the risk preferences of an individual, the forward exchange rate isn't simply related to expectations of future exchange rates. In fact, he showed that the forward rate could not be an unbiased estimate of the expected future exchange rate for investors in both the home country and the foreign country; if the world were populated by risk-neutral investors, no equilibrium could exist. His conclusion would have policy consequences for central banks, which used forward rates as a predictor of where the exchange rate was headed. This result became known as "Siegel's Paradox."

This might sound like a rather subtle result to be given a formal name. But Fischer Black (of Black-Scholes option-pricing fame) explained the paradox and its implications for investors in international equities.[12] Black presented an example of two countries that exclusively consume either apples or oranges. Although the current exchange rate between the countries in this example is 1:1, the exchange rate next year will be either 2:1 or 1:2 with equal probability. Surprisingly, it's still beneficial for consumers in each country to trade apples for oranges and vice versa. The broader implication is that investors should generally not hedge 100 percent of their foreign investments.

Siegel was surprised by the reception to his article. "The 'paradox' was not the major point of my article. I thought of it as a curiosity. The main point of the article was how to derive the probabilities that a currency would devalue. But the paradox intrigued so many economists. For many years afterwards, I would get articles from someone who claimed 'Dr. Siegel, I think I've solved your paradox.' But I never worked on solving it, since international economics was not my major field. As an aside, Professor Lars Hansen from the University of Chicago, and 2013 Nobelist, proudly introduced me at a conference and said, 'Quite a number of economists have won the Nobel Prize, but few have a paradox named after them!' I thanked him but said I would be most happy to trade my paradox for his Nobel Prize!"[13]

Siegel's first academic appointment, in 1972, was at the University of Chicago, but in the Business School, not the economics department, because at that time the department wasn't hiring. Nonetheless, he was excited to be at the same institution as Friedman. Siegel later reflected on having Friedman as his colleague. "I loved the way he analyzed the world, the way he looked at political issues. He was very interested in what was going on in the economy and in the financial markets, which was my field of interest. So, to me, having him as a colleague and a close friend was very special."[14] Siegel would often join Friedman for lunches at the Quadrangle Club, the faculty club of the University of Chicago. "Milton was not only a first-rate intellectual, he was a truly warm person. I felt very comfortable talking with him. We would discourse on so many topics: monetarism, the volunteer army, inflation and interest rates, and political trends around the world."[15]

Coincidentally, Siegel left for the Wharton School at the University of Pennsylvania around the time Friedman retired from academia. "My four years at Chicago (1972–1976) were the last four years Milton Friedman was there. Afterwards I went to Wharton; Milton retired to San Francisco. Friends jokingly asked, 'Well, Jeremy, did you leave because Milton left, or did Milton leave because you were no longer there?' Of course, Milton had long planned retirement for that time. He and his wife Rose had been at Chicago virtually all their lives, and Rose, being from the West Coast, craved warmer weather!"[16]

In 1976, Siegel arrived at Wharton, where he remains. He reflects that his time at Wharton has given him "lots of great memories. The students so enjoying my market discussions before the formal class.

Dinners with my honor students. Faculty lunches where we talked about everything from economics to politics to our students. Inviting Warren Buffett to Wharton to speak—the first time he had been back to the campus after leaving as a student almost a half century earlier. And being able to interview both Ben Bernanke and Janet Yellen at our huge Annenberg Theater. The list is almost endless."[17]

In 1990, Siegel spent a year as a research fellow at the Federal Reserve Bank of Philadelphia. "The Fed always fascinated me. I was a research fellow at the Board of Governors in the summer of 1968, after my first year at MIT. Monetary policy and the economy are my favorite topics, and there was always someone at the Fed to talk about this with."[18]

From Economics to Investments

Although trained as an economist, Siegel also had a strong interest in investments. His particular niche was applying academic economic concepts to the area of investments. One of his earliest ventures was investigating the relationship between the stock market and business cycles.[19]

The concept of the business cycle sometimes causes confusion, perhaps because its name suggests a regular, periodic motion. But the business cycle is no such thing. Business cycles capture changes in overall economic activity, as measured by the gross domestic product (GDP) of the country, and the occurrence of these changes is quite unpredictable. There are four key drivers of economic activity: consumption, including goods we buy and the services we pay for; business investment, such as capital expenditures made by corporations; government spending; and net exports, or a country's exports less imports. If economic activity and hence the GDP increases, the economy is in an expansionary phase of the business cycle. As the GDP declines—by an informal definition, for at least two consecutive quarters[20]—the economy is in a recessionary phase.

There is a connection between the stock market and the business cycle. As the economy grows, corporate profits and stock prices increase. Since stocks reflect expected future cash flows, we expect the stock market to be a leading indicator of where the economy is headed. However, no leading indicator is a perfect predictor. As Samuelson famously quipped, "The stock market has predicted nine out of the last five recessions."[21]

Siegel was able to establish that investors could potentially enhance their returns by actively switching between stocks and bonds—*if* they were able to anticipate turning points in the business cycle. It was also one of his first forays into investigating a long time series of data, almost two centuries' worth. He relied on a stock return index from 1802 through 1990 compiled by University of Rochester professor Bill Schwert. Siegel also tracked short-term interest rates and economic recessions, as determined by economists at the National Bureau of Economic Research. In the forty-one recessions in his sample, thirty-eight of them, or 93 percent, were preceded or accompanied by declines of at least 8 percent in the stock market. For recessions after World War II, the average lead time between the peak of the stock market and the economic peak was 6.4 months.

Over these two centuries of data, the average stock returns were 9 percent, while average short-term risk-free bond returns were 4.3 percent. Over this period, the economy was in recession just under one-third of the time and in expansion just over two-thirds of the time. Not surprisingly, stocks did better than bonds during expansions, and the reverse was true during recessions.

Siegel investigated how much better investors would do, relative to a benchmark buy-and-hold investor, if they could predict the turning points for expansions and recessions and invest all of their money in bonds in a recession and stocks in an expansion. Predicting turning points by three to six months in advance would improve an investor's average annual returns by nearly five percentage points. But even knowing precisely when each turning point was would only improve performance by half a percentage point. However, knowing you're at a turning point is not easy, and it can take economists a year or longer to conclude with confidence that a turning point has been reached. In addition, if the investor missed the turning points by just a few months, then he or she would be worse off compared to the buy-and-hold benchmark.

Siegel concluded that the ability to predict business cycle turning points could potentially enhance stock investment returns, but this is a feat that few can achieve. Beating the stock market by analyzing real economic activity requires a degree of prescience that forecasters don't yet have.

The Puzzling Premium

In 1992, Siegel published three articles that combined his economic background with his investment interests and his forte in creatively analyzing data. All three articles tried to solve the puzzling results of Rajnish Mehra and Nobel laureate Edward Prescott, who attempted to measure what is known as the "equity premium."[22]

To explain the puzzle, we'll need some background. The equity premium is the difference between the return on equities (such as the market portfolio) and a risk-free yield, such as the yield on Treasury bills. The equity premium is important because it helps us to estimate the cost of equity, which in turn helps us estimate the intrinsic value of stocks. It's also important in regulated industries such as utilities, where fair returns are prescribed that, in turn, determine the utility price. Mehra and Prescott compared their empirical results to predictions based on consumption-based asset pricing models, a variation of Bill Sharpe's capital asset pricing model (CAPM) that factors in consumption in order to calculate the expected returns on investment. Based on U.S. data between 1889 and 1978, Mehra and Prescott found that equity returns were much higher than expected, and the risk-free returns were much lower. Why were equity returns so high?

In his first 1992 article, Siegel used previous empirical studies to construct a long series of interest rates, adjusted for inflation, back to 1800 in both the United States and the United Kingdom.[23] (Interestingly, he relied, in part, on interest rate data collected by Sidney Homer, Marty Leibowitz's uncle-in-law.) Siegel found that the real return on bonds outside of Mehra and Prescott's sample period were 4 percent higher, explaining much of the puzzle. In other words, while Mehra and Prescott's sample period was long, its bond returns may not have been characteristic of future bond returns because their historical series did not go back far enough.

Siegel's second 1992 article, published in *Financial Analysts Journal*, was a winner of the Graham and Dodd Scroll Award.[24] Like with his previous article, Siegel used almost two centuries of data to examine the equity premium. This article provided a snapshot of the work that went into his famous book *Stocks for the Long Run*, published two years later. His research showed that over the period 1802–1990, equities provided returns that were better than bonds, gold, or commodities. He was surprised to find that the real (or inflation-adjusted) return on stocks was remarkably steady, while the real return on bonds declined dramatically. He concluded that going forward, stock returns would probably continue to dominate bond returns, but not as significantly as since the Great Depression, noting that "equities, however, still appear to be the best route to long-term wealth accumulation."[25]

Siegel's third 1992 article investigated the October 1987 stock market crash.[26] While a historical footnote for many, like those whose investments only began in the twenty-first century, the 20.5 percent decline in the broad S&P 500 index on October 19, 1987, is still the greatest one-day market drop in history. At the time, many commentators drew parallels to the October 1929 stock market crash and the Great Depression. Siegel pointed out that in both cases, there was no precipitating news event that justified such drops in prices. However, while the 1929 crash was followed by plunging profits, massive bankruptcies, and the greatest economic depression of all time, the 1987 crash was followed by increased corporate profits and a continuing expansion of the economy. He examined whether changes in expected equity returns could rationalize such a large decline in stock prices or if changes in the expectations of future corporate profits could account for it. Under the first assumption of changes in expected equity returns, Siegel concluded that the equity risk premium would have had to drop from around 5 percent in January 1987 to less than 2 percent in October 1987, then back to 5 percent in early 1988—an unprecedented shift in the premium. Using the second assumption of changes in expected corporate profits, however, Siegel found that around October 1987 there was considerable dispersion in the expectations of profit growth. Using the profit forecasts of the top 20 percent of the most optimistic forecasters, he calculated that the valuation of equities was two to three times greater than those using the forecasts of the most pessimistic 20 percent. Given this variation, he concluded that it was possible that a shift in sentiment between the most optimistic forecasters and the most pessimistic was a key factor in the 1987 crash.

Several years later, Siegel returned to investigating the equity premium with the future Nobel laureate Richard Thaler.[27] They investigated the empirical results of previous studies that tried to explain the equity premium (including Siegel's 1992 articles) and commented on the extent to which those papers solved the puzzle. Siegel's earlier article suggested that a longer time period was warranted when calculating the equity premium. Other studies suggested that there was a survivorship bias in the data: by focusing on a single market (the United States) with a growing economy and a vibrant stock market over the centuries, the data overlooked the rational worries of investors who thought there may be a small chance of an economic catastrophe. Siegel and Thaler also examined several theoretical explanations to solve the equity premium puzzle, including different models about the levels of risk aversion found among investors to account for their behavioral biases, that explain much but not all of the puzzle.

In their commentary, Siegel and Thaler argued that the equity premium should remain positive but at a lower level—around 3 percent. They used an analogy to Rip Van Winkle to imagine an investor who makes an asset allocation decision, then goes to sleep for twenty years. "For long-horizon investors such as the young saving for retirement, pension plans, and endowments, we find the case for equities compelling. However, if after reading this piece you decide to put more of your retirement savings in stocks, remember we are stressing long-term results and will not accept complaints for 20 years. Feel free to call us in 2017."[28] Ironically, 2017 was the year when Thaler won the Nobel Prize in Economics, and fortunately, stock returns did handsomely outpace bond returns over that period.

Siegel would again tackle the equity premium in another award-winning article in 1999, which was published in *Journal of Portfolio Management* and won the 1999–2000 Bernstein Fabozzi/Jacobs Levy Award.[29] In it, he continued to argue that given the high level of the stock market relative to corporate earnings (the price-earnings [P/E] multiple) in late 1999—around 32—the forward-looking equity premium might be considerably lower than the historical average of around 6 percent estimated by Mehra and Prescott. Siegel also argued that the reported historical risk-adjusted equity returns overstated the realized returns to investors, given the transaction costs and inadequate diversification that existed during much of this historical period.

How exactly did equities compare to risk-free investments for the twenty-year period between the beginning of 1998 (just after the publication of his article with Thaler) and the end of 2017, a period that included the bursting of the dot-com bubble and the most severe recession since the Great Depression? Using data from Ken French's website, the average annual compound U.S. stock market return was 7.6 percent, while the average Treasury bill return was 1.9 percent.[30] Over this period, the equity premium was 5.7 percent, in line with Mehra and Prescott's historical estimate, and almost double the conservative expected equity premium forecast by Siegel and Thaler. Even though their estimate was low, there should be no complaints (and hence no phone calls) about their comments from investors who put more pension money into stocks and heeded their advice!

Stocks for the Long Run

In 1994, Siegel published his most popular work, the book *Stocks for the Long Run*. It became a best seller, with hundreds of thousands of copies sold through its five editions.[31] The most recent edition has the subtitle "The Definitive Guide to Financial Market Returns and Long-Term Investment Strategies," and it certainly is that. The *Washington Post* included the book in its list of the ten best books for better investing.[32] Interestingly, the publication came seventy years after another book on the same topic, *Common Stocks as a Long Term Investment* by Edgar Lawrence Smith.[33]

How the book came to be is an interesting story. According to Siegel, "It was about 1987—I was at Wharton for ten years—when one of my colleagues, Marshall Blume [part of University of Chicago's "once-in-a-lifetime cohort" of PhD students], called me up and said, 'Jeremy, I just got a call from the New York Stock Exchange. They're coming on their two hundredth anniversary, and they want to write a book about the history of the exchange.' And he said, 'I know you've done a lot of macroeconomic research, but I know you like markets. Do you want to work with me on this project?' And I said, 'I'd love to.' I was ready for a change.

"I decided I was going to research historical returns for the project and let Marshall write the institutional material. I dug for data all the way back to 1800 using Bill Schwert's [data] and then used the Cowles Foundation data to come up with these long-term returns. We presented this material to the New York Stock Exchange. They said, 'We love the research, but there's too much here, and we have to pare it down. We think we want more of the policy and institutional results.' My colleague, Marshall Blume, in a tremendous act of kindness, said, 'Jeremy, stay coauthor on this work' (even though he did most of it). 'And why don't you write a book on all this other [material], yourself?' My good friend, Bob Shiller, also encouraged me to write a book. I wrote a couple of articles for *Financial Analysts Journal* and *Journal of Portfolio Management*, and I got wonderful receptions on both, so I decided, 'Yes, I'm going to write a book.' All these years of thinking about markets and how they fit into macroeconomics was finally going to pay off. Readers like the fact that the book is so well macro-grounded. That was not true of much of the other finance literature at the time. That was one of my special contributions."[34]

Siegel began his book with "the single most important chart." This chart (figure 11.1) presented total real returns on stocks, bonds, Treasury bills, gold, and the U.S. dollar from 1802 through the present on a logarithmic scale so that the slope of the curve represented the real return. The striking feature of this chart was the stability of the real returns for equities—it was apparent by how straight the long-term trend line was

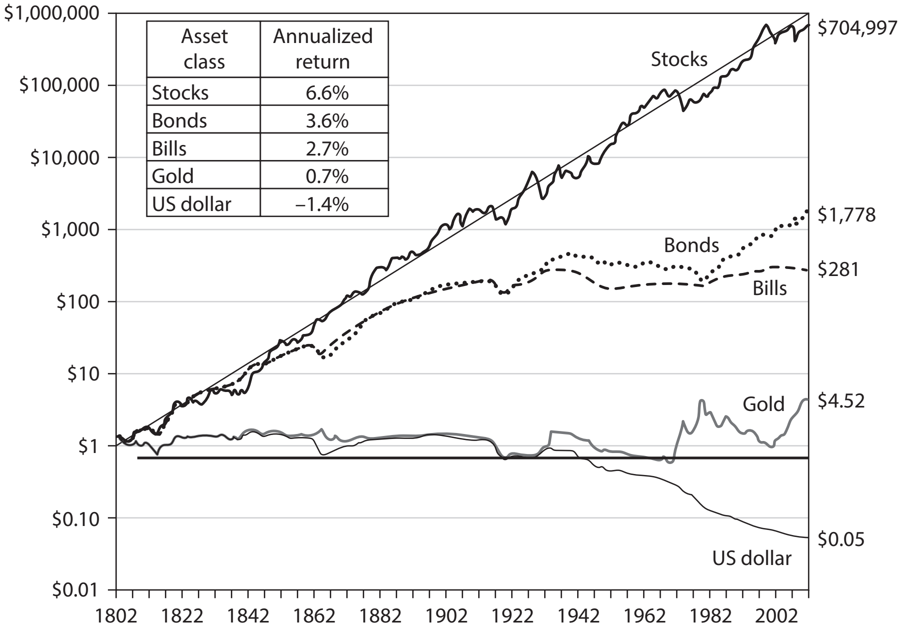

FIGURE 11.1: Total real returns on U.S. stocks, long-term government bonds, Treasury bills, gold, and the U.S. dollar, 1802–2012. Reprinted with permission from Siegel (2014, 6).

for stocks. The real returns for equities were just under 7 percent per year. This implied that the purchasing power of a basket of well-diversified stocks almost doubled in value each decade, on average, for over two centuries.

Stock returns might sometimes fluctuate above or below the trend line but eventually would return to the trend, a statistical property known as “mean reversion.” Siegel noted that none of the other asset classes exhibited that property. He emphasized that while in the short run stocks could be quite volatile—for example, due to business news related to corporate earnings, economic news such as changes in interest rates, or psychological factors such as investor optimism (greed) or pessimism (fear)—the short-term factors that preoccupied investors and the press appeared as mere blips compared to the overall upward trend. In other words, you should simply invest in stocks for the long run!

Siegel also tackled some major macroeconomic trends that might have an impact on the future of stock returns. Ever the optimist, he wanted to counter much of the pessimism in America in 2010 following the Great Recession of 2007–2009, when more than half of Americans felt that their children would actually be worse off than their parents. He argued that there were indeed "forces that might renew the American Dream and restore economic growth."[35] On the one hand, there are unprecedented numbers of individuals in the developed world entering retirement age, giving rise to the questions of who will produce goods and services for them to consume and who will buy the assets they will sell in order to finance their retirement. If countries rely only on their own populations, the retirement ages in a given country with low birth rates must increase in order to have a sustainable economic model for retirement. On the other hand, the strong growth in emerging economies such as China and India, may be able to produce enough goods and generate enough savings to purchase the assets of retirees in developed countries with low birth rates. Siegel concluded that such growth could still enable future stock returns to stay near their historical levels.

One of Siegel's most important insights focused on the riskiness of investing in stocks. While he noted that stocks were much riskier than bonds in the short run, he showed that stocks were actually safer than bonds for long-term investors who wanted to preserve the purchasing power of their wealth. For example, between 1802 and 2012, the range of real stock returns over a one-year period from worst to best was −38.6 percent to 66.6 percent, while for long-term government bonds the range was −21.9 percent to 35.2 percent. However, for thirty-year periods the annual real stock return ranged from 2.6 percent to 10.6 percent, while for long-term government bonds the range was −2.0 percent to 7.8 percent. Siegel concluded, "Historical data show that we can be more certain of the purchasing power of a diversified portfolio of stocks 30 years hence than we can of the buying power of the principal on a 30-year U.S. Treasury bond."[36]

Samuelson and others had argued that stock returns behaved as random walks. If this were true, then the relative risk of a portfolio shouldn't depend on the investment horizon. But that wasn't what Siegel found. In fact, as Siegel noted, the short run was different from the long run, contradicting Samuelson's position that "the long-run portfolio allocation should not be different from the short run—advisers had always thought it but couldn't prove it, [and] the fact [was] that if you really do have a long horizon, you should be more in equities than if you have a short-term horizon."[37]

This was the most profound finding in *Stocks for the Long Run*. "I think the main ideas that struck people, not so much that stocks had better returns—everyone knew, in the long run, they had better returns—but I think what they didn't know is that once you study longer periods, the relative volatility of stocks goes down. In other words, [stock returns were] not a random walk in the long run. In the long run, real returns reverted to a trend line. When my first edition came out, that trend line was 6.7 percent per year return after inflation. Even in the updated edition [twenty years later], it's 6.7 percent real return. After all the volatility we've had in the last twenty years, the long-term real return of stocks has remained constant. So, stocks are mean-reverting in the long run, which made the long-run profile of risk relative to bonds much less scary than the short run."[38]

Predicting the Tech Wreck

By April 1999, the Dow Jones Industrial Average had just surpassed the 10,000 level for the first time, while the tech-heavy Nasdaq index had risen from a level of 744 to 2,484 over the past five years, or over 233 percent. Siegel was concerned. "I worried that stock prices had reached heights from which they would yield poor returns. It was tempting to urge investors to sell and wait for prices to come back down before going back into stocks. But when I investigated the market in depth, I found that overvaluation infected only one sector—technology; the rest of the stocks were not unreasonably priced relative to earnings."[39] Siegel observed that the market value of the technology sector had reached almost one-third of the entire S&P 500, and for the first time ever the trading volume on the Nasdaq exchange was greater than on the New York Stock Exchange. This was when he decided to take a stand.

Siegel wrote an op-ed piece in *The Wall Street Journal* with a succinct question and answer in the title: "Are Internet Stocks Overvalued? Are They Ever."[40] This was the first time he sounded the alarm publicly on market valuations of Internet companies.[41] In his article, he argued that buyers of Internet stocks would only continue to make money if they convinced subsequent investors that the stock was going to be worth more tomorrow than it was today. "But no market in history has continued to rise without bound," he wrote. "Eventually the value of assets must confront the law of economics. This law dictates that the value of any asset must be tied to the future cash returns paid to the owner of the asset."

Siegel argued that merchandising margins for Internet companies were likely to be quite small, as Internet purchasers were interested in the discounted prices used to attract them compared to brick-and-mortar shopping. He also warned that buying out the competition at astronomical prices couldn't persist. "Eventually the big Internet companies must convert all this Monopoly money into hard earnings, or their prices will collapse."[42] He cited the example of AOL that was selling for more than 700 times its past annual earnings and 450 times its expected earnings, which made justifying its $200 billion market value difficult. At that time, AOL shares were trading at $139.75, a huge increase from a trading price of $29 in September 1996. (Shortly before its merger with Time Warner in January 2001, the stock would reach a low of $32.39.) He concluded his editorial with an important distinction between the Internet revolution and market valuations. "I have no doubt that the Web will revolutionize the way goods and services are marketed. The Internet will deliver billions of dollars of savings to consumers. But this in no way guarantees those billions will be handed over to the suppliers of this new form of communication."

On Wednesday, March 8, 2000, Siegel received a call from the editor of *The Wall Street Journal* asking if he wished to write another op-ed piece on what was happening with technology stocks listed on the Nasdaq.[43] Siegel agreed and a few days later submitted his article with the seemingly innocuous title, "The Lessons of History." On Friday, March 10, 2000, the Nasdaq index had risen to an all-time high of 5,048, more than double its level from the previous year. He was invited by Stuart Varney to be a guest on CNN's *Moneyline*, the network's main financial show for over twenty years. Siegel wanted to talk about Cisco and other tech companies without condemning them. He began mildly, first commenting that Cisco was a great company, and yet its stock was historically pricey at 150 times earnings. He then noted how the valuations of big-cap tech stocks had risen dramatically over the past five months and commented that the value could disappear just as quickly. Asked by Varney to conclude whether the tech market was in a bubble and whether the air would come out soon and fast, he replied, "It will come out. . . . I think we are going to see some very big declines in the sector this year." Later, Varney would claim that Siegel was the man who called the market top.

The following Tuesday, Siegel's follow-up piece in *The Wall Street Journal* appeared. He was shocked that the editors had chosen a new headline, "Big-Cap Tech Stocks Are a Sucker Bet."[44] While he was prepared to apologize for the headline that he hadn't chosen, he received little flak—since, after all, the timing of his article turned out to be right around the market top. Commenting recently on the timing of the article, he modestly observes, "Now, people said, 'Jeremy, you were within two or three days of calling the absolute peak of the Nasdaq. How did you do that?' And I said, 'It was damn luck.' Absolutely. I don't think I knew it was the peak. I just knew the markets were crazy."[45] His intuition stemmed from his earlier investigation of the "Nifty 50" stocks, such as Polaroid and IBM, that traded at high P/E multiples in the 1970s. "I said that no big-cap stock really deserved a P/E of over 50 or 60."[46]

In his article, Siegel explained that once companies got to such market values, they couldn't grow earnings fast enough to justify the valuations. "Investors who purchased these and many other stocks when the future looked brightest had much to regret."[47] He noted that no stock that sold above a 50 P/E ratio was able to outperform the S&P 500 index over the next twenty-five years. He identified nine large-cap stocks, among the top fifty largest by market value, that were selling for more than one hundred times their 1999 earnings. He then assumed that their earnings would grow at twice the rate as the S&P 500 over the next five years. Under this rosy forecast, the average P/E ratio of these stocks would only drop to 89.

Siegel once again observed that while the excitement generated by the technology and communications revolution was justified, this wouldn't necessarily translate into increased shareholder value. His conclusion: "Value comes from the ability to sell above cost, not from sales. . . . In a competitive economy, no profitable firm will go unchallenged. Margins must erode as others chase the profits that seem so easy to come by now. There is a limit to the value of an asset, however promising. Despite our buoyant view of the future, this is no time for investors to discard lessons from the past." Over the next two and a half years the Nasdaq fell over 75 percent, and it would be fifteen years before the Nasdaq index reached the 5,000 mark again.

Traps and Waves

In 2005, Siegel published his second major book, *The Future for Investors: Why the Tried and the True Triumphs over the Bold and the New*.[48] In it, he addressed two questions that audiences continually asked him in speaking engagements: "Which stocks should I hold for the long run?" and "What will happen to my portfolio when the Baby Boomers retire and begin liquidating their portfolios?" To answer these questions, Siegel coined the new term "growth traps" and discussed the global solution to the upcoming "age wave."

To address the question of long-run stock returns, Siegel compared an old-economy company, Standard Oil of New Jersey (which became ExxonMobil), with a new-economy company, IBM, and asked the question: Back in 1950, which stock would you buy and hold for the next fifty years (reinvesting all cash dividends into more stock)? He also provided investors with a crystal ball of sorts to assist in the decision-making process, giving them information on actual revenue, dividends, earnings, and sector growth. In all categories, IBM was the hands-down winner. So, would you have chosen IBM as the investment? If your answer, like most readers, is "yes," then you would have fallen victim to the growth trap. Between 1950 and 2003, a $1,000 investment in IBM would have grown to $961,000, but the same investment in Standard Oil would have grown to $1,260,000.

How does the growth trap happen? According to Siegel, "Because [Standard Oil] had a lower price and when you reinvest the dividends from that lower price or when the firm engages in buybacks at that lower price over long periods of time, that sends you ahead. That was a big surprise to me, because in Wall Street everything is earnings growth. In a short run, yes, that is an important factor, but really, in the long run, the P/E ratio matters more. Dividend yield became very, very important in long-run returns."[49]

Siegel dug deeper. He examined all of the five hundred stocks that constituted the original S&P 500 index when it was first formulated in 1957. He found that the original firms outperformed newcomers, many of which were in high technology and exciting new industries. Furthermore, the original firms outperformed while displaying lower risk. The growth trap is based on the incorrect belief that innovation and economic growth leaders automatically provide superior returns for investors. While earnings, sales, and even market values of the newer firms grew faster than those of old firms, the price paid by investors was often too high for investors. This is because higher prices implied lower dividend yields, and dividend reinvestment was a key to superior accumulated returns. Siegel's basic investor principle specified that growth alone didn't result in good stock returns; rather, only growth in excess of any overly optimistic estimates built into stock returns. He concluded, "Investors will receive a superior return only when earnings grow at a rate higher than expected, no matter whether the growth rate is high or low."[50]

To address the second question of the effect of baby boomer retirement on investor portfolios, Siegel examined the economic consequences of the rapidly aging U.S., European, and Japanese populations. "It worried me too because I knew there was a population bulge. I was a baby boomer, and I knew that we were going into retirement, and we were going to be selling our portfolios to finance our consumption.

Who was going to buy our assets? Are the younger generation rich enough to buy our assets? These were the questions."[51] He first observed that much of the rest of the world was quite young, and their economies were growing rapidly. He developed a model to forecast the world economy in broad terms and concluded that if the growth of developed countries could be sustained, this would mitigate the negative consequences of the age wave in the developed world. "The next half century will see a massive exchange of goods for assets that will not only shift the center of the world economy eastward but also negate the destructive impact of the age wave on asset prices and retirement opportunities. I call this 'The Global Solution.'"[52]

The Bull versus the Bear

Siegel's relationship with Bob Shiller goes back a long time. "I met Bob on my first day at graduate school at MIT in September 1967. So, it's now more than a fifty-year [relationship]. We liked each other immediately, and we've maintained a really close personal friendship."[53] According to Shiller, "I met Jeremy standing in line for a chest X-ray. They sent us in alphabetical order, Shiller and Siegel. . . . Our books tend to be adjacent to each other in book stores."[54] Both were in the same class of MIT's economics PhD program. Yet there is quite a contrast between some of their macro views. Given his warnings about the overvalued stock market around 2000 and the overvalued real estate market around 2006, Shiller has a reputation as a "bear." In contrast, Siegel has a reputation as a "bull," given the theme of his best-selling book, *Stocks for the Long Run*. Is it a surprise that they are such good friends?

According to Siegel, "People say, 'But he's been a bear.' Or they called Bob the 'perma-bear' and they called me the 'perma-bull.' And why do we get along? Because we respect each other's point of view. And you know, Bob turns out to be much more risk-averse than I am. He was always worried about risks in the real world. For example, when I would walk at the edge of a cliff or building because I wanted to see a view, Bob would say, 'Jeremy, come back from there! Don't go so far! Something could happen! You could trip!' I was always a little bit more risk-taking than Bob; maybe that has to do with our psychology of that. Nevertheless, we still maintain a very, very close friendship."[55]

Siegel and Shiller have shared the spotlight on countless occasions. They've had both agreements and disagreements. Recall that during the technology stock boom, Siegel wrote two opinion pieces for *The Wall Street Journal* warning of overvalued stocks. Shiller was also sending warnings. Siegel commented, "Well, I agreed with him. Don't forget the original irrational exuberance was the 2000 bubble, and . . . his timing couldn't have been better either. [Shiller's *Irrational Exuberance* book] comes out in March of 2000. . . . I mean, we both hit the jackpot then. And we were exactly in synch on that bubble."[56]

In 2016 when Donald Trump was elected president, Siegel and Shiller also shared similar views about Trump's likely effects on the stock market. "Right after Trump was elected, we both said, he and the Republican platform were good for the market. Believe it or not, Bob was a bull! We were filming in New York early in Trump's administration, and [the National Public Radio host] asked us a question, 'Do you think the market is going to be higher a year from now?' and both of us unequivocally said, 'Yes.'"[57]

Where Siegel and Shiller have had some vigorous discussions is in the area of Shiller's cyclically adjusted price-to-earnings (CAPE) model. As seen in chapter 9, its basic idea is that investors should be willing to pay for a stock several times what a company generated in earnings, since the investor expects more earnings in the future. To avoid the issues related to the volatility of earnings over the business cycle, Shiller and his coauthor Campbell used an average of earnings over a rolling ten-year period in their calculations. They found that periods of high valuation or high CAPEs tend to be followed by lower stock returns, as the CAPE ratio returns to more normal levels. In 2016, Siegel wrote an article in *Financial Analysts Journal* with a critique of the model.[58] While calling it "one of the best forecasting models for long-term future stock returns," Siegel added an ominous "but . . .".

Siegel's concern about Shiller's CAPE model was based on changes in the Generally Accepted Accounting Principles (GAAP) that may have led the model to be too pessimistic. "The reason why it has not been a very good predictor over the last decade is because since Bob wrote that article, FASB [Financial Accounting Standards Board] has changed the way firms are mandated to report what's called GAAP, or reported income, . . . particularly by forcing firms to mark their assets to the market. This meant that during the recession that followed the financial crisis, earnings just totally cratered, even more than during the Great Depression, because of the new accounting rules. So, as a result when Bob computes his ten-year average, you're going to have a very low denominator (ten-year average earnings), and the market is going to look like it is overvalued. So, I said the CAPE ratio should be recomputed, and I've suggested other ways of computing the CAPE ratio (such as with using operating earnings), which brought down dramatically the degree of market overvaluation. Now, I've talked to Bob about this and he said, 'Yeah, you might use another earnings concept.' I said, 'But your website only uses GAAP.' He said, 'Yeah, everyone's used to it. I'm leaving it alone.'"[59]

Siegel pointed out that all it takes is a few firms with large losses to distort the aggregate P/E multiple of a stock index. For example, during the financial crisis of 2007–2009, AIG, Citigroup, and Bank of America together lost in excess of $80 billion. The losses of AIG alone erased the aggregate profits of the thirty most profitable firms in the S&P 500 in the fourth quarter of 2008. Siegel proposed an alternative earnings measure that avoids the changes in GAAP: national income and products accounts, a measure of profits that have been compiled by economists, going back to 1928. Siegel's adjusted CAPE model explains more of the variability of future ten-year returns than Shiller's traditional CAPE model.

In August 2018, the U.S. stock market had the longest bull market in history, with the S&P 500 index rising from a low of 676 on March 9, 2009, to around 2,862 on August 22 and with no declines of 20 percent or more during that period. At that time, there was much uncertainty as to whether the market was overvalued. To try to answer that question, Siegel the bull and Shiller the bear made their cases at a Wharton-sponsored conference in New York City, "Financial Markets, Volatility and Crises: A Decade Later."[60]

Siegel first presented his bull case. Using S&P 500 company operating earnings, he estimated that the average P/E multiple between 1954 and 2018 was 17, with a low of around 7 in March 1980 and a high of 30 in June 1999. In September 2018, the P/E ratio was in the low 20s, based on the last 12 months of earnings, dropping to 18 based on current year earnings and to 16 based on forecasted earnings for 2019, not out of line with historical averages. Based on the current ratio, he forecasted real returns of about 5.5 percent (or nominal returns of 7.5 percent, assuming 2 percent inflation). With real ten-year Treasury notes yielding 1 percent, the equity risk premium was estimated at 4.5 percent, somewhat above the historical average of around 3–3.5 percent.

Siegel's conclusion: "Stocks are overvalued on a long-term basis, but bonds are enormously overvalued on a long-term basis. The relative valuation of stocks relative to bonds is actually among the more favorable in history."[61] Finally, he noted that investors today are able to buy index funds at virtually zero cost, which were not available before. Their availability is an argument for a higher-equilibrium P/E ratio compared to historical averages.

Shiller then presented his bear case. He agreed with Siegel that history was important but emphasized that large movements in P/E ratios don't happen very often, yet when they do you want to understand why they are happening. Around World War I, for example, there was a huge jump in the earnings of companies, and yet the stock market did not rise very much. Shiller made the claim that in 1916 markets "did the right thing" by not overreacting to the sudden increase in earnings, because it was just a temporary phenomenon.

In contrast, when earnings increased between 1921 and 1929, the market reacted dramatically. Shiller considered the peak in 1929 as an overreaction, because "it was a different atmosphere. It was the roaring 1920s. They just wanted to believe it."[62] In contrast, earnings were increasing in the early 1980s, but stocks were not. The spirit of the times was very different, with double-digit inflation and very high interest rates. "The market is filled with real people, and they have their own stories they're telling and ideas change from time to time. So, should we think like [it's] 1916 or not? Is this temporary?"[63]

Shiller concluded that the market was overreacting again. "It's likely to be a bad time for the stock market." With a then-current level of CAPE at 33, he observed that the average ten-year forward return was less than 1 percent. He remained convinced that stock valuations were "just too high at the present day." Time will tell who was correct.

The Wisdom of ETFs

Siegel is the senior investment strategy adviser at WisdomTree Investments, an asset manager with almost $70 billion in assets under management (as of 2021) that focuses exclusively on exchange-traded funds (ETFs).[64] The firm first launched ETFs in 2006 and now sponsors ETFs across many asset classes and globally. WisdomTree was founded by Jonathan (Jono) Steinberg, a Wharton graduate, son of Saul Steinberg, who was also a Wharton graduate and a major benefactor to Wharton (Siegel's office is in Steinberg-Dietrich Hall).

Since the late 1990s, Steinberg has been researching ways to reinvent index funds. He was one of the pioneers of fundamental weighted investments, developed in contrast to traditional market-value index weighting. Its intention was to mimic the positive characteristics of index funds including low fees, high liquidity, and diversification while producing better returns with less risk.[65] Around 2003 or 2004, Steinberg contacted Siegel and according to Siegel said, "'Jeremy, you know, I've been working on variant indexes. Instead of weighting by market capitalization, let's weight by earnings or dividends. But you guys, you have the ability to do all the econometrics and math. Would you like to look at it?'" Siegel replied, "'Yeah, I'll look at those.' And we actually looked at those and we said, 'Wow, these have very good historical risk-return.'"[66]

Siegel explained the logic behind the product. "Instead of weighting by just market-weighted, what you did was you weighted the firms by their share of either earnings or dividends, which of course means that every year or whatever time period you decide, you have to rebalance your portfolio. Those that have gone up more than their earnings, you sell down. Those that do not go up as much as their earnings, you increase. So, that adjustment of your portfolio on the basis of fundamental factors is called fundamentally weighted indexing. And when I asked him, I said well, 'Jono, what are you going to do?' He said, 'We're doing ETFs.' And back then, 2004, there wasn't very much [in terms of ETFs from which to choose]. There was a SPDR, which is S&P, and the Nasdaq. . . . I told him, 'You know, I've been a Vanguard fan, so we can't charge much.' He said, 'I agree with you.' When we actually came out, for nonindex, we were the cheapest of all the providers."[67]

Siegel cautioned that it will take decades to develop a record that can validate WisdomTree's theories. Vanguard's founder, Jack Bogle, is skeptical, while Gene Fama sees the strategy as a repackaging of the "value premium."[68] The verdict is still out on the fundamental weighting approach.

Siegel's Perfect Portfolio

What is Jeremy Siegel's view of the Perfect Portfolio? Much of it is rooted in his earlier writings, including *Stocks for the Long Run*. There, he concludes his classic with six guidelines to successful investing:[69]

1. Keep expectations in line with history, with inflation-adjusted stock returns of 6 to 7 percent and P/E multiples of about 15.
2. With longer investment horizons, put a greater proportion of investments in stocks.
3. Invest the bulk of your stock portfolio in low-cost stock index funds.
4. Invest at least one-third of your equity portfolio in international stocks.
5. Tilt your portfolio toward value stocks (such as those with low P/E ratios or higher dividend yields).
6. Establish firm rules to keep your portfolio on track in order to remove emotions.

Why invest for the long run? Siegel later described his reasoning. "In *Stocks for the Long Run,* I recommended that investors link the equity portfolio of their portfolio to broad-based indexes of stocks, such as the S&P 500 Index or the Wilshire 5000. I had seen so many investors succumb to the temptation of trying to 'time' the ups and downs of the market cycle that I believed a simple, disciplined, indexed approach was the best strategy."[70] This advice extended in particular to those saving for retirement. "If you're in a long-run orientation and anyone saving for 401(k)'s, IRAs, they're looking ahead to their retirement, the bulk of their assets should be in equities."[71]

In his 2005 book *The Future for Investors*, Siegel expanded beyond advising for a pure index fund approach with his three-pronged D-I-V Directive: dividends, international, and valuation.[72] First, buy stocks with sustainable cash flows that pay dividends to shareholders. Second, recognize that economic power is flowing away from the United States, Europe, and Japan toward China, India, and the rest of the developing world. In his book, Siegel recommended substantial 40 percent foreign-based equity allocations.[73] "Sticking with only U.S. equities is a risky strategy for investors. . . . Only those who have a fully diversified world portfolio will be able to reap the best returns with the lowest risk."[74] Third, buy stocks with reasonable valuations relative to their expected growth while avoiding hot stocks and IPOs.

Based on these considerations, Siegel suggested an equity holding made up of 50 percent in world index funds: 30 percent U.S. based and 20 percent non-U.S. based. The remaining 50 percent would be allocated to return-enhancing strategies in four areas, with 10–15 percent in each area: first, high-dividend strategies, such as high-yielding stocks, as well as real estate investment trusts; second, global firms, such as those in the S&P Global 100 index and diversified multinationals; third, sector strategies in oil and natural resources, pharmaceuticals, and brand-name consumer staples; and finally, stocks with a low price relative to growth, such as those with low P/E ratios.

Even past the age at which most people retire, Siegel continues to advocate for equities over bonds. "I don't own any treasuries, and especially today with yields being so extremely low, I prefer cash as my cushion rather than longer-term bonds."[75] However, he did state, "I like TIPS [Treasury Inflation-Protected Securities]."[76] As mentioned previously, these are government-issued bonds in which both coupon payments and the principal adjust as inflation changes. For equities, he continues to believe in low P/E or value stocks. "I would definitely tilt toward the value side."[77] Siegel is a believer in the notion of dollar-cost averaging, putting a fixed amount of money in investments on a regular basis (such as monthly), noting that it "serves a psychological purpose in the sense that people hate to buy at a point and then see it go down."[78] While cautioning against high-cost financial advisers, he does see the benefit of having an adviser: "If you need someone to help you stay focused and in equities when times are bad, definitely, an adviser can help you an awful lot in terms of doing that."[79]

Ever the optimist, Siegel remains bullish on markets and the aggregate economy. "I think there are good things coming. I mean, we see the advances in AI [artificial intelligence], nanotechnology, in robotics. They're on the horizon. You don't have to be in those companies; it will be fierce competition in terms of that. I think everyone is going to benefit. Keep focus on that long run, as I say."[80] And he remains bullish on emerging and developing markets such as China, India, and South Korea. "There is unbelievable potential in those countries to grow, and they're going to buy our goods as well. You don't have to buy their companies to get their returns, because our companies are going to serve them also."[81] Siegel's final observation? "Longer-term truths survive short-term fluctuations."[82]

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So, What Is the Perfect Portfolio?

IN AKIRA KUROSAWA's masterpiece film *Rashomon*, four witnesses to a terrible crime come up with vastly different and mutually contradictory accounts of the same event. Each witness had a personal motivation to present the events of the murder in his or her own way. Which of their narratives is correct? Kurosawa let the audience decide, a technique that still makes for compelling drama. Today, psychologists call this phenomenon of warring interpretations "the Rashomon effect."

In the same way, the Perfect Portfolio means different and even contradictory things to different people. Given the ten different luminaries we interviewed with such varied backgrounds, it's no surprise that we don't have consensus. The different viewpoints of our experts highlight the innate complexities of portfolio management, and we should acknowledge that one size doesn't fit all. In fact, the problem is even more difficult than *Rashomon*, since the Perfect Portfolio is a moving target. It's similar to the question "What should I do to be healthy?" The answer depends not just on your current medical condition but also on how far medicine has progressed and what tools are available today. Moreover, there isn't just one answer to how to be healthy—there are multiple combinations of diet, exercise, medicines, and supplements or "nutraceuticals" that can lead to longer and higher-quality life, even for one particular individual. And while the politically correct answer to our health question is to say "it's all of the above," this provides little comfort for the individual who wants to know exactly how to attain "optimal health." What we're all looking for is the particular regimen of diet, exercise, and medicines that is right for us. And this is why we need primary care physicians and—for those who can afford them such as professional athletes—personal trainers, dieticians, and even sports psychologists.

Similarly, there isn't a single answer to what good financial health looks like, and that's why we interviewed ten of the greatest minds the investment community has ever produced. The Perfect Portfolios of our experts are really building blocks for our own Perfect Portfolio, each meant to address only a few needs of any given investor but collectively capable of accommodating the goals and constraints of all investors if used in the right combination.

So, what's the right combination? As Hamlet acknowledged, "There's the rub." The question remains as to how to put their deep insights together to help you build that Perfect Portfolio. We start by recapping the highlights of their perspectives before attempting to synthesize them.

Markowitz's Perfect Portfolio

It's been seventy years since Harry Markowitz realized that what matters for a portfolio of stocks is how they vary in price relative to one another. Modern portfolio theory was born in that aha moment in the University of Chicago library. Markowitz gave us a process and a discipline to analyze stocks as a portfolio. He was the first to formalize the idea of diversification of investments mathematically, helping us to get closer to the holy grail of investing by showing us that risk can be reduced without sacrificing expected return through a portfolio of stocks that aren't perfectly correlated.

Thanks to Markowitz, we now understand that diversification is key to constructing the Perfect Portfolio. This calls for a top-down process: start with an asset class, such as stocks or bonds, before worrying about the choice of individual securities, such as whether to invest in Coca-Cola, Walmart, Alphabet, or Tesla. You don't need to be a stock picker like Warren Buffett to do well in the long term with your investments if you follow a disciplined process that will get you on or near the efficient frontier. Markowitz's efficient frontier means you don't need to focus on every individual security in your investment set; focus only on portfolios of securities that have the highest level of expected returns for a given level of risk or, conversely, the lowest level of risk for a given level of expected return. In other words, you don't need to get it absolutely right; rather, you just need to be close to getting it right.

At this point, Markowitz's process becomes almost magical. Not only can you use the efficient frontier for securities within a particular asset class, such as stocks, but you can use it across assets as well, for bonds, real estate, commodities, or other types of investment. This means you can analyze portfolios of securities across various asset classes for your Perfect Portfolio, such as stocks and bonds. Here, history should be your guide for developing estimates for the expected returns, variances, and correlations of the different asset classes that are the key inputs into efficient frontier analysis.

However, your output will only be as good as your input: as the ancient programmer saying goes, "garbage in, garbage out." Your forward-looking estimates will need to be determined very carefully. For example, if interest rates have gone down over the past ten years and bond prices have gone up, then historical bond returns will look pretty good. But if you start from a lower interest rate, expected bond returns may be much lower than historical bond returns.

You also need to have a good sense of your own level of risk tolerance. Once you understand what this means—no simple matter, since people aren't naturally used to thinking about asset-return volatility and what that means for one's retirement assets—find a well-diversified portfolio that reflects your desired risk level. Through experience and perhaps with assistance from a financial adviser, you will get a sense of the asset mix that's right for you.

How you implement this mix also matters. For Markowitz, the easiest way is through low-cost exchange-traded funds (ETFs) for equities, with a number of individual bonds for fixed income. You may also want to place constraints on how much weight you give to certain industries. Perhaps surprisingly, Markowitz doesn't feel that the market portfolio (consisting of *all* assets in the market) is particularly special, nor is it *the* investment one should necessarily make. But diversification is still the most important factor for the Perfect Portfolio.

For Markowitz, your Perfect Portfolio should evolve as you receive new information. You should update your beliefs relative to what you think will be happening in your life and what is important to you. The notion of perfection in a Perfect Portfolio is one that we pursue and one that's right for us. However, the asset mix remains the fundamental decision. As you age, your risk preferences and financial objectives may change, so your Perfect Portfolio should also change. Also, as you do your analysis, never forget about the impact of taxes: any analysis should be done on an after-tax basis.

Finally, Markowitz reminds us to look at the big picture. Keep in mind that the Perfect Portfolio isn't just about rational *investing* using his process. Rather, it's about rational *decision making* for financial planning in general.

Sharpe's Perfect Portfolio

Bill Sharpe's approach to the Perfect Portfolio is probably the most straightforward of all our experts, and it's also the closest to what their specific research suggests.

According to Sharpe's capital asset pricing model (CAPM; you can join Sharpe in pronouncing it as C-A-P-M instead of "Cap-em") and its close relative, the security market line, you should invest in a combination of a riskless asset and a market portfolio for your Perfect Portfolio. Here, Sharpe is very specific in his advice: you should invest in Treasury Inflation-Protected Securities (TIPS) for the riskless asset and index funds or ETFs that attempt to replicate all the tradable bonds and stocks in the world, ideally in market proportions, to approximate the market portfolio. Sharpe recommends a U.S. total stock market fund, a non-U.S. total stock market fund, a U.S. total bond market fund, and a non-U.S. total bond market fund for this component of the Perfect Portfolio, with an additional suggestion of currency-hedged global funds. He is a huge proponent of using low-cost investing to build a Perfect Portfolio.

Sharpe's other piece of advice regarding the Perfect Portfolio is to do some homework on longevity expectations. Save more now and be prepared to make some sacrifices for long-term financial stability during your retirement years.

Fama's Perfect Portfolio

In 1992, Gene Fama famously proclaimed that "beta is dead," and to further the *Rashomon* analogy, a case can be made that he was the killer. Surprisingly enough, however, Fama's Perfect Portfolio still begins with the market portfolio. Fama thinks of equity returns in the broader context of the risk-return trade-off, driven by other factors than just the market portfolio: for example, return differentials between small cap versus large cap stocks, value versus growth stocks, high- versus low-profitability firms, and aggressive versus conservative investment. He suggests that you may want to tilt your Perfect Portfolio toward smaller market capitalization stocks as well as toward so-called value stocks that have lower price-to-book ratios. Like our earlier witnesses, Fama is an advocate of low-cost investing, such as Vanguard.

Fama views your risk exposure as your personal choice while keeping the market portfolio as your anchor. However you decide to tilt, though, make sure it's through a diversified portfolio. You can never be too diversified. Keep in mind that there's no such thing as a free lunch: you can only achieve higher expected returns by taking on more risk. Finally, be careful of making any investment decision based strictly on past performance, which can be very noisy even over five-year periods.

Bogle's Perfect Portfolio

It shouldn't be a surprise that the founder of the Vanguard Group, Jack Bogle, believed that the Perfect Portfolio involved investing in diversified low-cost index funds. Under the floorboards of the house that Bogle built, however, are his four key elements to investing: risk, time, cost, and reward. While you can't control the reward, you can control the other elements. You can mitigate the risk of owning individual securities through diversification. Longer time horizons can help you build up your portfolio, and they will help reduce your risk as well. Ignore the short-term noise. And finally, as emphasized in Bogle's cost matters hypothesis (CMH), lower costs will increase your wealth.

The asset allocation of your Perfect Portfolio should change over time, starting out heavily in equities but holding some bond index funds as well as stock index funds. As a rule of thumb, your percentage of bond allocation should be close to your age. By the time you're at or near retirement, you should have a significant position in bond index funds. If your funds aren't in your retirement plan, then watch out for taxes. (Bogle specifically liked municipal bond funds because of their tax attractiveness.) According to Bogle, don't fret about rebalancing your portfolio, and certainly don't do it more than once a year. Place less emphasis on the value of your assets and more on the monthly income it can generate.

While Bogle's personal Perfect Portfolio was (unsurprisingly) almost entirely invested in stock and bond indexes, he also invested a small percentage in emerging market index funds and gold. Your Perfect Portfolio, however, really doesn't need to consider many if any investments outside of stocks and bonds. Bogle was a big proponent of U.S. markets, advocating only a 20 percent allocation to international equities. Whatever you decide, however, you should always take a buy-and-hold approach. Remember Bogle's mantra: "Don't do something, just stand there!"

Scholes's Perfect Portfolio

Unlike the previous experts, who stressed the importance of the market portfolio as a starting point, Myron Scholes stands out. For Scholes, the Perfect Portfolio is all about risk management. He starts from the assumption that what matters to you the most is your terminal wealth, such as the retirement nest egg that will allow you to retire in the lifestyle you want. Your investment success will depend most on avoiding the downside "tail risks," those relatively rare but severe stock market downturns, such as the financial crisis of 2007–2009 and the COVID-19 pandemic, while capitalizing on the positive "tail gains."

To manage your risk properly, you'll need to pay attention to what derivatives markets such as the VIX are telling you. For example, when the VIX is at a level below its historical average, you may feel more comfortable investing a greater proportion of your assets in risky stocks. Keep the risk of your portfolio at a target level by trying to minimize the peak-to-trough decline in the value of your portfolio, the drawdown. However, you not only want to avoid the negative tail risk but also want to take advantage of the positive tail gain. Don't just try to have low risk and instead consider taking on more risk when strong gains look probable.

While most of our luminaries are strong advocates for investing in index funds, Scholes is much more cautious. Be aware of the inherent and changing risks to these index fund strategies. For example, in the late 1990s and early 2000s, broad U.S. markets such as the S&P 500 had a huge weight in technology stocks. In Finland, at its peak Nokia by itself represented 70 percent of the country's stock market capitalization. That changing volatility can hurt compound returns, which in turn will hurt your terminal wealth. Another problem with index funds is that correlations between component stocks can increase dramatically in times of turmoil—but those are exactly the times when your Perfect Portfolio needs diversification the most. Think about what limits you're setting by investing in index funds.

Given his involvement in the development of the first index fund, it's a little ironic that Scholes sees a significant role for active management in the Perfect Portfolio. On the other hand, who better to see the risks of passive investment than one of its founders? Start by determining the maximum drawdown you feel comfortable with, then change your asset allocation (for example, between stocks and bonds) as the anticipated risks in the asset classes change.

Merton's Perfect Portfolio

Bob Merton begins like Markowitz in proposing that you should try to maximize returns in your Perfect Portfolio for a given level of risk. However, there are many more risks than mere stock volatility, which can be reduced by diversification. For example, think about the risk of not meeting your retirement needs. Ultimately, the Perfect Portfolio should be your very own risk-free asset, like government bond inflation-protected TIPS. For your retirement goal, ideally you would take your savings at retirement and buy an annuity that would provide a lifetime income to meet your anticipated needs. If it looks like you won't have enough saved by investing in a risk-free asset, then you'll need to invest some of your money in riskier assets in order to be able to achieve your goals.

That's where Merton feels the professionals can step in to help. Using his favorite car analogy, don't worry about what's under the hood of your Perfect Portfolio. You wouldn't know how to choose between an engine with a compression ratio of 10:1 versus one of 14:1; you just want to be able to get from point A to point B as safely and quickly as possible. So, leave it to the trusted professionals who might use a dynamic trading strategy to manage your risk exposure, particularly as you near retirement, through products similar to target-date or glide-path funds that change the asset allocation over time toward less risky assets—but in a more refined way and accounting for more than just your age.

According to Merton, you need meaningful information to make meaningful choices, and compression ratios aren't meaningful to the typical driver. So, don't worry about whether the asset allocation split between stocks and bonds in your Perfect Portfolio is 70/30 or 65/35; instead, find out from your professional adviser how likely you're going to be able to sustain your standard of living in retirement with a particular investment strategy. Provide your adviser with critical information including your current age, your desired retirement age, your income, your anticipated Social Security benefits, and the minimum income you would like to have in retirement. Then let the professionals tell you the odds of reaching that goal and what you'll need to do to reach it. But be realistic about how you can meet your goals if you're facing a potential shortfall: you may need to save more now, plan to work longer, be prepared to take on more risk, or adjust your financial goals.

Let's take a peek at what's under the hood at Dimensional Fund Advisors, where Merton has worked as resident scientist. Its defined contribution retirement products are connected to a global stock index and two TIPS bond portfolios with different durations, intermediate and long. Its Target Date Retirement Income Funds are similar. Merton's own Perfect Portfolio is similar to these products but includes a hedge fund. He also owns residential real estate, which brings us to his last point: Think about owning your own home in a place where you plan to live for the indefinite future.

Leibowitz's Perfect Portfolio

For Marty Leibowitz, the Perfect Portfolio is all about how much risk you can bear. If stock markets suffer a major decline, the usual course of action is to do nothing—but not always. While you want to avoid an emotional reaction of wanting to de-risk at the wrong time, if the level of risk in the market is higher than your ability to tolerate it, then you may need to reduce your equity exposure so you can sleep better at night. This means that while your Perfect Portfolio might begin with a buy-and-hold strategy, it may not always be that.

How do you know how much risk you can bear? Leibowitz wants you to think like a pension fund manager. First, estimate your funding ratio: the relative amount of investment assets you have (and the assured future income those assets can generate) compared to the discounted or present value of your future liabilities. In other words, see how much you have now versus what you'll need in the future. If you have a high funding ratio, then you can afford to take more risks with your Perfect Portfolio and invest more in riskier assets, such as equities.

But remember, there are no absolutes in investing. Just because you might be able to take on more risk doesn't necessarily mean that you *should* take on more risk. This is especially true when the markets appear to be expensive relative to historical averages (for example, think of Shiller's cyclically adjusted price-to-earnings [CAPE] measure) and the reward-to-risk ratio is well below what should be a reasonable level. It's also true when any additional return to you for more risk isn't worth it. If you already have enough assets in your Perfect Portfolio to cover your needs, you can simply invest in safer assets.

Be prepared to try to make some tough judgment calls in your Perfect Portfolio, and consider all of your circumstances, including potential life events, current taxes, and estate taxes, to name just a few. Recognize that your goals may change over time. Leibowitz feels that target-date funds can be helpful if you're looking to reduce risk as you age but, like Merton, is concerned about the rigidity of most target-date funds.

What assets should you include in your Perfect Portfolio? Not surprisingly, Leibowitz advocates that in addition to equities, it should include bonds and other fixed-income assets. Bonds can reduce the overall volatility of your portfolio and provide a relatively stable return. It all comes back to Markowitz's low-cost benefits to diversification. With a nod to Sharpe's CAPM, Leibowitz notes that you should take the risk level that you want to take, determined by your chosen beta. Don't ignore the risk of inflation, which even at modest levels over an extended period can erode your purchasing power. Finally, Leibowitz warns, make sure you have a contingency plan for how you will deal with serious adverse events.

Shiller's Perfect Portfolio

As one might guess from his reputation, behavioral economist Bob Shiller favors the exceptional and the individual. Your Perfect Portfolio should be widely diversified not only across major asset classes but internationally as well, since there is no way to predict accurately how one particular asset class or country is going to perform. Start by investing in U.S. stocks, but place a heavier than typical weight in stocks around the world, where Shiller's CAPE ratios—cyclically adjusted price-to-earnings ratios—are relatively low. Your Perfect Portfolio should also contain bonds, real estate, TIPS, and commodities, since these are investments with relatively low correlations with stocks. Then consider your own personal risks. Not only should you avoid investing in stocks in the industry in which you're employed, since you could face a double whammy by losing your job exactly when your company's stock is depressed, you might even consider a short position in your Perfect Portfolio to counterbalance that risk.

Shiller is personally a market timer. But while his CAPE ratio can be an indicator of when markets may be undervalued or overvalued, he cautions about market timing yourself. It isn't easy to call the top of a market bubble. Finally, be prepared to consider new financial instruments and products, such as Shiller's trill idea, that may become available as part of your Perfect Portfolio.

Ellis's Perfect Portfolio

As a highly informed spectator to the investment arena for over fifty years, Charley Ellis has witnessed many different players attempting to master the Perfect Portfolio. Can professionals really beat the market? Ellis wondered. He concluded that this premise appears to be false. For Ellis, your Perfect Portfolio should of course include index funds, especially if you want to have a good chance of being in the top 20 percent of funds over the next twenty years. It's all about minimizing your investment costs. However, you should invest in different kinds of index funds, including bond index funds and low-cost international funds benchmarked to the MSCI EAFE (Europe, Australasia, and Far East) index. Rebalance them to your desired long-term weights in different asset classes. Also, as in the Loser's Game, avoid blunders: be aware of your tendencies toward overconfidence, and keep your emotions in check.

For Ellis, the most important aspect of your personal Perfect Portfolio is that it should depend on who *you* are: your age, your dependents, your investment knowledge, your income, your spending habits, your assets, your comfort with risk, and your access to information. Pay attention to your taxes, including the turnover in any actively managed mutual fund. Finally, Ellis advises, remember that investing is all about you: your values, your history, and the Perfect Portfolio that will help you to reach your goals.

Siegel's Perfect Portfolio

Our last expert to weigh in on the Perfect Portfolio is Jeremy Siegel. His Perfect Portfolio starts with a few basic guidelines determined by his research into the long run. First, have reasonable expectations in line with history. Second, the longer your investment horizon, the *greater* proportion of your Perfect Portfolio should be in stocks. Your major investment should be in low-cost stock index funds, and at least one-third of your equity portfolio should be invested in international stocks. Tilt your portfolio toward value stocks with low price-earnings ratios. Finally, keep your emotions in check.

If you do invest in individual stocks for your Perfect Portfolio, Siegel suggests you buy ones with sustainable cash flows that pay dividends. Consider stocks from China, India, and the rest of the world beyond the United States, Europe, and Japan. However, only consider stocks with reasonable valuations relative to their expected growth, and avoid the hot stocks in the "new economy" and initial public offerings. The long run has a logic of its own.

Putting it all together, the recipe for Siegel's Perfect Portfolio includes an equity holding made up of 50 percent in world index funds: 30 percent U.S.-based and 20 percent outside of the United States. You should allocate the remaining 50 percent to strategies that will enhance your return, such as high-dividend stocks and real estate investment trusts; top global firms (e.g., those in the S&P Global 100 index) and diversified multinationals; sector strategies such as pharmaceuticals, oil, and natural resources, and brand-name consumer staples; and stocks with a low price relative to growth. For fixed-income investments, you should consider TIPS. Siegel also suggests putting a fixed amount of money in your Perfect Portfolio on a regular basis, the dollar-cost averaging approach, for the psychological value of the process. Finally, if you need help to stay focused (and in equities) when times are bad, consider a financial adviser for your Perfect Portfolio formation.

Putting It All Together

Like the events of *Rashomon*, we have multiple witnesses to the Perfect Portfolio, the equivalent of several centuries of observation and analysis made by ten of the brightest luminaries in the field. It shouldn't be a surprise that many of their broad answers are similar. After all, none of them are going to tell you to buy investments you can't afford and whose value will certainly drop.

It's the differences among these thinkers and, more importantly, the reasons behind their differences that demonstrate how they think about the Perfect Portfolio as a process. Their viewpoint is a function of their intellectual history and their experiences as scholars and practitioners. From the perspective of the adaptive markets hypothesis (AMH)[1]—the framework that one of us (Lo) has developed to reconcile the apparent conflict between behavioral and rational finance—the different narratives offered by our experts are adaptive responses to the unique experiences of each expert. For this reason, we have included events from their early lives and careers to see if there are hints of the seeds from which their convictions about the Perfect Portfolio have sprouted.

The basic idea behind the AMH is that the efficient market hypothesis isn't wrong so much as incomplete—it doesn't capture all aspects of how financial markets work, particularly during periods of crisis when investors are reacting emotionally rather than rationally. The AMH applies the principles of ecology and evolutionary biology to show that investors may not always act in the ways that economic theory predicts but that they do adapt to their environments and respond to economic incentives in ways that can be modeled and, in some cases, anticipated. One practical implication of the AMH is that the relation between risk and reward isn't necessarily stable over time. For example, the expected premium for investing in risky stocks compared to safe government bonds may be 5 percent at some times and 1 percent at other times. Another practical implication is that investment strategies will wax and wane, performing better in some environments and worse in others. For example, value stocks, with low price-to-book ratios, may do better over long periods but may experience underperformance relative to growth stocks, with high price-to-book ratios, over shorter periods.

The AMH also explains the variation between the Perfect Portfolios of our experts. When confronted with different environments or different investor preferences, individuals may adapt in different ways, yielding different Perfect Portfolios. There's nothing wrong or unexpected with such outcomes. As with John Maynard Keynes and his purported flip-flopping on the gold standard, it's okay to change your views when the facts change.

Starting from Markowitz, we can see that the idea of diversification of a portfolio as a means to reduce risk is universally accepted, but this may be the only thing our experts fully agree on. Even an idea as fundamental as the market portfolio, a portfolio of all assets in the global market, is only viewed as a starting point for the Perfect Portfolio by most of our experts. For instance, Siegel would tilt toward developing markets, despite their proportional lack of volume, while Bogle, surprisingly enough, would concentrate on U.S. indexes disproportionately. Markowitz himself doesn't think the market portfolio is all that important, while Scholes and Leibowitz make their analyses independent of it.

While most of our experts construct their Perfect Portfolios by considering risk versus return, Scholes and Leibowitz are unusual in that they think of risk as their primary consideration and work forward from there. From a purely statistical perspective this makes sense, because measuring risk is often easier than measuring expected return. If the old adage that "you can't manage what you can't measure" has any truth to it, then it should follow that you can better manage those things you measure more accurately. This is also the motivation for Bogle's CMH: you may not be able to accurately measure the future performance of a "hot" active manager, but you can certainly measure the fees that this manager charges. Given the various types of risk of any financial investment—market, liquidity, credit, and operational risk, just to name a few—these different starting points can lead to Perfect Portfolios that look very different from the variations on the basic theme of the market portfolio and a riskless asset on which our experts have converged.

We can also sort our experts by their preference for active versus passive management in their Perfect Portfolio. Bogle and Sharpe would stand at the passive end of the spectrum, while Scholes and Shiller would stand at the active end. Merton, on the other hand, would occupy a place entirely perpendicular to the spectrum, since he advocates letting a financial adviser help manage your Perfect Portfolio without you worrying about what's in it.

Is there any room left in the current world of index funds and ETFs for picking stocks in the Perfect Portfolio? Believe it or not, there is.

While not specifying any particular stocks, Fama's approach allows you to choose which factor tilts might improve your Perfect Portfolio, while Siegel suggests a variety of possible return-enhancement strategies to choose from. Meanwhile, Shiller suggests shorting your own employer's stock as a hedge (though that might trigger an uncomfortable conversation with your boss).

If there is one specific asset that a majority of our authorities recommend for your Personal Portfolio, it's TIPS, the inflation-linked bond issued by the U.S. Department of the Treasury. Inflation in recent years has been stable and low, but there is always the risk of macroeconomic change, something Leibowitz as the Bond Guru felt very keenly during the stagflation of the 1970s. There is also one particular asset that Merton recommends for the long run: owning your own residence.

Finally, while our luminaries have highlighted the importance of knowing your goals and your appetite for risk when developing your Perfect Portfolio, Markowitz, Sharpe, Bogle, Leibowitz, and Ellis also emphasize planning your Perfect Portfolio for the inevitable: taxes. In fact, this may be a corollary of Bogle's CMH—the most reliable cost of all is the cost imposed by government.

We've now arrived at the endgame in our pursuit of the Perfect Portfolio, where we hope to provide some structure and guidance. But please bear in mind our important investment disclaimer: We aren't providing you with financial planning advice—that's the job of a certified financial planner (CFP) or a chartered financial analyst (CFA) who is licensed to dispense advice and whose day job is focusing on private wealth management.[2]

As we mentioned earlier, the Perfect Portfolio is a moving target, one that depends intimately on *who* we are and *where* we are in our careers and stages of life and how favorable or hostile current market conditions are to our short-term and long-term goals. If you're a twenty-four-year-old computer engineer who just joined a tech startup, your Perfect Portfolio will look quite different than if you're a sixty-five-year-old bookkeeper who's looking to retire in the next few years.

Our endgame revolves around a fitting alliteration as the culmination to the *Pursuit of the Perfect Portfolio*: the Three P's of Investments. These three investment P's are *principles*, *process*, and *path*. We'll describe seven investment *principles* that apply universally and offer an important checklist for you to use before you invest. Our *process* involves a simple self-assessment of key characteristics that best describe who you are—related to investing, saving, and spending—and what kind of investment environment in which you find yourself. As Charley Ellis put it, "It is about you, your values, your history, your financial situation." Your answers to these simple questions help place you in one of sixteen categories or archetypes. These archetypes provide you with a quick assessment of your financial situation, which in turn points you to our final P, the *path* to the Perfect Portfolio, including what action you might need to take today.

Let's begin with the *principles* of how you construct your Perfect Portfolio, which is the same starting point for everyone:

P1. Determine how much expertise you have in financial planning and how much time and energy you're willing to devote to managing your Perfect Portfolio. This will determine whether you can embark on your investment pursuit alone or whether and when you should seek professional help. Back to our health analogy, in the same way that you may need to see an obstetrician, surgeon, or allergy specialist, you may also need to seek the assistance of financial specialists with expertise in mortgages, taxes, or estate planning.

P2. Determine what your current and future financial needs are. This isn't easy and requires deep personal reflection and a significant time commitment as well as regular reviews and some financial expertise, so you may also need the help of a professional here. Some obvious starting points are identifying your current income, both professionally and through any current investments. Next, identify your current expenses. The harder part is identifying future income and expenses. Don't forget about Social Security and the important decision of when to take it. There may be some tough decisions involving family planning, saving for education, and retirement planning.

The key is to start with overall life goals, then translate them into financial goals.

P3. Find your comfort zone regarding financial gains and losses. How much can you lose in your savings or retirement account before you begin to freak out and start moving your assets into safer investments? How much will you allow your portfolio to grow before you decide that you want to lock in your gains? Think about the riskiness of your job or your business and what illiquid assets you might hold. Even if you can't hedge against some risks, you don't need to double down. For example, you may not want to invest in your own company (if it's a publicly traded one), or even in companies in your industry. If recessions lead to big problems in your business, then a portfolio that might crash in recessions or becomes illiquid along with your job isn't such a good idea.

P4. Think about your investment philosophy and what you believe about markets. We hope that the journey with our investment pioneers has inspired you to reflect and develop your own philosophy. For example, are you in Fama's camp, and are you convinced that, by and large, markets are efficient (particularly the U.S. stock market)? If so, then index funds are the place to start. That's what the average investor would probably do. Do something else only if you think you're different from the average. But also recognize, as Shiller and other behavioralists point out, that almost everyone thinks they're smarter than average. Be prepared to update your investment philosophy based on new and convincing evidence.

P5. List all the assets that you have and the assets you're willing to hold, such as mutual funds, ETFs, stocks, bonds, real estate, and so on. Keep in mind that mutual funds and ETFs come in many different shapes and sizes. As Bogle pointed out, the traditional index funds (TIFs) that are broad-market, low-cost, no-load index funds are designed to be bought and then held for the long term. What about derivatives—are you comfortable with them, as Scholes and Merton are? You may not even be aware that many investment products are actually derivatives in disguise. Your list will be the menu of assets from which the Perfect Portfolio will be built. Also, think about assets you *aren't* willing to hold. Think about Leibowitz's dragon risks. Keep in mind, you should never make an investment based on what you *think* will happen if you don't know what *might* happen—a lesson many learned the hard way during the financial crisis of 2007–2009.

P6. Develop a sense of the current investment environment and how stable that environment appears to be relative to historical norms. In a stable environment, stable investment rules such as 60 percent stocks and 40 percent bonds might be sufficient, but in a rapidly changing economy, investment rules may have to be equally dynamic. The key here is to manage the risk of your Perfect Portfolio so you are (a) exposed to only those risks that you're comfortable bearing (based on principles P2 and P3 above), (b) maximally diversified across investments that carry the highest possible premium relative to their risk, and (c) comfortable monitoring your investments on a regular basis, especially as market conditions and your own personal circumstances change over time.

P7. Avoid obvious investing mistakes. Bogle and Ellis remind us that these mistakes may include paying higher fees than needed, experiencing high (and potentially costly) turnover in your portfolio, needlessly incurring taxes, and investing with active managers based solely on trust and friendly connections. That guy, Bernie, may be charming on the golf course, but be careful giving him your money. If you decide to take on a lot of additional risk by borrowing to invest, make sure you've got the cash reserves for margin calls. Shiller reminds us that we don't always act rationally. We may think of ourselves as *Star Trek*'s Mr. Spock, but often act more like Homer Simpson.

If this checklist of principles seems complex, well, it is. And this is why our ten experts ended up with ten different Perfect Portfolios.

None will be exactly right all the time for all investors, but they're all based on the seven principles we just described, and in the context of the AMH, they all make sense because they represent distinct adaptations to different environments and investor types.

Next, to our *process*, which flows directly from the principles. Let's better understand who you are and where you are today. Then we can see where you fit among sixteen different investor archetypes, which we hope will serve as a starting point for your quest to find your Perfect Portfolio. These sixteen archetypes depend on four key characteristics: (1) your degree of risk aversion, (2) the magnitude of your current and future wealth and earnings power, (3) the magnitude of your current and future financial needs, and (4) the investment environment. We call these the RISE criteria: risk, income, spending, and environment. Think of them as helping you to rise above it all so as to achieve your goals.

To make things concrete and yet very simple, let's give names to the two extremes for each of these four characteristics. For risk aversion, let's label the risk-averse investor "Dove" and the risk-seeking investor "Hawk." Markowitz got the ball rolling by creating the mean-variance framework, and both Scholes and Merton have emphasized that it's important to pay attention to risk. Here we're referring to your tolerance for risk, or the amount of risk you're willing to bear. Let's label the high-income investor "Midas" (everything he touches turns to gold) and the low-income investor "Penia" (the Greek goddess of poverty; yes, there really was such a mythological figure). We'll label the big spender "Gatsby" (from the eponymous novel by F. Scott Fitzgerald) and the miser "Scrooge" (from Charles Dickens's classic novella *A Christmas Carol*). And finally, let's divide the market environment into "expansion" and "recession." Of course, it's much easier said than done to categorize an environment as either expansionary or recessionary, as it often takes economists six months or more after the start or end of a recession to make such a categorization. However, Siegel's research shows us that if we can predict business cycle turning points and invest more heavily in stocks before the trough in the business cycle and then switch out of stocks before the peak of the business cycle, investors can outperform a buy-and-hold equity strategy—again, much easier said than done.[3]

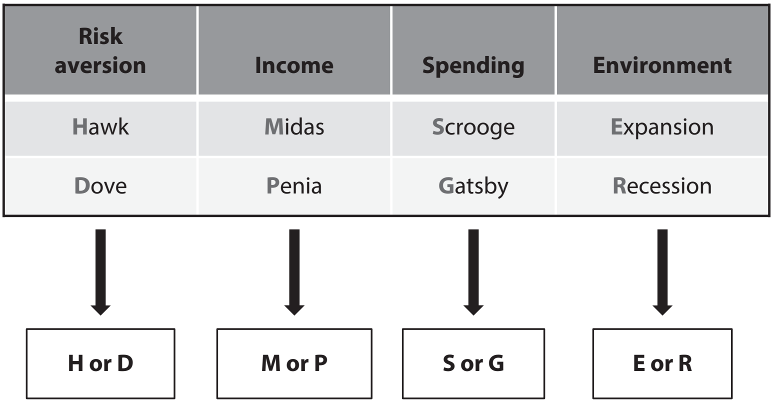

FIGURE 12.1: Determine which of sixteen investor types fits you best based on four key characteristics: (1) risk aversion (Hawk or Dove), (2) income level (Midas or Penia), (3) spending needs (Scrooge or Gatsby), and (4) economic environment (expansion or recession).

You may want to rely on professionals such as economists, who in turn often rely on business cycle models, to answer this question about where we are in the current environment.

With these simple binary categories, we've now subdivided the population of investors into $2 \times 2 \times 2 \times 2 = 16$ unique archetypes (see figure 12.1), each of which has a different set of financial concerns in particular environments and a different Perfect Portfolio that's ideally suited to address them. For example, a Hawk with the Midas touch who's a Scrooge with her money and living in an expansion is in great shape and can be fully invested in the stock market—including investments in active strategies (if that's consistent with her investment philosophy) and sector-specific funds such as biotechnology—so as to take full advantage of the equity risk premium. However, a Dove with the Penia touch who's a Gatsby with the little money that he has and is living in a recession has to be exceedingly careful about not just his portfolio but also controlling household expenditures and anticipating unexpected expenses such as health care issues or property damage. For this individual, a balanced portfolio tilted toward fixed-income securities but with some passive equity exposure may be more appropriate.

These sixteen investor archetypes are, of course, a gross oversimplification of the different types of investors. Although we were inspired to develop this framework from the typology of the Myers-Briggs personality instrument, keep in mind that our classification is determined by not just the investor's financial traits but also external conditions such as the market environment. Also, even personal traits such as income levels and spending patterns aren't immutable properties of your psyche and can easily change due to changes in your circumstances. And the binary categories are all clearly extremes that may not reflect the more common middle-ground characteristics that make up everyday experience; sometimes we're Doves, other times we're Hawks, and most of the time we're somewhere in between.

Nevertheless, these categories can be very helpful in coming up with the path to your own Perfect Portfolio. Figure 12.2 enumerates all sixteen archetypes, each coded in ovals (OK), rectangles (caution), or hexagons (danger) to reflect the degree of concern you should have with respect to your financial health (we'll discuss the last column shortly). Ovals indicate no immediate issues in achieving your financial goals; rectangles indicate potential problems that may require readjusting your spending, saving, or investment patterns in the near term; and hexagons signal imminent financial danger that requires your immediate attention. Table 12.1 contains narrative descriptions that provide more concrete examples of all sixteen investor archetypes.

The way we arrived at the OK/caution/danger categorizations was based on a simplistic equal weighting of each of the four characteristics—scores of 4 or 3 were deemed to be OK, scores of 2 were caution, and scores of 1 or 0 were danger. The intuition behind our scoring was as follows. Hawks are willing to take on more risk than Doves and so are willing to invest in riskier assets such as stocks, which historically have rewarded investors with higher expected returns. Midas earns a higher income than Penia and so has greater savings and investing potential. Scrooge spends less than Gatsby and so also has greater savings and investing potential. Finally, stocks tend to do better than bonds in expansions but not in recessions.

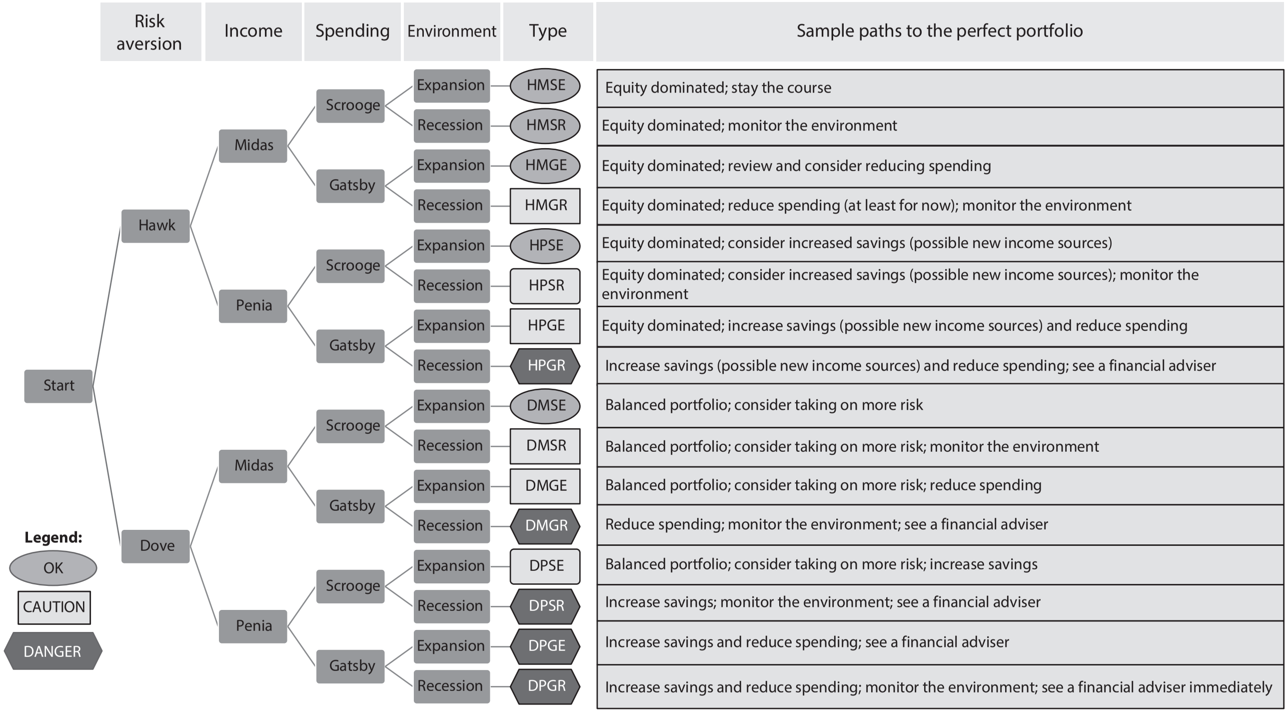

FIGURE 12.2: The sixteen investor archetypes, as determined by four key characteristics: (1) risk aversion (**H**awk or **D**ove), (2) income level (**M**idas or **P**enia), (3) spending level (**S**crooge or **G**atsby), and (4) economic environment (**E**xpansion or **R**ecession). Based on which archetype fits you best, the coding shape indicates the degree of financial security you face: oval for no significant issues in achieving your financial goals, rectangle for potential problems that may require readjusting your spending/saving/investment patterns, and hexagon for financial danger that requires your immediate attention.

TABLE 12.1. Narrative examples of sixteen different investor archetypes.

Archetype	Example
HMSE	An orthodontist living quietly in the suburbs who does excellent work but wants to ride the current economic wave into beachfront early retirement
HMSR	A lawyer at a top local firm always saving some mad money for a rainy day, but this seems to be a rainy year, and she/he doesn't know where to begin
HMGE	A high-rolling architect in the prime of her or his career with expensive tastes and expensive fees and a client base willing to pay for the occasional long shot
HMGR	A systems engineer for that company you've definitely heard of who likes the good life but knows that the recent boom has gone bust
HPSE	A single parent who scrimps and saves for her or his children's future, as bright as they can possibly imagine
HPSR	A struggling small business owner who works in the shop to save on expenses but despite the retail apocalypse is still betting on a small nest egg
HPGE	A college student partying hard who wants to go for the gold now and the good job out there will take care of it later
HPGR	A college student partying hard who wants to go for the gold now because there doesn't seem to be a good job that will take care of it later
DMSE	A heart surgeon who gets a large enough share of risk on the operating table, thank you very much, and doesn't need to hear about those schemes of yours on the golf course, Bernie
DMSR	An anesthesiologist who remembers the market collapse that happened in the old country as a child and sees the recent downturn as confirmation
DMGE	A pediatrician who likes nice things but thinks the stock market boom is barely a step above a lottery ticket
DMGR	A flight engineer who loves the layovers in Las Vegas, even though those flights are down with the economy, but never gambles there
DPSE	A worker at a nonprofit who sees that donations are going up but is skeptical that the capitalist system will be able to do anything worthwhile with her or his savings
DPSR	A retail clerk who is saving the way he or she has been brought up, but the pay isn't very good, the economy isn't very good, and those investments in those subway ads look very shady
DPGE	A schoolteacher who spends so much out of pocket on enrichment for her or his students that taking a vacation is unaffordable and has been watching the boom but just wants to park her or his money somewhere safe
DPGR	A new assistant manager with a new family and new expenses who is relieved to have been hired at all in this job market

Of course, there are quite a few limitations to our simplistic categorization: different scores and categorizations might have resulted from different weights, other characteristics that we haven't included may be important, and few people represent the extremes in our categories, to name just a few. The main point of this exercise is to get you to think about the four RISE characteristics and the impact they may have on reaching your financial goals and to recognize when you may need to reach out for professional advice.

Our final element is the *path* to the Perfect Portfolio, also shown in the last column in figure 12.2. Some of the descriptions indicate whether you should be equity dominated (considerably more than 50 percent) or more balanced (roughly equal in stocks and bonds), based on your willingness (or unwillingness) to assume risk. These simple sample portfolios don't include other important assets such as real estate—which for many people is your largest investment of all—nor do they suggest active versus passive investments, sectors, or individual stock investments. What would be included in your own Perfect Portfolio depends on your investment principles discussed earlier (in particular, see principle P5). Other parts of the description encourage increased savings (and hence increased investing) or decreased spending, depending on where you fit as Midas/Penia or Gatsby/Scrooge, and on monitoring the environment during recessionary periods. And finally, other parts indicate when you should really reach out for help from a financial adviser for specific advice. Back to our medicine analogy, we're trying to do some triage here.

The path to the Perfect Portfolio highlights four levers you have available to help in achieving your financial goals: (1) the target size of your financial goals, (2) how much you're willing and able to regularly contribute by way of savings and investing, (3) the length of time you have to achieve your goals, and (4) the expected return of your savings and investing. These dovetail with Bogle's emphasis on risk, time, cost, and reward as well as with what Merton suggested to us in the face of financial challenges: "Save more, work longer, or take more risk." When we talk about the Perfect Portfolio per se, we're really only focusing on the last lever, the expected return on your portfolio. That's because expected returns are driven by your choice of assets in which to invest. But the *path* to the Perfect Portfolio involves all four elements. Let's explore each component further.

First, there's the size of your financial goals. For example, at retirement you want to have enough financial assets to cover the stream of expected expenses. You can think about those assets as being converted to an annuity on your retirement date that will provide a steady stream of income to cover the expected expenses. Of course, you also need to account for anticipated inflation, unanticipated medical expenses, bequest motives for heirs if any, and so on. If you're anticipating a shortfall or just want to be prepared for one, then you may have to readjust your financial goals—perhaps just one big vacation each year instead of two.

Second, there are your savings and investments. Here we need to consider both your income and your spending—it's the difference between the two that's the key. Perhaps you have opportunities to become more like Midas by supplementing your employment income with another source of income—for example, by unleashing your dormant entrepreneurial spirit and creating a side business. Perhaps there are expenses that can be curtailed so you can become more Scrooge-like. As our luminaries such as Sharpe have implored, it's all about savings, which in turn is about making sacrifices.

Third, timing is key. The best time to start investing and saving was yesterday. The next best time is today. Bogle touted the magic of compounding. (Warren Buffett used a snowball analogy.) In order to achieve your financial goals, you may need to postpone some of your life goals and choose to work a few extra years.

Fourth, we can make different investment choices that change our expected returns—for example, with a 75/25 percent split in stocks/bonds instead of a 25/75 split. But we need to recognize the important risk implications of such choices. Siegel shows us that stocks have higher expected returns and are riskier than bonds in the short run although not necessarily in the long run. Capturing the equity premium—the expected stock market return in excess of the expected government bond return—implies a willingness to take on more risk. So, if you have dovish tendencies, are you prepared to be more hawkish with your portfolio and invest more in risky assets such as stocks? Before you do so, you may need to really understand the nature of any increased risks and what might cause stock prices to drop suddenly.

Our Perfect Portfolio today is really just a snapshot of what's best for you at the moment and in the current environment. Expected returns are ever evolving. In the early 1990s it was relatively easy to find safe government bonds with yields of 4 percent or more in excess of inflation. In the 2020s such inflation-adjusted yields are negative. The pursuit of the Perfect Portfolio is all about adapting to our current income, our spending habits, our financial goals, the environment, and expected returns. If Zen masters are correct that you can never step into the same river twice, it follows that you may never have the same Perfect Portfolio twice if you're adapting as frequently as you should. Nevertheless, even the most enlightened Zen master must agree that no matter which river you step into, you're going to get wet.

So, back to the archetypes, in practice you're likely to switch from one archetype to another as you age and your financial and life circumstances change and as the investment environment changes. By familiarizing yourself with these different categories and their particular financial implications, you'll become more adaptive to changes in your life and in the economic climate. And that, after all, is the most important key to survival: adaptation. In the end, our approach to the Perfect Portfolio leads us to an important conclusion, the ancient Greek philosophers' maxim "Know thyself." Easier said than done, but at least we have principles, a process, and a path to guide us on where to start in designing our own Perfect Portfolio.

It's been over three centuries since English philosopher John Locke coined the phrase "the pursuit of happiness" and almost two and a half centuries since Thomas Jefferson incorporated that phrase into the Declaration of Independence. Locke noted that the pursuit of happiness is the foundation of liberty. In a similar way, the pursuit of the Perfect Portfolio is the foundation of financial liberty—the freedom to reach your financial goals and all the happiness it may bring. We hope you enjoyed accompanying us on this journey with our financial pioneers, and we wish you great success and happiness in your pursuit of the Perfect Portfolio.

NOTES

Chapter One

1. See Lo and Hasanhodzic (2010, chap. 1).
2. See Kuijt and Finlayson (2009).
3. See Goetzmann (2016, 23–24).
4. See Goetzmann (2016, 41).
5. See "History of Bonds," E. R. Munro and Company, https://www.ermunro.com/bonds/history/.
6. See Weber (2009, 434).
7. See Goetzmann (2016, 48–50).
8. See Killgrove (2018).
9. See "A Case for the World's Oldest Coin: Lydian Lion," RG.Ancients, http://rg.ancients.info/lion/article.html.
10. See Palaniappan (2017) and Chatnani (2010, 23).
11. See Poitras (2009, 489–90).
12. For his speech against Aphobus, see Demosthenes, *Against Aphobus 1*, 27.1, Perseus Digital Library, http://www.perseus.tufts.edu/hopper/text?doc=Perseus%3Atext%3A1999.01.0074%3Aspeech%3D27.
13. See Sosin (2001).
14. See Sosin (2014).
15. See Kampmann (2012a).
16. See Kampmann (2012b).
17. See Goetzmann (2016, 229–30) and Goetzmann and Smith (2019).
18. See Nath (2015, 162).
19. See "Bank of England," Britannica, https://www.britannica.com/topic/Bank-of-England.
20. See Cummings (2015).
21. See Nisen (2014).
22. See Bernstein (2004, 152–56) and Neal (2005, 165–76).
23. For a short account, see Narron and Skeie (2013).

24. Mackay ([1841] 2006). For detailed accounts, see Kindleberger and Aliber (2015). For a time, Mackay's book was recommended reading by the CFA Institute for those preparing for Chartered Financial Analyst exams.

25. Rotblut and Shiller (2015).

26. Garber (2000).

27. Garber (2000, 26).

28. For a detailed portrait of Law, see Buchan (2018). See also Mackay ([1841] 2006), Murphy (2005), and Kindleberger and Aliber (2015). For a short account, see "Mississippi Bubble," Britannica, https://www.britannica.com/event/Mississippi-Bubble.

29. See Velde (2007).

30. While there are many accounts of the South Sea Bubble, this brief accounting is based on Hoppit (2002).

31. See Velde (2009).

32. Murphy (1991, 1112).

33. Velde (2009, 119).

34. In a review of Garber's book, John Cochrane (2001, 1154) concludes that Garber's careful accounting of these purported bubbles provides an important lesson for researchers: "The traditional historian's rhetoric of checking original sources can delightfully undress the occasional emperor."

35. See Rouwenhorst (2016, 217).

36. See Rouwenhorst (2016, 224).

37. Chambers, Dimson, and Foo (2015).

38. For an interesting investigation of the origins of the purported quotation, including Paul Samuelson's involvement, see "When the Facts Change, I Change My Mind. What Do You Do, Sir?," quoteinvestigator.com, https://quoteinvestigator.com/2011/07/22/keynes-change-mind/.

Chapter Two

1. Interview with authors.

2. For background related to Markowitz's early years and for events surrounding the serendipitous moment described in this chapter, see Markowitz (1991), Bernstein (1992), Markowitz (1993), Yost (2002), Buser (2004a), Fox (2009), and Markowitz (2010).

3. Interview with authors.

4. Interview with authors.

5. Interview with authors.

6. Interview with authors. Markowitz was particularly proud to be a recipient of the John von Neumann Theory Prize, awarded to an individual or group that has made fundamental and sustained contributions to theory in operations research and the management sciences. "I have von Neumann's picture with the first computer posted on the cork board in one of my rooms."

7. See Friedman (1976). First awarded in 1969 and commonly known as the Nobel Prize in Economics (as we will typically refer to it), but not one of the original categories, the formal name of the prize is the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel.

8. See Savage's biography, "Leonard Jimmie Savage," MacTutor, http://www-history.mcs.st-andrews.ac.uk/Biographies/Savage.html. For the academic study itself, see Friedman and Savage (1948).

9. See Friedman and Friedman (1998, 146).

10. See Koopmans (1975).

11. See Marschak (1946).

12. Fox (2009, 348n13) attempted to determine the identity of the stockbroker. Markowitz had no recollection. Marschak's son Thomas said his father wasn't a major investor but did own some stocks, so it was possible that it was Marschak's stockbroker. It is also possible that the stockbroker was waiting to see someone else at Cowles or was simply making cold calls. It remains, according to Fox, "a great (and at this point probably unsolvable) mystery of financial history."

13. Interview with authors.

14. For a variety of perspectives of events described in this section, see Markowitz (1991), Bernstein (1992), Markowitz (2002), Yost (2002), Buser (2004a), and Fox (2009).

15. Interview with authors.

16. See "Cowles Foundation for Research in Economics," Yale University, https://cowles.yale.edu/about-us.

17. Interview with authors.

18. Markowitz (1991). A 1952 twenty-year retrospective document succinctly described Harry Markowitz's contribution as having "studied the financial behavior patterns of open-ended investment trusts and set up equations to describe them." See "Economic Theory and Measurement: A Twenty Year Research Report," Cowles Commission for Research in Economics, 1952, 50, https://cowles.yale.edu/sites/default/files/files/pub/rep/r1932-52.pdf.

19. Interview with authors.

20. See Cowles (1932) and Cowles (1938).

21. Markowitz (2002) references Graham and Dodd (1951), the third edition of the book. The first edition of the book was published in 1934, followed by the second edition in 1940. If Markowitz had his epiphany in 1950, then it is likely that he had read the 1934 or 1940 edition.

22. See Wiesenberger (1941).

23. See Williams (1938). At a *Journal of Investment Management* conference in 2011 in tribute to Harry Markowitz, Markowitz speculated that it was possible that that very book might still be in the University of Chicago Business School library.

24. One main difference with today's application of the dividend discount model is in the estimation of the discount rate used to determine present values. Today, we might estimate the rate by applying the capital asset pricing model (described in chapter 3). Williams (1938, 58–59) advocated that each investor apply his or her own personal discount rate.

25. See Bernstein (1992).

26. See Bernstein (1992, 42).

27. Interview with authors.

28. Markowitz (2002) himself used the term "epiphany" to describe his thoughts in the library that day.

29. Interview with authors.

30. See Uspensky (1937).

31. Interview with authors.

32. In the formula, the term $Corr_{ABC,XYZ} \times SD_{ABC} \times SD_{XYZ}$ is also equivalent to the covariance between ABC and XYZ. Correlation is essentially a normalized version of covariance, as it is always a value between −1 and +1.

33. In statistical terms this case is known as perfect positive correlation.

34. Technically, this statement assumes a normal distribution; more on that in chapter 4.

35. See "Tjalling Charles Koopmans," MacTutor, https://mathshistory.st-andrews.ac.uk/Biographies/Koopmans/.

36. This account of the assignment for Koopmans is described in Bernstein (1992, 49).

37. As noted by Bernstein (1992, 55) and others, Markowitz curiously went against the tradition of mathematicians by putting the main variable of interest or the dependent variable, expected return, on the horizontal axis, and putting the independent variable, risk, on the vertical axis. At a *Journal of Investment Management* conference in 2011, Markowitz joked that "in the 1960s everyone switched the axes on me." He was referring to current textbooks that describe Markowitz's seminal work, which show expected return on the vertical axis and risk (as often measured by standard deviation, not variance as Markowitz had originally proposed) on the horizontal axis.

38. See Yost (2002).

39. See Markowitz (1952a).

40. Later, Markowitz was asked why he chose such a new and relatively untested journal. See Buser (2004a). Markowitz stated that he felt that his article was a finance contribution, he had heard of the journal, and he knew that Fred Weston at UCLA was associated with the journal. It was then pointed out by the interviewer (Stephen Buser), to Markowitz's apparent surprise, that Marshall Ketchum—who had provided Markowitz with a reading list of investment publications while Markowitz was searching for a dissertation topic—was then the journal's editor. Markowitz could not recall if it might have been Ketchum who suggested he submit his article for publication with the journal.

41. Markowitz (1952a, 91).

42. Markowitz (1952a, 91).

43. We're using the now common representation to show expected return on the vertical axis and variability—typically measured by standard deviation rather than variance—on the horizontal axis.

44. This is determined mathematically by the formula $n \times (n-1)$, where n is the number of stocks in the portfolio. In this case n is 20, and the number of covariance terms is $20 \times 19 = 380$. In practice, estimating a large portfolio can be complicated. In mathematical terms, this involves inverting covariance matrices, which can be unstable.

45. Markowitz (1952a, 82).

46. Markowitz (1952a, 83).

47. Markowitz (1952a, 89). To put his hypothetical example in context, a check of the University of Chicago CRSP database for all listed stocks in 1952 sorted by industry indicates that there were actually about fifty such railroad stocks (i.e., SIC code 40) listed.

48. For a description and the quotations in this section, see Buser (2004a).

49. Buser (2004a).

50. See Fox (2009, 55).

51. See Markowitz (1990). While Markowitz assumed that investors care about mean and variance, we now know that this comes from an assumption about the utility function, or ordering of preferences. As a result, we *can* think of portfolio theory in economic terms, as a simple application of the theory of consumer choice, maximizing utility subject to budget constraints.

52. See Rubinstein (2002).

53. See Merton (1968).

54. See "Bruno de Finetti," MacTutor, https://mathshistory.st-andrews.ac.uk/Biographies/De_Finetti/.

55. See Rubinstein (2006).

56. See de Finetti (1940) and the accompanying reference to the 2006 English translation of the first chapter.

57. See Kaplan (2010) for an interesting conversation with Sam Savage, the son of Leonard Jimmie Savage, who describes his interactions, years apart, with both de Finetti and Markowitz. Markowitz was a student of Sam's father Leonard (who went by the name Jimmie). While Jimmie Savage was on a sabbatical in Paris in 1950, the family visited Italy, where the Savages met de Finetti. Jimmie also spent a year in Rome in 1958 and worked closely with de Finetti then. Years later, in 1994, at the eightieth birthday party for well-known mathematician George Dantzig, codiscoverer (along with Koopmans) of linear programming, Sam was introduced to Markowitz. "I remember I was introduced to Harry and said, 'Oh my God, it's Harry Markowitz!' As I recall, Harry said something like, 'Oh my God, it's Jimmie Savage's son!' He told me he had been indoctrinated at point-blank range in expected utility theory by my dad."

58. See Markowitz (2006).

59. Markowitz's description as reported in Kaplan (2010).

60. See Markowitz (1999, 5).

61. For Roy's background, see Bernstein (1992, chap. 2).

62. See Bernstein (1992, 56).

63. See Roy (1952).

64. See Markowitz (1999).

65. There was one other minor difference. As described in an earlier footnote, Markowitz drew his graphs in the unconventional manner, with the dependent variable, expected return, on the horizontal axis and the independent variable, risk (variance), on the vertical axis. Roy used the more conventional, and now common, approach with expected return on the vertical axis and risk (also using the commonly used standard deviation) on the horizontal axis.

66. Actually, Roy did write one follow-up paper. See Roy (1956).

67. See Markowitz (1959) and Markowitz (1987).

68. See Marschak (1950).

69. For further discussion, see Maclachlan (2010).

70. For further discussion, see Maclachlan (2010).

71. See Markowitz (1999).

72. See Marschak (1938).

73. See Markowitz (1999, 12).

74. For a description and overview of Markowitz's (1959) book as recounted in this section, see Markowitz (1999).

75. See Markowitz (1952a, 79).

76. This paragraph is based on Markowitz's comments at the March 2011 *Journal of Investment Management* conference in San Diego, attended by the authors.

77. RAND, which adopted its name from a contraction of *R*esearch *AN*d *D*evelopment, began in 1948 as an offshoot of the Douglas Aircraft Company. Its Article of Incorporation was brief and broad: "To further and promote scientific, educational, and charitable purposes, all for the public welfare and security of the United States of America." Amazingly, thirty-two Nobel laureates have been affiliated with RAND in a variety of capacities. For additional background, see "History and Mission," RAND Corporation, http://www.rand.org/about/history.html.

78. Interview with authors.

79. See Rubinstein (2002).

80. Interview with authors.

81. Kahneman and Tversky (1979). In 2002 Kahneman was a corecipient of the Nobel Prize in Economics.

82. Markowitz (1952b).

83. Interview with authors.

84. Interview with authors.

85. For a description of the development of prospect theory, see Kahneman (2011, chap. 26).

86. Interview with authors.

87. Interview with authors.

88. Interview with authors.

89. See Rubinstein (2002).

90. See Kaplan (2010).

91. See Kritzman (2011).

92. Interview with authors.

93. Interview with authors.

94. Interview with authors.

95. Interview with authors.

96. Interview with authors.

97. Markowitz (2016, xvii).

98. Interview with authors.

99. Markowitz (2005).

100. Interview with authors.

101. Interview with authors.

102. Interview with authors.

103. Interview with authors.

104. Interview with authors.

105. Interview with authors.

106. Interview with authors.

107. Interview with authors.

108. See Markowitz and Blay (2014), Markowitz (2016), and Markowitz (2020).

109. Interview with authors.

Chapter Three

1. Unless otherwise noted, the factual information in this section is from Sharpe (1991) and Sharpe (2009).

2. Snyder (1993). These statistics are for individuals who completed four-year undergraduate degree programs.

3. See Lansner (2011).

4. Sharpe (2009).

5. Sharpe (2009).

6. Sharpe (2009).

7. Interview with authors.

8. Interview with authors.

9. Sharpe (2009).

10. Sharpe (2009).

11. Weston, who died in 2009 at the age of ninety-three, chaired or served on sixty-six doctoral committees with these students publishing over 220 papers in top journals at the time of his death. They were known as "Fred's folks." See "J. Fred Weston (1916–2009)," The American Finance Association, https://afajof.org/in-memoriam/.

12. Sharpe (2009).

13. Sharpe (2009).

14. Unless otherwise noted, most of the factual information in this section is from Sharpe (1991) and Sharpe (2009).

15. Interview with authors.

16. Sharpe (1961).

17. Sharpe (2009).

18. Interview with authors.

19. Interview with authors.

20. Buser (2004b). Another way to think about this is to consider the formula for a two-stock portfolio, described earlier. That formula included two variance terms and two covariance (or correlation) terms, like in a 2×2 matrix. As the number of stocks increases, say to ten, there are ninety covariance terms relative to only ten variance terms—the ones along the diagonal.

21. According to IBM archives, the first 7090 was installed in December 1959. It cost $2,898,000 and rented for $63,500 a month. It could perform 229,000 additions or subtractions in one second. See "7090 Data Processing System," IBM, http://www-03.ibm.com/ibm/history/exhibits/mainframe/mainframe_PP7090.html.

22. In his dissertation, Sharpe (1961, 23) points out that the potential cost reduction from a diagonal or index model was also noted by University of Chicago professor Merton Miller in October 1960 in his *Journal of Business* review of Markowitz's *Portfolio Selection* book. This is most likely the earliest reference to a connection among the three scholars. Thirty years later Markowitz, Sharpe, and Miller went on to share the 1990 Nobel Prize in Economics.

23. Interview with authors.

24. Unless otherwise noted, the factual information in this section is from Sharpe (1991) and Sharpe (2009).

25. Interview with authors.

26. See Sharpe (1963).

27. See Sharpe's curriculum vitae, "William F. Sharpe: STANCO 25 Professor of Finance, Emeritus, Graduate School of Business," Stanford University, http://www.stanford.edu/~wfsharpe/bio/vitae.htm.

28. Buser (2004b).

29. The derivation of the famous equation, when eventually published, is actually buried in an 18-line footnote in Sharpe (1964, 438n22), and not in the form as we know it today—it was Fama (1968), in a clarifying article, that gave it a different form.

30. See Fama (1968), which is probably the earliest published reference to the term "beta" in a CAPM context.

31. Sharpe (2009).

32. See Bernstein (1992, 194–95).

33. According to Kavesh, Weston, and Sauvain (1970), Harold G. Fraine of the University of Wisconsin was the *Journal of Finance* editor from 1961 to 1963, succeeded by Lawrence S. Ritter (1964–1966).

34. See Gans and Shepherd (1994).

35. Sharpe (1964).

36. See "User Profiles for William Sharpe," Google Scholar, https://scholar.google.com/citations?hl=en&user=JPi34mwAAAAJ.

37. In an interview with the authors, Sharpe said he thought that Gene Fama might have coined the term "cap-em." However, according to Fama, Chicago professor Robert Hamada coined the term. See Mehtais (2006). Sharpe wasn't concerned with how it was pronounced (or mispronounced) but was simply glad that it received the attention it did.

38. Referring to the notion that under certain economic assumptions there are prices such that aggregate demand and supply are equal. See Arrow and Debreu (1954).

39. Interview with authors.

40. These were also the days when Sharpe used punch cards to execute his Fortran programs on a mainframe computer.

41. Sharpe's reference to the ad relates to the 1976 reaction to Vanguard's introduction of the first indexed mutual fund and is discussed further in chapter 5.

42. Interview with authors.

43. Interview with authors.

44. Treynor (1962).

45. Sharpe (1991).

46. Factual information in this and following paragraphs related to Treynor, Lintner, and Mossin is from Sullivan (2006). See also French (2003).

47. See Modigliani and Miller (1958).

48. Sullivan (2006).

49. Sullivan (2006).

50. Lintner (1965).

51. Fama (1968).

52. Sullivan (2006).

53. See Mossin (1966).

54. Mossin (1966, 769).

55. See Sharpe (1991) and Sharpe's curriculum vitae, "William F. Sharpe: STANCO 25 Professor of Finance, Emeritus, Graduate School of Business," Stanford University, http://web.stanford.edu/~wfsharpe//bio/vitae.htm.

56. For example, see Sharpe (1965, 1966).

57. Sharpe (1991).

58. Sharpe (1991).

59. Buser (2004b).

60. See "Decentralized Investment Management (Presidential Address, American Finance Association Annual Meeting, Denver, Colorado)," Stanford University, https://www.gsb.stanford.edu/faculty-research/working-papers/decentralized-investment-management-presidential-address-american.

61. Litzenberger (1991).

62. See "Our Mission," Financial Engines, https://www.edelmanfinancialengines.com/about-us/.

63. Interview with authors.

64. Interview with authors.

65. Sharpe (1992).

66. Sharpe (2007).

67. Sharpe (2009).

68. Lake Wobegon was the fictional town in Minnesota said to be the boyhood home of Garrison Keillor for a segment on the radio show *A Prairie Home Companion* (http://prairiehome.org/), where Keillor claimed that "all the women are strong, all the men are good looking, and all of the children are above average."

69. Television personality and host of CNBC's *Mad Money*.

70. Sharpe (2009).

71. Sharpe (2009).

72. Bell (2008).

73. Sharpe (2002).

74. Sharpe (2002).

75. Fox (2009).

76. Zweig (2007).

77. Unless otherwise noted, quotations in this section are from an interview with authors.

Chapter Four

1. Jensen (1978).

2. Bachelier (1900).

3. Fama (1970).

4. Unless otherwise noted, the factual information in this section about Fama is from Fama (2011) and Fama (2013).

5. Interview with authors.

6. While this position was in functional use in the professional game at that time, there is no reason Fama could not have reinvented it.

7. Iovino (2013).

8. Iovino (2013).

9. See "Dr. Harry Ernst," BC Eagles, http://bceagles.com/hof.aspx?hof=279&path=&kiosk=.

10. See "Harry Ernst, at 84; Successful Economist, Consultant Whose Lifelong Passion was Golf," *Boston Globe*, November 13, 2005, http://archive.boston.com/news/globe/obituaries/articles/2005/11/13/harry_ernst_at_84_successful_economist_consultant_whose_lifelong_passion_was_golf/.

11. Mehtais (2006).

12. Fama (2013).

13. Interview with authors.

14. Mehtais (2006).

15. Interview with authors.

16. Fenner (2013).

17. Fama (1965a).

18. Clement (2007).

19. Fama (2013).

20. Fama (1965a).

21. The expression "black swan" was common in London in the sixteenth century to convey an impossible event, since all swans at the time were known to be white. However, in the late 1600s, Dutch explorers became the first Europeans to observe black swans in western Australia.

22. For decades, the CRSP data were stored on magnetic tapes that were accessed through large mainframe computers and then programmed to be read and analyzed, typically using Fortran.

23. Interview with authors.

24. Fama, Fisher, Jensen, and Roll (1969).

25. Interview with authors.

26. Fama, Fisher, Jensen, and Roll (1969, 2).

27. Fama (1965b, 1970).

28. Fama (1970). Subsequent to the popularization of the efficient market notion in the *Journal of Finance*, a similar concept circulated among the economics profession. Associated with prominent economists such as Nobel Prize in Economics recipients Robert E. Lucas Jr. and Thomas Sargent, it was known as rational expectations.

29. Ball and Brown (1968). While their paper appeared in print prior to the publication of the 1969 FFJR paper, Ball and Brown referenced the earlier completed 1967 version of the FFJR paper and noted that the FFJR paper had been accepted for publication although it wasn't yet in print.

30. Jensen (1968).

31. Interview with authors.

32. Fama (1970, 384).

33. Fama (2011).

34. Fama (1991).

35. Fama (1991, 1576).

36. Fenner (2013).

37. See Ben Cohen, "The Golden State Warriors Have Revolutionized Basketball," *The Wall Street Journal*, April 7, 2016, http://www.wsj.com/articles/the-golden-state-warriors-have-revolutionized-basketball-1459956975.

38. Fama (2013).

39. See Fama and MacBeth (1973). As of 2021, the paper had received almost sixteen thousand Google Scholar citations—alas, only the sixth most cited of Fama papers.

40. Interview with authors.

41. Black, Jensen, and Scholes (1972).

42. Fama (2011).

43. Basu (1977).

44. Banz (1981).

45. Rosenberg, Reid, and Lanstein (1985).

46. Fama and French (1992, 1993).

47. Interview with authors.

48. Fama (2011).

49. Fama and French (1992, 427).

50. Berg (1992).

51. While certainly not a voting mechanism, a Google search in 2021 of "beta is dead" led to about 3.3 million results, while a similar search of "beta is not dead" led to about 670,000 results.

52. Interview with authors.

53. Much of the popularity of the Fama-French model stemmed from a clever and (at the time) unique use of data sharing. Ken French makes available extensive updates on a myriad of data related to variations on the Fama-French studies on his popular website. Kenneth R. French, "Data Library," http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html.

54. Interview with authors. In a famous critique of asset pricing tests, Roll (1977) points out that testing the CAPM requires identification of the market portfolio, consisting of all investable assets. If we can't identify the market portfolio, then we can't test the CAPM.

55. Interview with authors.

56. Fama and French (2015).

57. Interview with authors.

58. Fama (2011).

59. Fama (1975).

60. Fama (1976b).

61. Fama and Schwert (1977).

62. Fama (1981).

63. Fama and Bliss (1987).

64. This example is inspired by John Cochrane's introductory chapter, "Return Forecasts and Time-Varying Risk Premiums," in Fama (2017).

65. Fama and French (1988a).

66. Fama and French (1988b).

67. Schwert and Stulz (2014).

68. Fama and Miller (1972).

69. Fama (2011).

70. Interview with authors.

71. Fama (1976a).

72. Interview with authors.

73. Fama (2011).
74. Fama (2011).
75. Fama (2011).
76. Schwert and Stulz (2014).
77. Interview with authors.
78. Interview with authors.
79. Schwert and Stulz (2014).
80. Schwert and Stulz (2014).
81. Schwert and Stulz (2014).
82. Comments to authors.
83. Interview with authors.
84. Interview with authors.
85. Interview with authors.
86. Interview with authors.
87. Berkshire Hathaway Inc., *2013 Annual Report*, http://www.berkshirehathaway.com/2013ar/2013ar.pdf.
88. Interview with authors.
89. Interview with authors.

Chapter Five

1. Rostad (2013, 18).
2. Buerkle (2019).
3. Rostad (2013, 18).
4. Biographical information is based on Slater (1997, chap. 1).
5. Jack Bogle's grandfather actually founded the Sanitary Can Company, which was acquired by the American Can Company. Much later and under subsequent leadership, American Can diversified and morphed into Primerica, which later became part of Citigroup.
6. Coincidentally, within a few months of this realization, Harry Markowitz would have his own epiphany in another library, in Chicago.
7. "Big Money in Boston" (1949).
8. Bogle (2013).
9. Interview with authors.
10. Breslow (2013).
11. Bogle (2003a).
12. Bogle (2003a).
13. Bogle (2003a).
14. Bogle (1951).
15. Allebrand (2009).
16. Bogle (2005a).
17. Interview with authors.

18. Interview with authors.

19. See "Report of the U.S. Securities and Exchange Commission on the Public Policy Implications of Investment Company Growth; Report of the Committee on Interstate and Foreign Commerce, Pursuant to Section 136 of the Legislative Reorganization Act of 1946, Public," Securities and Exchange Commission, December 2, 1966, http://www.sechistorical.org/museum/galleries/tbi/gogo_c.php.

20. Interview with authors.

21. Bogle (2003a).

22. Interview with authors.

23. Bogle (1951).

24. Interview with authors.

25. See Bogle (2004).

26. Interview with authors.

27. Original quote from Regan (2016), with minor editing by Jack Bogle.

28. Armstrong (1960).

29. Renshaw and Feldstein (1960).

30. Armstrong (1960).

31. Interview with authors.

32. Bogle (2004).

33. Interview with authors.

34. Regan (2016).

35. Interview with authors.

36. Bogle (2012).

37. Interview with authors.

38. Regan (2016).

39. Original quote from Levy (2017), with minor editing by Jack Bogle.

40. Interview with authors.

41. Anson et al. (2006).

42. Regan (2016).

43. Anson et al. (2006).

44. Anson et al. (2006).

45. Ehrbar (1976).

46. Bogle (2014b) acknowledges there were other attempts at forming index funds, although not index *mutual* funds. American Express Asset Management Company created the Index Fund of America in 1974, designed for institutional investors with at least $1 million in investments, aimed to "loosely approximate" S&P 500 index returns. This fund filed for an IPO but withdrew, and the project was abandoned. Nobel laureate Milton Friedman was purported to have written a letter to the trustees of TIAA–CREF in 1971 suggesting it eliminate all investment analyst positions and adopt a policy of indexing its stock portfolio to the S&P 500 index. The "main claimant" for the creation of the concept of *indexing* (versus an *index mutual fund*) is Wells Fargo Investment Advisors and its leader, John "Mac" McQuown, who worked with such luminaries as Fischer Black, Michael Jensen, Harry Markowitz, Jack Treynor, and Bill Sharpe. In 1971,

Wells Fargo managed $6 million of pension money for Samsonite Corporation using an index strategy, equally weighting fifteen hundred stocks listed on the New York Stock Exchange. In 1973, Dean LeBaron and Jeremy Grantham of Batterymarch began offering an index-based pension account and attracted their first client in 1974, but soon abandoned the strategy. Also, in 1974 American National Bank of Chicago created a common trust fund modeled on the S&P 500 index with a minimum $100,000 investment, but no data on the fund appear to exist.

47. Ehrbar (1976, 148).

48. Bogle (2011).

49. Bogle (2013).

50. Sommer (2012).

51. Samuelson (1974).

52. Interview with authors.

53. Bogle (2014b).

54. Bogle was also encouraged by other articles he read later, including Charles Ellis's 1975 "The Loser's Game" that appeared in *Financial Analysts Journal*, discussed in chapter 10.

55. Bogle (2011).

56. Bogle (2011).

57. Bogle (2011).

58. Bogle (2011).

59. Samuelson (1976).

60. Samuelson (1976).

61. Interview with authors.

62. Anson et al. (2006).

63. Anson et al. (2006).

64. Allebrand (2009).

65. Rostad (2013, 85).

66. Rostad (2013, 86).

67. Original quote from Allebrand (2009), with minor editing by Jack Bogle.

68. Interview with authors.

69. Regan (2016).

70. Interview with authors.

71. Bogle (2003b).

72. Interview with authors.

73. Bogle (2003b).

74. Bogle (2005b).

75. Allebrand (2009).

76. Allebrand (2009).

77. Bogle (2014a).

78. Boyle (2007).

79. Interview with authors.

80. Bogle and Nolan (2015).

81. According to the constant growth version of the dividend discount model and applying the formula for a growing perpetuity, the price of a stock at time t, P_t, is equal to next year's

expected dividend, D, divided by the expected stock return less the anticipated perpetual dividend growth rate, $R_t - G_t$. Rearranging and solving for R_t gives $D/P_0 + G_t$, where D/P_0 is the dividend yield, D_0.

82. Boyle (2007).
83. Jaffe (2014).
84. Interview with authors.
85. Allebrand (2009).
86. Bogle (2001).
87. Bogle (2001).
88. Bogle (2007).
89. Bogle (2007).
90. Bogle (2007).
91. Bogle (2007).
92. Allebrand (2009).
93. Allebrand (2009).
94. Anson et al. (2006).
95. Allebrand (2009).
96. Best (2016).
97. Anson et al. (2006).
98. Levy (2017).
99. Jaffe (2014).
100. Best (2016).
101. Jenkins (2016).
102. Interview with authors.
103. Jaffe (2014).
104. Jenkins (2016).
105. Levy (2017).
106. Bogle (2016).
107. Interview with authors.
108. Interview with authors.
109. Interview with authors.
110. Interview with authors.
111. Bogle (2015).
112. MacBride (2015b).
113. MacBride (2015b).
114. See, for example, Philips (2014).
115. Regnier (2015).
116. Interview with authors.
117. Here's the math behind this: $(1 - 0.03)^{30} = 0.40$.
118. Regan (2016).
119. Interview with authors.
120. Bogle (2012, 322).

Chapter Six

1. Unless otherwise noted, the factual information in this section about Scholes is from Scholes (1997).

2. See Roll (2006).

3. Tragically, Barilko died in a plane crash later that summer, and what followed became known as the Barilko Curse. The Leafs had won four Stanley Cups in five years but didn't win another until 1962, only six weeks before Barilko's plane wreckage was discovered. His overtime feat and subsequent death were immortalized in the Tragically Hip's 1992 song "Fifty Mission Cap."

4. Other Timmins-born hockey greats included the Mahovlich brothers. Frank, "the Big M," was on six Stanley Cup–winning teams, was inducted into the Hockey Hall of Fame, and became a Canadian senator. Younger brother Pete, "the Little M," was on four Stanley Cup–winning teams.

5. Roll (2006).

6. Smith (2008).

7. Smith (2008).

8. Smith (2008).

9. Smith (2008).

10. Unless otherwise noted, the factual information in this section about Scholes is from Scholes (1997).

11. See Eugene F. Fama, "My Life in Finance," Dimensional Investing, March 4, 2010, https://famafrench.dimensional.com/essays/my-life-in-finance.aspx.

12. Roll (2006).

13. Roll (2006).

14. Roll (2006). Given the high competition and rigorous application process for top-tier finance PhD programs today, it's interesting to reflect on how both Fama and Scholes made it into what is today still considered one of the most prestigious finance PhD programs without applying and whether someone with their backgrounds and qualifications today would even be accepted. As a current University of Chicago finance professor shared with the authors, "And it's not like we're producing hundreds of Fama and Scholeses a year either."

15. Bernstein (1992, 212).

16. See Breit and Hirsch (2009, 241).

17. See Breit and Hirsch (2009, 241).

18. Bernstein (1992).

19. Scholes (1997).

20. Roll (2006).

21. Scholes described the meeting in Roll (2006).

22. This description of the story behind the first collaboration among Black, Scholes, and Jensen is from Roll (2006) and Ancell (2012).

23. Interview with authors.

24. Roll (2006).

25. Interview with authors.

26. Interview with authors.

27. Roll (2006).

28. See Black, Jensen, and Scholes (1972).

29. Stewart (2013).

30. Black (1989a).

31. Black (1989a).

32. As described by Scholes in Roll (2006).

33. Roll (2006).

34. Black (1989a).

35. Black (1989a).

36. Black (1989a).

37. Sprenkle (1961).

38. Cootner (1967).

39. Boness (1964).

40. Roll (2006).

41. Interview with authors.

42. Interview with authors.

43. Interview with authors.

44. See Black (1989a) for a description of the road to publication. To put the Black-Scholes citations into perspective, by 2021 Scholes's paper with Black and Jensen had received 4,700 citations, and Scholes's research with Black on dividends (Black and Scholes 1974) had received 1,600 citations. The Black-Scholes option pricing study has even received more citations than any of Gene Fama's papers.

45. Interview with authors.

46. Interview with authors.

47. Roll (2006).

48. Black (1989a).

49. See Black and Scholes (1973).

50. See Black and Scholes (1972).

51. Unless otherwise noted, the factual information in this section about Scholes is from Scholes (1997).

52. In a bold move by the university, Black, who was working outside of academia and had a physics degree, was granted tenure. An appointment in such circumstances is unimaginable today.

53. See "CRSP Celebrates," CRSP, http://www.crsp.org/main-menu/crsp-celebrates#95_Years_of_Data.

54. See Scholes and Williams (1977).

55. See Scholes, Wolfson, Erikson, Hanlon, Maydew, and Shevlin (2014). Scholes and Wolfson were coauthors through the fifth edition. The most recent edition was published in 2020.

56. Interview with authors.

57. Interview with authors.

58. For a history of Long-Term Capital Management, see Lowenstein (2000).

59. See "Award Ceremony Speech Presentation, Speech by Professor Bertil Näslund of the Royal Swedish Academy of Sciences," The Nobel Prize, December 10, 1997, http://www.nobelprize.org/nobel_prizes/economic-sciences/laureates/1997/presentation-speech.html.

60. It is worth noting that trading is one of the principal reasons for the existence of options. Suppose you have news about a public company that no one else has, and you want to capitalize on that news. Making a highly leveraged purchase of the stock—say, borrowing 90 percent of its value—might not be feasible, and even if it were, there would still be a large risk of default. As an alternative, you could buy a call option, effectively with 10:1 leverage. Trading is not necessarily bad, but options trading is much better than leveraged stock trading with the possibility of default.

61. See "Myron S. Scholes, 1941–," The Library of Economics and Liberty, http://www.econlib.org/library/Enc/bios/Scholes.html.

62. For background on CBOE, see "About Us," CBOE, http://www.cboe.com/aboutcboe/default.aspx.

63. Scholes (1998).

64. According to Black (1989a), there were fewer opportunities to make money from mispriced options by the late 1980s compared to the early 1970s, because by then traders used the Black-Scholes/Merton option pricing model extensively.

65. See "OTC Derivatives Statistics at End-December 2019," Bank for International Settlements, May 7, 2020, https://www.bis.org/publ/otc_hy2005.htm.

66. Trading on the VIX index commenced in 2004. The levels back to 1986 are based on CBOE back-testing, showing what the level would have been given S&P 500 option prices at the time. While the official record closing high on the VIX of 82.69 occurred on March 16, 2020, near the start of the COVID-19 pandemic, the October 19, 1987, level would have been almost twice as high, at 150.19.

67. Interview with authors.

68. Interview with authors.

69. Interview with authors.

70. See Warren E. Buffett, "Berkshire's Corporate Performance vs. the S&P 500," Berkshire Hathaway, February 21, 2003, http://www.berkshirehathaway.com/letters/2002pdf.pdf.

71. See Warren E. Buffett, "Berkshire's Corporate Performance vs. the S&P 500," Berkshire Hathaway, February 27, 2009, http://www.berkshirehathaway.com/letters/2008ltr.pdf.

72. See Tony Boyd, "Warren Buffett Still Says Derivatives Are 'Weapons of Mass Destruction,'" Financial Review, June 17, 2015, http://www.afr.com/markets/derivatives/warren-buffett-still-says-derivatives-are-weapons-of-mass-destruction-20150617-ghpwoa.

73. Interview with authors.

74. Interview with authors.

75. Between July 2015 and April 2017, Valeant Pharmaceuticals's stock (now called Bausch Health Companies Inc.) lost over 95 percent of its value.

76. Interview with authors.

77. Interview with authors.

78. Interview with authors.

79. Quotations in this section are taken from interviews with authors. Scholes credits Ashwin Alankar as co-originating the ideas that are part of his beliefs in the Perfect Portfolio. Alankar is the Head of Global Asset Allocation at Janus Henderson Investors, where Scholes is the chief investment strategist. Scholes and Alankar have coauthored white papers for Janus

(available only to institutional investors), including "The Key Catalysts to Compound Returns" (January 2016), which articulates many of the ideas that Scholes describes in this section.

80. The mathematics behind this are $\$100 \times (1 - 0.20) \times 1.20 = \$96$.

81. Lo (2016) also documents the changing volatility of broad indices such as the S&P 500 and notes that lack of risk management is perhaps the single greatest weakness of passive investing.

Chapter Seven

1. See Griehsel (2004).
2. Black (1989a).
3. Unless otherwise noted, factual information in this section is based on Merton (1997a).
4. Kaufman (2003).
5. Buser (2005).
6. Griehsel (2004).
7. Interview with authors.
8. Buttonwood (2019).
9. Interview with authors.
10. Merton (1966).
11. Interview with authors.
12. Merton (2014).
13. Griehsel (2004).
14. Interview with authors.
15. Interview with authors.
16. Background information on Harold Freeman is from "Prof. Harold Freeman of Economics Dies at 88," MIT News, November 26, 1997, http://news.mit.edu/1997/freeman-1126.
17. Merton (1997a).
18. Merton (1969a).
19. Interview with authors.
20. Interview with authors.
21. Samuelson and Merton (1969). The complexity of the article was highlighted by the editor of the journal, who commented in the paper's abstract: "Further elaboration of the theory and its application is supplied in two appendices which follow the article. Good luck."
22. Merton (1969b).
23. Merton (1971).
24. Interview with authors.
25. Merton (1992).
26. Jarrow (1999a).
27. Merton (1970).
28. Merton (1973b).
29. Merton (1974). The paper was presented at the American Finance Association Meetings in December 1973, and the proceedings were published in 1974.

30. Merton (1973a).

31. Interview with authors.

32. MIT Sloan School of Management (2013).

33. Merton (2014).

34. Merton (2014).

35. Interview with authors.

36. Interview with authors.

37. Bernstein (1992).

38. Merton (2014).

39. Merton (1973c) refers to “the Black and Scholes model,” “the Black-Scholes formula,” and simply “Black-Scholes.” This was the first published article to refer to Black-Scholes. However, as Merton (1998, 326n5) described, Merton’s 1970 working paper presented at the July 1970 Wells Fargo Capital Markets Conference was the first to use the “Black-Scholes” label.

40. MIT Sloan School of Management (2013).

41. MIT Management (1988, 28).

42. Merton (1973a).

43. The description of the road to publication for this paper is from Bernstein (1992).

44. MIT Sloan School of Management (2013).

45. Merton (2014).

46. Interview with authors.

47. Merton (1974). He modestly refers to options as “relatively unimportant financial instruments” (449).

48. Carr (2006).

49. See Carr (2006) and Mitchell (2004).

50. Mitchell (2004).

51. Lobel (2010).

52. Lo (2020).

53. Lo (2020).

54. Buser (2005).

55. Information in this paragraph is from Merton (1997a).

56. In his entertaining book *Liar’s Poker*, Michael Lewis recounts his days with Salomon Brothers, providing an inside look into the investment bank culture in the 1980s. The title of the book is based on his recounting of how John Meriwether challenged John Gutfreund to a game of liar’s poker—a game of mathematical reasoning and bluffing based on serial numbers on random dollar bills—for a stake of $10 million.

57. Strategies and events were described in a series of Harvard Business School case studies titled “Long-Term Capital Management, L.P.” written by Andre F. Perold and labeled (A), case number 9-200-007; (B), case number 9-200-008; (C), case number 9-200-09; and (D), case number 9-200-010.

58. See Lowenstein (2000, 234). Certain derivatives allowed investors to place bets on the overall volatility of equity markets.

59. Lafont (2006).

60. Peltz (2007).

61. Merton (1997b).
62. See Duffie (1998).
63. See Jarrow (1999b).
64. Spedding (2002).
65. Lafont (2006).
66. Nickerson (2008).
67. Merton (2003).
68. Interview with authors.
69. Patel (2007). For the patent description, see "Method and Apparatus for Retirement Income Planning Abstract," Google Patents, http://www.google.com/patents/US20070061238.
70. Interview with authors.
71. Interview with authors.
72. Interview with authors.
73. Interview with authors.
74. For a brief description, see Gleason (2009).
75. Interview with authors.
76. Interview with authors.
77. Interview with authors.
78. Interview with authors.
79. Interview with authors.
80. See Michael Paterakis and Greg Iacurci, "DFA to Launch Next-Gen TDF," Money Management Intelligence, September 17, 2014, http://www.moneymanagementintelligence.com/Article/3381246/Search/DFA-To-Launch-Next-Gen-TDF.html#/.WJCdWlMrKUk.
81. See DFA, "Dimensional Fund Advisors Launches Groundbreaking Target Date Solution," November 2, 2015, http://www.prnewswire.com/news-releases/dimensional-fund-advisors-launches-groundbreaking-target-date-solution-300169968.html.
82. White (2013).
83. Goldstein (2014).
84. Haoxiang (2014).
85. See Schifrin (2013).
86. See "Dimensional 2030 Target Date Ret Income Fund," Dimensional Investing, https://us.dimensional.com/funds/dimensional-2030-target-date-retirement-income-fund.
87. Solman (2009).
88. Mitchell (2004).
89. Interview with authors.

Chapter Eight

1. Fabozzi (1992).
2. Unless otherwise noted, the factual information in this section about Leibowitz is from Fabozzi (1992), Bernstein (2007), and Anson et al. (2011).
3. See "York Peppermint Pattie," Internet Archive, https://web.archive.org/web/20070807115621/http://www.hersheys.com/products/details/york.asp.

4. CFA Institute (2015).

5. See "Dr. Carl Sagan," National Aeronautics and Space Administration, https://starchild.gsfc.nasa.gov/docs/StarChild/whos_who_level2/sagan.html. Sagan and Leibowitz had not seen each other for years after their university time together until sharing a limousine to a bar mitzvah. As related in Dunstan (2008), Sagan, who was known to have quite an ego, asked Leibowitz, "What have you been up to all these years?" With a straight face Leibowitz handed over a copy of *Institutional Investor* magazine that he had just received, with him on the cover, captioned "Marty Leibowitz: Wall Street's Bond Guru."

6. CFA Institute (2015).

7. See "About SRI International," SRI International, https://www.sri.com/about.

8. See Martin L. Leibowitz and Gerald J. Lieberman, "Optimal Composition and Deployment of a Heterogeneous Local Air-Defense System," *Journal of the Operations Research Society of America* 8, no. 3 (1960): 324–37.

9. See "James Marcus Dies—Pioneer, Innovator in Contract Carpet," FloorBiz, October 31, 2007, http://www.floorbiz.com/BizNews/NPViewArticle.asp?ArticleID=2634. Marcus retired (for the third and final time) at age 95 and died just three weeks short of his 103rd birthday.

10. CFA Institute (2015).

11. Interview with authors.

12. Interview with authors.

13. See Laurence Arnold, "William Salomon, Who Modernized Family's Firm, Dies at 100," Bloomberg, December 9, 2014, https://www.bloomberg.com/news/articles/2014-12-09/william-salomon-who-made-firm-a-wall-street-force-dies-at-100.

14. Homer (1975).

15. Interview with authors.

16. Interview with authors.

17. CFA Institute (2015).

18. Most of this description is from Homer (1975).

19. Miles (1969).

20. Interview with authors.

21. The descriptions about Leibowitz in this and the next few paragraphs are from Fabozzi (1992) and Bernstein (2007). The quotations are from Bernstein (2007).

22. Williamson (1970).

23. CFA Institute (2015).

24. For a general description of the memoranda, see Fabozzi (1992), "Biographical Sketch" section, and Homer and Leibowitz (2013, 113–120).

25. Homer and Leibowitz (2013, 118).

26. Interview with authors.

27. Homer and Leibowitz (2013, 118).

28. Interview with authors.

29. In an interview with the authors, Leibowitz shared that he came up with the idea of how to categorize bond swaps while sitting in a dentist's chair. "The dentist was drilling away, and by the time it was finished I almost said, 'Can you take a few more minutes?' And I borrowed a

pencil from him and some paper. And I wrote down these thoughts, and that turned out to be the basis for what I thought was, at that time, a pretty important chapter [of our book]."

30. Leibowitz noted that newer readers often mistakenly refer to the book as "Inside the Yield Curve" given their unfamiliarity with the *Yield Book*.

31. See Homer and Leibowitz (2013).

32. CFA Institute (2015).

33. See Fabozzi (1992), "Biographical Sketch" section.

34. See Leibowitz (1986).

35. See Leibowitz (1987).

36. CFA Institute (2015).

37. See Langetieg, Leibowitz, and Kogelman (1990).

38. Ilmanen, Leibowitz, and Sullivan (2014).

39. Ilmanen, Leibowitz, and Sullivan (2014).

40. Anson et al. (2011).

41. As described in Dunstan (2008).

42. Bernstein (2007, 201).

43. Bernstein (2007, 201).

44. Leibowitz and Bova (2005).

45. Ilmanen, Leibowitz, and Sullivan (2014).

46. Ilmanen, Leibowitz, and Sullivan (2014).

47. Leibowitz (2010).

48. Leibowitz (2006).

49. Dunstan (2008).

50. Dunstan (2008, 223).

51. Leibowitz (2005).

52. Interview with authors.

53. Leibowitz (2005).

54. Leibowitz (2005).

55. Interview with authors.

56. See Leibowitz, Emrich, and Bova (2009).

57. See Leibowitz (2004).

58. Ilmanen, Leibowitz, and Sullivan (2014). For the book reference, see Leibowitz, Bova, and Hammond (2010).

59. According to Meyer (2013), there aren't actually any old maps that say "here be dragons" or the Latin equivalent "*Hic sunt dracones*," but there is an ancient globe that does: the Hunt-Lenox globe, made of copper and built in 1510 and now residing in the New York Public Library. To view a 3D digital model online see "Spin and Explore One of the World's Oldest Globes," futurity.org, https://www.futurity.org/hunt-lenox-globe-3d-model-2293262/.

60. Ilmanen, Leibowitz, and Sullivan (2014).

61. Interview with authors.

62. Interview with authors.

63. Interview with authors.

64. Interview with authors.

65. Interview with authors.
66. Interview with authors.
67. Anson et al. (2011).
68. Anson et al. (2011).
69. Interview with authors.
70. Interview with authors.
71. Interview with authors.
72. Anson et al. (2011).
73. Ilmanen, Leibowitz, and Sullivan (2014).
74. Interview with authors.

Chapter Nine

1. Shiller (2013a).
2. Unless otherwise noted, the factual information in this section about Shiller is from Shiller (2013a).
3. Shiller (2013a).
4. Grove (2008).
5. Shiller (2013a).
6. Shiller (2013a).
7. Read (2013).
8. Read (2013).
9. Kalamazoo College (2013).
10. Kalamazoo College (2013).
11. Interview with authors.
12. Interview with authors.
13. Shiller (1972).
14. Godar (2013).
15. Shiller (2013a).
16. See Shiller and Shiller (2011).
17. Benner (2009).
18. Benner (2009).
19. Grove (2008).
20. The Real Deal (2007).
21. Interview with authors.
22. Interview with authors.
23. Shiller (1981).
24. See Cowen (2013).
25. Shiller (2013b).
26. Variance bounds, or volatility tests, are mathematically equivalent to regression forecasts of stock returns on dividend-to-price ratios. Volatility tests put a spotlight on the dramatic implications of those forecasts, which might not look so important by themselves.
27. Shiller (1981).
28. LeRoy and Porter (1981).

29. Shiller (2003).

30. Cochrane (2013).

31. These details are recounted in Wessel (1997).

32. Recounted in Leonhardt (2005) and an interview with authors.

33. Interview with authors.

34. See "Remarks by Chairman Alan Greenspan" (our emphasis), Federal Reserve, December 5, 1996, http://www.federalreserve.gov/boarddocs/speeches/1996/19961205.htm.

35. From Robert J. Shiller, "Definition of Irrational Exuberance," http://www.irrationalexuberance.com/definition.htm.

36. Leonhardt (2005).

37. Leonhardt (2005).

38. Greenspan (2007, 176).

39. Greenspan (2007, 177).

40. See "Robert Shiller: Stocks, Bonds and Real Estate are Overvalued," GuruFocus, May 30, 2015, https://www.gurufocus.com/news/338699/robert-shiller-stocks-bonds-and-real-estate-are-overvalued.

41. Grove (2008).

42. Kindleberger (2000).

43. Kindleberger (2000, 16).

44. See "Robert Shiller: Stocks, Bonds and Real Estate are Overvalued," GuruFocus, May 30, 2015, https://www.gurufocus.com/news/338699/robert-shiller-stocks-bonds-and-real-estate-are-overvalued.

45. Rotblut and Shiller (2015).

46. For a discussion of narrative economics, see Shiller (2017).

47. Rotblut and Shiller (2015).

48. See "Robert Shiller: Stocks, Bonds and Real Estate are Overvalued," GuruFocus, May 30, 2015, https://www.gurufocus.com/news/338699/robert-shiller-stocks-bonds-and-real-estate-are-overvalued.

49. Shiller (2014).

50. Milner (2015).

51. Interview with authors.

52. Interview with authors.

53. Interview with authors.

54. Interview with authors.

55. Interview with authors.

56. Interview with authors.

57. Clement (2007).

58. Fama (2014).

59. Fama (2014) makes twenty-five references to "bubbles," and in twenty-two of the references he uses quotation marks. The only exceptions are when he refers to a Federal Reserve policy prescription or to one of Shiller's predictions. This isn't new. In Fama's 1965 dissertation, his three mentions of bubbles are also in quotation marks.

60. Fama (2014, 1476-77) argued this point.

61. Hilsenrath (2004).

62. Fama (1998).
63. Interview with authors.
64. Clement (2007).
65. Mehtais (2006).
66. Clement (2007).
67. Cassidy (2010).
68. See Campbell and Shiller (1988). For a practitioner-oriented description, see Campbell and Shiller (1998).
69. Shiller (2014).
70. Interview with authors.
71. See "Robert Shiller: Stocks, Bonds and Real Estate are Overvalued," GuruFocus, May 30, 2015, https://www.gurufocus.com/news/338699/robert-shiller-stocks-bonds-and-real-estate-are-overvalued.
72. Jeffries (2014).
73. Shiller (2014).
74. Interview with authors.
75. Schwartz (2016).
76. Schwartz (2016).
77. Shiller (2013a).
78. Schwartz (2016).
79. Interview with authors.
80. Case and Shiller (2003).
81. Laing (2005).
82. See "About Us," Fannie Mae, https://www.fanniemae.com/about-us.
83. See "Our Business," Freddie Mac, http://www.freddiemac.com/about/business/.
84. Grove (2008).
85. Grove (2008).
86. Benner (2009).
87. Shiller (2013a).
88. Benner (2009).
89. Benner (2009).
90. Interview with authors.
91. Interview with authors.
92. Interview with authors.
93. See "Robert Shiller: Stocks, Bonds and Real Estate are Overvalued," GuruFocus, May 30, 2015, https://www.gurufocus.com/news/338699/robert-shiller-stocks-bonds-and-real-estate-are-overvalued.
94. Rotblut and Shiller (2015). As of 2021, thirty-year TIPS had slightly negative yields.
95. Grove (2008).
96. Roth and Shiller (2000) and Grove (2008).
97. Grove (2008). In 2002 Kmart filed for bankruptcy protection, and in 2003 the shares expired with no value.
98. Milner (2015).
99. Grove (2008).
100. Interview with authors.

101. Interview with authors.

102. Interview with authors. For a description of trills, see Kamstra and Shiller (2009). See also Benford, Ostry, and Shiller (2018).

103. Interview with authors.

104. See Kamstra and Shiller (2009).

105. Interview with authors.

106. See Kamstra and Shiller (2009).

107. Jeffries (2014).

Chapter Ten

1. Ritholz (2015).

2. Ritholz (2015).

3. Ritholz (2015).

4. Ritholz (2015).

5. Ritholz (2015).

6. Ritholz (2015).

7. Ellis (2013).

8. Ellis, Ilmanen, and Sullivan (2015).

9. See Eric Pace, "J. Richardson Dilworth, 81, Philanthropist," *The New York Times*, December 31, 1997, http://www.nytimes.com/1997/12/31/arts/j-richardson-dilworth-81-philanthropist.html.

10. See Ellis (2013, 6) and Ritholz (2015).

11. Zweig (2016).

12. Ellis (2013).

13. Interview with authors.

14. See Ellis (1979). His PhD dissertation, "Investment Policies of Large Corporate Pension Funds," compared a normative model based on modern portfolio theory with actual survey data of pension fund investment policies. He found that behavior and beliefs consistently conflicted with academic portfolio theory, and the investment policies were penalizing investment performance. His final chapter is titled "Reluctant Acceptance of Indexing."

15. Ellis (1964).

16. Ellis (2013).

17. Ellis, Ilmanen, and Sullivan (2015).

18. Interview with authors.

19. Zweig (2016).

20. Ritholz (2015).

21. Ellis (1968a).

22. Ellis (2013).

23. Ellis (1968b).

24. Ellis (1971).

25. See MacBride (2015a) and "About Us," Greenwich Associates, https://www.greenwich.com/about-us.

26. Interview with authors.

27. Interview with authors.

28. Interview with authors.

29. MacBride (2015a).

30. "About Us," Greenwich Associates, https://www.greenwich.com/about-us.

31. Ellis (1975).

32. For the eighth edition, see Ellis (2021).

33. Pae and Hennigan (2016).

34. Ramo was also known for his sharp sense of humor. According to Pae and Hennigan (2016), Ramo was watching the first U.S. ballistic missile launch with a U.S. Air Force general. When the missile rose about six inches before toppling over, Ramo turned to the general and said, "Well, Benny, now that we know the thing can fly, all we have to do is improve its range a bit."

35. Interview with authors.

36. Interview with authors.

37. Interview with authors.

38. Interview with authors.

39. Ellis (1975).

40. Ellis (1975).

41. Interview with authors.

42. Ellis (2013, 8). The book quotations cited in this chapter are from the book's sixth edition, published in 2013. The book's eighth edition was published in 2021.

43. Ellis (2013, 9–10).

44. Ellis (2013, 75).

45. Ellis (2013, 23).

46. Lange (2013).

47. Ellis (2013, 32).

48. Ellis (2013, 54).

49. Ellis (2013, 64).

50. Ellis (2013, 83).

51. Ellis (2013, 150–52).

52. Ellis (2013, 219).

53. See "The Yale Investments Office," http://investments.yale.edu/.

54. See "The Yale Investments Office," http://investments.yale.edu/.

55. TIFF Commentary (2006).

56. Ellis (2013).

57. TIFF Commentary (2006).

58. TIFF Commentary (2006).

59. Zweig (2016).

60. Interview with authors.

61. Ellis (2012).

62. Ellis (2014a) and Ellis (2014b).

63. Powell (2016).

64. Lange (2013).

65. Powell (2016).

66. ThinkAdvisor (2017).

67. Ellis (2016).

68. ThinkAdvisor (2017).
69. ThinkAdvisor (2017).
70. Ellis (2017).
71. Ellis (2017).
72. Malkiel and Ellis (2013).
73. MacBride (2015a).
74. Malkiel and Ellis (2013, 39).
75. Interview with authors.
76. Malkiel and Ellis (2013, 87).
77. Wong (2013).
78. Wong (2013).
79. Interview with authors.
80. Allen and Hebner (2015).
81. Original quote from Lange (2013), updated by Charley Ellis.
82. Zweig (2016).
83. Zweig (2016).
84. Interview with authors.
85. Original quote by Lange (2013), updated by Ellis.

Chapter Eleven

1. See, for example, "'Wizard of Wharton': US Credit Downgrade Will Create 'Chaos,'" CNBC, October 1, 2013, https://www.cnbc.com/2013/10/01/warning-from-the-wizard-of-wharton.html.
2. Biographical information in this section is from the Biographical Note in Siegel (1971) and from conversations with the authors. For a short bio, see "Jeremy James Siegel, Finance Educator," Prabook, https://prabook.com/web/jeremy_james.siegel/802141.
3. Correspondence with authors, November 28, 2018.
4. Correspondence with authors, November 28, 2018.
5. Interview with authors.
6. See "About," The Woodrow Wilson National Fellowship Foundation, https://woodrow.org/about/.
7. Interview with authors.
8. Interview with authors.
9. Interview with authors.
10. Interview with authors.
11. Siegel (1972).
12. See Black (1989b).
13. Interview with authors.
14. Interview with authors.
15. Interview with authors.
16. Interview with authors.
17. Interview with authors.
18. Interview with authors.

19. Siegel (1991).

20. This is the textbook definition of a recession. In fact, the National Bureau of Economic Research has a committee of economists who examine other factors in addition to GDP in order to officially date the start and end of recessions.

21. Samuelson (1966).

22. Mehra and Prescott (1985).

23. Siegel (1992c).

24. Siegel (1992a).

25. Siegel (1992a, 37).

26. Siegel (1992b).

27. Siegel and Thaler (1997).

28. Siegel and Thaler (1997, 199).

29. Siegel (1999b).

30. See "Kenneth R. French: Data Library," Tuck School of Business, Dartmouth, http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html.

31. The most recent edition is Siegel (2014).

32. James K. Glassman, "Try These Ten Books to Be a Better Investor," November 9, 1997, https://www.washingtonpost.com/archive/business/1997/11/09/try-these-ten-books-to-be-a-better-investor/5d7b64f4-b9cd-419d-8126-8a0d0fc96aff/.

33. See Smith (1924). Smith examined data covering the period 1866–1922. At the time, conventional wisdom was that bonds were a better investment than stocks.

34. Interview with authors.

35. Siegel (2014, 58).

36. Siegel (2014, 103).

37. Interview with authors.

38. Interview with authors.

39. Siegel (2005, x).

40. Siegel (1999a). Siegel did point out that it was an editor at *The Wall Street Journal* who was responsible for any article's title, despite what the author may have suggested.

41. Siegel (2005, x).

42. Siegel (1999a).

43. Siegel (2005).

44. Siegel (2000).

45. Interview with authors.

46. Interview with authors.

47. Siegel (2000).

48. Siegel (2005).

49. Interview with authors.

50. Siegel (2005).

51. Interview with authors.

52. Siegel (2005).

53. Interview with authors.

54. Knowledge@Wharton (2018).

55. Interview with authors.
56. Interview with authors.
57. Interview with authors.
58. Siegel (2016).
59. Interview with authors.
60. Knowledge@Wharton (2018).
61. Knowledge@Wharton (2018).
62. Knowledge@Wharton (2018).
63. Knowledge@Wharton (2018).
64. "ETFs," WisdomTree, https://www.wisdomtree.com/etfs.
65. See Woolley (2008).
66. Interview with authors.
67. Interview with authors.
68. Woolley (2008).
69. Siegel (2014, 374–76).
70. Siegel (2005, ix).
71. Interview with authors.
72. Siegel (2005, chap. 17).
73. Siegel (2005, chap. 16).
74. Siegel (2014, 206).
75. Interview with authors.
76. Interview with authors.
77. Interview with authors.
78. Interview with authors.
79. Interview with authors.
80. Interview with authors.
81. Interview with authors.
82. Interview with authors.

Chapter Twelve

1. See Lo (2004), Lo (2012), and Lo (2017).
2. For more information, see what Certified Financial Planners do, https://www.cfp.net/ or what CFA charterholders do, https://www.cfainstitute.org/en/programs/cfa/charterholder-careers.
3. Siegel (1991).

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