



WP/19/226

# IMF Working Paper

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## Instruments of Debtstruction: A New Database of Interwar Debt

by Nicolas End, Marina Marinkov and Fedor Miryugin

**IMF Working Papers describe research in progress by the authors and are published to elicit comments and to encourage debate.** The views expressed in IMF Working Papers are those of the authors and do not necessarily represent the views of the IMF, its Executive Board, or IMF management.

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**IMF Working Paper**

Fiscal Affairs Department

**Instruments of Debtstruction:  
A New Database of Interwar Debt****Prepared by Nicolas End, Marina Marinkov and Fedor Miryugin<sup>1</sup>**

Authorized for distribution by Era Dabla-Norris

October 2019

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**Abstract**

We construct a new, comprehensive instrument-level database of sovereign debt for 18 advanced and emerging countries over the period 1913–46. The database contains data on amounts outstanding for some 3,800 individual debt instruments as well as associated qualitative information, including instrument type, coupon rate, maturity, and currency of issue. This information can provide unique insights into various policies implemented in the interwar period, which was characterized by notoriously high debt levels. We document how interwar governments rolled over debts that were largely unsustainable and how the external public debt network contributed to the collapse of the international financial system in the early 1930s.

**JEL Classification Numbers:** E6, F5, H6, N10**Keywords:** Economic History, Debt Policy, Public Finance, Macroeconomics**Authors' E-Mail:** [nend@imf.org](mailto:nend@imf.org), [mmarinkov@imf.org](mailto:mmarinkov@imf.org)

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## I. INTRODUCTION

Governments' liabilities are complex and involve different types of securities, domestic and external commitments, with varied characteristics (e.g., denomination, maturity, coupon rates, and marketability). Even under benign economic conditions, public debt management requires a deep understanding of these elements to ensure that governments can borrow when they need to and that the sovereign is not overly exposed to risks. Debt management practices are more complicated during times of high and rising debt levels and when global interconnectedness is high. From this perspective, the interwar period, the focus of our paper, lends itself as a natural case study for investigating debt management.

The interwar period was rich in macroeconomic events, including hyperinflations, deflations, depressions, liquidity constraints, debt conversions, and debt defaults. It was a transition period between two international monetary systems and a laboratory for experiments in adjusting monetary and foreign exchange rate policies and regulating the global financial and trade architecture. However, since this period was politically and economically turbulent, available data on sovereign debt are often sparse, aggregated or hard to interpret. Even so, several researchers have compiled historical databases on public finance, enabling a review of past policies and comparisons with present day. These studies typically rely on country-specific sources to compile fiscal and debt aggregates.<sup>2</sup> The absence of generally-accepted statistical standards to ensure comparability of aggregates, however, can obscure cross-country comparisons. The coverage and granularity of debt data also varies across time and countries.

This paper describes a new historical database on public debt for 18 countries, which adds to existing databases in two ways. First, we provide instrument-level data on debt issued domestically and abroad for a relatively large group of countries. Second, we construct public debt aggregates using this instrument-level data. We believe that this database is not only rich in detail but allows for a greater degree of comparability of aggregates across countries. The debt security can be thought of as a common denominator of public finance across countries for this period, providing objective, contractual, cash-based information on public debt and fiscal policy. This is because a debt contract by its very nature corresponds to a series of predictable cash flows.

The resulting database (the interwar debt database, or IDD, henceforth) contains data on amounts outstanding for some 3,800 individual debt instruments as well as detailed instrument-level characteristics. The latter include the nature of the instrument, coupon rates (the nominal interest

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<sup>2</sup> We refer the reader to Abbas et al. (2011:719-20) for a broad review of databases on public debt published up to 2010. Since then, there have been others, including Abbas et al. (2010), Reinhart and Rogoff (2011), Reinhart et al. (2012), Mauro et al. (2013), Abbas et al. (2014), and Jordà et al. (2017). While these databases cover more countries and a longer timeframe than we do, they focus on debt-to-GDP ratios, with aggregate breakdowns (external vs. domestic and long vs. short-term). The World Wars and interwar period are generally covered with substantial gaps; and since historical GDP statistics are of varying quality, we argue that debt ratios are not reliable.

payment promised on issuance, excluding the various premia that were often granted upon issuance or redemption), maturity dates, currency denomination, and taxation regimes. From an international perspective, the database also sheds light on who owed what, and to whom (that is, to which country). To our knowledge, this is the first cross-country database that captures instrument-level information on debt obligations for a large sample of countries and for the entire gamut of debt instruments.<sup>3</sup> The period is limited to 1913–1946, but we focus on 18 key economies that provide a reasonable geographic coverage and constitute majority of public debt issued in the interwar period.<sup>4</sup> The qualitative information included in the database provides useful information about the nature of the public debt instruments and the purpose for which they were issued. The IDD complements existing databases by improving the breadth and depth of instrument coverage and addressing data gaps (especially the two World Wars).

The level of detail contained in the IDD provides new insights on debt management in the interwar period—for example, what types of instruments were most widely issued, what was the maturity structure of debt, in what currency public debt was denominated, and what kind of incentives were offered to bondholders. Most of the economic literature considers debt management to be broadly irrelevant for the debt burden in real terms.<sup>5</sup> As summarized by Sargent (1993), this irrelevance no longer holds when taxes are accounted for and when the government operates under imperfect commitment, so that the risk premium increases with debt maturity. Debt also implicitly constrains the set of tax policy choices available to future governments. In other words, debt management matters when the government’s credibility—about future taxes or future inflation—is in question or when taxes are distortionary. This was clearly the case for many countries in the interwar period. We draw on sustainability tests from the empirical literature to show that public debt was unsustainable for a majority of countries in our sample. The wide variety of debt instruments issued during the interwar suggests that the design of debt instruments in terms of promised cash flows and embedded options matters—especially so when the investor base is segmented and when governments fail to credibly secure debt sustainability. Debt management in the interwar period entailed pursuing different objectives: enhancing the credibility of sovereign bonds, managing short-term financing pressures, and financing ambitious

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<sup>3</sup> Hall and Sargent (2015) and Hall, Sargent, and Payne (2018) compile instrument-level information on government debt for the US over the period 1776–1960. Ellison and Scott (forthcoming) construct a dataset for public debt over the period 1694–2017 for each individual bond issued in the UK. Kaminsky (2019) and Meyer et al. (2019) compile cross-country instrument-level data, but only for external debt bonds that were traded on international markets.

<sup>4</sup> In 1935, for example, our sample covers some 88 percent of the total debt reported in the League of Nations publications

<sup>5</sup> This is a consequence of term structure formulas à la Hicks (1939). The irrelevance of debt management also arises from Barro’s (1974) Ricardian equivalence proposition, which postulates that it is irrelevant whether the government decides to finance itself using debt or taxes, or whether the government borrows using short-term or long-term debt. Theories of optimal debt management hinge on failures of one or more of the assumptions underpinning this proposition.

spending defense and social programs. Central banks also played a significantly supportive role, highlighting fiscal dominance.<sup>6</sup>

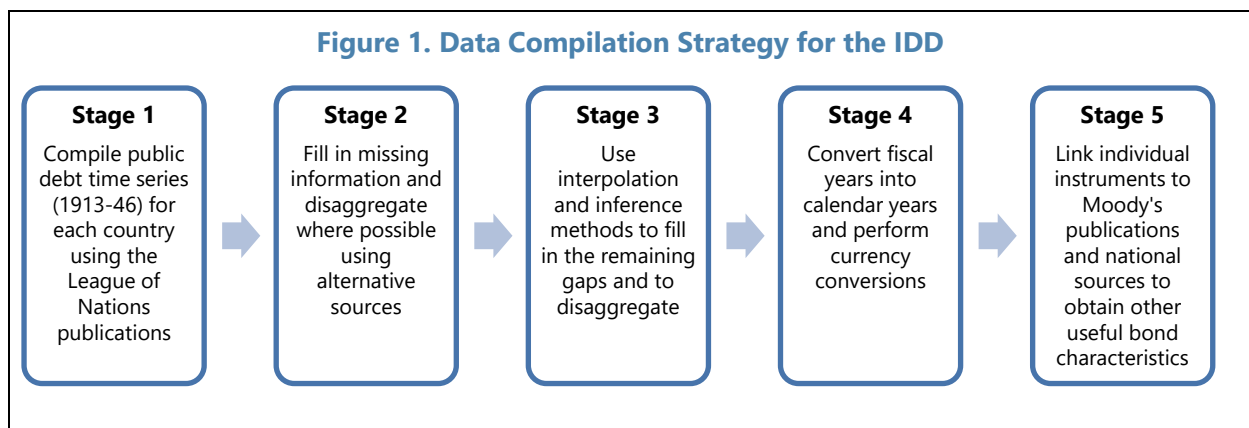
Using graph (network) analysis, we then examine the structure and evolution of the external public debt network, initially generated by World War I and reparation loans. We document how the structural weaknesses of this network contributed to the collapse of the international financial system in the early 1930s. Such a systematic analysis of the public debt network could not be undertaken without instrument-level information. In our view, this is another contribution of this paper to the literature.

This paper proceeds as follows. Section II describes the database, while the extensive appendices document the data compilation strategy and database characteristics. Then we show how interwar governments rolled over debts that were largely unsustainable (Section III.A) and how the external public debt network contributed to the collapse of the international financial system in the early 1930s (Section III.B). Section IV concludes.

## II. THE INTERWAR DEBT DATABASE

### A. Methodology

This section outlines our broad methodological approach to compiling the IDD (Figure 1). More details are provided in Appendices A–E. We took the League of Nations publications as a starting point to construct the IDD. The League compiled information on public finances for about 60 countries over the 1913–1946 period. The data on public debt, in particular, are quite detailed, with amounts outstanding reported for various instruments and debt aggregates. Figure 2 provides a snapshot of a public debt table for the UK: in addition to aggregates such as domestic and floating debt (short-term debt of maturity that is usually two years or less), the tables published by the League of Nations would also include amounts outstanding for each instrument (for example, “4% Victory Bonds”).



<sup>6</sup> We do not investigate whether a specific composition of debt instruments, financial repression, debt restructuring contributed to strengthen or weaken debt sustainability.

To compile such data, the Financial Section and Economic Intelligence Service of the League (in many ways a precursor to the IMF) sent regular questionnaires for countries to complete. Countries used information from several sources, including national accounts, budgetary accounts, central bank reports, and statistical yearbooks. This created several statistical challenges, which include varying definitions of fiscal years, different recording standards for revenue and expenditure items (cash versus commitment bases, gross versus net), lack of comprehensiveness of national budgets, and nature of the national debt figures.<sup>7</sup> For national debt data in particular, the League highlighted two reasons that make international comparisons difficult: (i) there are differences in what various countries included in their aggregates for public debt (i.e., inclusion or otherwise of debts of special funds, debts to national banks, etc.), and (ii) there are differences in how public debt is organized into various classifications (i.e., domestic versus foreign debt, classifications according to currency of issue or according to terms of repayment, etc.). The IDD circumvents a bulk of these issues by focusing explicitly on instrument-level data.

Despite the League of Nations' efforts to produce regular and comprehensive coverage of public debt statistics, there were gaps in reporting. In most cases, there are years for which amounts of debt outstanding are not reported or disaggregated information is unavailable (such as "Treasury bills" in Figure 2). To fill these gaps, we supplemented the League of Nations data with several sources. These typically consisted of national sources, such as budget documents, statistical yearbooks and other specific resources (an exhaustive list of sources is in Appendix A).

Where even additional sources were insufficient to fill the gaps, we used inference and interpolation methods. We also decided to convert fiscal years into calendar years and all amounts into common currencies to ensure cross-country comparability. Details are in Appendix B.

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<sup>7</sup> See for example the methodological notes in League of Nations (1922b, 1924c).



Figure 2. A Snapshot of a League of Nations Table on Public Debt

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The following table gives particulars regarding the Public Debt as on March 31st, 1922 and 1923.  
(£'s (000,000's omitted).)

	Maturity.	March 31st, 1922.	March 31st, 1923.
<b>DOMESTIC DEBT:</b>			
<i>Funded Debt:</i>			
Consols, etc. . . . .	Permanent	314.5	314.2
Terminable annuities * . . . .	For life and terms of years	16.2	13.4
3 1/8 % Conversion Loan . . . . .	Permanent	266.1	684.-
3 1/8 % War Loan . . . . .	1925-28	62.7	62.7
5 % War Loan . . . . .	1929-47	1,886.9	2,030.5
4 % War Loan . . . . .	1929-42	65.5	64.8
4 1/8 % War Loan* . . . . .	1925-45	12.8	12.8
4 % Funding Loan * . . . . .	1960-90	403.-	400.6
4 % Victory Bonds . . . . .	Annual drawings	355.9	353.9
3, 5, and 5 1/4 % Exchequer Bonds . . . .	1922-30	185.-	150.-
5 and 5 1/4 % Treasury Bonds . . . .	1925-35	453.-	409.-
4 and 5 % National War Bonds . . . .	1922-29	1,201.-	956.-
National Savings Certificates . . . . .	---	342.-	354.2
Sundry debts . . . . .	---	2.1	1.8
Other capital liabilities . . . . .	---	66.2	68.-
Total Funded Debt . . . . .		5,632.9	5,875.9
<i>Floating Debt:</i>			
Treasury bills . . . . .		873.6	616.-
Ways and Means advances . . . . .		147.3	193.9
Total Floating Debt . . . . .		1,020.9	809.9
Total Domestic Debt . . . . .		6,653.8	6,685.8

Source: League of Nations (1923a).

The final step in the data compilation strategy for the interwar database was to use Moody's publications and national sources to obtain qualitative information for each instrument. Taking once again the example of the UK's 4 percent Victory Bond, Moody's provided additional information for this instrument, such as interest payable, maturity, rating, whether the instrument had a sinking fund, and where it was listed. Although Moody's publications covered a significant portion of the instruments included in the IDD, it excluded instruments that were not traded on the largest stock exchanges or instruments that were of less interest to the American investors (Moody's target audience).<sup>8</sup> In these instances, we used the alternative sources listed in Appendix A.

Although the IDD is a fairly comprehensive database, some caveats apply:

- (1) The IDD is based on the *amount outstanding* concept of government debt (reported in the database in local currency units, US dollars, or gold equivalent), not the *market value* of government debt. Collecting price data for the individual instruments included in the IDD

<sup>8</sup> For instance, nominative bonds (which were sold over the counter; Thomson, 1921), pension-like instruments, annuities, or debt issued through state-owned enterprises or banks.

requires more extensive efforts that fall beyond the scope of this paper. There are recent studies focusing on single countries that provide instrument-level price and quantity data.<sup>9</sup>

- (2) The IDD does not include information on the ownership of the individual instruments. We do, however, supplement IDD data with detailed information on central bank balance sheets for the countries included in the database (Appendix E). This gives an idea about the extent of central bank exposure to sovereigns and fiscal dominance during the interwar period.
- (3) Some information included in the IDD remains incomplete despite our best efforts. Data quality is inevitably worse during times of war and political tensions. Many interwar governments also hid or misreported items they felt uncomfortable disclosing.

Nevertheless, we still consider the IDD as the best starting point for research on individual bonds and debt management practices for a wide range of countries during the interwar period.

## B. Resulting Database

The IDD covers 18 countries for the period 1913-1946. Some salient features of the IDD are shown in the panels of Figure 3. These panels showcase the various characteristics of instruments included in the IDD, details of which are presented in Appendices C–D. This subsection documents some stylized facts.<sup>10</sup>

**Country coverage.** The IDD has a reasonable geographic coverage while also accounting for majority of public debt issued in the interwar period (Figure 3.A).<sup>11</sup> In terms of contributions to global debt in the interwar period, Europe and the Americas were by far the two most dominant regions (Figure 3.B).

**Instruments.** The IDD contains some 3,800 individual debt instruments, which were classified into eight different types, defined by the nature of promised cash flows (see Appendix C for details):

- *Bond.* Debt instrument that obligated the government to two types of cash flow: (1) a principal when the bonds were presented to the paying agent on or after their maturity date; (2) interest payments when attached coupons were presented to the paying agent.
- *Perpetual.* These instruments, also called “consols” or “rentes”, had no maturity date, which means that the principal was never paid unless the government or the bondholder activated their potential options to redeem it.

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<sup>9</sup> Hall and Sargent (2015), Hall, Payne, and Sargent (2018) compile detailed data on the market value of debt for the US; see Ellison and Scott (forthcoming) for the UK.

<sup>10</sup> This is a non-exhaustive taxonomy to examine public debt: since the IDD includes data on individual instruments, other representations of interwar debt are also possible.

<sup>11</sup> We estimate that in 1935, some 88 percent of the total debt reported by the League of Nations was covered by the 18 countries in our sample.

- *Bill*. These are debt instruments without coupons, generally with a shorter-term maturity than bonds. The interest was implicitly or explicitly pre-counted, that is, deducted upfront, as a discount between the issue price and the principal.
- *Credit*. These instruments were generally contracted with financial institutions or in the form of bilateral trade credits and entailed annual payments of some principal and interest. They came in the form of either one-off borrowing, or as lines of credit on which governments could draw on demand.
- *Advance*. These financing facilities were arranged with local bodies, government departments (e.g., Treasury, central bank), savings banks, or foreign authorities. They generally involved a low or null interest rate, and an open-ended maturity.
- *Account*. Governments often had access to demand or term deposits. This instrument is similar to a credit line, but it is up to the account owner (e.g., public companies) to change the outstanding amounts.
- *Annuity*. Annual budget payments could be pledged by law (e.g., compensation for old-age or war pensions) and were recorded as capitalized annuities. It differs from a perpetual because the annual payment is not a contractual coupon rate, but a lumpsum allocated in each annual budget.
- *Other*. Public debt instruments or aggregates for which no decomposition was possible fit in none of the above categories (e.g., arrears).

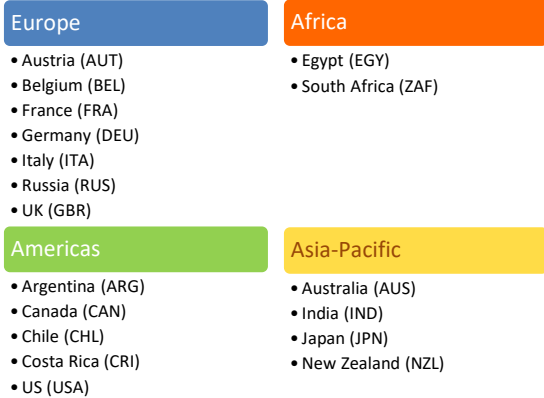
Although bonds were most popular, other instruments such as bills, advances and perpetuals also featured in the interwar period (Figures 3.C–D). Shorter-term instruments, such as bills and advances, were used in difficult financial circumstances.

**Instrument characteristics.** The database contains a wealth of detailed information on characteristics of individual instruments (see Appendix D for details).

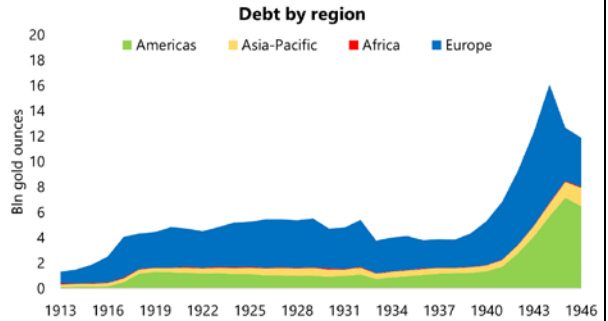
*Residency and currency.* As today, information about sovereign bond ownership is scarce. However, it appears that interwar governments segmented and tailor-made their debt instruments to specific investor bases. Consequently, we can as a first approximation assume that the currency of issuance of an instrument was a good indication of where it was held. In particular, we classify a security as “foreign” when it was issued mainly on foreign stock exchanges, in foreign currency, or with exchange rate guarantees (typically, a “gold clause”). Majority of the bonds were issued in the United Kingdom and United States. Although the latter gained prominence at the start of WWI, it was not until the mid-1930s that United States overtook the United Kingdom as a dominant market for debt issuance (Figure 3.E).

Figure 3. Features of the IDD 1/

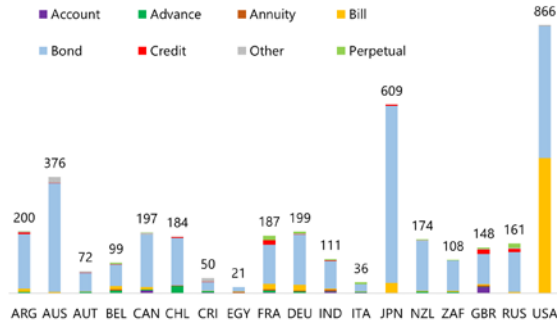
**A. Country coverage**



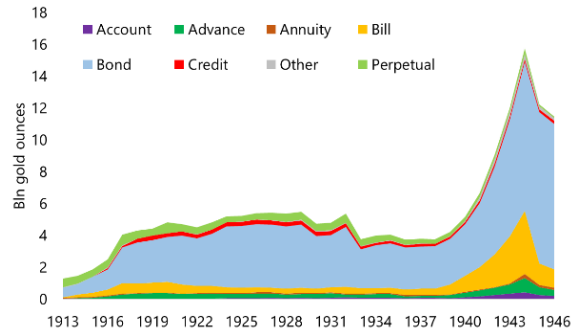
**B. Total sovereign debt, by region**



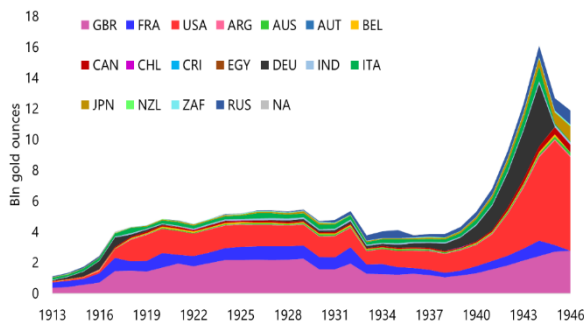
**C. Number of instruments by country**



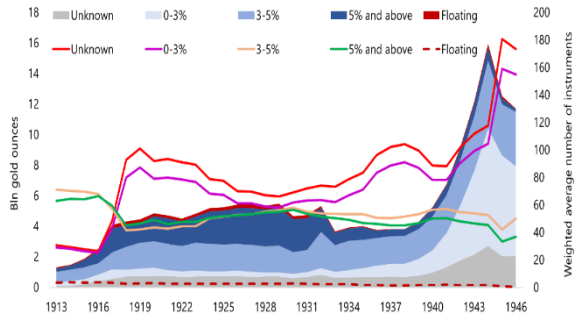
**D. Total debt by instrument**



**E. Decomposition by residency**



**F. Coupon rates /2**



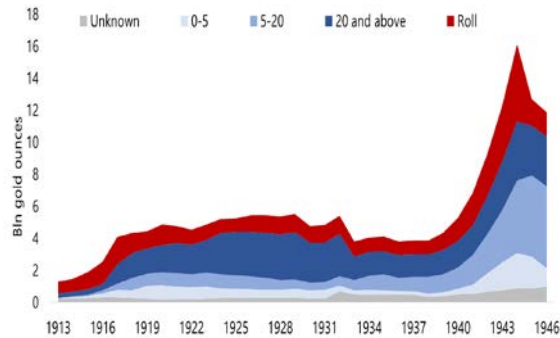
1/ We use gold as the common currency, as this was the reference at the time; even countries outside of the gold standard used gold in the formulation of their monetary policy and diplomatic negotiations. This also prevents us from choosing a reference currency to describe a period where leading international currencies competed for that status.

The formulas used for amounts (areas) and numbers (lines) at time  $t$  of all instruments  $i$  having a characteristic  $X_i = x$  are respectively:  $D_{x,t} = \sum_{i|X_i=x} D_{i,t}$  and  $N_{x,t} = \sum_c \omega_{c,t} \{i|X_i = x, D_{i,t} \neq 0, C_i = c\}$ , where  $C_i$  is the country that issued  $i$  and  $|\cdot|$  is the cardinality. We need to account for the fact that some countries have lots of small instruments, while other focus on a handful of large issuances; hence, we weigh observations using a country-specific weight  $\omega_{c,t} = \frac{\{i|C_i=c, D_{i,t} \neq 0, X_i \text{ is known}\}}{\{i|D_{i,t} \neq 0, X_i \text{ is known}\}}$ .

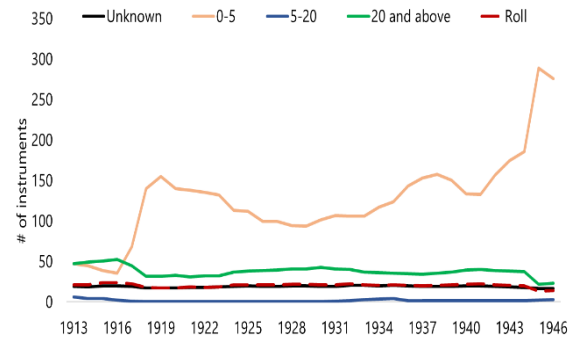
2/ The "unknown" category includes indexed and floating rates (i.e., very-short-term T-bills for which there is sometimes no breakdown by instrument available).

**Figure 3. Features of the IDD (continued)**

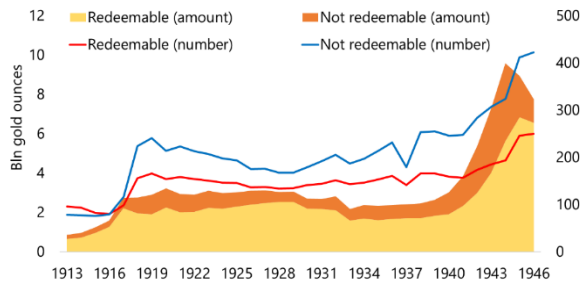
**G. Debt instruments by maturity – amounts 3/**



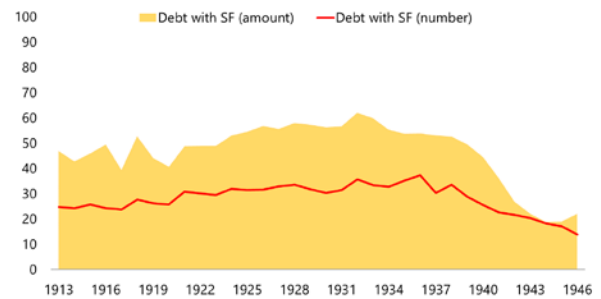
**H. Debt instruments by maturity – number of instruments**



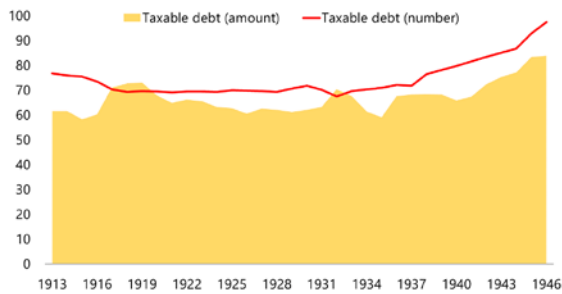
**I. Redeemable versus non-redeemable instruments**



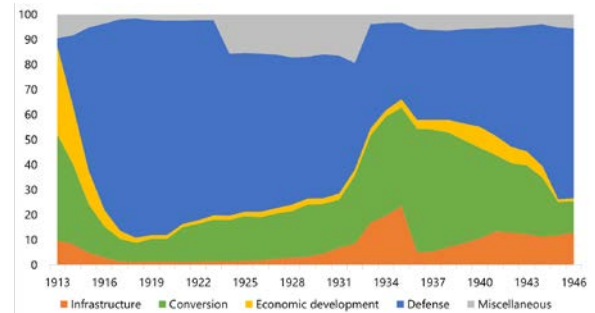
**J. Debt with sinking fund (in percent of total debt)**



**K. Taxable debt instruments (in percent of total debt)**



**L. Purpose of public debt (in percent of total debt)**



3/ Roll refers to instruments that were issued on tap and often renewed automatically unless lenders opted out.

*Coupon rates.* Almost half the debt between 1920 and 1930 had coupon rates of 5 percent or higher (Figure 3.F). Low-coupon debts (or prepaid interest bills) represented a large number of instruments but only a small portion of the outstanding amount of debt. However, average coupon rates decreased in the 1930s as financial repression policies were implemented by many interwar governments.

*Maturity.* Longer-term maturity debt dominated the first half of the interwar period (with perpetuals and maturities above 20 years). However, governments were progressively issuing more shorter-term debt into the 1940s (Figures 6.G–H).

*Redeemability.* Since debt instruments were largely very long term, they contained an embedded option, for either the government or the lender to trigger principal repayment earlier than maturity. This was necessary for the government to be able to restructure its debt, smooth its repayment profile, and ensure some liquidity for investors, as secondary markets were underdeveloped. Government's early redemptions could involve lotteries or randomizations when computing the current latent value of the bond. More than half of the instruments in the IDD, in value, were redeemable (Figure 3.I).

*Sinking fund.* Permanent or funded debt was usually debt for which a sinking (redemption) fund had the liability to pay the interest. This was an important feature that helped in placing long-term bonds because it served as a commitment-enhancing mechanism. Earmarked revenues or budget transfers were allocated to these funds. During the interwar period, these mechanisms were instrumental in enhancing the credibility of public debt management. Almost half of the instruments in the IDD for which information was available had sinking funds (Figure 3.J).

*Tax.* Tax incentives to hold sovereign debt were common at the beginning of the interwar period but became progressively less important (Figure 3.K). Tax exemptions could be granted for interest gains under the income tax or for capital gains related to holding sovereign bonds; blanket exemptions were almost always granted to foreign bondholders. Such tax incentives changed the debt instruments' effective rate of return.

*Purpose.* Interwar governments often earmarked a specific instrument to a specific purpose, as parliaments often had to approve each issuance. This was also a marketing tool for investors, who liked to know what they were contributing to finance (e.g., war or liberty loans). Figure 3.L provides a broad categorization of the purposes for which debt was issued. Unsurprisingly, war and reconstruction took the lion's share of financing resources during the interwar period. By contrast, the number of bonds that were explicitly issued to support banks through the banking crises that occurred in the 1920s and 1930s does not stand out, but the related amounts provide a rough quantification of the fiscal cost of these banking crises.

### III. DEBT MANAGEMENT IN THE INTERWAR PERIOD

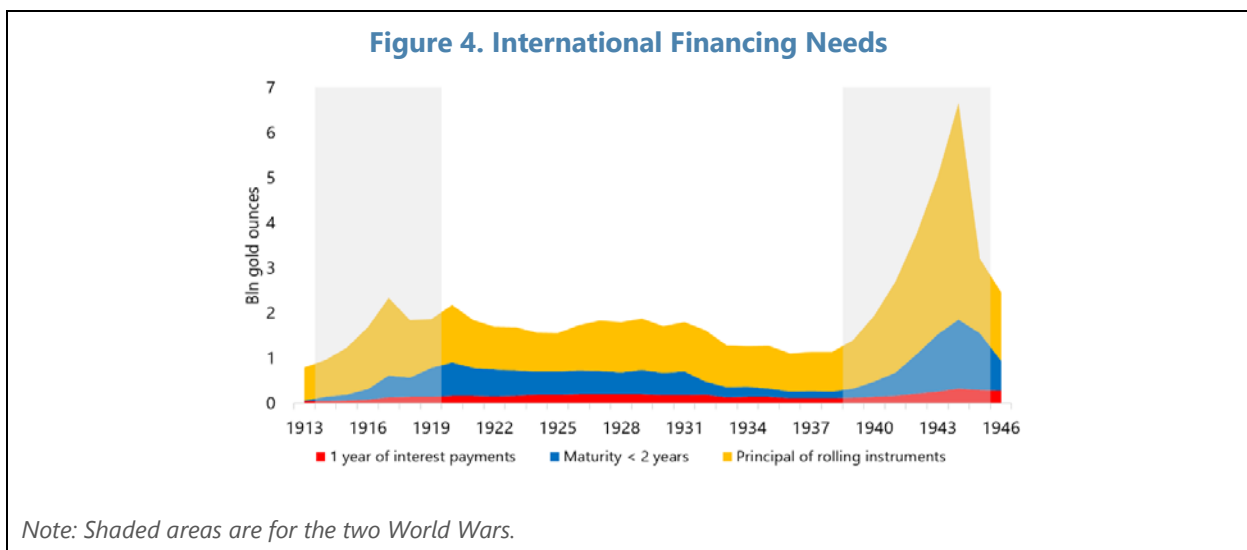
In this section, we use the IDD to illustrate: (i) how interwar governments rolled over debts that were largely unsustainable, and (ii) the manner in which the external public debt network contributed to the collapse of the international financial system in the early 1930s.

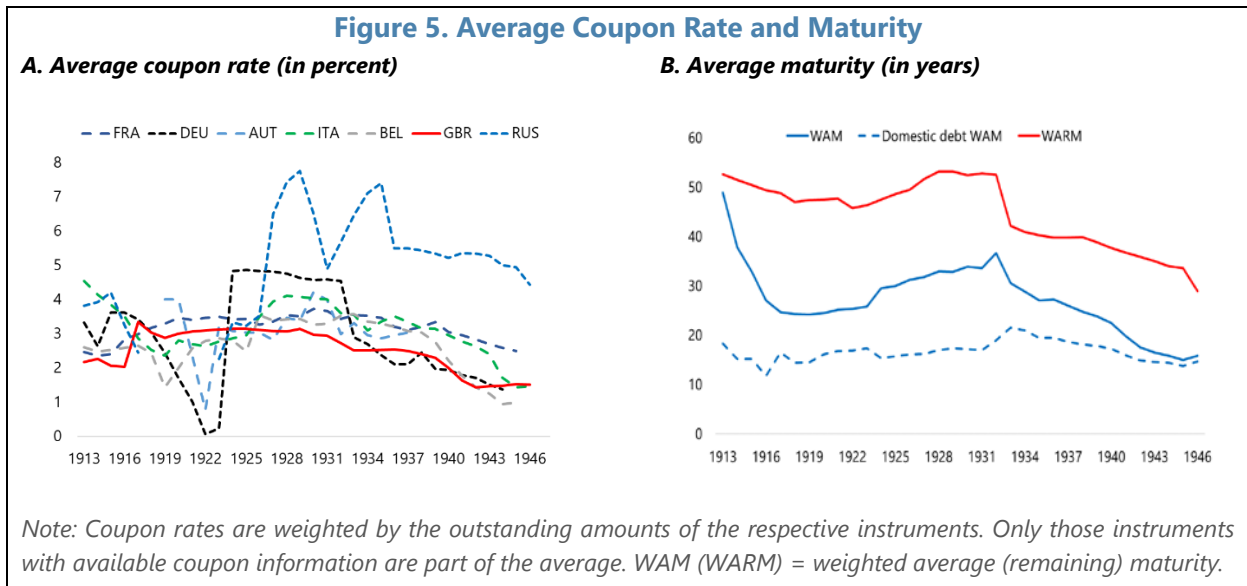
#### A. Managing Rollover Risks in the Interwar Period

Interwar governments regularly faced liquidity and refinancing issues. This was not surprising as most countries ended WWI with a massive stock of public debt, often exceeding their national income and revenues by several multiples. Was public debt unsustainable for many of the belligerent countries in the interwar period? There is no easy answer to this question as a universally acceptable indicator of fiscal sustainability does not exist.

In Appendix F, we draw on sustainability tests from the empirical literature to show that public debt was unsustainable for most belligerent countries. We first we run stationarity tests on our series of government debt for each country. We then use Bohn's (1998) sustainability criterion, which is based on a time series regression of the primary surplus of debt on public debt and other controls for each of the countries in our sample. Our results suggest that for most countries in our sample, the response of the primary fiscal surplus to variation in our measure of government debt was not consistent with meeting the intertemporal budget constraint, and the debt ratio was not stationary.

The IDD also sheds light on how governments managed the imminent refinancing needs that they faced. As shown in Figure 4, the short-term debt-servicing needs were sizable, representing 2bn gold ounces in the overall international system (or two fifths of 1920 US GDP). This raises several questions: were short-term financing needs so large because average maturity was short, interest payments were large, or governments were simply too indebted? The IDD allows us to compile average maturities and effective interest rates to address these questions.





We need to proxy effective interest rates since interwar budgets did not report debt service consistently. To do this, we average the coupons serviced by each instrument. Figure 5.A demonstrates on a European sample how the average rate could vary and differ across sovereigns. However, the resulting rates are surprisingly low, by comparison with levels sometimes observed today. This is in part because bond payoffs included other forms of remuneration than coupons.<sup>12</sup> Further, some countries relied on monetary policy incentives to issue discounted short-term Treasury bills, which do not carry any coupon—these instruments were typically used by central and commercial banks for liquidity management purposes.<sup>13</sup>

As for maturity, there are different ways to envisage the maturity of a security  $D$  issued in  $t_0$ . First, the contractual maturity is  $\tau = t_f - t_0$  where  $t_f$  is the latest payment date (typically, when all the principal has been paid back). This measure underpins the general classification of short-term versus long-term bonds. Second, at any point in time  $t$ , it is possible to account for the remaining maturity  $t_f - t$ . Third, duration is a measure of the average maturity of all future cash flows, weighted by these cash flows. For a bullet bond, duration and maturity are identical. Figure 5.B

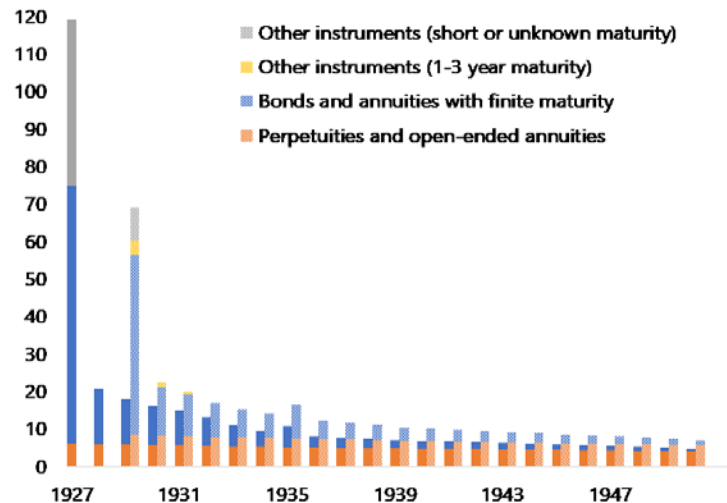
<sup>12</sup> For instance, the dollar-indexed zero-coupon Treasury bills that Germany issued during the hyperinflationary period promised to repay the indexed principal with a premium. The latter could in some instances be as high as 70 percent, which, for a maturity of twelve years, and leaving aside compounding, roughly corresponds to a 6 percent annual interest rate.

<sup>13</sup> It is well-documented that the Austrian and German Finance Ministries forced their central banks to hold large amounts of such discounted Treasury bills during the period of high inflation/hyperinflation. This explains the low average coupon rate for these two countries on Figure 5.A.



plots two maturity measures at the aggregate level.<sup>14</sup> We find that, even though average maturity declined throughout the interwar period (especially during the war when emergency short-term financing had to be promptly tapped), maturities were much longer than those found today in most emerging countries.

**Figure 6. The Effect of the Poincaré Conversion on Expected Debt Service**



Source: Dabla-Norris (forthcoming).

Note: the plain/dotted bars show the expected debt service profile before/after the conversion.

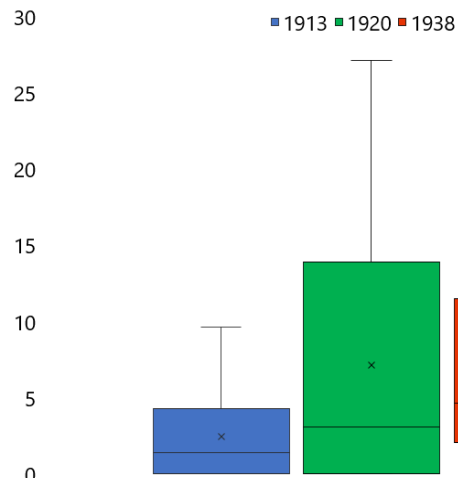
Taking advantage of the granularity of our database, we can also simulate what the expected debt service structure was at any given point in time. This requires making some assumptions, as most instruments included stochastic and discretionary elements—see Dabla-Norris (forthcoming) for details. As an illustration, Figure 6 shows how the 1926 Poincaré debt conversion in France succeeded in reducing short-term expected repayments by half. Implementing such conversions was a common practice at the time as a means for governments to reprofile their debt maturity structure and benefit from favorable market prices. Many sovereign bonds included a call option that could be triggered in good times, in which case a markup was generally paid. Moral suasion and premiums were also used to entice bondholders to swap old instruments for new ones. Less benign debt conversions occurred as well in several countries on the eve of WWII, in conjunction with financial repression (e.g., in Japan, Italy, and France).

Many countries had to roll over unsustainable public debts, while doling out new and costly spending (either social protection policies or military spending). In terms of debt management,

<sup>14</sup> To aggregate the maturity of a debt portfolio composed of  $n_t$  instruments  $(D_{it})_{1 \leq i \leq n_t}$ , we weigh each instrument by its outstanding amount. Therefore, the weighted average maturity is  $WAM_t = \frac{\sum_i \tau_i D_{it}}{\sum_i D_{it}}$ ; and the remaining maturity is  $WARM = \frac{\sum_i (t_f - t) D_{it}}{\sum_i D_{it}}$ .

they optimized the debt profile through conversion operations and were able to secure relatively long average maturities and low interest rates. Bond design was often complex as bonds were tailor-made for different classes of investors, at odds with today's standardization of bonds. According to contemporary sources, short term bonds were intended for institutional investors and perpetuities for small savers. Features such as lotteries, perpetual annuities, indexation mechanisms, tax incentives, and premia also targeted different investors.

**Figure 7. Central bank exposure to government (percent of total debt)**



*Note: This chart shows the distribution of ratios of central bank claims on the government to public debt in 1913, 1920, and 1938. The crosses represent mean average values.*

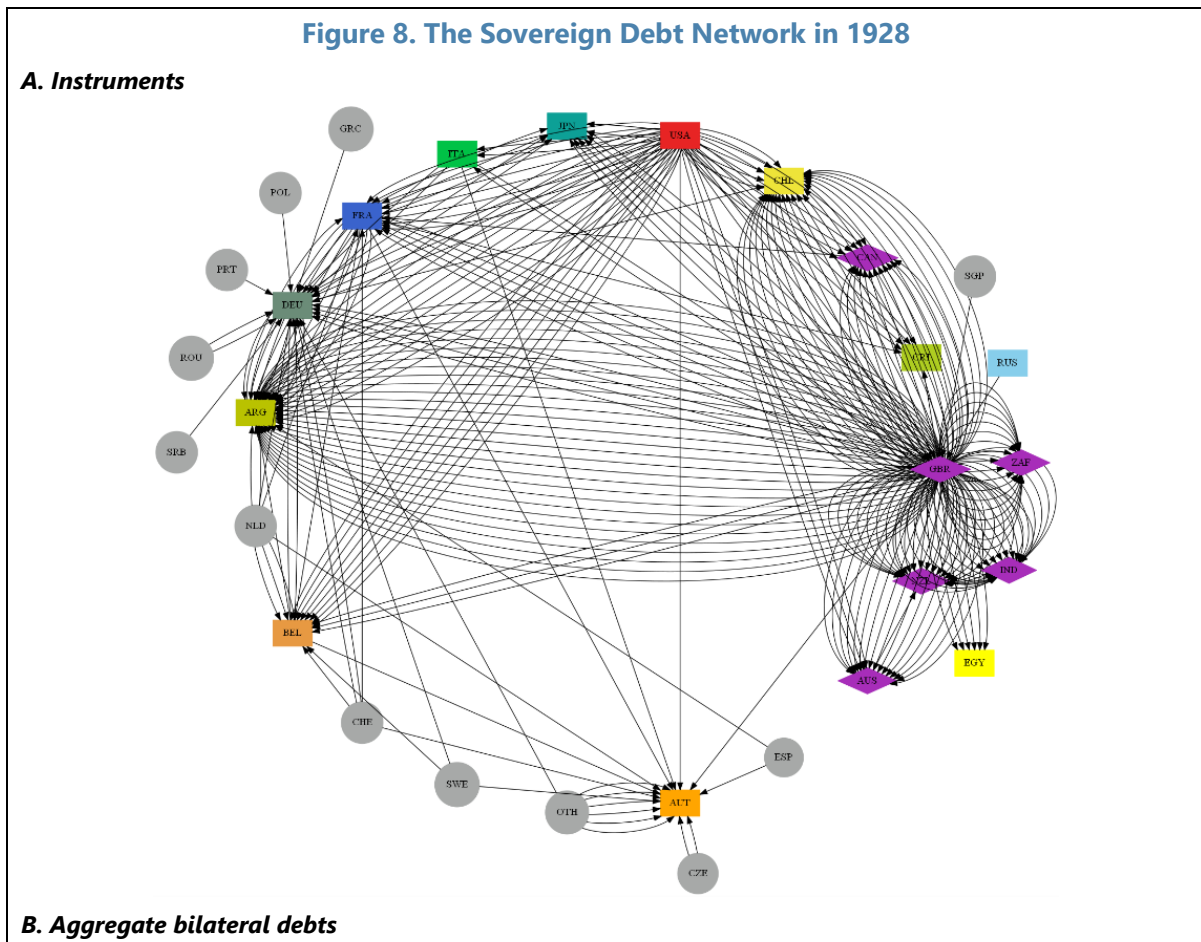
Another perennial challenge was to convince creditors that the government would pay back debt. Adding a form of collateral (e.g., an implicit claim on future taxes through a sinking fund) to the debt contract was used to lower the risk premium. Bignon and Flandreau (2018) note that there were two alternative credibility models before WWI: either the central bank was focused on monetary policy and the government relied on sinking funds; or the central bank was actively involved in financing sovereign debt. War financing created the need for both. Figure 7 uses our central bank balance sheet data to illustrate how central bank exposure to government rose steadily in the interwar period. As the monetary policy standard was to adhere to the gold standard (or a gold exchange standard), a large central bank exposure implied fiscal dominance.

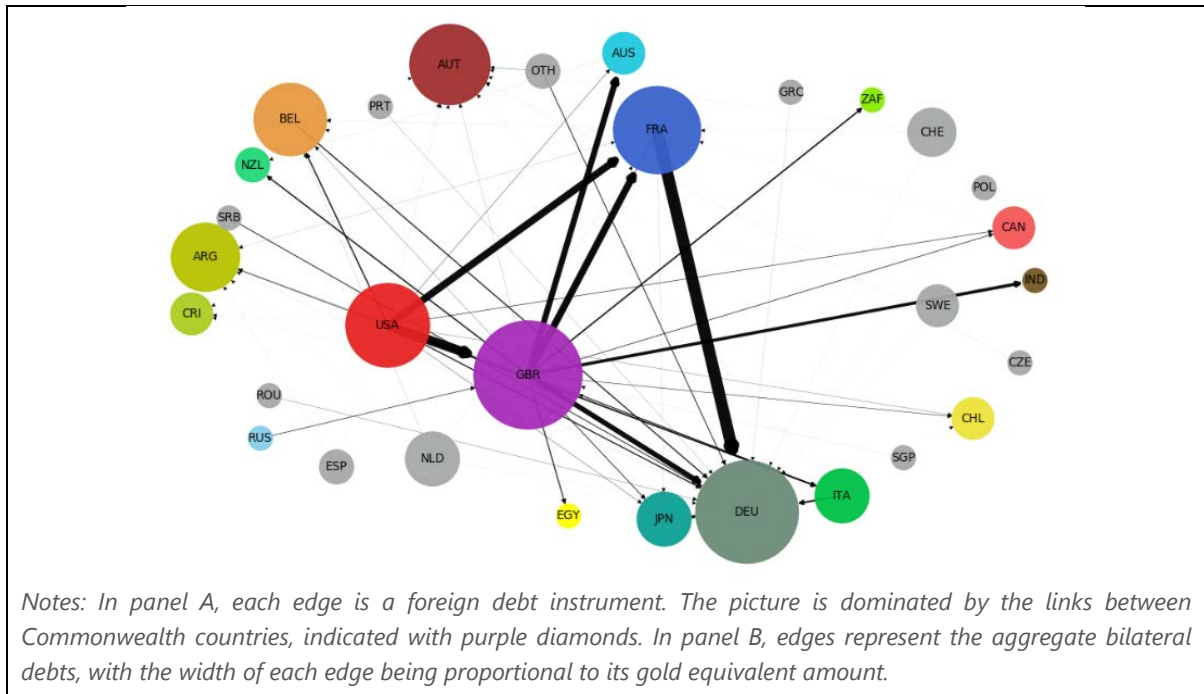
### **B. The External Public Debt Network in the Interwar Period**

The 1920s are often viewed as an earlier period of globalization. Studying the interwar period from the public debt perspective can provide interesting insights into international financial linkages between private and public agents. Existing research on this period mostly focused on overall external imbalances and the role of monetary and exchange rate policies, thereby largely ignoring the role of sovereigns.

The role of sovereign debt in the intensifying financial network and its collapse in the early 1930s is striking. Large foreign borrowing during WWI and the subsequent reconstruction resulted in a complex sovereign debt network (Figure 8). In 1928, continental European sovereigns owed 10 percent of US GDP to the US government and 27 percent of UK GDP to the UK government (De Broeck et al., 2018). By 1933, most of this debt had been written off from governments' balance sheets. In addition to initial large intergovernmental debt flows, the period between WWI and WWII saw sharp movements in private external financing of sovereigns. The stage of the interwar finance drama was set with constant renegotiations of the reparation payments from defeated countries (mainly Germany) to Allied countries (see Figure 9 for the timeline of negotiations).

The network was vulnerable in many ways. First, the extent of interconnectedness was greater than what one would infer from net positions alone. Second, various manifestations of interconnectedness fed into each other, rendering the global financial system vulnerable to sovereign stress.

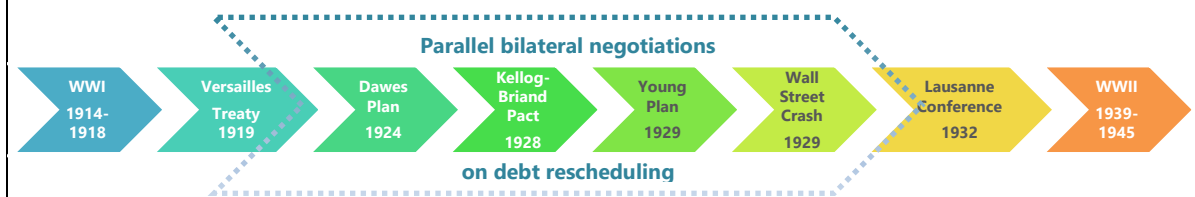




The IDD allows us to describe the external sovereign debt network in a systematic way. Formally, the external debt network is a dynamic graph whose nodes are countries and whose directed edges are the outstanding public debts owed to each other.<sup>15</sup> Drawing on graph theory and topology metrics, we analyze the evolution over time of some graph metrics. Specifically, we examine the role played by some countries and bilateral financial bonds in the overall network, and the transformation of that network during the successive rounds of international negotiations and the advent of the Great Depression. Appendix G provides a graph theory background and formal definitions.

<sup>15</sup> Either on each instrument as in Figure 8.A or in aggregate terms as in Figure 8.B.

**Figure 9. Chronology of International Loans**



**First World War.** *US government financial links with Europe intensified*

- Prior to this point, main worldwide lenders were UK and France
- During the war, US lent more than US\$10bn to the Allies through Liberty Loans Acts
- After the war, US continuously rejected calls to cancel these debts, but gradually accepted to renegotiate

**Treaty of Versailles.** *Conclusion of the Paris Peace Conference and establishment of the Reparation Commission*

- Allies demanded that Germany compensated war costs and damages
- Reparation Commission determined the amount and nature of reparation and schedule payments in Spring 1921
- As soon as December 1921, Germany requested a partial postponement of the scheduled payments. Germany found it increasingly difficult to make the payments, repeatedly activating its escape clause and eventually defaulting in January 1923 (thus triggering France and Belgium's invasion of the Ruhr)
- US endorsed only partially the treaty and requested amendments, particularly on the issue of collective security and the League of Nations (which the US never joined)

**Bilateral negotiations on debt rescheduling.** *Buildup of the web of war, reconstruction, and reparation debts*

- Under pressure to repay its significant debt to the US, the UK formally addressed its European debtors with the Balfour note, pointing out that UK cannot really be expected to meet its obligations to the US without some international settlement that would address Ally obligations to the UK and German reparation payments (i.e. an attempt to link reparations to inter-allied war debt); US rejected this proposal and formed its World War Foreign Debt Commission in 1922, to negotiate repayment plans with debtor countries (on concessionary terms)
- France and Italy used the same strategy of conditioning its debt service to German payments

**Dawes Plan.** *Formalization of interconnectedness, proposed by Reparation Commission*

- Lower annual reparation payments by Germany (become higher as economy recovers), although the total amount was not determined
- Germany's economic policy was to be supervised by foreign powers, and new currency adopted
- US (mainly) banks lent to German government to help economic recovery; Germany started reparation payments to the European Allies, who in turn repaid their war debts to the US

**Kellogg-Briand Pact.** *International agreement to renounce war as an instrument of national policy*

- Originally signed by Germany, France and the US in 1928; most other nations followed
- Limited prospects to enforce debt contracts through military invasion

**Young Plan.** *Reviewing German reparations once more*

- Some of the earlier terms were revised, most notably the total amount of reparations was reduced
- Another loan would be floated on the foreign markets (the "Young Bond")
- The Young Plan also established the Bank for International Settlements, tasked with facilitating payment of reparations in lieu of the ad hoc Reparation Commission

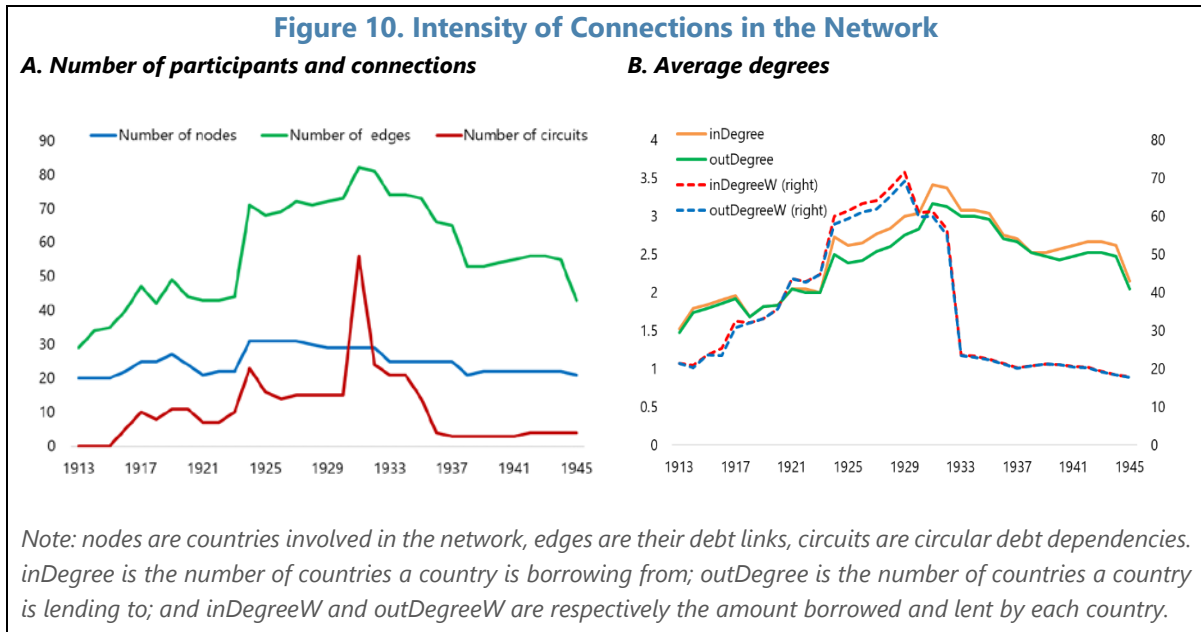
**Wall Street Crash.** *Beginning of a breakdown in the financial system*

- US banks had to recall flows to Europe; German and Austrian banks failed
- Hoover moratorium issued in 1931, suspending reparation payments for one year

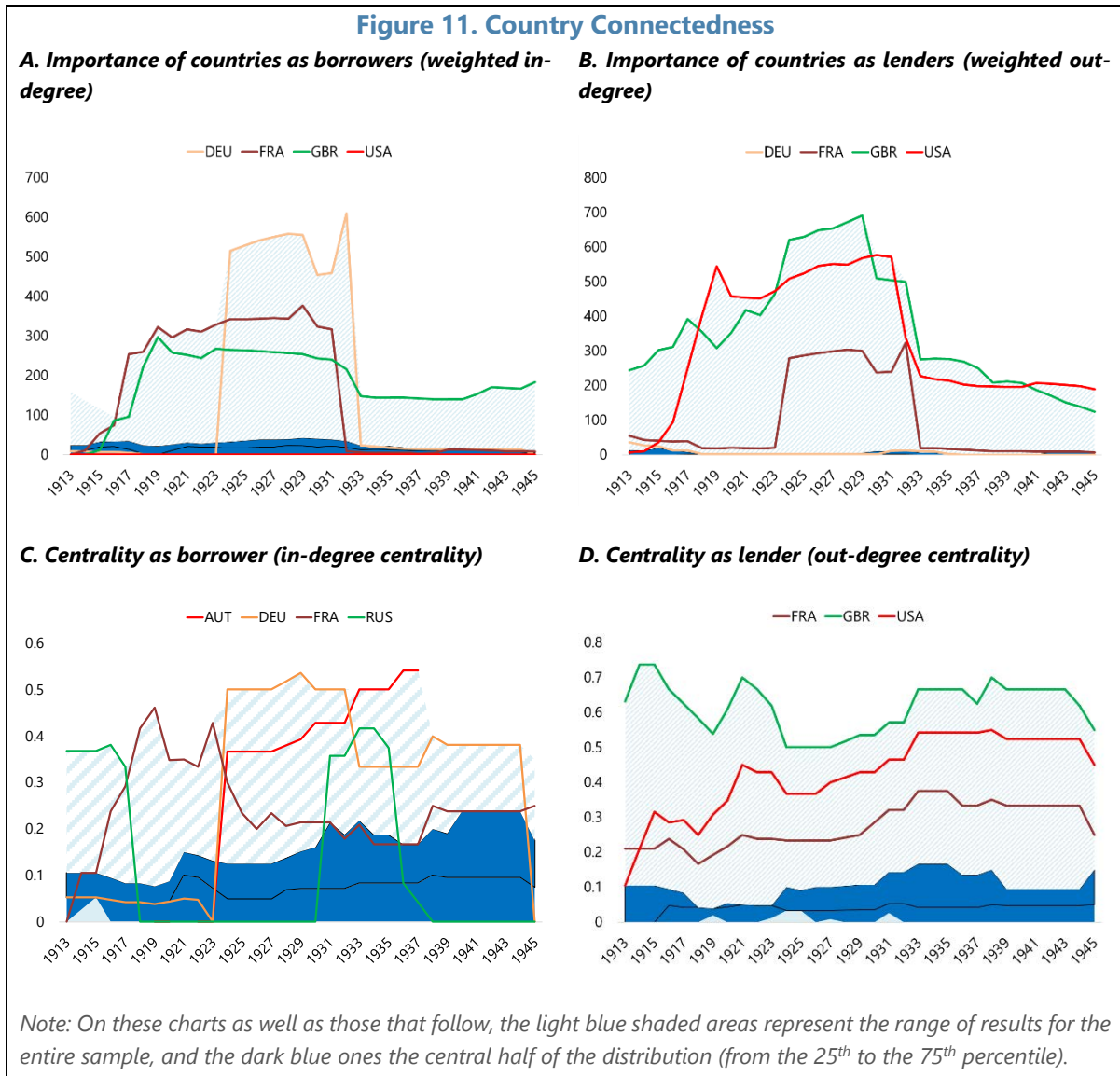
**Lausanne Conference.** *Final attempt to extract reparations from Germany*

- Total amount of reparations reduced even further; interallied debt implicitly repudiated
- Agreement rejected by US congress, but newly-elected Hitler nevertheless suspended all payments shortly thereafter

First, we look at the topology of the network. As shown on Figure 10.A, the cross-country sovereign debt network grew tremendously in 1924, as a likely consequence of the Dawes plan, which restructured Germany's reparations and allowed the country to tap private international financing. This helped to restore confidence in the international debt network while adding a new layer of loans to existing liabilities. We find also new evidence that the Great Depression was precipitated by the cross-country public debt network: the number of elementary circuits, that is the number of debtor-creditor paths that involved distinct countries and formed a cycle, spiked dramatically in 1931.



To measure the extent to which the *number of connections* increased in the network, we compute several statistics. The *degree of a node* is the number of nodes in direct connection and can be interpreted as the number of countries that directly depended on a given country. The *in-degree* is the number of incoming connections to a country (the number of countries lending to it), while the *out-degree* is the number of countries borrowing from a country. The degree can also be weighted by the size of each connection—i.e., by the amount of outstanding debt. Figure 10.B plots the evolution of the average degree metrics over time. It confirms that the network became more intricate in the mid-1920s. Unsurprisingly, we observe that the network collapsed in terms of volumes in the wake of the Great Depression, with total external sovereign debt in the network dropping by approximately two thirds and returning to pre-WWI levels. However, there were always some satellite countries that were not connected to all others.

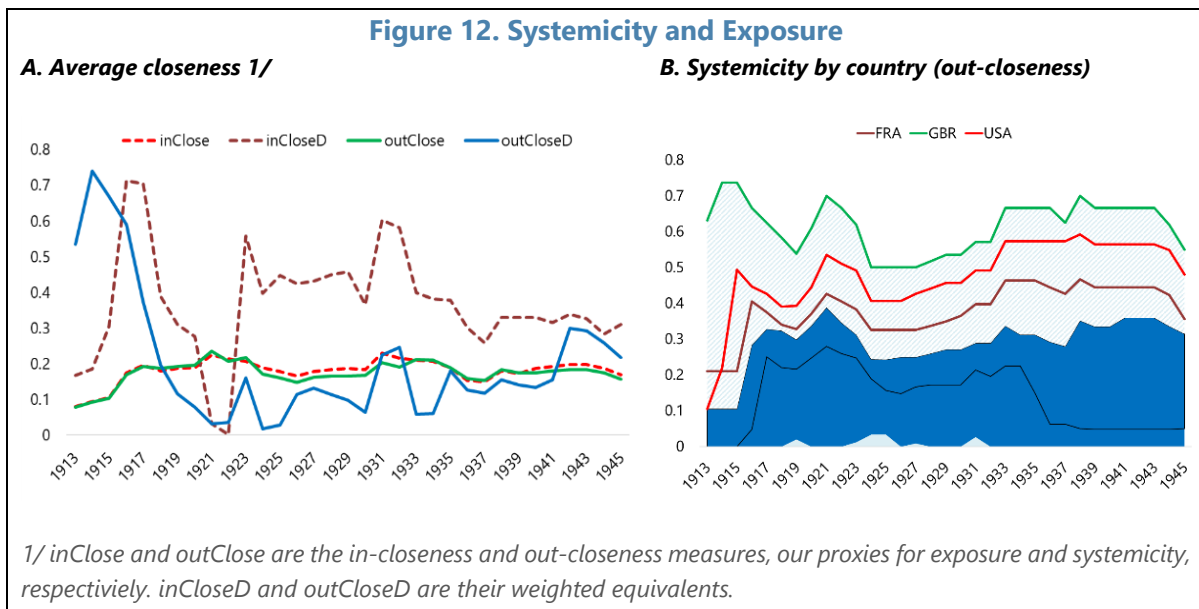


Second, we investigate what countries dominated the network, either as a source or as a recipient of funds in the form of sovereign debt. Figures 11.A–B show that the network was dominated (until the early 1930s) by:

- Germany, France, and the UK as sovereign borrowers. External debt in these countries was mostly related to war financing and subsequent reconstruction.
- The US and the UK, and to a smaller extent France, as the main lenders to other sovereigns. This reflects both the dominance of London and New York as international financial centers as well as the financing provided to their allies during the war. Contrary to the recent literature on international currencies (Chitu et al., 2015; Eichengreen and Flandreau, 2009), we find no clear evidence that the United States dominated the external sovereign debt market since WWI. Instead, our analysis suggests the United Kingdom maintained its prominent role, regularly

outpacing the United States during the interwar period. This finding thus goes along with the conventional historical narrative (Triffin, 1960).

Degree centrality is another informative measure of connectedness as it quantifies how many countries were exposed to a given sovereign's default or to a sudden stop from a given country. On the one hand, there was no clear universal borrower; most countries had a constant in-degree centrality, apart from Russia's sudden appearance in the first half of the 1930s and the high number of creditor countries to Germany, Austria, and post-WWI France (Figure 11.C). On the other hand, the out-degree centrality exhibits the same outsiders as the weighted out-degree: United Kingdom, United States, and France (Figure 11.D). Notably, while in terms of amounts the United Kingdom and United States were roughly on equal footing; the United Kingdom financed more countries than the United States, in part owing to its close ties within the Commonwealth.

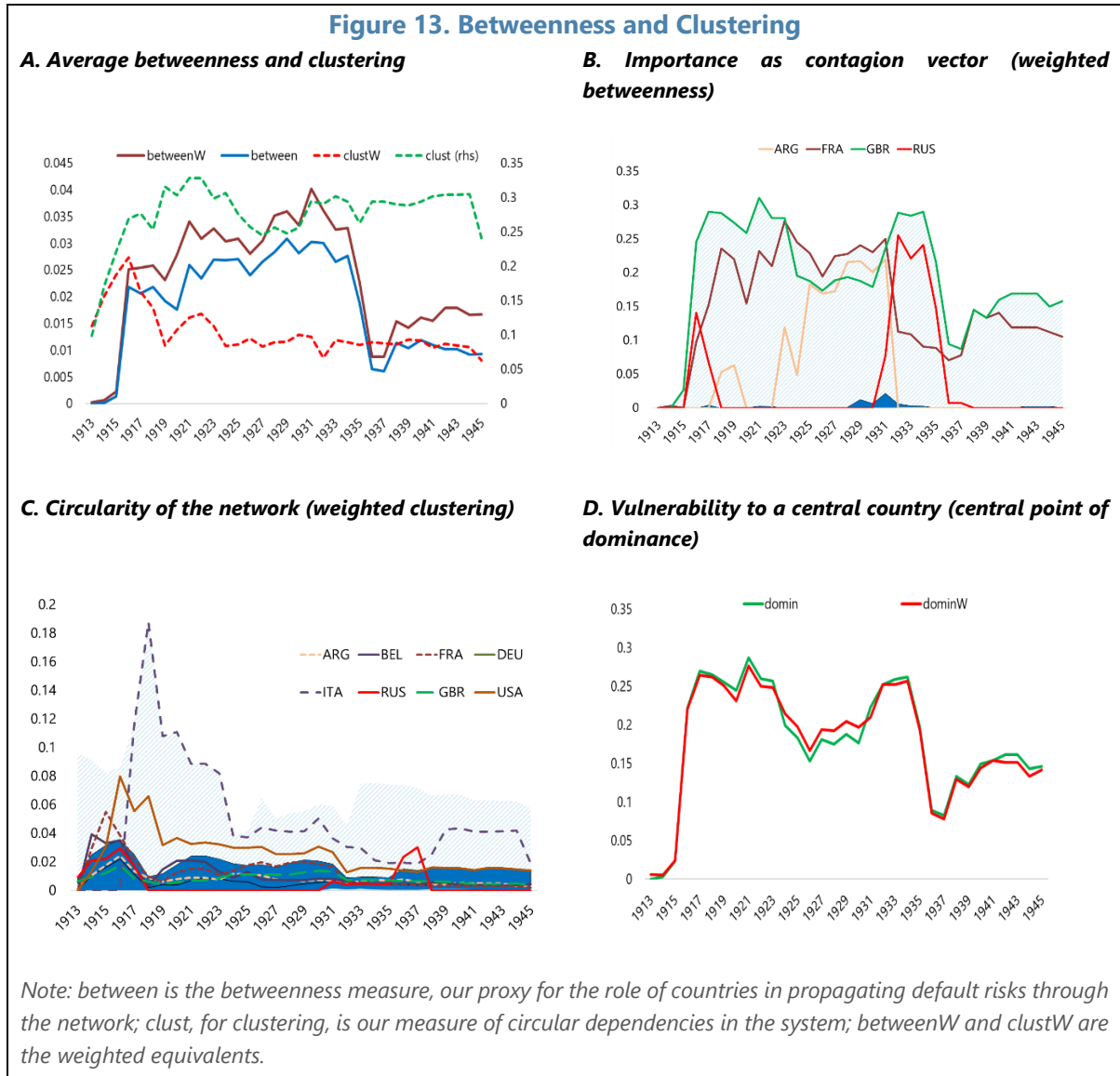


Next, we turn to the importance of a country, as debtor or creditor, for the overall system. The overall "systemicity" and exposure of a country can be proxied by its closeness to other nodes in the network. While the average exposure (in-closeness) built up during WWI and in the runup to the Great Depression, the average weighted systemicity remained low (Figure 12.A). Such an asymmetry between a high number of borrowers and a small and central number of lenders likely contributed to propagate the shock in the early 1930s. Surprisingly, the United Kingdom, the United States, and France were not only the main lenders (and thereby closely exposed to the network), but they were also close in the sense that their default would have quickly impacted most countries in the network (Figure 12.B).

So far, we have only looked at countries that could generate or receive a shock. Next, we investigate the importance of a country as a vector of contagion, that is its *betweenness*. Figure 13.A shows



how betweenness increased with WWI and decreased only with mounting isolationism in the mid-1930s. Figure 13.B sheds light on the role of specific countries, as it reveals that Argentina in the 1920s and Russia in the 1930s were possible financial stress conduits, along with France and the UK. This is yet another result that narrative evidence had so far overlooked.



The last systemic weakness we investigate is the extent of *clustering*, which is indicative of circularities in the financial dependencies. Such circularities can potentially transmit and amplify shocks in the overall financial system and complicate the workout of defaults or stress episodes. To measure this, we rely on a clustering coefficient that can be understood as the probability that two neighbors of a node are neighbors themselves. On Figures 13.C, we observe the high values

obtained by Australia and Italy. These countries, even though not outstanding in terms of external public debt or credit to other sovereigns, found themselves in the middle of intricate networks.<sup>16</sup>

We can also measure to what extent the network was vulnerable to a few nodes using the central point of dominance statistics. As can be seen from Figure 13.D, the Dawes plan was successful in that it broadened the network to more players (simultaneously diffusing the risks). After the Great Depression hit, the network became once again much more centralized, with a small number of countries upon which the entire system became dependent.

In conclusion, graph theory shows how the network was vulnerable to the dominance of a few influential actors, while the actual exposure of each country was blurred by an intricate network.

#### IV. CONCLUSION

This paper describes a new, instrument-level database of sovereign debt for 18 countries over the period 1913–46. The interwar debt database contains data on amounts outstanding for some 3,800 individual debt instruments as well as the associated qualitative information, including instrument type, coupon rate, maturity, and currency of issue. We believe that this is the most comprehensive and comparable data to conduct research on public finances during the turbulent interwar period. The information contained in the database can provide unique insights into macroeconomic and sovereign debt policies implemented in the interwar period. We show for instance how interwar governments rolled over debts that were largely unsustainable. The database also sheds new light on public debt management policies.

We document how the external public debt network contributed to the collapse of the international financial system in the early 1930s. The graph analysis conducted in this paper highlights the inherent vulnerabilities of debt networks. The dominant or exposed positions of some influential players and the circularity of some financial dependencies posed risks. These risks were underestimated because of the intricacy of the network. Incidentally, such an analysis is not possible for today's network, which is most likely even more intricate, because data on bond ownership is fragmentary.

We believe the IDD's rich quantitative and descriptive content will find different users. Historians might find it useful to quantify their narratives, in particular about war financing. Potential links with broader policies—agricultural, social, financial—and the development of providence states are multiple. Economists should also be able to draw interesting parallels with today's economies, particularly since numerous episodes of macro instability happened during the interwar period.

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<sup>16</sup> Incidentally, the maximum  $k$ -core of the network, that is the list of countries with maximal degree, happens to be quite stable and contains not only France, Germany, the UK, and the US, but also Argentina, Belgium, Italy, and for some years the USSR.

Future work could also extend the database, compiling data to the other countries that reported to the League of Nations—chiefly Latin American countries and smaller European countries— and collecting price data for marketable government debt securities.<sup>17</sup>

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<sup>17</sup> Such extensions would also contribute to digitize rare information contained in publications that have long been out of print.

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## Appendix A. Sources

The League of Nations' Statistical Committee was designed to collect and publish economic and financial statistics (Nichols, 1942). It progressively steered statistical cooperation between member countries, leading to the 1929 International Convention on Economic Statistics that imposed on ratifying countries to publish certain classes of economic statistics according to common principles. The IDD draws mostly from the League's *Public Finance* and *Public Debt* publications.<sup>18</sup> We also used the *Money and Banking* and *Statistical Yearbooks* to infer credit lines and advances offered by central banks to governments, as well as exchange rates.<sup>19</sup> Although the League of Nations publications contain surprisingly detailed information, they were only sporadic, resulting in data gaps. Further, coverage was not equally comprehensive for each country.

**Figure A1. A snapshot of information from national sources**

4 PER CENT. VICTORY BONDS :			
Outstanding on 31st March 1921	-	-	357,734,945 - -
Drawn Bonds repaid 1st September 1921 (see page 82)	-	-	1,868,500 - -
Outstanding on 31st March 1922	-	-	355,866,445 - -
Carried forward	-	-	4,891,941,127 16 4

*National War Bonds.*—In addition to the nominal amounts shown above, premiums of 2, 3, or 5 per cent., according to the currency of the Bonds, are payable on 5 per cent. National War Bonds on maturity.

m 88 F

Source: *Finance Accounts of the United Kingdom of Great Britain and Ireland for the Financial Year 1921-22, ended 31st March 1922.*

Our second systematic source of information was Moody's. But their reporting was not watertight. In some instances, instruments were sometimes forgotten, or outstanding amounts were not correctly updated. Some other instruments were listed before their actual issuance—and sometimes they eventually failed to be issued. Therefore, as a rule, we use Moody's outstanding amounts only in cases where no other source was available or in conjunction with aggregates provided in other sources. Moody's also attributed a rating to each security; however, the narrative analysis provided in De Broeck et al. (2018) suggests that these ratings proved ex post not to be a good proxy for the underlying risk of default. For instance, they failed to anticipate the early 1930s sudden stop on external borrowing that followed the Great Depression.

Apart from the League of Nations' and Moody's publications, other sources of information useful in the compilation of the IDD generally fell into three main categories: (1) national sources, (2) literature and commentaries (often contemporary), (3) international treaties and conventions (for example, the Dawes and Young Plans).<sup>20</sup> National sources used include Statistical Yearbooks,

<sup>18</sup> League of Nations (1923a, 1927, 1929, 1936b, 1948).

<sup>19</sup> League of Nations (1931b, 1935, 1936a, 1945).

<sup>20</sup> Reparation Commission (1922–30), Young Committee (1930), and the Hague Agreement (1930).



Government Manuals, Central Bank Bulletins, and other statistics compilations (Figure A1). Detail by country is listed in Table A1 below. The IDD documents clearly the source underpinning each number.

<b>Country</b>	<b>Source</b>
<b>Argentina</b>	<ul style="list-style-type: none"> <li>- <i>Memoria de la Contaduria de la Nacion</i> (1913-1926)</li> <li>- <i>Memoria del Departamento de Hacienda</i> (1913-1926)</li> <li>- <i>Revista de Economia Argentina</i> (1918-1922)</li> </ul>
<b>Australia</b>	<ul style="list-style-type: none"> <li>- Yearbook Australia: Section 19 – Commonwealth Finance (1913-1927)</li> </ul>
<b>Belgium</b>	<ul style="list-style-type: none"> <li>- <i>Annuaire statistique de la Belgique et du Congo belge</i> (1913-1922)</li> </ul>
<b>Canada</b>	<ul style="list-style-type: none"> <li>- Public Accounts (1914-1927)</li> </ul>
<b>Chile</b>	<ul style="list-style-type: none"> <li>- <i>Anuario Estadístico – Hacienda</i> (1913-1922)</li> <li>- Chilean Public Finance (1932)</li> </ul>
<b>Costa Rica</b>	<ul style="list-style-type: none"> <li>- <i>Memoria de la Secretaria de Hacienda y Comercio</i> (1913-1922)</li> </ul>
<b>France</b>	<ul style="list-style-type: none"> <li>- Annual <i>Compte général de l'administration des finances</i>, French Ministry of Finance</li> <li>- <i>Annuaire Statistique</i>, Statistical Institute (INSEE)</li> <li>- CAEF Archives</li> <li>- Fisk (1922), Huet (1935), Laufenburger (1947), MoF (1946), National Shawmut Bank (1915); Sauvy (1965), Teillard (1921)</li> </ul>
<b>Germany</b>	<ul style="list-style-type: none"> <li>- <i>Reichstagsprotokolle</i> (1913-1924)</li> <li>- The Hague Agreement (1930)</li> <li>- <i>Reichsanzeiger</i></li> <li>- Lotz (1927), Will (1921)</li> </ul>
<b>India</b>	<ul style="list-style-type: none"> <li>- Combined finance and revenue accounts of the central and provincial governments in India (1913-1922, 1948)</li> <li>- Accounts and Estimates (1923)</li> <li>- Dubey (1930)</li> </ul>
<b>Italy</b>	<ul style="list-style-type: none"> <li>- <i>Banca d'Italia</i> Annual Reports (1923-1938)</li> </ul>
<b>Japan</b>	<ul style="list-style-type: none"> <li>- <i>Financial and Economic Annual of Japan</i>, Department of Finance (Okurashō)</li> <li>- <i>A Financial History of Shōwa [Shōwa Zaisei Shi, 昭和財政史]</i>, Ministry of Finance (1954)</li> <li>- Bank of Japan (1962, 1966)</li> <li>- Metzler (2006), Tomita (2005), Fujino &amp; Teranishi (2000), Mitzakis (1939)</li> </ul>
<b>New Zealand</b>	<ul style="list-style-type: none"> <li>- Statistical Year Book (1913-1926)</li> <li>- Public Accounts (1913-1946)</li> </ul>
<b>Russia</b>	<ul style="list-style-type: none"> <li>- Statistical Year Book of the Russian Empire (1913-1915)</li> <li>- Statistical Year Book of the Soviet Union (1922-1926, 1934-1945)</li> <li>- Statistical Book "State Budget vol. I (1918-1937) and vol. II (1938-1950)"</li> <li>- Dyachenko (1978), MoF (various issues), RSAE (various issues)</li> </ul>
<b>South Africa</b>	<ul style="list-style-type: none"> <li>- Official year book of the Union (1916-1921)</li> </ul>
<b>U.K.</b>	<ul style="list-style-type: none"> <li>- Bank of England ("A millennium of Macroeconomic Data for the UK")</li> <li>- Finance Accounts (1917-1950)</li> <li>- Pember and Boyle (1950), Wormell (2000)</li> </ul>
<b>U.S.</b>	<ul style="list-style-type: none"> <li>- Monthly Treasury reports (1913-1946)</li> </ul>

## Appendix B. Methodological Notes

### General assumptions

Sources described in Appendix A contributed to the bulk of the information contained in the IDD, but there were some remaining gaps. Although these could potentially be filled with other sources that require more extensive efforts to obtain and process, the IDD relies on several inference methods. Besides, to make the information in the IDD comparable across countries, we also applied fiscal-to-calendar year and currency conversions.

**Bond life cycle.** A typical debt instrument has an outstanding amount that can only decline over time, going to zero after the maturing date. This property is respected in the IDD, except for the following categories: (1) credit lines and advances, whose amounts could fluctuate over time; (2) bonds issued in foreign currency, in which case the amount in issuing currency would respect the declining property over time; (3) rolling short-term bonds that were quasi-automatically reissued and that were hard to disaggregate into separate issuances.

**Linear interpolation.** Interpolation made sense in some cases (for example, gaps between two points with the same amounts outstanding, or between two points with declining values).

**Disaggregation.** In some instances, various bond issuances were aggregated into one broad category (for example, Treasury bills, whose coupon rate changed at each issuance). We denote such bonds in the database as `Rolling` issuance dates and `Floating` coupon rate. As far as possible, we tried to break these categories down into separate issuances, particularly for categories constituting a sizable portion of public debt. To do so, we relied on Moody's publications which reported amounts outstanding for each issuance and applied the breakdown to the aggregates reported in the League of Nations publications.

**Fiscal to calendar year conversions.** Fiscal years differed for the sample of 18 countries included in the IDD, and in some cases fiscal years changed over the interwar period (Table B1). All the series in the IDD were converted to calendar years (ending December 31), thus reflecting the end-of-year amounts outstanding for all instruments. That allows us to apply December exchange rates to the underlying series and obtain the amount of debt in any available currency.

**Currency conversions.** The League of Nations reported amounts outstanding in domestic currency, even for instruments that were issued in foreign currencies and/or on foreign markets. Country-specific methods of debt conversion used by the League of Nations undermine the comparability of debt series across countries. When compiling IDD data, we first expressed outstanding debt amounts in currencies of issue, then performed interpolation and end-of-period harmonization. The resulting series were finally converted to nominal US dollars, a common currency. However, accounting for the fact that the US dollar was unpegged from gold in 1934 and consequently depreciated, we introduced another proxy for the universal currency—gold. For currency conversions we used the exchange rates published by the Federal Reserve (1943).

Table B1. Fiscal years, by country

Country	Coverage	End of fiscal year	Exceptions	Country	Coverage	End of fiscal year	Exceptions
<b>EUROPE</b>				<b>AMERICAS</b>			
Albania		March 31		Argentina		December 31	
Austria		December 31	1918 and 1919 = June	Bolivia		December 31	
Belgium		December 31	1922 = Oct	Brazil		December 31	1933 = March
U.K.		March 31		Canada		March 31	
Bulgaria		December 31	1927-1933, 1934 = March; 1935 = Aug	Chile		December 31	
Czechoslovakia		December 31	December, except 1938 = March	Colombia		December 31	
Denmark		March 31		Costa Rica		December 31	
Estonia		March 31	1928 = Jan	Cuba		June 30	
Finland		December 31		Dominican Rep.		December 31	
France		December 31	1921, 1929-1932 = Mar; 1920 = May; 1923, 1925 = Apr; 1924 = Jun; 1926 = Mar and Dec	Ecuador		December 31	
Germany		March 31	1922 = June	Guatemala		December 31	1944 = June
Greece		March 31	1911 = Sep; 1913-1918 = Dec; 1922 = Jul; 1935 = Jan; 1940 = Feb	Haiti		September 30	
Hungary		June 30	1940-1943 = December	Honduras		July 31	1937-1945 = June
Ireland		March 31		Mexico		December 31	1914-1916 = June
Italy		June 30	1923 = March	Nicaragua		December 31	1916 = October; 1921 and 1929 = March; 1930-1936 = Feb; 1937-1938 = Jan
Latvia		March 31		Panama		June 30	1926, 1932 = Sep; 1931, 1935 and 1939-1944 = Dec
Lithuania		December 31		Paraguay		November 30	1935, 1936, 1946, and 1947 = Dec; 1939-1945 = Oct
Luxemburg		December 31		Peru		December 31	
Netherlands		December 31		Salvador		December 31	
Norway		June 30		U.S.		June 30	
Poland		March 31	1919-1924, 1933-1934 = Dec; 1934 = July; 1945-1946 = Sep	Uruguay		December 31	
Portugal		December 31	1913-1934 = June	Venezuela		June 30	
Romania		March 31	1923-1931 = Dec	<b>ASIA-PACIFIC</b>			
Spain		December 31	Floating debt not available for 1924	Australia		June 30	
Sweden		June 30	1914-1922 = Dec	China		??	
Switzerland		December 31		India		March 31	
Turkey		May 31	1945-46 = December	Iran		??	
U.S.S.R.		December 31	1921-1929, 1934-1935 = Sep	Iraq		??	
Yugoslavia		June 30		Japan		March 31	March, except 1946 = Feb
<b>AFRICA</b>				New Zealand		March 31	
South Africa		March 31		Siam		Various*	March, except 1940 = Dec, 1940 = Sep, 1946 = Oct
Egypt		April 30					

### Country-specific issues

**Argentina.** Several instruments reported by the government and included in the domestic component of the public debt possess all features of foreign obligations. Three instruments called *Credito Argentino Interno* were included in the internal debt section, while they were issued on European markets with the option of for both principal and interest payments to be made abroad. Even though some of these bonds were also issued domestically, we assume that these instruments were foreign in their full amount. Besides, the League of Nations reported Argentinian debt under "legal parity" and "contractual exchange rates." We relied on information on amounts of debt issued in the original currency to back out amounts by instruments in a common convertible currency.

### Australia.

- (1) Australia issued substantial amount of war loans that only are vaguely described in the League of Nations' books, while representing a substantial chunk of debt. We used the amount of

loans issued and aggregates reported by Moody's and assumed the shares of each instrument to be constant.

- (2) The Commonwealth of Australia agreed to take over the foreign debt issued by the States in 1928. The League of Nation did not report debt of the States up until this year, while they represented a sizable portion of the overall Australian financial obligations. We retroplated individual State debt instruments by using Moody's articles covering the Australian States as well as the State Finance section of Australian Yearbooks.
- (3) Most instruments summarized in the League of Nations tables do not have issuance date, only the maturity date, which complicated the interpolation process.

**Austria.** Changing country borders led to complex arrangements for the settlement of the pre-Austria imperial debt and of the relief loans received after the first World War.

**Chile.** The League reported foreign debt, which was entitled in various currencies, after converting to domestic currency under the assumption of the fixed exchange rate, because the spot exchange rate fluctuated considerably. By contrast, we applied flexible end-of-year exchange rates, so that our aggregates are substantially different from that of the League.

**France.** A number of complementary sources were used.

- (1) Both League of Nations and national sources relied on a changing public debt perimeter—in particular, some debts were issued or bought by public banks and corporations, and the government at times assumed the debt service of public companies (such as railways), guaranteed local and colonial governments, and built financial liabilities in the form of annuities rather than public debt. We included any instrument that seemed to ultimately be a central government liability.
- (2) In the 1920s, the French realized they could not service their debt towards allies and investors in allied countries if Germany did not honor its war reparation obligations. Consequently, the French stopped reporting their foreign liabilities transparently. In 1924, they stopped reporting foreign debts in actual francs and referred only to the gold franc value—thereby underestimating them roughly fivefold. As international negotiations to solve the war debt issue stalled, national statistics stopped reporting these debts altogether.
- (3) Most of the WWI and WWII accounting occurred *ex post* and is complicated by changing borders and the German occupation. It is especially difficult to gauge i) the implicit debt imposed by the Reich onto the Vichy government through the occupation levy, ii) the money borrowed in 1945 from the US.

**Germany.** Estimation of German reparation stock required us to refer to original agreements, since the League of Nations books do not provide such information. We split the period from 1924 to 1936 into three subperiods.

- (1) According to the Dawes plan introduced in 1924, Germany was obliged to pay 1bn RM in 1925, 1.22bn RM in 1926, 1.5bn RM in 1927, 1.75bn RM and starting from 1929 2.5bn RM

annually over the period of 45 years. The volume of reparations using the Dawes plan annuities is 41.6 bn RM in 1924 prices, which is consistent with Ritschl (2012)'s estimation.

- (2) The German economy was incapable of servicing the reparations which resulted in several rounds of renegotiation. In 1930, the Young plan lowered the annual reparation payments and spread them over a period of 58 years. Using the annuities from the Young plan, we could identify the sharp decrease in outstanding reparations from 46.9bn in 1929 to 37.5bn in 1930. The German tranches of the Young Loan of 1930 were issued in British pounds, distributed among the domestic investors, and thus recorded under domestic debt, while the League of Nations statisticians considered them as part of foreign obligations. We decided to follow the residency criterion and classify these loans as domestic.
- (3) With the rise of the Nazi party in 1933, reparation payments were substantially reduced, followed by an indefinite halt of payments in 1936. The reparation stock for the remaining period (1933-1936) is calculated based on the actual transfers to the BIS from Germany.

**Japan.** Japanese bonds are characterized not only by a maturity and coupon rate, but also by a mark or a counter. Marks are letters in the *hiragana* alphabet (e.g., ro, tsu, ne)—they come from the ancient way of enumerating in Japan. The League reports were widely incomplete and missed the differences between all these instruments. Using national sources, we managed to disentangle aggregates and have a fuller picture.

**New Zealand.** For New Zealand, the League of Nations publications do not contain sufficient information for disaggregation or interpolation. For example, debt instruments were reported without issuance dates. Turning to national sources, we encountered some issues with the lack of information on whether a debt instrument was issued locally or abroad. We therefore supplemented national sources with Moody's publications, matching instruments with their descriptions using the due date. Furthermore, instruments were grouped differently across various vintages of national sources. In earlier vintages, the amounts were grouped by authorization acts, while the same instrument could be divided across several different acts in later vintages.

**Russia/USSR.** The stock of debt contracted under the tsarist regime stopped being published in 1915 and the Soviets repudiated it formally in February 1918. To fill in the gaps between 1915 and 1918, we used data on debt service to infer the evolution of the stock of imperial debt. For a couple of years after repudiation, no debt was apparently issued, until the first bread loan in 1923. Detailed annual information on outstanding external debt in the 1930s, which mostly took the form of mostly governmental loans, is sparse. When unavailable, we assumed that the credit amount remained unchanged for the entire initially agreed period. Moreover, we exclude the liability created by the 1941 Lend-Lease agreement with the US, absent a reliable valuation. Several attempts were made to assess the value of goods, equipment, vehicles and food delivered by the US during WWII, but the various estimates differ widely. Eventually, after several decades of negotiation about the amount of goods received, Russia agreed to repay the US a small fraction of what was delivered and outlived the war.

## Appendix C. Taxonomy of Debt Instruments

Public debt in this database refers to debt contractually incurred by the central government of a country. This definition excludes municipal and other sub-central government debts, as well as debt guaranteed by the government (typically, securities issued by state-owned industries or banks). However, debt taken over explicitly by the central government are part of our database starting on the date of debt assumption. Hence, some instruments can appear in this database well after their issuance dates. The database also includes non-marketable debt—obligations that specific agencies or individuals (e.g., a central bank advance or a pension annuity) hold nominatively and cannot sell either over the counter or on a secondary market.

Since domestic debt markets were not yet internationalized during the interwar period, instruments were not harmonized across countries and time. Bond denominations did not follow any specific standards and were not necessarily in line with today's understanding. For instance, a sovereign "loan" was a security, not a credit. Against this backdrop, liabilities in the IDD were classified by the nature of promised cash flows into the following instrument types:

**Bond.** Debt instrument that obligated the government to two types of cash flow: (1) a principal when the bonds were presented to the paying agent on or after their maturity date; (2) interest payments when attached coupons were presented to the paying agent. During the interwar period, bullet bonds were rare; most bond principals could be paid before the maturity date. In addition to principal, some premiums or prizes could be given away by the government. They could be called "loan" or "notes," depending on national traditions. Some bonds, such as the British "stocks," were inscribed or held at a deed register; they could only be transferred through a deed, which was considered a more secure method of transferring ownership of the claim. Inscription entailed a process of writing ownership into the lenders' books.

**Perpetual.** A particularly popular type of bond in the beginning of the twentieth century were perpetuals. These "consols" or "rentes" had no maturity date, which means that the principal was never paid—unless the government or the bondholder activated their potential options to redeem it. Formally, the promised cash flow is an infinite series of interest payments.

**Bill.** These are debt instruments without coupons, generally with a shorter-term maturity than bonds. The interest was implicitly or explicitly pre-counted, that is, deducted upfront, as a discount between the issue price and the principal. This category includes numerous Treasury bills. Some of the bills, usually very short-term ones, were implicitly rolled-over unless creditors objected.

**Credit.** These instruments were generally contracted with financial institutions and entailed annual payments of some principal and interest. They came in the form of either one-off borrowing, or as lines of credit on which governments could draw on demand (within pre-agreed ceiling). Another type of credit common during wars was trade credits agreed with the intercession of allied governments; for instance, Morgan & Co. would provide trade credits to France for war supplies during WWI, with the Commerce and Treasury Secretaries' implicit approvals. In contrast to bonds

and bills where multiple small-denomination contracts were signed with a myriad of lenders, credits were by nature bilateral and more sizable. Consequently, they were probably more likely renegotiated on an ongoing basis. The debt reported in the IDD corresponds to the outstanding amount to be repaid.

**Advance.** These financing facilities were arranged with local bodies, other government departments (e.g., Treasury, central bank), savings banks, or foreign authorities. They generally involved a low or null interest rate, an open-ended maturity, and were governed by by-laws rather than commercial contracts. A peculiar sort of advance were tax bonds; taxpayers gave the government an advance on future tax payments.

**Account.** Demand or term deposits were sometimes made available to the government, either regulatorily or voluntarily. Typically, the government compelled or enticed through moral suasion state-owned enterprises (SOEs), colonial and subnational governments, to make their cash available to the government. This instrument is similar to a credit line, but it is up to the account owner (e.g., SOEs) to change the outstanding amounts.

**Annuity.** Annual budget payments could be pledged, by law, as compensation for several reasons. For instance, old-aged or war pensions were recorded as capitalized annuities. Such debt had no set maturity date, and the government could amend its cash flow by law. It is different from a perpetual because the annual payment is not a contractual coupon rate, but rather a lumpsum allocated in each annual budget.

**Other.** Some public debt instruments or aggregates for which no decomposition was possible fit in none of the above categories. These include arrears, a less trackable form of debt were payment delays, that were sometimes recorded as part of public debt. Arrears could be securitized—i.e., suppliers could be paid in sovereign securities instead of cash, what some authors describe as forced loans. The “other” category also encompasses debt transferred from provinces to central government, which it is typically hard to decompose into individual instruments. Unidentified small portions of public debt without any characteristic reported in the official documents were added to this category as well.

## Appendix D. Instrument Characteristics

In addition to the amounts outstanding and the typology detailed in Appendix C, the IDD includes a variety of instrument characteristics. Below are detailed definitions for each characteristic. The IDD also contains more detailed information, upon availability.

**Issuer.** The country whose sovereign issued or guaranteed the instrument (i.e., 18 countries included in the IDD).

**Instrument name.** Taken directly from the League of Nations publications, national sources and/or the Moody's documents. Instrument names typically contained information about the type of instrument, the coupon rate, and either issuance date or maturity. Instrument names were also useful for tracking different instruments across various sources used to compile the IDD.

**Residency and currency.** The market on which the instrument was issued and the currency of issue (Table D1 lists all the currencies in the IDD). This can be any one of the values under "Issuer", or a combination of the values for bonds that were issued on multiple markets. For instruments issued in multiple currencies, we were generally able to apply more precise breakdowns, but sometimes we had to assume equal breakdown. Foreign debt refers primarily to residency, which we define somewhat subjectively. Since there is no information about the ownership of individual bonds, we classify a security as foreign when it was intended for foreign investors—typically, when it was issued mainly on foreign stock exchanges, in foreign currency, or with exchange rate guarantees (e.g., a 'gold clause'). Sometimes, the same instrument was issued in several countries. Whenever possible, we tried to break the instrument down between the various countries of issuance.

**Table D1. List of currencies included in the IDD**

Currency	Code	Currency	Code
Argentinean Paper Peso	<b>ARS</b>	Greek Drachma	<b>DRA</b>
Australian Pound	<b>AUP</b>	Indian Rupee	<b>INR</b>
Austrian Krone	<b>AUK</b>	Italian Lira	<b>ITL</b>
Austrian Schilling	<b>ATS</b>	Japanese Yen	<b>JPY</b>
Belgian Franc	<b>BEF</b>	New Zealand Pound	<b>NZP</b>
British Pound	<b>GBP</b>	Norwegian Krone	<b>NOK</b>
Canadian Dollar	<b>CAD</b>	Russian (Gold/Soviet) Ruble	<b>RUB</b>
Chilean Peso	<b>CLP</b>	South African Pound	<b>SAP</b>
Costa Rican Colon	<b>CRC</b>	Spanish Peseta	<b>PTA</b>
Czechoslovak Koruna	<b>CZK</b>	Swedish Krone	<b>SEK</b>
Dutch Guilder	<b>NLG</b>	Swiss Franc	<b>CHF</b>
Egyptian Pound	<b>EGP</b>	Uruguayan Peso	<b>UYU</b>
French Franc	<b>FRF</b>	US Dollar	<b>USD</b>
German Mark	<b>DEM</b>	Gold	<b>Gold</b>



**Entity.** The entity issuing the instrument. In the database, this column contains the following values: `Bank`, `CB` (central bank), `CG` (central government), `LG` (local government), and `SOE` (state-owned enterprise).

**Transferability.** Refers to whether (or not) the debt was transferable through secondary markets. The dataset includes the following values: `Y` (transferable), `N` (non-transferable), `NA` (no information available) and `T` (for inscribed stocks).

**Coupon rate.** Interest rate associated with the instrument (expressed in percent). Coupon rate is generally the easiest characteristics to report. This is the nominal interest payment that was promised upon issuance, given on a yearly basis (interest payments were generally semi-annual or quarterly).<sup>21</sup> Therefore, it does not include the various premia that were often granted upon issuance or redemption. If interests were pre-counted (i.e., paid upfront at issuance), then we assume a zero-coupon rate. If interest rates were readjusted regularly, then we would classify them as `floating` (for example, in the case of either short-term bills that were automatically or regularly reissued or formal indexation to a reference rate).

**Interest payable.** Months in which interests were paid to the instrument bearer. This information is always mainly for tradable bonds.

**Issuance.** Date on, or year during which the instrument was issued. For the few instruments that were issued on tap, this would be the time of first issuance.

**Maturing date.** Ultimate redemption date for the principal. When the instruments were semi-automatically rolled over, this is coded as `rolling`.

**Maturity.** Difference between **Maturing date** and **First issuance**. Items where no information was provided on maturity were classified based on the instrument type: bills, credit, notes, advances and allied bonds and miscellaneous borrowings considered as short-term obligations; while loans, bonds, stocks, and annuities are considered long-term. Perpetual bonds, which were quite common until WWII, are classified as long-term bonds, even though they technically never repay any principal. Implicitly, the maturity can be found as the date at which interest payments total the initially borrowed amount  $P$ . For an annualized coupon rate  $c$ , the implicit maturity is:  $\tau = 1/c$ . For a 5-percent perpetual, for instance, this is 20 years. Alternatively, the duration would be a function of bondholders' average life expectancy.

**Redemption.** Some debt instruments had embedded options that let either the government or the lender trigger principal repayment earlier than the maturity date. Government's early redemptions could involve lotteries or randomizations, as well as largesse when computing the

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<sup>21</sup> Technically, coupons were pieces of paper attached to bonds, which holders had to exchange at given dates for cash at the Treasury. Hence, it is used as shorthand for the nominal rate of interest on a security (Wormell, 2000).

current latent value of the bond. Possible values are Y, N, and NA, with additional details in the adjacent column: for example, who could call the redemption option (Holder, Issuer, Issuer/Holder) and how redemption was organized (Lottery or SF for sinking fund).

**Start redemption.** Usually, governments kept the option to redeem their bonds to benefit from improving market conditions. However, this type of redeemability would often start a few years after issuance (thereby respecting some sort of grace period) and involve a randomization (or lottery) to decide which bonds would be redeemed first.

**Grace period.** Difference between **Start redemption** and **First issuance**.

**Sinking Fund.** These were cash reserves established to assist in the redemption of public loans on maturity. Portions of budget revenues were sometimes devoted to these funds. Permanent or funded debt was usually debt for which a sinking (redemption) fund had the liability to pay the interest. Possible values are Y, N, and NA.

**Tax.** Taxability is an important characteristic of debt management, although often overlooked by the literature. Tax incentives to hold sovereign debt were common and changed the effective return on such an investment. Tax exemptions could be granted for interest gains under the income tax, for capital gains related to holding sovereign bonds, or more generally for all taxes. Blanket exemptions were almost always granted to foreign bondholders. Possible values are Y, N, and NA.

**Purpose.** A broad categorization of the purposes for which instruments were issued. It was common at the time for Parliaments to approve each issuance, and that was generally done within the context of a legal instrument that implemented specific policies. In addition, it was part of the advertisement of the bond placement to familiarize the buyer what they were contributing to finance (e.g., war or liberty). Possible values are: Conversion, Defense, Economic development, Infrastructure, Miscellaneous, and NA.

**Miscellaneous information.** Complementary information is added on an ad hoc basis. For instance, the rare cases of bond indexation, details on taxation regimes, or the debt's official purpose are recorded whenever it was possible. More detail on any of the other columns is also provided here. For Japan, we document the mark attributed to each series of securities—a Japanese character used in Imperial Japan to enumerate things. For Argentina and Chile, we add law or decree number that authorized the issue if available.

### Appendix E. Central Bank Balance Sheet Data

To gauge the central bank's exposure to the sovereign—in other words, the extent of monetary financing and fiscal dominance—we also compile itemized balance sheet data for the central banks of the countries in our dataset.

The main source for this is the League of Nations publications on *Money and Banking*.<sup>22</sup> Since these publications were sporadic, we cannot cover the entire 1913–46 period and generally miss 1914–17, 1926–28, and the outer years of WWII. In addition, the League of Nations changed its standardized balance sheet classification after the Great Depression. In the IDD, we document clearly how we approximate the post-Great Depression classification into that prevailing before 1929. For instance, we assume implicitly that collateral involved in repo transactions or discounted by central banks had to be mostly constituted of sovereign or quasi-sovereign papers. Similarly, we recorded deposits under other deposits by default, unless it was obvious that it was a current account.

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<sup>22</sup> League of Nations (1922a, 1923b, 1924a, 1924b, 1926, 1931a, 1934, 1935, 1936a).

## Appendix F. Assessing Public Debt Sustainability

As in Bohn (1998), debt sustainability can be related to the intertemporal financing constraint that the government faces. This relates the increase in public debt ( $D_t$ ) to the primary fiscal balance ( $PB_t$ ) and the interest rate ( $r$ ):<sup>23</sup>

$$D_t = (1 + r)D_{t-1} - PB_t \quad (\text{F1})$$

Iterating this debt dynamics equation forward yields a transversality condition, also known as non-Ponzi game condition:

$$\lim_{t \rightarrow +\infty} \frac{D_t}{(1 + r)^t} \leq 0$$

When the transversality condition holds, equation (F1) can be rewritten as:

$$D_t \leq \sum_{s=t+1}^{+\infty} \frac{PB_s}{(1 + r)^{s-t}}$$

To test whether these relations hold, empirical studies run stationarity tests on fiscal variables. For example, Hamilton and Flavin (1986) conclude that US debt was sustainable between 1962 and 1984 by showing that annual series of government debt and deficit were both stationary. In line with this, we run stationarity tests on our series of government debt. We find that the public debt was not stationary for the vast majority of the countries in our sample (Table F1).<sup>24</sup> Since our sample covers 1913–46, the sharp increases in public debt during the World Wars could bias this finding. However, running the same stationarity tests on the interwar sub-sample leads to comparable results.

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<sup>23</sup> The same equation holds in nominal and real terms. Deflating by a price index could however hide complacent monetary policies that help inflating debt away. In this presentation, we omit stock-flow adjustments and assume interest rates are constant.

<sup>24</sup> As a robustness check, we run the same tests on different debt series: in local currency units vs US dollars vs gold equivalent, and for foreign vs domestic debt, finding each time broadly similar results. To account for the limited number of annual observations we have for each country (at most 33 years), we also run panel unit root tests, which confirm that public debt was globally unsustainable during the period.

**Table F1. Unit root tests on debt in local currency**

	Level					First difference				
	ADF <sub>nc</sub>	ADF <sub>c</sub>	PP <sub>nc</sub>	PP <sub>c</sub>	KPSS <sub>c</sub>	ADF <sub>nc</sub>	ADF <sub>c</sub>	PP <sub>nc</sub>	PP <sub>c</sub>	KPSS <sub>c</sub>
Argentina					**					*
Australia					***	*		***	***	
Austria				*		***	***	***	***	
Belgium				**		**		**		
Canada				**		***	**	**	*	
Chile					***	***	***	***	***	
Costa Rica		*		**	*	***	**	***	**	
Egypt					***	***	**	***	***	
France					*	**				
Germany			*			**		***	***	
India						**	*	***	**	
Italy					*					
Japan					**					**
New Zealand					**	**	*	***	***	
South Africa					*			***	***	
UK					*			**		
US					**	***	***	**	*	

Notes: DF, ADF, PP, and KPSS stand for Dickey-Fuller, Augmented Dickey-Fuller, Phillips-Perron, and Kwiatkowski-Phillips-Schmidt-Shin tests. Nc and c denote without and with constant. \*\*\*, \*\*, and \* indicate rejection of the null hypothesis at the 1, 5, and 10 percent level of confidence respectively, while the tests fail to reject it when the cell is empty. The null hypothesis is the existence of a unit root, except for the KPSS test where it is that the series is stationary.

Another strand of empirical studies uses cointegration techniques to test whether debt is sustainable. Haug (1991) demonstrates that a sufficient condition for the transversality condition to hold is that the primary deficit and debt series be cointegrated. We run cointegration tests using the fiscal series compiled by Mauro et al. (2013) and government revenue data from Mitchell (1998) (see Table F2). Columns (2)-(3) report Engle-Granger tests for debt, primary balance and revenue as a percent of GDP, while columns (4)-(5) report the same as nominal amounts in local currency. We do not find any evidence of cointegration. Additionally, we estimate Bohn equations to see whether the fiscal deficit is negatively correlated with the level of debt in the previous year. For most countries of our sample, the primary balance is at best weakly responsive to public debt. Lastly, since many countries reformed their tax systems during the period, we examine debt-to-revenue ratios and find them to be non-stationary as well, confirming that debt was not sustainable.

**Table F2. Cointegration tests and Bohn estimates**

	Bohn	Cointegration tests			
	coefficient	D/Y+B/Y	D/Y+R/Y	D+B	D+R
	(1)	(2)	(3)	(4)	(5)
Argentina	-0.036			na	
Australia	0.039 **			na	
Austria	0.192 **				
Belgium	0.123 **			*	*
Canada	0.060 **				
Chile	0.076 **				
France	0.040 *				
Germany	0.091 ***				
India	0.062 *				
Italy	0.066 *				
Japan	0.003 *				**
New Zealand	0.003 *			*	*
South Africa	0.072 **				
UK	0.083 ***				
US	0.051 ***				***

Notes: The Bohn coefficient is the estimator  $\hat{\beta}$  in the Bohn equation  $\frac{B_t}{Y_t} = \alpha + \beta \frac{D_{t-1}}{Y_{t-1}} + \gamma \frac{B_{t-1}}{Y_{t-1}}$ . B/Y, R/Y, and D/Y are respectively the primary balance, revenue, and debt ratios to GDP. \*\*\*, \*\*, and \* respectively indicate the 1, 5, and 10 percent level of confidence for statistical significance in column (1) and the Engle-Granger test rejection of the null hypothesis that there is no cointegration in columns (2)-(5). Empty cells are for non-rejection and "na" for insufficient data availability.

### Appendix G. Network Analysis Concepts

The debt network is formally a dynamic, directed graph whose nodes are the countries  $(i)_{1 \leq i \leq n}$  and whose directed edges  $(D_{i \rightarrow j, k, t})_{1 \leq i, j \leq n}$  are the outstanding debt lent by country  $i$  to country  $j$  on the  $k$ th instrument at time  $t$ , expressed in gold equivalent. An aggregate version is the (simpler) network composed of the bilateral debts  $D_{i \rightarrow j, t} = \sum_k D_{i \rightarrow j, k, t}$ .<sup>25</sup>

The **degree of a node** is the number of nodes in direct connection and can be interpreted as the countries directly dependent on a given country. In a directed graph, the in- and out-degrees of a node are respectively the number of edges directed into and out of that node, in other words the number of countries lending to and borrowing from a specific country. They can formally be written as:

$$Deg_{\rightarrow i, t} = \sum_j \delta_{D_{j \rightarrow i, t} \neq 0} ; Deg_{i \rightarrow, t} = \sum_j \delta_{D_{i \rightarrow j, t} \neq 0}$$

where the Dirac function  $\delta_x$  is 1 if  $x$  and 0 otherwise. The degree can also be weighted by the size of each connection—i.e., by the amount of outstanding debt. The average in- and out-degrees are simply the average amount of outstanding debt per country.

The **maximum k-core** of the network is the subgraph of countries with maximal degree.

**Degree centrality** is the unweighted in/out-degree normalized by the number of possible connections:

$$DegCentr_{\rightarrow i, t} = \frac{1}{n_t - 1} \sum_j \delta_{D_{j \rightarrow i, t} \neq 0} ; DegCentr_{i \rightarrow, t} = \frac{1}{n_t - 1} \sum_j \delta_{D_{i \rightarrow j, t} \neq 0}$$

While it does not account for the amounts involved, it quantifies how many countries were exposed to a given sovereign's default or to a sudden stop from a given country.

**Closeness** to other nodes in the network is a measure of the importance of a node for the overall network, rather than direct neighbors. If  $H_{i \rightarrow j, t}$  is the hopcount (i.e. the length of the shortest path) from country  $i$  to country  $j$ , we can compute measures of systemicity and exposure as the out- and in-closeness:<sup>26</sup>

<sup>25</sup> To simplify the presentation, we keep all debt instruments at all time; their outstanding value is simply nil before they are first issued or after they are fully amortized. At year  $t$ , the adjacency matrix is therefore  $A_t = (\delta_{D_{i \rightarrow j, t} \neq 0})_{i, j, t}$  and the number of active nodes is  $n_t = \sum_i \min\{1, \sum_j \delta_{D_{i \rightarrow j, t} \neq 0} + \delta_{D_{j \rightarrow i, t} \neq 0}\}$ . The Dirac function  $\delta_x$  is 1 if  $x$  and 0 otherwise.

<sup>26</sup> Since our graphs are in general not strongly connected and may have several disconnected components, we apply Wasserman and Faust (1994)'s correction, attributing small components a smaller closeness value.  $n_{i \rightarrow, t}$  and  $n_{\rightarrow i, t}$  are the number of reachable nodes from/to  $i$ .

$$\text{Systemicity}_{i,t} = \frac{(n_{i \rightarrow, t} - 1)^2}{n_t - 1} \left( \sum_{j \neq i} H_{i \rightarrow j, t} \right)^{-1}; \text{Exposure}_{i,t} = \frac{(n_{\rightarrow i, t} - 1)^2}{n_t - 1} \left( \sum_{j \neq i} H_{j \rightarrow i, t} \right)^{-1}$$

These two measures can also be computed by replacing the hopcount with the distance between nodes; namely, the inverse of the outstanding debt tying countries together.

The **betweenness** represents the importance of a node as a vector of contagion. If  $P_{j \rightarrow i, t}(k)$  is the number of shortest paths from  $j$  to  $i$  that transit through  $k$ , then we have:

$$\text{Betweenness}_{k,t} = \text{Average}_{i,j} \frac{P_{j \rightarrow i, t}(k)}{\sum_{\ell} P_{j \rightarrow i, t}(\ell)}$$

**Clustering** is another source of systemic weakness. The existence of clusters hosting circular dependencies is potentially conducive and amplificatory of shocks. To measure this, we rely on a clustering coefficient that can be understood as the probability that two neighbors of a node are neighbors themselves. The weighted, directed definition of this clustering coefficient is (Fagiolo, 2007):

$$\text{Clust}_{i,t} = \frac{1}{\sum_{j,k} D_{j \rightarrow k}} \frac{\sum_{j \neq k \neq i} \sqrt[3]{D_{j \rightarrow i, t} D_{i \rightarrow k, t} D_{k \rightarrow j, t}}}{\text{Deg}_{i,t} (\text{Deg}_{i,t} - 1) - 2 \text{Deg}_{i \leftrightarrow i, t}}$$

where the total degree is  $\text{Deg}_{i,t} = \text{Deg}_{i \rightarrow, t} + \text{Deg}_{\rightarrow i, t}$  and  $\text{Deg}_{i \leftrightarrow i, t}$  is the number of nodes with which  $i$  forms a simple loop.

The **central point of dominance** is a measure of how much the network is vulnerable to a few nodes:

$$\text{Dominance}_t = \frac{1}{n_t - 1} \sum_i \max_k \text{Betweenness}_{k,t} - \text{Betweenness}_{i,t}$$