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Measuring Financial Market Integration over the Long Run: Is there a U-Shape?

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Measuring financial market integration over the long run: Is there a U-shape?

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Abstract

Using long time series for sovereign bond markets of fifteen industrialized economies from 1875 to 2009, I find that financial market integration by the end of the 20th century was higher than in earlier periods and exhibited a *J*-shaped trend with a trough in the 1920s. The main reason for the higher financial integration seen today is the recent extensive globalization. Around the turn of the 20th century, countries frequently drifted apart. Conversely, in recent years, the bond markets of most countries have moved together. Both policy variables and the global market environment play a role in explaining the time variation in integration, while “unexplained” changes in the overall level of country risk are also empirically important. My methodology, based on principal components analysis, is immune to outliers and accounts for global and country-specific shocks and, hence, can capture trends in financial integration more accurately than standard techniques such as simple correlations.

JEL Classification: F02, F36, G15, N20

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1 Introduction

The extent of international financial integration has important implications for economic theory and policy debates. The relative degree of financial integration during the two capital market booms, before World War I and after the collapse of the Bretton Woods system, remains subject to disagreement. Typical measures of integration include proxies for intensity of legal restrictions on cross-border capital flows, price-based criteria, and quantity-based criteria.¹ Quinn (2003) argues that financial markets were more integrated during the pre-WWI era, whereas Mauro et al. (2002) find that they are more integrated post-Bretton Woods.² Others, including Obstfeld and Taylor (2003; 2004) and Goetzmann et al. (2005), argue that financial markets demonstrate a U-shape and hence an equal amount of integration before 1914 and after 1971.³ It is important to know which period has been associated with a higher degree of capital market integration because these periods differ drastically in terms of the economic environment and policies.

I argue that mixed results in the literature are a result of studies using different methodologies and the failure to differentiate between global or country shocks. I propose a systematic methodology based on the method of principal components. The advantages of this approach are as follows. First, it accounts for several dimensions of integration including market comovement and segmentation, within a straightforward statistical methodology that is widely used in microeconomic research. Second, it is robust to the presence of outliers or heavy-tailed distributions. Third, the current method is robust to the choice of a reference country (such as the United States or Great Britain). Fourth, the methodology has a clear theory-based interpretation. Finally, using this method I was able to account for global shocks while several other methodologies spuriously interpret large global shocks as integration because common

¹Price-based criteria include various interest parity conditions or the purchasing power parity condition, while quantity-based criteria are based on the volume of capital flows and the stocks of external assets and liabilities. See Kose et al. (2009) for a discussion of advantages and disadvantages of various measures.

²Quinn (2003) makes this conclusion based on an indicator of the official restrictions on international financial transactions over the 1890-1999. Mauro et al. (2002) focus in comovement of spreads on emerging markets sovereign bonds and find that spreads today comove across emerging markets to a significantly higher degree than prior to 1914.

³Obstfeld and Taylor (2003, 2004) arrive to this conclusion using a variety of methods—both price criteria and quantity criteria—to evaluate market integration. Goetzmann, et al. (2005) confirm the U-shape in historic stock markets correlations but stress the importance of the number of equity markets which defines investment opportunity set.

global shocks make financial variables move together.

Standard no-arbitrage theory predicts that, when investors are neutral to exchange (or currency) risk and market frictions are negligible, free international capital flows result in the Uncovered Interest Parity (UIP) condition. This result implies that similar assets in different locations have the same expected rate of return regardless of exposure to the exchange risk. However, literature has accumulated abundant evidence of non-negligible exchange, default, and political risk across countries and over time. Further, these risks may result in persistent and volatile risk premia and hinder the ability of countries to tap into international capital markets. If these risks depend on, or are correlated with, legal restrictions to capital flows or the underdevelopment of financial markets, international arbitrage opportunities may also be limited. These combined factors reduce financial integration.

I do not expect to find perfect capital mobility anywhere in history given all the evidence from the literature. Rather, I intend to concentrate on a weaker notion of integration characterized by smaller and more stable risk premia that would result in a higher *comovement* (but not necessarily equalization) of a country's financial returns.⁴ Even if a greater comovement is driven by common global shocks, the fact that such shocks propagate across countries and these shocks are frequent might also be a sign of greater interconnection between individual economies (Bordo et al., 2001). I also verify how comovement of returns has changed over time conditional on time-varying determinants of the risk premia.

My empirical methodology is based on principal component analysis (PCA). The PCA is a non-parametric empirical methodology used to reduce the dimensionality of data and describe common features of a set of economic variables. This method transforms the observed data vectors into new variables referred to as *components*, which are linear combinations of the original data that maximize variance.⁵ The goal of the method is to capture most of the observed variability in the data in a lower-dimensional object and, thereby, filter out noise. Often, a single component summarizes most of the variation of the original data.

I argue that the “first” principal component (with the components ordered according to how much of the data-variation they capture) has a natural interpretation when the PCA is applied

⁴Clarida and Taylor (1997) demonstrate that the nominal interest rate differential is stationary even if we allow for deviations from the simple efficient markets hypothesis due to risk premia and deviations from rational expectations if the resulting deviations from UIP are themselves stationary.

⁵Appendix A is a short primer on the method. See Jolliffe (2002) for a more detailed treatment of the PCA.

to a comparable series (prices, returns, etc.) across markets. When the observed economic variables have a high signal-to-noise ratio, which would be the case under economic integration, a few principal components with larger variance would capture the dynamics that will be informative of the extent of market integration. This result should also be consistent with the standard no-arbitrage theory that implies if the majority of countries are integrated into the world financial markets, their interest rates move together with the world rate. The proportion of total variation in individual returns explained by the first principal component serves as an *index of integration*. I estimate the index of integration over the long-run dynamically via rolling windows. Using the dynamic PCA in the context of market integration is an innovation of this paper as it reveals important trends in integration and country- or group-specific shocks hidden when a single estimate corresponding to the entire period is reported.⁶ Furthermore, using individual country weights (called “loadings” in PCA) on the first principal component, I developed two complementary *indices of segmentation*, which summarize country or group-specific effects, to investigate possible reasons for the changing degree of integration.

Being a price-based measure, the PCA-based index of integration has several practical advantages. The first advantage is the reliance on historic price data, which has a better quality compared to the volume of capital flows used to construct quantity-based measures (Obstfeld and Taylor, 2004). Second, issues that plague price-based measures over the short-term would not affect the results as much when we look at very long time periods.⁷ Finally, the long historic context allows researchers to compare the *relative* degree of integration in the present and during previous periods rather than to test for “full integration” or “no integration” which necessitates the choice of some questionable benchmarks and creates difficulty when the absolute values of these measures have to be interpreted.

My primary data are monthly series of sovereign bond yields from 1875 to 2009 available in the *Global Financial Database* (GFD). The sample includes 15 economies whose sovereign debt was continuously traded in a major international financial center (London) and was available

⁶Due to problems with interpretation, the PCA has not found a widespread application in the integration literature. To best of my knowledge, all existing studies do not explore the dynamic integration pattern.

⁷If two countries share the same technologies, tastes and endowments asset prices in these locations might be identical even with the most stringent barriers to capital flows (Obstfeld and Taylor 2004, p. 46). Such “coincidence” is not likely to persist over the long-run however. Separately, the recent research on the UIP condition in developed countries surveyed by Alper et al. (2009) finds unfavorable evidence mostly at short horizons.

in other locations as early as the mid-19th century.⁸ Historically, sovereign bonds have been the most actively traded segment of financial markets.⁹ In contrast to the stock market indices, the characteristics of the underlying instruments in bond markets (maturity, coupon payments, the identity of the issuer, etc.) are similar across countries and over time. This comparability makes these data attractive for long-term study of the dynamics of financial integration. I prefer using bonds payable in national currency and do not convert the data into a single currency or constant prices because I take the perspective of an investor in international financial markets and want to analyze all possible reasons for changes in comovement (currency and country risk, cross-border frictions, and other limits to arbitrage).¹⁰ Prior to World War II, the database reports multiple bond series, while the unified series became available from the 1920s onward. I carefully select those early bond series that are most comparable with the subsequent series in order to minimize breaks and make the long-term series consistent.

I estimate the index of integration over 1875–2009 using a relatively wide rolling window of 156 months (13 years), which makes the results relatively immune to short-term noise and to conditional heteroskedasticity in returns. Over the very long-term, the evidence points to higher financial market integration at the end of the 20th century compared to earlier periods. Therefore, the integration followed a *J*-shaped trend with a trough as early as the 1920s rather than a U-shape as documented by Obstfeld and Taylor (2004) and others. This pattern is also confirmed by time-series regression analysis. According to the indices of segmentation, around the turn of the 20th century countries frequently drifted apart while in the recent years the most countries move together. This uncovers the changed nature of shocks prevalent in the two eras of globalization. Finally, I find that both policy variables (average inflation and the exchange-rate regime) and the global market environment (proxied by average trade openness) play a role in explaining the time variation in the index of integration, while “unexplained” changes in overall level of country risk are also empirically important.

⁸The largest sample includes Austria, Belgium, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom, and the United States. The motivation for this sample is described in Section 5.1.

⁹Obstfeld and Taylor (2004) also stress that long-term bond yields are most appropriate for a study of the international capital mobility because they are most directly related to the financing costs for capital investments.

¹⁰As a robustness check, I also deflate the nominal yields by the national CPI (also from the GFD) to compute the expected real returns. The qualitative results about the pattern of integration are not sensitive to this adjustment while there are some short-run differences, particularly in the 1950s. Appendix E discusses this issue more.

For illustrative purposes, Figure 1 presents a smoothed estimate of the index of integration over 130 years. As illustrated in this figure, and consistent with the literature, the dynamics of integration have not been even throughout history. Specifically, integration grew from the late 19th century up to 1914, when World War I began. Following that period, the trend in integration turned negative and reached a historic low around the time of the Great Depression in the 1930s. The partial recovery of international financial linkages in the 1920s is invisible in the graph since it was short-lived. After World War II, the trend in integration turned positive and continued its upward crawl almost uninterrupted to a historic high by the end of the 20th century. It is clear that integration reached levels comparable to the Gold Standard era as early as the late 1960s. This evidence is consistent with the view expressed by Kose et al. (2009) that evaluating integration based on the de jure government restrictions on capital flows may be misleading because capital controls could be avoided, as was the case in the 1960s, which was characterized by rapid expansion of trade, offshore banking, and Eurocurrency markets.¹¹ This result casts a serious doubt on the Macroeconomic Trilemma paradigm: clearly, during the Bretton-Woods era of tight controls some capital flows were possible in spite of fixed exchange rates and monetary policy that was designed to keep rates fixed.

My measure of integration does not rely on any particular underlying model; nevertheless this measure has a clear theory-based interpretation. In the case of countries' interest rates, the first principal component may naturally be interpreted as the "world" rate. Figure 2 illustrates the individual country yields used in this study with the values on the left axis and the estimated world return on the right axis. This figure demonstrates that the world return captures the dynamics of individual rates remarkably well while it is not affected by country-specific shocks. This is because the world return uses country weights based on features of the data and not subjectively asserted by the researcher. This proxy also reflects the continuously changing individual countries' influence on the world return. For example, when a country

¹¹ While Eichengreen (1996, pp 120-122) cites some evidence that the capital controls still mattered in the 1960s to keep covered interest differential relatively large, he stresses that with the relaxing of current-account restrictions it became easy to over- and under-invoice trade and channel money abroad. The growth of multinational corporations also helped undermine capital controls. Krugman and Obstfeld (2009) textbook discusses some anecdotal evidence. Eurodollars were introduced in the 1950s to support the needs of the growing international trade; after the late 1950s offshore markets for other currencies emerged when these currencies became increasingly convertible. Official regulations and political concerns further contributed to growth of Eurocurrency trading and undermined the official controls.

shuts down its capital markets, its domestic financial market behavior diverges from the world market. First principal component will immediately capture this decoupling, which will show up as a lower loading that corresponds to this country.

The remainder of this paper is organized as follows. The following section discusses related literature. In Section 3, I lay out a conceptual framework that motivates the empirical analysis and helps interpret the results. Section 4 discusses the methodology used to quantify integration in various markets. Section 5 describes the data and the pattern of integration. Section 6 offers some explanations of the observed pattern. Finally, Section 7 concludes.

2 Historic integration patterns: Evidence in the literature

Researchers have not yet reached an agreement regarding the extent of international integration in the 1990s-2000s compared to the first era of globalization, prior to World War I. Quinn (2003), Bordo and Flandreau (2003), and Bordo and Murshid (2006) argue that financial markets were more integrated during the pre-WWI era. Quinn (2003) compiles an indicator of official restrictions on international financial transactions from 1890–1999. He documents that virtually all (industrialized and developing) countries were almost completely open by the late 19th century and concludes that financial globalization was deeper in 1890-1913 than subsequently. Bordo and Flandreau (2003) argue that the recent integration is largely an advanced country phenomenon, whereas it was relatively easier for “periphery” countries to borrow in “core” countries currencies before 1914.¹² Finally, Bordo and Murshid (2006) focus on the transmission of shocks and currency crises and find that financial shocks were more globalized before 1914 compared to the present.

In contrast, Bordo et al. (1999b, 2001), Mauro et al. (2002), and Quinn and Voth (2008) find that the markets are more integrated post-Bretton Woods. Bordo et al. (1999b) point out that the globalization of commodities and financial markets is deeper and broader now, if we take into account such impediments as transportation costs, the degree of contract enforcement, government trade barriers, and information asymmetries. While in the past long-term capital flows were large relative to the size of the world economy, the commodities trade was much

¹²Obstfeld and Taylor (2004) also stress large (compared to the size of their economies) external liabilities of the “periphery” countries then.

smaller relative to countries' outputs. Today's trade and direct investments span previously "non-traded" sectors including services, retail trade, and public utilities. Bordo et al. (2001) analyze the 120-year history of financial (banking, currency, and twin) crises and find that these incidences are more frequent today due to unprecedented capital mobility (especially of short-term capital) and higher risk-taking aided by modern financial safety nets. Today's prevalence of more disruptive twin crises also points on the larger breadth of financial integration; however, in general, today's crises are not more severe in terms of length and output losses.¹³ Mauro et al. (2002) study bond market correlations and Quinn and Voth (2008) focus on stock market correlations and find that, from the early 1990s, these correlations are at the historic high, even compared to the pre-World War I period—the period of zero restrictions according to the Quinn's capital restrictions measure. Mauro et al. attribute sharp changes in bond spreads to global events in the 1990s and to country-specific events in 1870–1913.

The third group, represented by Obstfeld and Taylor (2003; 2004) and Goetzmann et al. (2005), argues that there is a U-shape and hence an equal amount of integration before 1914 and after 1970.¹⁴ Obstfeld and Taylor (2003; 2004) arrive at this conclusion using a variety of price and quantity criteria of integration. Goetzmann et al. (2005) confirm the U-shape in the historic stock markets correlations; however, they also document the changing number of equity markets, which defines investment opportunity set. While they find that today the average correlation among the *available markets* is lower, the *number* of world markets available for the international investor is larger. This explains why we do not see a larger comovement of today's stock markets with average correlations.¹⁵

The examples above demonstrate that, methodologically, the existing literature mostly draws conclusions about financial integration from one or a few metrics of integration. Re-

¹³Kose et al. (2005) provide the evidence that the common factor explains a larger fraction of output, consumption, and investment volatility of the Group of Seven countries compared in the globalization period 1986–2003 than in the Bretton Woods period 1960–1972.

¹⁴Zevin (1992), Neal (1985, 1990), Obstfeld (1995) are the earlier papers showing that historical periods in the 18th century and the 1890s are quite similar with respect to the degree of capital markets integration to the late 1980s–1990s.

¹⁵Several papers provide indirect evidence that financial integration was high both in the past and today. Clemens and Williamson (2000) study historical British capital flows and find that both prior World War I and recently integration of capital markets was sufficient to eliminate the influence of international market failures on capital flows. Rajan and Zingales (2003) show that financial development is positively correlated with a country's openness to trade, both in the beginning of the century (1913) and towards the end of the century (the late 1990s).

searchers seem to lack a uniform measure of integration (an “integration index”) that is theory-based and transparently and clearly reflects the extent and dynamics of integration in a particular market. One solution suggested by Goetzmann et al. (2005) and Obstfeld and Taylor (2003) is to explore the changes in time-series correlations of returns across countries over time. Obstfeld and Taylor admit, however, that a higher correlation among markets might be the result of common shocks among a group of countries and not necessarily evidence of globalization. To overcome this problem Obstfeld and Taylor (2003; 2004) investigate the pattern of financial integration based on a *combination* of price and quantity criteria. In my view, it is important to pursue a more systematic study—more in spirit of Obstfeld and Taylor (2003; 2004)—to quantify integration, explore its dynamics, and capture episodes of market segmentation.

3 Conceptual Issues

The financial literature has a long tradition of measuring financial markets integration (or market efficiency) by comparing returns on similar financial assets. The standard no-arbitrage theory predicts that free international capital flows result in the UIP condition between expected rates of return of two countries, expressed in a common currency, such that $1+i_{t,k} = (1+i_{t,k}^*) \frac{S_{t,k}^e}{S_t}$ or, as log-approximation,

$$i_{t,k} - i_{t,k}^* = \Delta_k^e s_t \tag{1}$$

where $i_{t,k}$ and $i_{t,k}^*$ are the nominal interest rate on domestic asset (in domestic currency) and foreign asset (in foreign currency), S_t and $S_{t,k}^e$ are today’s and expected future spot exchange rate k periods ahead, quoted as the domestic-currency price of one unit of foreign currency, and $\Delta_k^e s_t \equiv s_{t+k}^e - s_t$ (with the lower-case exchange rates being in logs). Under the UIP, a domestic investor’s exchange risk exposure is uncovered.¹⁶ By extension, in the multi-country case, perfect capital mobility would preclude local asset prices to deviate from global prices.

The international macroeconomics literature has established that “frictions” associated

¹⁶The UIP condition in Eq. (1) assumes that the number of international investors is sufficiently large, the investors are exchange-risk-neutral, transaction costs are negligible, and assets located in different countries are identical with respect to liquidity, maturity, political and default risk. UIP hypothesis can be empirically tested by estimating a regression $\Delta_k s_t = s_{t+k} - s_t = \alpha + \beta(i_{t,k} - i_{t,k}^*) + u_{t+k}$ and testing the joint hypothesis of $\alpha = 0$, $\beta = 1$, and u_{t+k} is orthogonal to the information available at t . Such test assumes the rational expectations by which $s_{t+k} = E(s_{t+k}|I_t) + u_{t+k}$ and the forecast error u_{t+k} is independent of the information at time t .

with national borders are the reason for having lower integration in the recent decades than what we would expect in theory.¹⁷ Explicit government trade and capital controls, sovereign and default risk, information asymmetries, poor institutions, and high price of physical capital are examples of such cross-border frictions.¹⁸ Various aspects of ‘country risk’ determine the ability to access global capital markets on favorable terms. Institutions that historically contributed to financial integration include the adherence to the Gold Standard prior to the 1913 (Bordo and Rockoff, 1996), the credibility of this commitment (Mitchener and Weidenmier, 2009), the reestablishment of the Gold Standard at pre-World War I parity in the 1920s (Bordo et al., 1999a), the return to gold at a devalued parity in combination with prudent government fiscal policy and country reputation with respect to previous defaults (Obstfeld and Taylor, 2003; 2004), stable economic and political environment (Flandreau and Zúmer, 2004; Ferguson and Schularick, 2008), and avoidance of excessive borrowing (Reinhart and Rogoff, 2009). Obstfeld and Taylor (2004) conclude that the changes in quantity and price indicators of financial integration over the last 150 years have been caused by changes in barriers to international capital flows (or changes in arbitrage opportunities) over time, not by the structural changes within economies. Obstfeld and Taylor and also Eichengreen (1996) further emphasize the dramatic political, economic and intellectual changes over the course of the century and stress the political economy considerations behind the changes in international integration over time in accordance with the Macroeconomic Policy Trilemma. According to the Trilemma hypothesis, growing political tensions at home pushed national governments toward a greater macroeconomic activism in the 1920s–1930s compared to prior to World War I, when government policies were subject to maintaining the “rules of the game” of international Gold Standard arrangement.

Consequently, the UIP with risk is a natural benchmark to study the relationship between the degree of international financial integration and economic policies, fundamentals, and international market environment, all of which determine the “risk” for an international investor.

¹⁷The manifestations of low international financial integration include home bias in equity holdings (French and Poterba, 1991; Tesar and Werner, 1995), high correlation between country savings and investment (Feldstein and Horioka, 1980), lower cross-country consumption correlations than output correlations (Backus et al., 1992), lack of flows of capital from rich to poor economies (Lucas, 1990).

¹⁸See Wei (2000), Reinhart and Rogoff (2004), Alfaro et al. (2008), and Caselli and Feyrer (2007). Kalemli-Ozcan et al. (2010) show that net capital income flows *within* the United States are predicted well by a frictionless open-economy neoclassical model.

Theoretically, the deviations from the parity condition in (1) could be attributed to the non-rationality of market expectations, risk aversion of investors (by which investors would demand a premium for holding assets they consider risky), existence of transaction costs, market frictions, government interventions, and limits to speculation (investors engage in arbitrage only if the excess return per unit of risk is large enough). Retaining the assumption of rational expectations, the deviation from the UIP in (1) can be represented as:

$$i_{t,k} - i_{t,k}^* - \Delta_k^e s_t = \rho_t \quad (2)$$

where ρ_t is the time-varying risk premium (broadly defined). Risk premium is positive if domestic interest rate is higher than the level predicted by the UIP.¹⁹ To see various sources of the risk premium consider some options for an international investor from 1880–1913.²⁰ The investor could purchase the Danish 3.5% Internal Debt Loan of 1887 denominated in kronor floated in Copenhagen and paying $i_{t,k}$, the Danish 4% Loan of 1912 in British pounds floated in Copenhagen and paying $i_{t,k}^{\mathcal{L}}$, the Danish 3% Gold Loan of 1897 in pounds floated in London and paying $i_{t,k}^{\mathcal{L},Lon}$, or the British consol bond in pounds floated in London and paying $i_{t,k}^*$. Using this notation, the equation (2) can be decomposed into:

$$i_{t,k} - i_{t,k}^* = \Delta_k^e s_t + (i_{t,k} - i_{t,k}^{\mathcal{L}} - \Delta_k^e s_t) + (i_{t,k}^{\mathcal{L},Lon} - i_{t,k}^*) + (i_{t,k}^{\mathcal{L}} - i_{t,k}^{\mathcal{L},Lon}) \quad (3)$$

$$= \Delta_k^e s_t + \rho_t^E + \rho_t^D + \rho_t^P \quad (4)$$

The term $i_{t,k} - i_{t,k}^{\mathcal{L}} - \Delta_k^e s_t$ reflects the exchange risk ρ_t^E because the assets it represents are identical in terms of the issuer and the jurisdiction (Denmark) but different by the currency denomination. The assets in the term $i_{t,k}^{\mathcal{L},Lon} - i_{t,k}^*$ differ by the issuer country but both are in the foreign currency and floated in foreign market from the perspective of Denmark. This term represents the default risk ρ_t^D . The assets in the third term $i_{t,k}^{\mathcal{L}} - i_{t,k}^{\mathcal{L},Lon}$ differ by the jurisdiction but are the same in terms of currency (the pound) and the issuer (Denmark), reflecting the

¹⁹With the failure of the rational expectations assumption, the expected depreciation term $\Delta_k^e s_t$ in (2) could be represented by the actual exchange-rate change $\Delta_k s_t$ plus a forecast error ν_{t+k} that depends on the information exploitable at time t . Sarno and Taylor (2002) stress the importance of risk premia, expectations, and the use of survey data in testing of the UIP. See Alper et al. (2009) for a recent survey.

²⁰The following historical example follows similar UIP decomposition in Frankel (1992) and Alper et al. (2009) with the information on Danish bonds obtained from Bordo and Flandreau (2003).

political risk ρ_t^P of shifting the capital across borders. The nominal interest differential then equals to an anticipated change in the exchange rate plus the sum of the exchange risk ρ_t^E , the default risk ρ_t^D , and the political risk ρ_t^P . Hence, in general, risk-neutral investors (who care only about expected returns) would ask for the country-risk premium $\rho_t^D + \rho_t^P$, and risk-averse investors would in addition require the exchange-risk premium ρ_t^E .²¹

One approach to the study of financial integration within the UIP-with-risk paradigm is to identify the degree of integration with the risk premium and analyze its time-series pattern and properties (see Lothian, 2002 for a group of industrial countries over the long-term; Holtemöller, 2005 for the EU accession countries). The second approach consists primarily of country studies and relates the total risk premium or its components to macroeconomic fundamentals, transaction costs, or monetary policy (see Alper et al., 2009 for the survey).²² As Obstfeld and Taylor (2004) stress, we always face the problem that “every test [for capital mobility] is usually a matter of degree,” and the choice of benchmark to which today’s integration should be compared is difficult. Furthermore, the data availability often poses a challenge to the direct studies of the UIP over the long-term. Considering this, I combine these approaches to face the challenges experienced by previous researchers. Similarly to the first literature, I study the deviations from UIP indirectly by looking at *comovement* of the nominal returns over time. I also follow the second strand of literature and verify how the comovement of returns changed over time, *conditional* on time-varying determinants of risk premia.

4 Empirical Methodology

4.1 Correlations as measures of integration: A critical assessment

Interpreting a high correlation of economic series as evidence of substantial integration has several issues.²³ First, the literature often measures correlations of return spreads relative to a

²¹In case of government bonds, ρ_t^D and ρ_t^P represent the “country risk” as defined by Frankel (1992) which captures “all barriers to integration of financial markets across national boundaries: transactions costs, information costs, capital controls, tax laws that discriminate by country of residence, default risk, and risk of future capital controls.”

²²Alternatively, the capital asset pricing models (CAPM) suggest that only non-diversifiable “systematic” risk can be interpreted as a risk premium. According to the CAPM literature, if exchange and country risks cannot be (completely) diversified they are the part of the systematic risk and hence would explain return differentials.

²³In historical studies of equity market integration this measure was used, among others, by Goetzman et al. (2005), Obstfeld and Taylor (2003), and Quinn and Voth (2008).

particular economy. Over relatively long time periods, the choice of the reference country, and thus the trends of its returns, might affect conclusions drawn from the correlations of spreads versus that country. This is indeed the case in my data as Figure 3 shows where the correlations of spreads versus the U.S. and Great Britain demonstrate the opposite pattern. Second, while the conventional Pearson product-moment correlation coefficients do not require that data is normally distributed, it is defined in terms of moments (covariance and the standard deviations) that must exist. As such, one can always compute a sample correlation if the range of the distribution is bounded. However, the sample correlation is not a robust statistics in the presence of outliers or a heavy-tailed distribution (see Wilcox, 2005; Huber and Ronchetti, 2009). Third, conclusions about integration drawn from correlations may be biased by the conditional heteroskedasticity of market returns, or the hypothesis that cross-market correlations depend on market volatility, as argued by Boyer et al. (1999), Forbes and Rigobon (2002), and Longin and Solnik (2001) among others. Boyer et al. (1999) demonstrate that one cannot correct the problem by comparing an estimated correlation conditioned on the observed (or ex post) realization of market returns because the conditional correlation is highly nonlinear with respect to the level of return on which it is conditioned. Forbes and Rigobon (2002) focus on clearly-defined episodes when a crisis in one market increases market volatility elsewhere. They argue that in such cases conventional correlation coefficients are biased upward and suggest a correction that crucially relies on certain statistical assumptions including that the shock originates in a clearly identified market, there are no exogenous global shocks and feedback from the other markets, the variance of the noise in links between countries remains the same. Not only are these assumptions fairly restrictive in general, but we also need to identify a clear exogenous event that could have caused a change in market volatility. Longin and Solnik (2001) show that the correlation of market returns is mainly affected by market trends, not the high volatility of returns per se. Correlations seem to increase only when asset prices fall (bear markets); however, not when they are expected to rise (bull markets). These issues are inherent flaws of correlations and the literature seemingly has not reach a consensus on how to correct this problem in general. Fourth, and related to the previous, if the financial markets are affected by a global shock in a similar fashion, the correlation across countries might be high even without substantial integration. One cannot distinguish high integration

and a common shock as both may show up as a higher value of correlation. The adjustment by Forbes and Rigobon (2002) breaks down when a high cross-market volatility results from the aggregate shock that is much larger than an idiosyncratic shock transmitted to a country's neighbors.

These interpretational and statistical issues make correlation coefficient an inadequate measure of *integration*. Very often, the observed differences in correlations result from the changes in statistical properties of a sample rather than from actual economic links. Therefore, the study of integration over time should be complemented with an analysis of the shocks pertinent to a group of countries in corresponding time periods.

4.2 Principal component analysis

I use principal component analysis to overcome the limitations of correlations in measuring integration. This method is valid without needing specific assumptions regarding the particular distributions of the data except that it does require the data is interval-level.²⁴ This is the first obvious advantage over the correlation, which is not a robust statistic in the presence of heavy-tailed distributions observed in financial series.

Principal component analysis is a non-parametric empirical methodology used to reduce the dimensionality and describe common features of the data (Appendix A discusses the background of this method). This method transforms the observed data vectors into unobserved orthogonal linear combinations, referred to as *components*, with a goal of maximizing the variance of the components. The components are then ranked by their variance, with the first component having the largest variance. The lower-order components typically yield a larger variance compared to the original series. Additionally, each component of a higher order “explains” most of the *residual* variation in the data that is not captured by the previous component, and so on. As a result, a smaller number of components, often just the first component, summarizes most of the observed variation in the data and filters out noise.

A few available papers have used the PCA to complement other techniques of measuring financial integration. Most notably, Mauro et al. (2002) find that the first principal component

²⁴The data is interval-level if there is a meaningful continuous scale of measurement such that equal differences in the scale correspond to equal differences in the physical quantities they measure. See Jolliffe (2002) for a detailed treatment of the PCA.

explains a large proportion of variation of sovereign bond spreads for a group of emerging market countries from 1877–1913 and an even larger proportion in the 1990s. Earlier, Nellis (1982) used PCA to compare interest rate comovement among industrialized countries before and after the move to a floating exchange rate regime in the early 1970s and Gagnon and Unferth (1995) examined their trends in 1977–1993. These studies look at the proportion of the total variation in economic series described by the first principal component arguing that a single variable explaining most of the variation in the data would indicate market integration. Nellis (1982, p.346) cautions against the mechanical interpretation of the first principal component as a measure for integration, however, does not explore this issue further. A high and growing degree of integration among *a subset* of countries might generate a strong component; therefore, we would find financial interdependence within that subset, but not integration in the entire sample.²⁵ The existence of several factors, each affecting only a subset of countries in the total, would imply market segmentation according to Bordo and Murshid (2006). They study the first three principal components in sovereign bond spreads and find sharp distinctions in the patterns between advanced and emerging countries in the 1990s.

As such, the existing studies limit the use of PCA to calculating the principal components over a particular time period. In extension of the previous literature, I propose a systematic methodology based on the method of principal components to measure economic integration over time. The details of practical implementation are discussed in Appendix B. The combined approach I advocate differs from the previous literature along several dimensions. First, I estimate principal components with rolling windows. In doing so, I use the proportion of the total variation in the level of individual returns explained by the first principal component as a *dynamic* measure of integration in a group of countries. This *index of integration* can be plotted over time to provide a visual illustration of the time path of integration and be used to explain the discovered patterns in a regression framework.

Second, I recognize that the extraction of principal components from spreads requires the choice of a reference country. The resulting patterns are benchmark-specific, and this could affect the interpretation of results. In contrast to the studies by Mauro et al. (2002) and

²⁵The indicators of such possibilities include the following: (1) the first principal component does not affect all countries uniformly (this means that correlation of individual variables with first principal component differs a lot among countries), and (2) the remaining factors explain considerable amount of the residual variation after the first component is accounted for.

Bordo and Murshid (2005), who work with bond return spreads, I apply PCA to the *levels* of financial returns. In this case, assuming some integration across markets, the the first principal component may naturally be interpreted as the unobserved “world” return since this factor captures the most variation in individual returns. Of note, spreads versus this estimate of world return are independent of a particular reference country, which is an advantage. Similar interpretation is applicable to other markets with available price data, i.e., to the markets where the notion “world price” exists.

The third consideration involves capturing possible group divergencies or country-specific shocks. A high and growing degree of integration among a subset of countries, or simply peculiar characteristics of a group, might generate a component with large variance. This is why Bordo and Murshid (2005), who studied the data for advanced and emerging markets, discover several components with large variance. The interpretation of the higher-order components is generally theoretically difficult. For this reason, I analyze country, or group-specific effects using two complementary *indices of segmentation* computed from country weights on the first component. Tying financial integration and segmentation to the estimated world return has a solid theoretical interpretation related to the UIP condition.

The final consideration involves the treatment of conditional heteroskedasticity. This issue is an inherent flaw of correlations; however, is not known to plague the results of PCA, which is a more outlier-resistant and distributionally robust method. Still, I choose a relatively wide window to guard against the short-term noise and possible issues of conditional heteroskedasticity in returns.

5 Evidence from the index of integration

5.1 Historic sovereign bond data

Data availability and quality are the major challenges for empirical studies of integration over the long-run. For example, to directly test for UIP or to estimate risk premia in (3), one would need a relatively long time series of returns on comparable (in terms of currency, maturity, liquidity, risk) assets, spot and forward exchange rates, determinants of risk, and reliable estimates of market expectations. For the majority of countries such data is largely

not available or non-existent over the long run. Historical studies of integration focus on asset data in the same currency and priced in a single market. As seen in (3), using such data allows researchers to isolate country risk (if assets are in foreign currency) and default risk (if they are also floated in a foreign financial center).²⁶ This approach is appropriate if one studies only the time period when the corresponding instruments are available; however, this might be problematic over the long-term as pointed out by Obstfeld and Taylor (2003, 2004) who argue that one cannot credibly compare two periods when the data are not consistent.

I use monthly bond data over 1875–2009 from the *Global Financial Database* (GFD). This database contains monthly financial data from about 100 countries with bond and equity series for some countries beginning as early as the 18th century. The GFD reports bond yields for comparability. I make the following decisions to achieve data consistency (Appendix C provides details on bond data), referring to the descriptions of particular historical bond issues in the GFD manual, *Kimber's Record of Government Debts and other Securities*, published in 1920 and 1922, Bordo and Flandreau (2003), and other sources. First, I focus on long-term sovereign bonds. Historically, this is the most actively traded segment of internationally financial markets.²⁷ In contrast to stock market indices, the characteristics of the underlying financial instruments (e.g., maturity, coupon payments, the identity of the issuer, and so on) are similar across countries and remain relatively stable over time. Second, I choose the series with fewest breaks. Most governments started to publish the unified indices of bond yields only in the 1920s.²⁸ The breaks in the series are sometimes present when historic series are spliced in GFD with the subsequent modern series. When multiple historical bond series are available I choose the earlier series most comparable with the subsequent series. Third, where possible, I use the series of bonds payable in national currency, even when some issues were floated in London, because my goal is to analyze all possible reasons for changes in comovement including exchange, political, default risk, cross-border frictions, and

²⁶Examples are secondary market yields on long-term government bonds in London (Bordo and Rockoff, 1996; Mauro et al., 2002; Obstfeld and Taylor, 2003; 2004) or the yields at the moment of new bond floatation in New York that became an important bond market in the interwar period (Bordo et al., 1999a).

²⁷Obstfeld and Taylor (2004) also stress that long-term bond yields are most appropriate for a study of the international capital mobility because they are most directly related to the financing costs for capital investments.

²⁸The League of Nations began to compile the internationally comparable financial data in 1920, but the coverage improved only by the late 1920s. Goetzmann, et al. (2005) say that this was roughly the case for the stock market indices.

other limits to the arbitrage discussed in Section 3. The later series are always payable in national currency. Fourth, I use a fairly homogenous but representative sample of 15 relatively advanced economies whose sovereign debt was continuously traded in the major international financial center (London) as early as the mid-19th century. It is reasonable to assume that all these countries had similar structural or institutional conditions, at least in relation to the development of financial markets, if not the level of overall economic development. With a few exceptions, there were no major defaults on government debt by these countries that would create discontinuities in the time series. Countries include Austria, Belgium, Denmark, Finland, France, Germany, Italy, Japan, the Netherlands, Norway, Spain, Sweden, Switzerland, United Kingdom, and the United States.²⁹ For the longest time period, I use a sub-sample of 11 countries with appropriate yield data available for the entire time period.³⁰ I decided to exclude British Empire countries since colonial ties with the UK influenced their spread behavior (i.e., over the 1880–1930, the Empire countries typically had interest rates within two percentage points of British rates; see Obstfeld and Taylor, 2004).

Figure 2 illustrates the individual country returns used in this study with the values on the left axis and the estimated “world” return (the first principal component) on the right axis. Table 1 presents the summary statistics for bond returns across exogenous periods according to prevailing international monetary arrangements as defined by Bordo and Schwartz (1999). With slight modifications these periods include (1) Classical Gold Standard, 1875:01–1914:07; (2) Interwar Period, 1919:01–1939:08; (3) Bretton Woods System, 1945:06–1971:07; (4) Modern Float, 1971:08–1990:12; and (5) Modern Globalization, 1991:01–2008:09 (I also combine the latter two periods into a single Post-Bretton Woods period).³¹ The first two columns report the average return and corresponding standard deviation for each country over the entire time

²⁹Obstfeld and Taylor (2004) study similar set of countries and refute the idea that these countries faced different “shocks to technology” over the century. Bordo and Schwartz (1996) classify Austria, Denmark, Italy, Japan, Spain and the U.S. to be emerging countries in pre-World War I period.

³⁰I exclude Austria, Finland, Japan, and Switzerland whose consistent bond yield series start in the GFD after World War I. For example, for Switzerland the only data available before 1925 is the average of 12 state and federal railway bonds. In other cases, I only have the data for the sovereign bonds payable in gold until the late 1920s, which does not allow to investigate the currency risk.

³¹I omit the years of two world wars because then markets were usually inactive and reliability of data is questionable. I also define the sub-periods to obtain the maximum coverage across countries. Sometimes I have to fill the missing values with linear interpolation but preferred not to do interpolation where the data were missing in the beginning of the sub-sample for a particular country. In such case the series for this country is started from first available observation.

period. The remainder of the table reports the average returns across five historical periods. For all the countries, bond returns remained low and stable throughout the first half of the 20th century. Following World War II, the returns rose continuously reaching double digits in the 1970s–80s, then turned down sharply in the 1990s. The 1971–1990 period was also exceptional as evidenced by the highest variability of returns. Volatility decreased somewhat in the 1990s; however, did not reach the low pre-World War II level. A similar pattern is observed in the behavior of cross-section variability of returns. Specifically, both unadjusted and mean-adjusted cross-section standard deviations imply a hump-shaped pattern of variability with the top during the Bretton Woods and Modern Float and the tendency for convergence during the last period. The general ranking of countries in terms of levels of returns is approximately preserved over time despite some important changes in individual yields over time.

5.2 Trend in bond markets integration

Before turning to my method, I follow a few existing studies and calculate the proportion of total variation in 11 bond returns explained by the first principal component over the pre-defined periods. The proportion is equal to 76% over 1875–1913, 55% over 1919–1939, 84% over 1945–1971, 60% over 1971–1990, and 95% over 1991–2008.³² Based on this measure, the comovement of bond markets is higher “now” than ever before. In addition, the comovement was relatively high from the end of World War II until the collapse of the Bretton Woods system and was interrupted by the turbulent 1970s–80s. Still, a single factor explained more than a half of the variation in bond yields over the five periods, and 83% over the entire period from 1875 to 2008. These findings are broadly consistent with the other studies, however, mask interesting dynamics.

The dynamic approach outlined in Section 4 reveals shorter-run patterns in comovement that are obscured when comparing only two exogenously-chosen (and arguably ad hoc) periods of globalization. I estimate principal components for 11 bond series using 156 month centered rolling window.³³ The graph of the total variation in returns explained by the first principal

³²The pattern is similar for 15-country sample with Austria, Finland, Japan, and Switzerland over four periods starting 1919.

³³Estimations with the bandwidth of 120 and 180 months produced very similar pattern. In addition, I used the historic bond data from 1880 to 1914 kindly shared by Marc Weidenmier, used in Mitchener and Weidenmier (2009). The resulting pattern of index of integration is very similar.

component, the index of integration, is presented in Figure 4 together with a smoothed trend line. Based on this figure, we can draw the following conclusions. First, consistent with the literature, the dynamics of integration was not even over 130 years. Integration grew from the late-19th century up to 1914, when World War I broke out. Following this, the trend in integration turned negative and reached a historic low around the time of the Great Depression during the 1930s. There was a partial recovery of international financial linkages in the 1920s; however, it was very short-lived. After World War II, the trend in integration turned positive and continued its upward crawl almost non-interrupted to the present time. Second, despite the common view, it is clear that in the present group of countries integration in sovereign bond market reached the levels comparable to the Gold Standard era as early as the late 1960s, on the verge of the collapse of the Bretton Woods system. Third, the evidence points to a higher financial market integration at the end of the 20th century compared to the earlier periods. The integration thus followed a *J*-shaped trend with a trough as early as the 1920s, rather than a U-shape, as documented by Obstfeld and Taylor (2004).

To verify whether the graphical evidence for the *J*-shaped pattern holds true in a statistical sense, I run a regression of the index of integration on linear and quadratic time trend over the period 1975–2002.³⁴ I assume the error structure is heteroskedastic and autocorrelated up to 12 months, and also control for the periods of two world wars. Column (1) of Table 2 shows the regression for the monthly index of integration. The coefficients of linear and quadratic trends are highly significant and point to a non-linear trend line. The values of the coefficients imply that the trough in the trend in integration is around Sept. 1928, which is remarkably consistent with the historical evidence pointing at the Great Depression as a “watershed” of financial integration (Obstfeld and Taylor, 2003; 2004). The fact that the minimum in integration corresponds to the late 1920s, closer to the beginning of the sample period used for this estimation, is evidence that the trend line follows a *J*-shape over the period 1975–2009. Columns (2) and (3) repeat the exercise using quarterly or yearly averages of the monthly data. The results using these “smoothed” series are very similar, with the minima around the time of the Great Depression.

³⁴Since the index of integration is estimated by a centered moving window of 156 months (13 years), the ends of the periods would use less observations. In the regressions I prefer using the index estimated with all the data. The results over longer period of time, up to 2008:09 are very similar.

6 Toward explaining integration patterns

To prove that my method reflects dynamics of bond market integration and not something else, in particular common shocks, I employ a series of additional checks. The evidence provided so far shows that the recent period is characterized the largest proportion of variation attributed to a single important factor than ever before. Potentially, the index of integration may have a lower value due to country- or group-specific effects. The situation when the majority of countries move in different directions would imply a true “lack of integration” since some forces impair the comovement of most countries. However, if just a few countries drop out of the group, this would be an example of a “regional crisis” since most of the countries would still be moving together with the world and only a small number would diverge. I conjecture that the previous period of high integration, prior to World War I, witnessed many country- or group-specific shocks.³⁵ Principal component analysis allows for the testing of this conjecture.

As discussed in Appendix A, the PCA normalizes the original series to a variance of one. Normally, the lower proportion of total variation explained by the first component implies the existence of a larger number of components with variances (eigenvalues) greater than one, each of them explaining more variation than any original series. In my sample, the number of principal components with eigenvalues greater than one indeed varies over time. Across exogenous historical periods, this number is two over 1875–mid-1914, three over 1919–1939, one in 1945–1971, two over 1971–1990, and one over 1991–2009 or over 1971–2009. This finding further alarms us about the possibility of market segmentation and country-specific shocks before the two world wars and during the Bretton Woods period.

6.1 Country effects, group divergencies, and index of segmentation

Country loadings on the first principal component, represented by the coefficients α_{1i} in (A-1) of Appendix A, help identify the periods of sudden drops in individual country comovement with the world, or group divergencies. Countries with larger loadings contribute the most to the unobserved world return approximated by the first principal component; low or negative loadings reveal those countries whose bond returns move independently. I investigate time

³⁵This claim would be consistent with the conclusion of Mauro et al. (2002) that sudden changes in spreads in recent years were associated with global crises whereas country events had a bigger role in the 1870–1913.

patterns of loadings, close in spirit to study by Nellis (1982) does.³⁶ Using country loadings on the first principal component, one can recover correlations of the unobserved world return with country returns, which are easier to interpret.³⁷ The dynamics of the correlations are reported in Figure 5. Overall, the correlations of country bond yields with the world are quite high—all the countries remain relatively integrated into international financial markets. However, there are noticeable periods when the individual bond returns moved independently from the world return. In addition, there are some periods when several countries have such decoupling simultaneously. For example, there are noticeable clustering of lower correlations for Belgium, Germany, Italy, Spain, and the United States from approximately 1894 to 1902; for Belgium, France, Germany, and Spain in the mid-1920s–late 1930s; for Germany and Great Britain in 1973–early 1980s; and for Norway and Sweden in the 1980s.

In addition to index of integration, I develop a companion measure that summarizes country- or group-specific effects. I argue that such *index of segmentation* should supplement analysis of markets comovement to give a more complete picture about the dynamics of integration. Figure 6 presents two versions of the index of segmentation. The line is the standard deviation of the individual country loadings associated with the first principal component and the bars represent the number of countries out of 11 (the sample size) with negative loadings. Both indices of segmentation show that the “crises” picked up by the index of integration in various time periods are in fact brought about by very different causes. There was little integration in the entire sample at the turn of the 20th century: all countries frequently diverted from the group and their weights in the world return varied. In contrast, post-World War I “crises” were caused by some individual divergences, where at most two countries diverted from the group. The post-Bretton Woods era does not observe even this kind of divergences. Notably, there is a short period of discontinuity in British rate comovement and some instability at the end of the 1970s. Otherwise, integration of bond markets of in-sample countries

³⁶Bordo and Murshid (2005) explore the loadings of the first and higher-order principal components and use cluster analysis to divide countries into the groups. In this study I am more interested in the analysis of integration of all in-sample countries. Grouping of countries based on some criterion is an important exercise but is of the secondary interest for my study.

³⁷As discussed in Joliffe (2002), the estimates of the correlation between observed variables x_i and unobserved first principal component f_1 can be derived from the eigenvalue decomposition of the sample covariance matrix. The correlations are equal to the product of a country loadings $(\alpha_{11} \ \alpha_{12} \ \dots \ \alpha_{1n})'$ and the square root of corresponding eigenvalue. Therefore, the loadings are proportional to the correlation coefficient. In the rest of the paper I study correlations calculated in this way.

is remarkable. In Appendix D, I name a number of global and country events that could have caused the time pattern of integration discovered by indices of integration and segmentation seen in Figures 4–6. Overall, the methodology advocated in this paper matches country events and global crises in financial integration remarkably well.

6.2 Role of global market environment, economic policies, and shocks

I include proxies for market frictions, policies and institutional arrangements into the time-series regression of Table 2 in order to study which factors were associated with the observed pattern of integration more formally. The first variable is a proxy for pro-globalization market environment, measured by the average trade openness. I test whether financial integration was higher in the periods when the world was more open to trade. In the classical Heckscher-Ohlin-Mundell trade theory, trade and finance are substitutes since trade integration equalizes factor prices reducing, or altogether eliminating, the incentives for capital to flow into capital-scarce countries. However empirical evidence, supported by alternative theories, suggests that international capital flows often follow trade patterns, making them complements (see for example Lane and Milesi-Ferretti, 2004).³⁸ Rose and Spiegel (2004) argue that creditors might systematically lend more to countries with which they share closer trade links if the threat of trade sanctions could effectively prevent sovereign default as in the “default penalties” model of Bulow and Rogoff (1989).³⁹ The complementarity can also be explained by goods or asset market frictions (trade costs, information asymmetry) as in the models of Obstfeld and Rogoff (2000) and Martin and Rey (2004). Aviat and Coeurdacier (2007) stress the role of scale economies emerging from market size and argue that a large volume of trade between two countries would make the foreign exchange market more liquid and more efficient and thus reduce transaction costs for financial investments. In the model with financial frictions by Antras and Caballero (2009) and in political economy “interest groups” theory by Rajan and Zingales (2003), both trade and capital flows become market mechanisms to promote

³⁸Recently Kalemli-Ozcan and Nikolsko-Rzhevskyy (2010) provide evidence for the complementarity between trade and financial flows of Germany, France, and the UK to the Ottoman Empire over 1859–1913, with the causality running from trade to financial flows even conditional on the Ottoman sovereign default and following the “supersactions” imposed.

³⁹Mitchener and Weidenmier (2005) examine the role of various sanctions in promoting debt repayment during the classical gold standard period, and find a significant decline in trade as a result of default only when gunboat diplomacy or fiscal control (the “supersanctions”) was used by creditor countries.

financial development and correct the misallocation of capital induced by financial frictions. The *average trade openness* is defined as average over in-sample countries of exports plus imports over GDP. I supplement the historic trade data on the merchandize trade from Brian Mitchell's International Historical Statistics with the modern data on trade in goods and services by splicing the series from approximately 1960 so that the break is minimized.

The second set of variables includes measures of domestic economic policy and macroeconomic fundamentals. These variables could give investors an idea about the extent of debt burden or laxity of lending standards in a given country. I use the cross-sectional *average inflation rate* as a proxy of overall laxity of government policy, such as the degree of commitment to a fixed exchange rate regime or inclination to finance excessive government expenditures. Flandreau and Zúmer (2004) point that investors prior to 1913 assigned a secondary or indirect role to fiscal and monetary variables. Bordo et al. (1999a) find that inflation became important in explaining return spreads during the interwar period. I calculate inflation rate as an ex post year-on-year change in monthly CPI, based on GFD data supplemented by data from the International Historical Statistics volumes and the IMF's International Financial Statistics database starting from 2003. In the regressions I use annual averages of these series to smooth volatility and because earlier price data is often available only at the annual frequency. In addition, to control for fiscal policy, I compute the cross-sectional *average government deficit to GDP* using annual data from Bordo et al. (2001), supplemented with the negative of the overall budget balance from the World Bank's World Development Indicators database in the 1990s and 2000s.⁴⁰ *Fixed exchange rate regimes* were an important part of international monetary arrangements throughout the history, and, depending on the degree of policy credibility, such rule-based monetary policy could be stabilizing for globalization, as was the case during the Gold Standard (Bordo and Rockoff, 1996), or disruptive, as seen in the late 1920s (see Bordo and Schwartz, 1999), around the collapse of Bretton Woods, and during the early years of the European Monetary System. Hence, their effect is ambiguous. The explicit *capital*

⁴⁰The series is the Cash surplus/deficit, %GDP. Such flow measure was used by Bordo and Rockoff (1996) and Bordo et al. (1999a) while Flandreau et al. (1998) and Obstfeld and Rogoff (2004) advocate the stock of public debt to GDP as a better measure of overall country solvency. Besides the difficulty to construct a consistent series of debt/GDP ratio over 100+ years, Flandreau and Zúmer (2004) argue that the nominal debt is a poor measure of true indebtedness because the burden depends on the interest rate at which the debt is issued, not on its nominal amount.

controls and other restrictions on current and capital account transactions are implemented by the governments in the effort to tame the international capital flows. The effectiveness of these measures is an empirical question. For each country in my sample, I construct the monthly binary variable equal to 1 if the country pursued an exchange rate regime other than a free float in a given time period. I also construct the binary variable equal to 1 for periods of capital controls. Similarly to Bordo (1999), I treat the ‘capital controls’ broadly to include various restrictions on capital (in/out)flows or foreign currency transactions, foreign exchange controls, and other frictions related to currency convertibility. I use annual dummies from Bordo et al. (2001) and adjust them to the exact months of changes in the regimes and capital controls using qualitative descriptions in this paper, Bordo and Schwartz (1996), Bordo and Rockoff (1996), Eichengreen (1994; 1996), Bordo (1999), and other sources (the details of these adjustments are available from the author). The variable Prevalence of Capital Controls is the fraction of countries with restrictions on capital flows in a given time period. The variable Prevalence of Pegged Exchange Rate Regimes is constructed similarly using monthly exchange rate regime dummies.

Ferguson and Schularick (2008) find that pre-WWI foreign investors in developing nations paid more attention to these countries’ vulnerability to economic and political shocks than to their commitment to a rules-based arrangement, such as the gold standard. The poorer developing countries often lacked the credibility to convince lenders that they would stick to the standard despite a formal commitment to it. Therefore, my third set of variables includes proxies for economic shocks such as financial and economic crises or hyperinflation episodes. In order to control for the episodes of *financial crises* I refer to the chronology described in Bordo et al. (2001) and define a binary variable taking the value of 1 in the first and ongoing years of banking, currency, or twin crisis, excluding the recovery period. The variable Prevalence of Financial Crises is the fraction of in-sample countries in the crisis state. I also control for “*economic disasters*”, defined by Barro and Ursua (2008) as cumulative declines in consumption by at least 10% and shown to significantly affect the rates of return for stocks, bills, and bonds. Typically, GDP and consumption fall concurrently; however, I prefer using consumption disasters since these might cause more pressure on the government to change policies because of social unrest. The variable Prevalence of Consumption Disasters Disasters

is the fraction of countries that have experienced extreme declines in consumption during a given time period. I also control for the *hyperinflation years* including the incidents covering my larger sample of 15 countries: Germany (1923), Italy (1944), Greece (1946), and Japan (1946-47) based to Bordo et al. (2001). Despite being a country phenomenon, hyperinflation could have international effects. Finally, in this group, I include the *average country risk*, computed as the cross-sectional average of individual bond spreads versus the estimated “world” return, to capture all unaccounted country characteristics that may discourage foreign investment and thus negatively affect integration.

Table 3 presents the regressions of the monthly index of integration on the time trend, world war periods, and groups of controls separately. The definitions of the variables imply the following interpretation of results. If a particular explanatory variable is positive significant then this factor may be consistent with market integration or reflect a common shock affecting all or most of the countries, which may be interpreted as evidence of market integration too (see Bordo et al., 2001). Negative significance would be consistent with declines in integration. Column (1) indicates that trade openness was, on average, complementary to financial openness as the literature shows. In fact, the loss of significance of the trend terms indicates that trade openness is quite important. Columns (2)–(6) focus on policies. Columns (2)–(3) indicate that high-inflation and high-government deficit policies generally were associated with a divergence of returns or lower integration; the average inflation and budget deficit have negative coefficients individually and together. In column (5), the addition of the Prevalence of Pegged Exchange Rate Regimes results in the budget deficit variable being insignificant, while the average inflation remains negative significant. Pegged exchange rate regime itself is positive significant in support of the argument that these policies mostly served as a credible commitment device in this group of countries. The last policy variable, the Prevalence of Capital Controls, added in column (6), is negative significant, although at the 10% level only. I do not consider this evidence strong enough to conclude that over the last 100+ years governments have been generally successful in containing capital mobility. It is important to observe that the trends remain significant in the regressions with policy controls. This implies that policy variables have a secondary importance in explaining time variation in integration. The remainder of the table looks at the role of various economic shocks. The majority of

crises happened during the turbulent 1920s and post-WWII, which also saw the remarkable hyperinflation spells in central European countries. When included, the hyperinflation years are negative and very significant. Apparently, hyperinflations were detrimental to the overall integration but were not global shocks that would force most of the yields to move together and result in a positive coefficient. Columns (7)–(9) show that financial (banking, currency, or twin) crises have an expected negative sign but are insignificant, whereas the episodes of extreme falls in consumption are significant and associated with lower values of index of integration. Finally, column (10) includes the Average Country Risk, which can be interpreted as a broad proxy for the “unexplained” factors priced into the country yields. As seen, the country risk is significant and negatively correlated with the index, which I interpret as evidence of the overall backlash against integration when the overall (actual or perceived) level of risk rose. Upon inclusion of this control, both explicit measures of crises are negative, as expected, but insignificant. As in the case of policy controls, the measures of economic shocks by themselves are not sufficient to “explain” the J-shape in integration.

Table 4 combines these controls in one multiple regression to determine which of them are “preferred” by the data. Column (1) shows that trade openness and the prevalence of pegged exchange rate regimes remain significantly positively correlated with the index of integration while average inflation rate and the measure of overall unexplained country risk have negative significant coefficients. The hyperinflation years saw lower integration while world wars still appear as important global shocks. Capital controls did not seem to tame financial returns from moving together, and financial or macroeconomic crises seem to work their way through the overall country risk. The linear time trend lost its significance while the quadratic trend remains positive and significant. One might argue that 6-lags (half-year) order assumed for the error structure might be too short to account for autocorrelation and to produce consistent standard errors. In column (2), I allow for 12 lags (one year) in errors with similar results except that now the trend terms and world war dummies are insignificant at conventional levels. This result is intuitive since usually there is a great deal of persistence in monthly financial data. The inspection of Figure 4 reveals some short-term volatility in the index of integration and the same could be true in the monthly explanatory variables. Even so, short-term noise in the dependent variable would end-up in the error term and would not bias the coefficient estimates.

It is also unlikely that the noise would affect the regression results given the long-run horizon. Still, in the remainder of the table I smooth the data by taking quarterly and annual averages of the monthly series and preserve one year-long lag structure in the Newey-West errors. The results in columns (3) and (4) match the results of monthly data well. The significance of the coefficients with annual averages decreases, especially for trade, perhaps due to over-smoothing or a smaller sample size.

6.3 Discussion and implications

The evidence from the multiple regression analysis show that both policy variables and global environment factors are correlated with broad long-term integration trends. I must stress that the evidence in these regressions should not be interpreted as causal. It is possible that governments would respond to changes in integration or arbitrage opportunities with certain policies. As such, establishing a causal relationship is an important but difficult task because of simultaneity in the degree of integration, policies, institutional changes, market frictions, shocks, and so on. In addition, my measure of integration does not tell what parties, private or public, dominated the sovereign debt markets in a particular time period. For example, it is possible that a relatively high degree of integration in the late 1960s was due to the lending/borrowing by governments instead of by private parties, while the anecdotal evidence points on the growing role of the private sector (see Eichengreen, 1996; Krugman and Obstfeld, 2009; and footnote 11). The task of this paper was more modest and included a search for broad patterns of integration that are common across countries and over a very long period. Uncovering explicable factors that are correlated with the degree of integration could point to policies and local or global institutional arrangements that are conducive to financial globalization.

The historic data shows that in general, when inflation rates were relatively low and countries adopted some form of pegged exchange rate arrangement, integration was higher. When the world was open to trade, finance generally followed (or went hand in hand). This evidence should not be interpreted literally as, for example, the case for the fixed exchange rate regimes in order to promote integration. Rather, the low inflation, international monetary arrangements based on certain rules, and openness to trade seem to signal the commitment

of countries to good economic policies and global cooperation in general. The fact that the pattern of integration resembles a J-shape in combination with the finding that these particular policies have the strongest correlation with the integration index indirectly show that such policies were likely to have caused the upward trend in integration we have experienced since the 1930s. The significance of the war and hyperinflation stresses the importance of accounting for global and large country shocks in measuring integration. Finally, the results show that there remains an unexplained variation in integration, captured by the average level of country risk. Further research might shed light on additional explanations of financial integration patterns.

7 Conclusion

I propose a systematic methodology based on the method of principal components to quantify economic integration, explore its dynamics, and capture the episodes of market segmentation. This method overcomes the limitations of conventional approaches. Despite its computational simplicity, the suggested methodology is quite general and applicable to a variety of markets.

I explore why the existing empirical literature, which relies on comovement of economic variables, lacks consensus on whether the highest degree of integration was achieved before World War I under the Gold Standard or by the late 20th century. I argue that a conventional measure of *comovement*, the coefficient of correlation, has limited applicability as a measure of economic *integration*. Based on the suggested methodology I find clear evidence of higher financial integration at the end of the 20th century compared to the earlier periods.

Time-series regressions show that both policy variables (average inflation and the exchange-rate regime) and the global market environment (approximated by the average trade openness) played a role in explaining the time variation in the index of integration. I also find that “unexplained” changes in overall level of country risk are also empirically important, which warrants further research on the factors behind the unexplained country risk.

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Table 1: Historic bond data. Descriptive statistics

	Full Period		Gold Standard		Inter-War		Bretton Woods		Modern Float		Globalization		Post-Bretton Woods	
	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.	Mean	Std. dev.
	1875:01–2008:09	1919:01–1939:08	1945:06–1971:07	1971:08–1990:12	1991:01–2008:09	1971:08–2008:09	1971:08–2008:09							
Austria	6.0	1.7	4.6	1.0	6.6	0.9	6.1	1.2	8.4	1.1	5.5	1.5	7.0	1.9
Belgium	5.3	2.4	3.3	0.3	4.6	0.8	5.4	1.1	9.6	2.0	5.7	1.7	7.8	2.7
Denmark	6.3	3.8	3.8	0.3	4.9	0.6	6.1	1.9	13.9	3.6	5.9	1.8	10.0	4.9
Finland ^a	7.9	2.8	4.5	0.1	6.9	1.5	8.0	1.8	10.9	1.8	6.1	3.3	8.6	3.5
France	5.5	2.8	3.4	0.4	4.7	0.9	5.3	0.9	11.0	2.5	5.5	1.7	8.4	3.5
Germany	5.4	1.8	3.8	0.3	5.9	1.8	6.0	1.1	7.7	1.5	5.2	1.5	6.5	2.0
Italy	6.6	3.7	4.5	0.7	4.8	0.4	5.9	1.3	13.4	3.8	7.2	3.5	10.4	4.8
Japan	5.7	2.2	5.7	0.9	5.1	0.7	7.5	2.3	7.1	1.6	2.2	1.6	4.7	2.9
Netherlands	4.9	2.0	3.4	0.4	4.4	1.2	4.5	1.5	8.3	1.5	5.4	1.5	6.9	2.1
Norway	5.4	2.7	3.8	0.5	5.3	0.8	4.0	1.2	10.3	2.8	6.2	1.8	8.3	3.1
Spain	7.7	4.3	7.7	5.6	5.8	0.5	5.9	1.2	12.9	2.4	6.7	3.1	9.9	4.2
Sweden	5.4	2.8	3.7	0.5	4.1	0.8	4.6	1.4	10.7	2.0	6.4	2.5	8.6	3.1
Switzerland ^a	4.1	1.2	–	–	4.6	0.9	3.5	0.8	4.9	1.0	3.6	1.3	4.3	1.3
United Kingdom	5.4	3.1	2.9	0.2	4.1	0.7	5.2	1.8	11.3	2.0	6.2	1.9	8.9	3.2
United States	4.7	2.4	3.4	0.6	3.6	0.8	3.7	1.5	9.2	2.3	5.5	1.2	7.5	2.6
All countries	5.8	3.0	4.2	2.0	5.0	1.3	5.4	1.9	10.0	3.3	5.5	2.4	7.9	3.6
Number of months	1,483		475		248		314		233		213		446	
Average σ_{CS}	2.14 (2.06)*		2.03		1.30		1.91		3.27		2.43		2.87	
Average CV_{CS}	0.39 (0.37)*		0.49		0.26		0.35		0.33		0.44		0.38	

Notes: For individual countries the mean and standard deviation represent the time statistics for the sub-period. World War periods (1914:08-1918m11 and 1939:09-1945:08) are excluded. ^aData for Finland starts from 1910:09; data for Switzerland starts from 1915:02. Average σ_{CS} is the time average of the cross-sectional standard deviation across in-sample countries. Average CV_{CS} is the time average of the cross-sectional standard deviation divided by the cross-sectional mean across in-sample countries. * without Finland, and Switzerland with missing data in Gold Standard period.

Table 2: Trend in bond markets integration. Time-series regressions, 1875–2002

	(1)	(2)	(3)
Dependent variable: Index of Integration			
Type of data	Monthly	Quarterly	Yearly
Time Trend	−.636*** (.081)	−1.91*** (.263)	−7.65*** (1.86)
Time Trend ²	.493*** (.049)	4.43*** (.477)	70.50*** (13.20)
World Wars	.013 (.057)	.013 (.062)	.014 (.106)
Observations	1,526	509	128
Lags Included	12	4	1
F-stat	48.52	42.33	13.61

Notes: Newey-West standard errors in parentheses. ***, **, *, and † denote significance at 1%, 5%, 10% and 15% levels. The error structure is assumed to be heteroskedastic and autocorrelated up to the lag order shown in the table. Index of Integration is the estimate of the proportion of variation in the group of 11 bond returns explained by the first principal component. The estimation of the component is performed as the centered rolling window with the bandwidth of 156 months. Time period is for monthly regression is 1875:01–2002:02 and chosen to always have 156 month of data to estimate the dependent variable. In-sample countries are Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, United Kingdom, and United States. The estimation of the component is performed as the centered rolling window with the bandwidth of 156 months. World Wars is the indicator variable taking the value of one in 1914:08–1918:11 and 1939:09–1945:08 and zero otherwise. Quarterly and yearly data uses the corresponding averages of the monthly data. See Section 6 for the detailed explanation of the variables.

Table 3: Determinants of bond markets integration. Time-series regressions with groups of controls, 1875–2002

Groups of Controls	Dependent variable: Index of Integration									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	Global Market Environment	Policies				Economic Shocks				
Time Trend	-.155 (.161)	-.586*** (.083)	-.588*** (.082)	-.571*** (.082)	-.610*** (.079)	-.487*** (.129)	-.566*** (.085)	-.487*** (.096)	-.487*** (.096)	-.382*** (.091)
Time Trend ²	.136 (.110)	.461*** (.050)	.468*** (.049)	.457*** (.049)	.522*** (.049)	.470*** (.070)	.450*** (.051)	.385*** (.062)	.385*** (.063)	.303*** (.061)
Average Trade Openness	.463*** (.113)									
Average Annual Inflation Rate		-.029*** (.003)		-.025*** (.003)	-.012*** (.003)	-.013*** (.004)				
Average Government Deficit			-.870** (.346)	-.800** (.339)	.391 (.411)	.390 (.410)				
Prevalence of Pegged Exchange Rate Regimes					.167*** (.034)	.184*** (.035)				
Prevalence of Capital Controls						-.061* (.036)				
Hyperinflation Years							-.122*** (.024)	-.117*** (.027)	-.117*** (.027)	-.160*** (.039)
Prevalence of Financial Crises							-.019 (.056)	.000 (.056)	.000 (.056)	-.015 (.051)
Prevalence of Consumption Disasters								-.162* (.092)	-.162* (.093)	-.110 (.080)
Average Country Risk										-.257*** (.057)
World Wars	.022 (.029)	.012 (.043)	.116* (.060)	.108* (.060)	.068 (.055)	.096* (.056)	.015 (.042)	.099+ (.062)	.099+ (.063)	.073 (.052)
Observations	1416	1416	1416	1416	1416	1416	1416	1416	1416	1416
Lags Included	6	6	6	6	6	6	6	6	6	6
F-stat	47.85	166.72	41.94	147.21	130.33	114.56	50.67	42.09	35.62	24.68

Notes: Regressions are estimated using monthly data. Newey–West standard errors in parentheses. ***, **, *, and † denote significance at 1%, 5%, 10% and 15% levels. The error structure is assumed to be heteroskedastic and autocorrelated up to the lag order shown in the table. Index of Integration is the estimate of the proportion of variation in the group of 11 bond returns explained by the first principal component. The estimation of the component is performed as the centered rolling window with the bandwidth of 156 months. Time period is chosen to always have 156 month of data to estimate the dependent variable. In-sample countries are Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, United Kingdom, and United States. The estimation of the component is performed as the centered rolling window with the bandwidth of 156 months. Average Country Risk is the average across in-sample countries of the bond spread versus the estimate “world” return. The “world” return is the first principal component of country bond returns. “Prevalence of X” denotes a fraction of countries where X occurs in a given time period. See Data Appendix for detailed definitions of the variables. Quarterly and yearly data uses the corresponding averages of the monthly data.

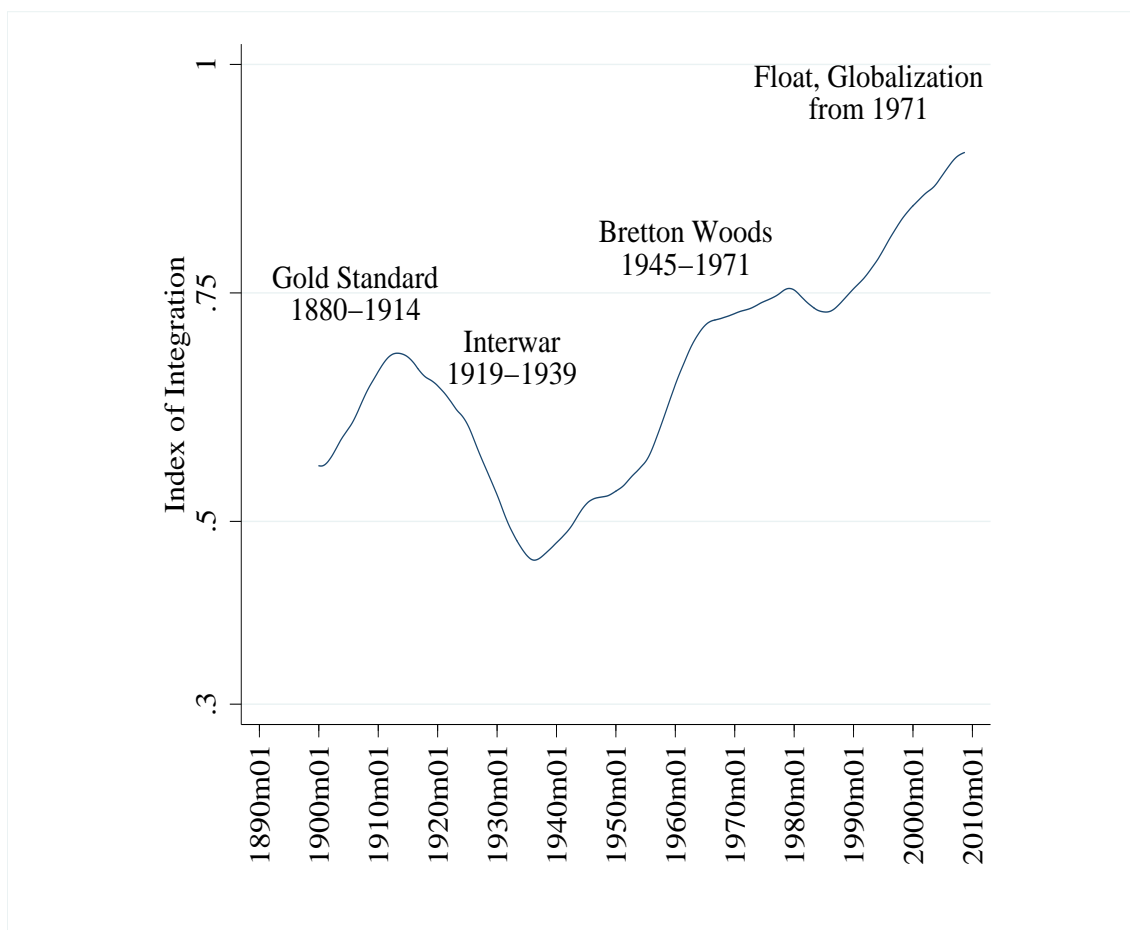
Table 4: Determinants of bond markets integration. Time-series regressions, 1875–2002

	(1)	(2)	(3)	(4)
Dependent variable: Index of Integration				
Type of data	Monthly		Quarterly	Yearly
Time Trend	-.237 (.152)	-.237 (.204)	-.702 (.520)	-2.69 (3.41)
Time Trend ²	.215** (.104)	.215 (.140)	1.919* (1.067)	29.84 (27.84)
Average Trade Openness	.326*** (.122)	.326** (.163)	.318** (.139)	.278 (.227)
Average Annual Inflation Rate	-.020*** (.007)	-.020** (.009)	-.021*** (.008)	-.025* (.013)
Average Government Deficit	-.024 (.346)	-.024 (.434)	-.084 (.403)	-.365 (.702)
Prevalence of Pegged Exchange Rate Regimes	.147*** (.031)	.147*** (.040)	.146*** (.035)	.136** (.058)
Prevalence of Capital Controls	.037 (.034)	.037 (.045)	.035 (.039)	.025 (.065)
Hyperinflation Years	-.064*** (.024)	-.064** (.028)	-.063** (.027)	-.058 (.042)
Prevalence of Financial Crises	.046 (.044)	.046 (.054)	.047 (.049)	.051 (.068)
Prevalence of Consumption Disasters	.023 (.064)	.023 (.083)	.014 (.075)	-.026 (.122)
Average Country Risk	-.234*** (.061)	-.234*** (.081)	-.239*** (.071)	-.270** (.119)
World Wars	.096** (.049)	.096 (.060)	.110* (.060)	.174 (.119)
Observations	1416	1416	472	118
Lags Included	6	12	2	1
F-stat	44.23	39.60	38.08	30.07

Notes: Newey-West standard errors in parentheses. ***, **, *, and † denote significance at 1%, 5%, 10% and 15% levels. The error structure is assumed to be heteroskedastic and autocorrelated up to the lag order shown in the table. Index of Integration is the estimate of the proportion of variation in the group of 11 bond returns explained by the first principal component. The estimation of the component is performed as the centered rolling window with the bandwidth of 156 months. Time period is chosen to always have 156 month of data to estimate the dependent variable. In-sample countries are Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, United Kingdom, and United States. The estimation of the component is performed as the centered rolling window with the bandwidth of 156 months. Average Country Risk is the average across in-sample countries of the bond spread versus the estimate “world” return. The “world” return is the first principal component of country bond returns. “Prevalence of X” denotes a fraction of countries where X occurs in a given time period. See Data Appendix for detailed definitions of the variables. Quarterly and yearly data uses the corresponding averages of the monthly data.

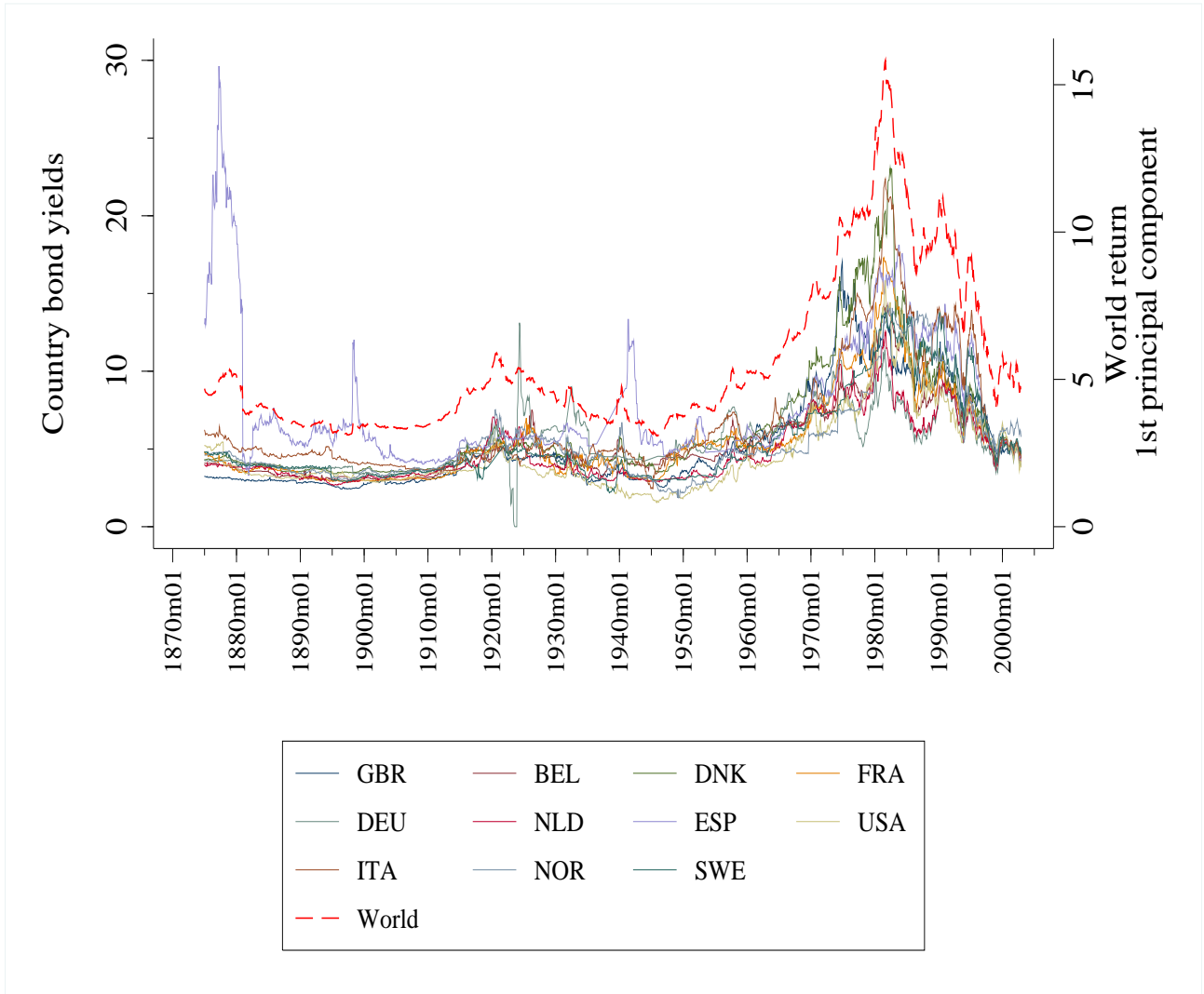
Figure 1: Long-run trend in bond market integration, 1900–2008

Proportion of variation in bond returns explained by the 1st principal component (smoothed series)



Notes: Estimates of the proportion of variation in bond returns explained by the first principal component smoothed using the uniformly weighted moving average smoother. Government bond returns are in levels. In-sample countries are Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, United Kingdom, and United States. The estimation of the component is performed as the centered rolling window with the bandwidth of 156 months.

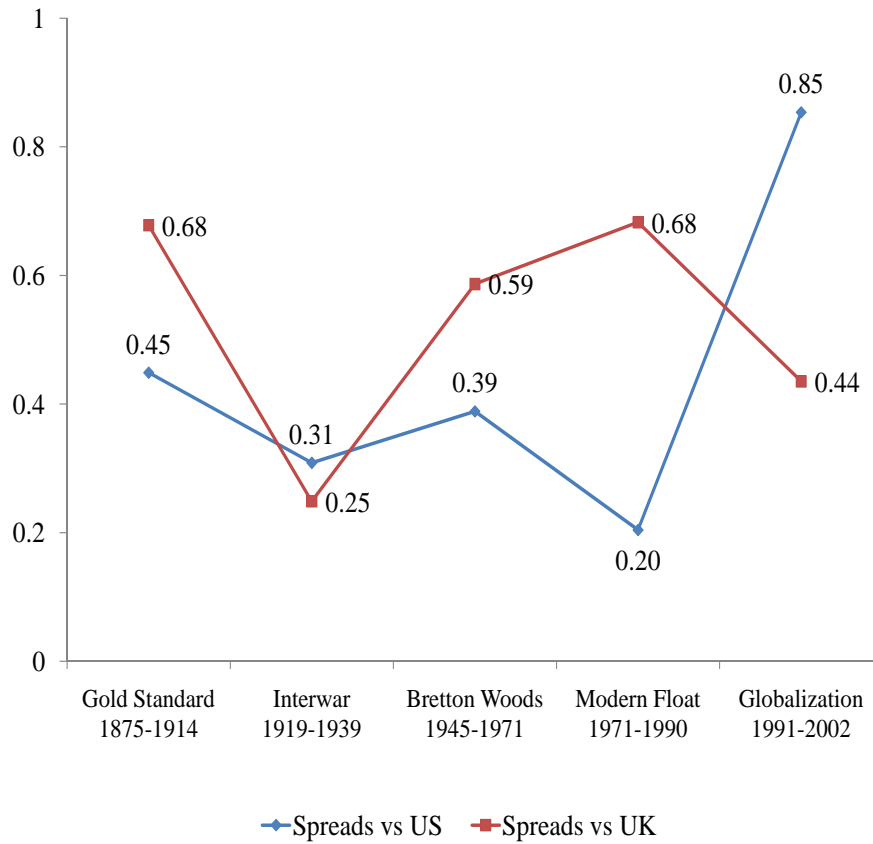
Figure 2: Yields on sovereign long-term bonds and the estimated “world” return, 1875–2002



Notes:

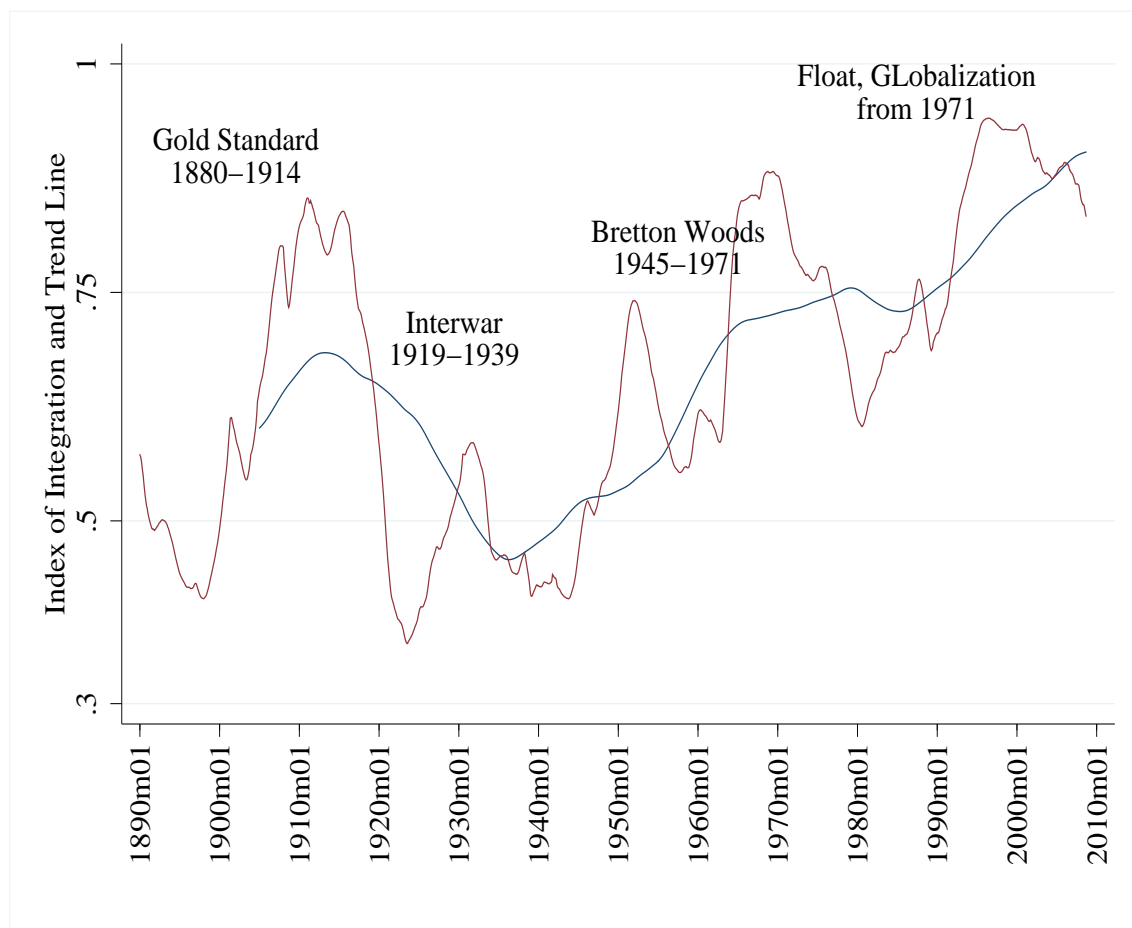
The graph depicts historical monthly series for the yields on long-term government bonds issued by industrialized economies (thin solid lines, left axis) and the estimated “world” return (thick dashed line, right axis). The following abbreviations for the country names are used at the graph: AUT for Austria, BEL for Belgium, DNK for Denmark, FIN for Finland, FRA for France, DEU for Germany, ITA for Italy, JPN for Japan, NLD for the Netherlands, NOR for Norway, ESP for Spain, SWE for Sweden, SWI for Switzerland, GBR for United Kingdom, and USA for the United States. World is the estimate of the first principal component using all countries (the “world” return). The estimation of the component is performed as the centered rolling window with the bandwidth of 156 months.

Figure 3: Long-run trends in bond market correlations, 1875–2002
 Average correlation for bond spreads versus U.S. and Great Britain
 Estimation over historical sub-periods



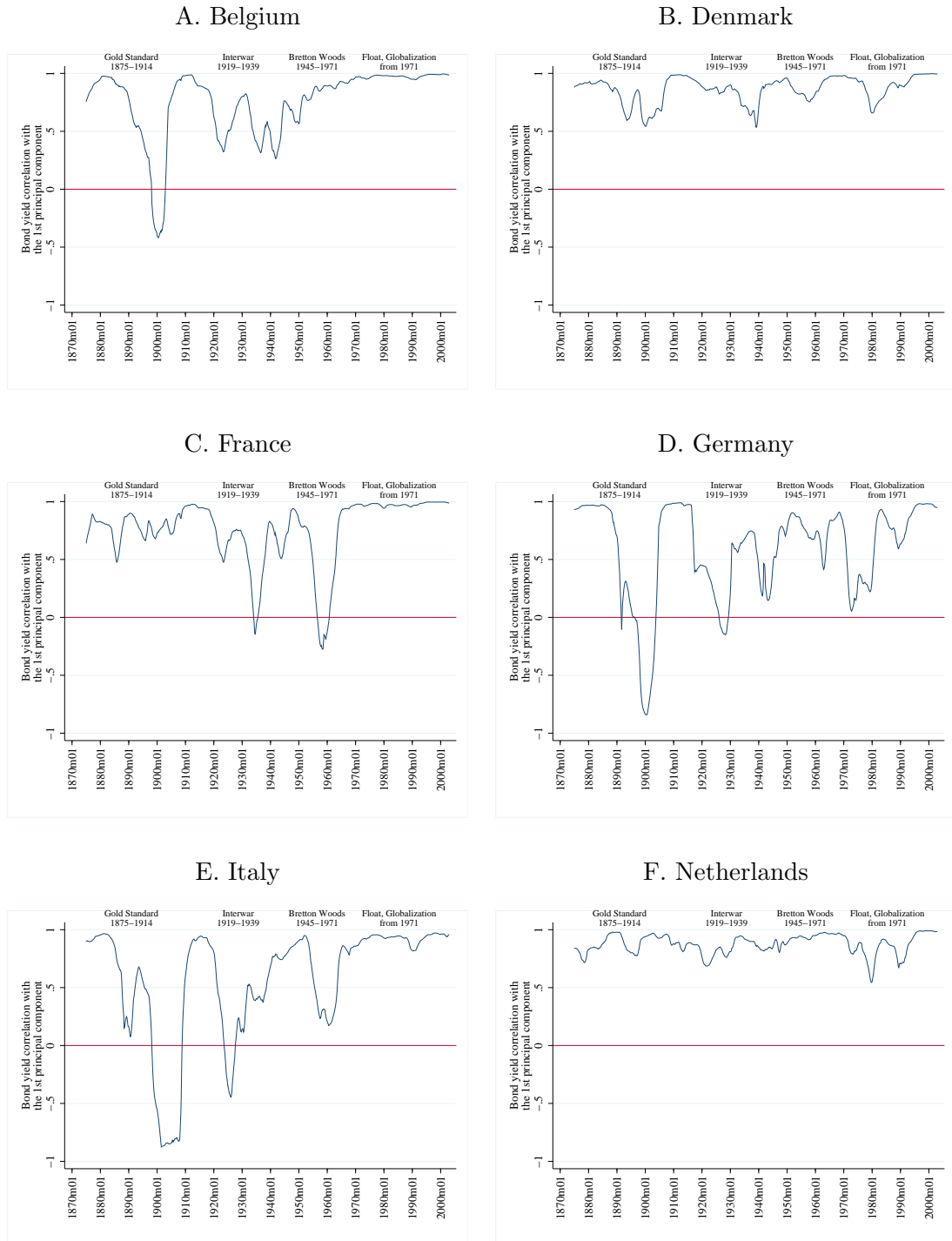
Notes: Average correlation is calculated as the arithmetic average of off-diagonal pairwise correlation coefficients of individual country bond spreads versus the U.S. 10-year bond and British Consol. The correlations are calculated using monthly data over historic sub-periods defined in Section 5.1. Country sample includes countries used in the empirical analysis; they are: Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Spain, and Sweden. Austria, Finland, Japan, and Switzerland were omitted due to lots of missing observations before 1919.

Figure 4: **Index of integration in bond markets and its long-run trend, 1875–2008**
 Proportion of variation in bond returns explained by the 1st principal component



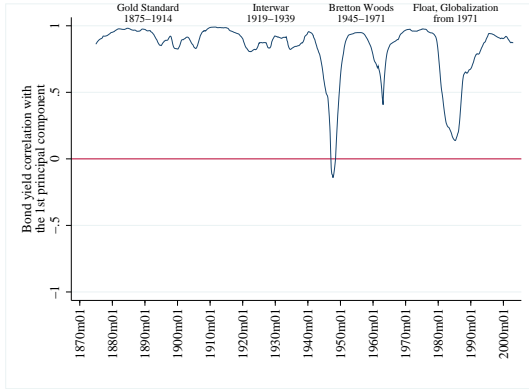
Notes: Index of integration (thin red line) is the proportion of variation in bond returns explained by the first principal component. The trend line (thick blue line) is the smoothed estimate of the Index of integration using the uniformly weighted moving average smoother. Government bond returns are in levels. In-sample countries are Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, United Kingdom, and United States. The estimation of the component is performed as the centered rolling window with the bandwidth of 156 months.

Figure 5: Country-specific effects. The correlations of individual returns with the 1st principal component, 1875–2002

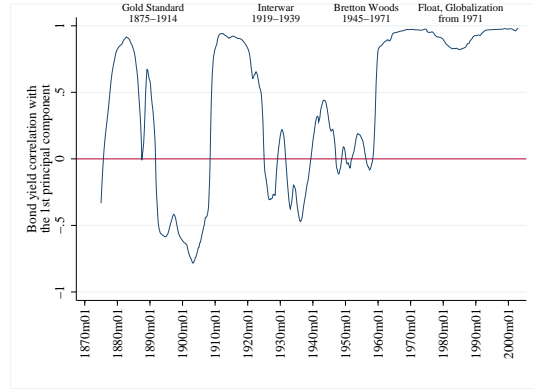


Notes: For detailed notes see the continuation of this figure on the following page.

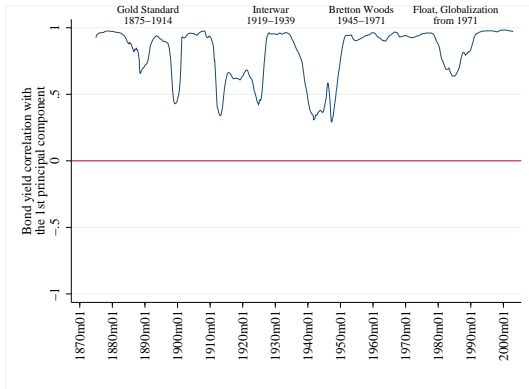
G. Norway



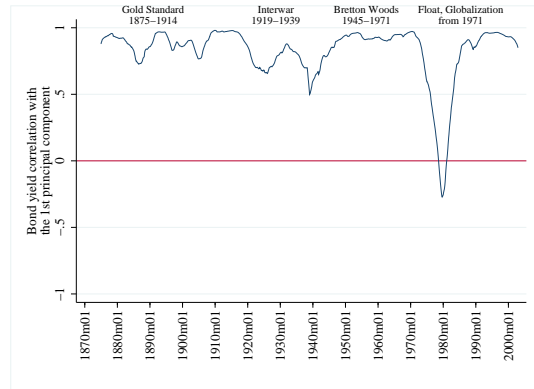
H. Spain



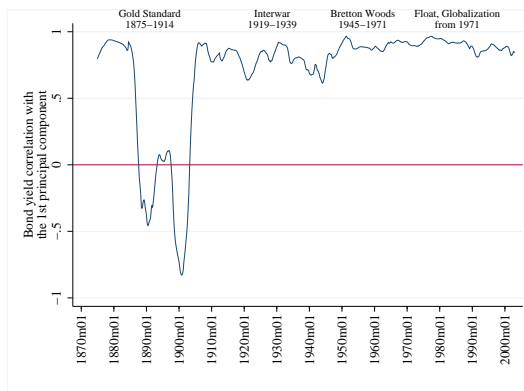
I. Sweden



J. Great Britain



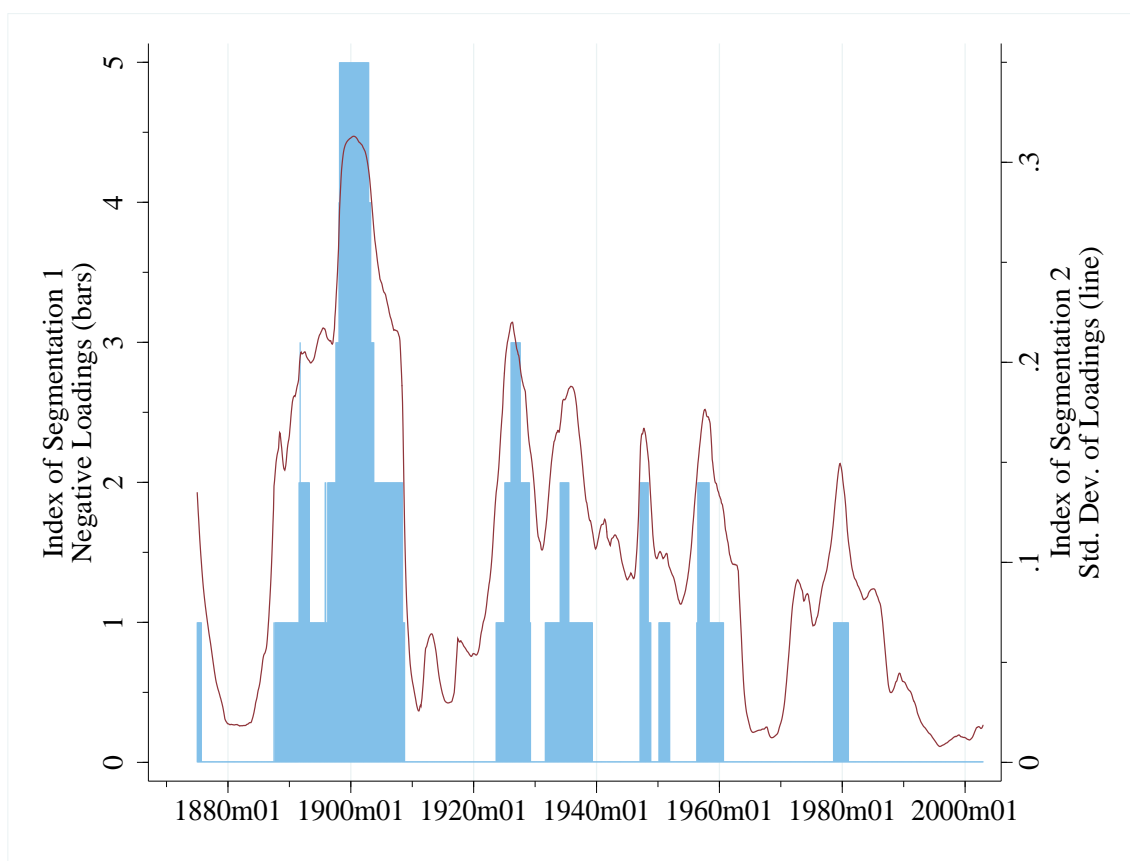
K. United States



Notes: Correlations of individual returns with the 1st principal component. The correlation between an observed returns and unobserved first principal component is computed as explained in Section ???. The extraction of the 1st principal component is performed for the sample of 11 countries using centered moving window time sub-sample with 156 months bandwidth. In-sample countries are Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, United Kingdom, and United States.

Figure 6: Segmentation in bond markets, 1875–2002

Variability of the loadings of the bond returns
on the 1st principal component (Indices of segmentation)



Notes: The line is the standard deviation of the individual countries' component loadings associated with the 1st principal component (right scale). Bars represent number of countries out of 11 with negative loadings (left scale). The extraction of the 1st principal component is performed for the sample of 11 countries using centered moving window time sub-sample with 156 months bandwidth. In-sample countries are Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, United Kingdom, and United States.

Appendix A Principal Component Analysis: Background

Assume $\mathbf{X}_{n \times 1} = \{x_i\}_{i=1}^n$ is a set of a relatively large number n of observed variables, and we are interested in reducing the dimensionality of the data while retaining most of the information about their variation. One of the methods to achieve this is the method of *principal components*. The components are weighted linear combinations of the original variables x_i represented by the matrix system:

$$\mathbf{F}_{n \times 1} = \boldsymbol{\alpha}_{n \times n} \mathbf{X}_{n \times 1} \quad (\text{A-1})$$

where, for example, the first line of the system takes the form $f_1 = \mathbf{a}'_1 \mathbf{x} = \alpha_{11}x_1 + \alpha_{12}x_2 + \dots + \alpha_{1n}x_n$. The coefficients of the component f_1 , $\alpha_{11}, \alpha_{12}, \dots, \alpha_{1n}$, are called scoring coefficients or *loadings*. They are calculated in a way to guarantee the maximum sample variance of f_1 . The restriction is imposed on $\mathbf{a}_1 = (\alpha_{1i}) = (\alpha_{11} \ \alpha_{12} \ \dots \ \alpha_{1n})'$ such that the $\mathbf{a}'_1 \mathbf{a}_1 = 1$ since otherwise the variance of f_1 can be artificially increased by picking larger α_{1i} . Each subsequent component is orthogonal to the previous one (e.g., $\mathbf{a}'_1 \mathbf{a}_2 = 0$) and also has the maximum variance. Hence, f_2 explains maximum of the residual variation after the previous component f_1 is removed from the data, and so forth.

Technically, the coefficients α_{ji} are the elements of an eigenvector of the sample covariance matrix \mathbf{Z} corresponding to the j -th largest eigenvalue, λ_j . With the above restriction on \mathbf{a}_1 to be a unit-length vector, the variance of the component f_j are the corresponding j -th eigenvalue of \mathbf{Z} . In case when the variables x_i have different scales, the variables with larger standard deviations might have larger weight by construction. In such case it is advisable to calculate the components from the sample correlation matrix which is analogous to standardizing all the variables prior to calculation.

Principal components can be ranked by the proportion of the total variation in a series they explain.⁴¹ In practice one is only interested in components which explain more variation than any single variable—the ones with eigenvalues greater than one, the average of all eigenvalues. The other components are less significant and may be considered the noise.

Appendix B Implementation of Principal Components Analysis for Measuring Markets Integration

I advocate the following strategy to apply PCA for measuring markets integration.

1. Perform extraction of components from the data $\{x_i\}_{i=1}^n$ allowing for as many components as there are series, n . This will give estimates of n eigenvectors containing coefficients $\{\alpha_{ji}\}_{j,i=1}^n$, $j = 1, \dots, n$, and corresponding eigenvalues. Rank them by the value of eigenvalue from the largest to the smallest.
2. Count the number of components with eigenvalues greater than one to explore the possibility of market segmentation. In practice, if one studies comovement of the similar variables across “individuals” (such as countries or regions) there will be a single most important factor with eigenvalue greater than one.

⁴¹The total variance of n standardized data vectors x_i is n . The proportion explained by, say, the first component is calculated as a ratio of its variance (the first eigenvalue of \mathbf{Z}) and the data total variance, n .

3. Estimate the proportion of the total variation in variables x_i explained by the first principal component f_1 (with the largest eigenvalue) as a dynamic measure of integration (the index of integration) in the full group of countries. This measure may be plotted versus time to provide visual illustration of the time path of integration.
4. To reveal the possible country- and group-specific patterns in integration, study the loadings associated with the first component, $\{\alpha_{1i}\}_{i=1}^n$. Notice that if the loadings are multiplied by the square root of the f_1 's eigenvalue the products will provide estimates of the correlation between an observed variables x_i and unobserved first principal component, which are easier to interpret than eigenvalues.
5. To explore market segmentation calculate the cross-sectional standard deviation of the individual country loadings associated with the 1st principal component and the number or fraction of in-sample countries with negative loadings (the "indices of segmentation").

Appendix C Characteristics of historic bonds data

This Appendix describes historical bond yields data used in the analysis. I get the characteristics of the particular historical bond issues using the *Global Financial Database* manual compiled by Bryan Taylor and supplement it from the *Kimber's Record of Government Debts and other Securities* published in 1920 and 1922 and Bordo and Flandreau (2003). For historical periods prior to World War II the yields are calculated by dividing the coupon by the price of bond. "LY" stands for London bond yield quotations in GFD. The information in brackets after the bond issue name is i) the time period when the issue is used, ii) the currency of denomination, iii) the currency and the city/country in which the coupon was payable (Gld for gold; Slv for silver; £ for sterling; LC for local currency; * for fixed exchange rate clauses). Otherwise the bonds were payable in domestic currency in the country-issuer.

Austria: The Austria Silver 5s (Mar 1874–May 1879 [LY]; Florins; Vienna in Slv), the Austria Gold 4s (Jan 1880–1915; Florins; Vienna in Gld, Germany, Brussels, Amsterdam, Paris in LC*); no data 1916–Aug 1923; the Austrian 6s of 1923–1943 (Sep 1923–1932; Kronen; London in £); the government bonds series by the Institut für Konjunkturforschung (1933–1937); the 4.5% Bundesanleihe of 1930 (1938–1959 [no data Dec 1941–May 1945; annual Apr 1954–Sep 1957]; the Austrian government bonds traded in Zurich (1955–1970; Zurich in LC); an index of all government bonds of more than one year, issued and not redeemed (1971 on).

Belgium: The Belgian 3% bond (1859–1938 (annual 1859–1884, 1898–1910) [LY in 1911–38]; Francs; Belgium in LC; London in £, Paris in LC*); no data May–Jul 1940, Sep 1944–May 1945 due to war and occupation; the 4% Belgian unified debt bond series (Jan 1939–1956); bonds with a maturity of 5–20 years (1957–1963); bonds issued after 1962 with a maturity of 5–20 years (1964–67); bonds with a maturity over 5 years (1968–93); 10-year bonds (1994 on).

Denmark: The Consolidated 4s used till conversion to 3 1/2% consols in 1895 (1865–1894; Kroner; Copenhagen in LC, London in £); the consolidated bond (1895–1976; Kroner; pre-1914 in Copenhagen in LC, in London in £, in Paris, Germany, Geneva, Stockholm in LC*);

the 10-year bond (1977-on).

Finland: The 4.5% Grand Duchy of Finland Railroad Bonds (1910–1917; £; in London in £, in Helsinki, Switzerland and Amsterdam in LC*); no data Feb–Oct 1915, 1918–Feb 1924; the Finland 6s of 1945 (1924–1945; US\$; in New York in \$); the Helsingfors 6.5% municipal bonds of 1960 (1946–1948); the Finland 5s of 1961 (1949–1953); no data Nov 1953–1959; the central government taxable bonds of more than five years (1960 on [annual 1960–65, quarterly 1966–71]).

France: The 3% consol [Perpetual Rente] (May 1825–1949 [LY]; Francs; France in LC). The 5% consols issued in 1949 (1950–1971; in Paris in francs); an index of public and semi-public bond yields for issues guaranteed by the government (1972 on; in francs).

Germany: The Bavarian 3.5s (1842–1869; Marks; in Berlin, Frankfurt in LC); the Prussian 4% Consols (1870–Mar 1899 [LY]; Marks; in Berlin, Frankfurt in LC, in London in £) the German 3% Imperial Loan (Apr 1899–Jul 1914; Marks; *only* in Germany in LC); no data 1915; annual data 1916–1918; in 1923, the hyperinflation made the yield on the bonds virtually meaningless; the 5% mortgage bonds (1924–1927); the 6% mortgage bonds (1928–Mar 1935); the yields for miscellaneous bonds (Oct 1931–March 1932 when the stock market was closed in 1931/1932); no data Aug 1931; the 4 1/2% conversion bonds (Apr 1935–Oct 1943); the 4 1/2% bonds in the Western zone (1946–1947); no data Jan–Jul 1948; the 5% tax-free bonds (Aug 1948–Dec 1955); the fully taxed 6% government bonds (since May 1956). The current series uses 7–15 year public sector bonds.

Italy: The consolidated bond of Italy (1862–1946) is based on the Italian government 5% Rentes (1862–1900 [LY]; Lire; in Italy in LC*, Paris, London in Gld); the 3.5% Rentes (1900–1953 [LY till 1922]; annual data 1900–02; Italy in LC*, London in Gld); the 5% reconstruction loan of 1978 (1954); an index of government treasury bonds with the average maturity of six years (1955 on).

Japan: LY (pre-1914; £; in London in £; in Paris, New York, Germany in LC at LC/£*); Tokyo yields (Dec 1914 on). The Japanese 9s issued in 1870 (Nov 1870–May 1873); the 7% bonds (June 1873–1897); the 5% bonds [the 7s were converted into] (1898–Nov 1900); the 4% Japanese sterling bond (Dec 1900–Nov 1914); the 5% Japanese Bond (1914–1926); an index of government bonds (1927–1946); no data Aug 1923 (closure of the exchange after the earthquake), Jan 1947–Nov 1948; bonds newly issued during a month or a previous month (1948–1957); the Nippon Telephone and Telegraph Bonds instead of the government bonds (Jul 1957–Dec 1968); the 7-year government bonds (1969 on).

Netherlands: The Dutch 3s (1814–June 1870; Florins; in Amsterdam in LC, in London, Paris, Germany in LC); the 2.5% consol (July 1870–Jul 1914 [annual Jul 1870–Mar 1873, 1874, Apr 1880–Jul 1882]; Florins; in Amsterdam in LC); no data Aug 1914–Oct 1915; the 3% consol (Nov 1915–Dec 1917 [LY]; Florins; in Amsterdam in LC, in London, Paris, Germany in LC); no data in 1918; an index of public bonds (1919–25); the 3% consol (Jan 1926–1945 [Quarterly 1931–34]; see above); no data in May 1940–Sep 1940, Sep 1944–Dec 1945; the 2 1/2% consol

(1946–1954); the 3 1/4% issue of 1948 (1955–Oct 1964); an index of the three or five longest running issues of the Dutch government (Nov 1964 on).

Norway: The 4.5s (Dec 1876–Apr 1881 [LY]; £; in London in £, in Christiania, Hamburg, Paris in LC*); the 4s (May 1881–Feb 1887 [LY]; same as 4.5s); the 3.5s (Mar 1887–Oct 1893 [LY]; as 4.5s); the 3s (Nov 1893–1918 [annual average in 1918]; as 4.5s); no data in Feb–Oct 1915, Apr–Jun 1940; an index of six 5% bonds (1919–33); 4 1/2% bonds (1934–Jun 1940); 3.6% bonds (Jul 1940–1943); 3 1/2% bonds (1944–Jun 1946); the actual yields plus 1% (Jul 1946–1956; because the government bonds paid an artificially low 2 1/2%); the 4% bond of 1955 maturing in 1975 (Jun 1956–1961); the 5% bond of 1961–96 (1962–1980); an index of 6–10 year government bonds (1981 on).

Spain: The 3s (Sep 1836–80); the 3s converted into a 1% bond (1881);⁴² the 4% Perpetual Exterior Debt bonds (1882–1913 [LY]; Peseras/Francs/£; [for foreigners] in London in £/Gld, in Paris, Berlin, Lisbon, Amsterdam, Brussels in LC*; in Madrid in LC to Spanish citizens); 4% Perpetual Interior Debt bonds (1914–58 [Madrid yields; annual averages 1934–57, no data Jul 1936–Feb 1940 due to the Spanish Civil War]; in Madrid in LC); an index of private bonds is (1958–Mar 1978 [monthly since Jul 1959]), an index of government bonds with a maturity of over 2 years (Apr 1978–Mar 1992); the 10-year bond (Apr 1992 on).

Sweden: The Swedish 5s (Jun 1868–Sep 1878 [LY]; £; in London in £, in other markets in £ or LC*, in Stockholm and Copenhagen in kronor); the 4s (Oct 1878–Oct 1894 [LY]; as 5s); the 3s (Nov 1894–Jul 1914 [LY]; as 5s); no data in Feb–Oct 1915; the Swedish bonds paying 4% (Nov 1915–1917 [LY]; as 5s); 3.5% (1918–Jun 1919; as 5s); no data Jul 1919–1921; an average of 7 government loans (1922–29); an average of 6 government loans (Jan 1930–Jul 1934); the 3% loan of 1888 (Aug 1934–Oct 1937); the 3% consol of 1934 (Nov 1937–1956); the average yield on bonds maturing in 15 years or more (1957–79); 10-year government bonds (1980 on).

Switzerland: An index for 12 state and federal railway bonds (1915–24; Francs; in Berne in LC, in London in £); an index of 12 Swiss Confederacy Bonds (1925 on; in Switzerland in LC).

United Kingdom: The British consol [consolidated stock] (from August 1753 on; £). The coupon rate paid was 3% in Aug 1753–Dec 1888; 2 3/4% in 1889–1906; and 2 1/2% from 1907.

United States: The 6% U.S. Government bonds of 1881 (Feb 1862–Dec 1877 [LY]; \$); the 4% U.S. Government Bonds of 1907 (Jan 1878–Jan 1895 [LY]; \$); the 4% U.S. Government Bonds of 1925 (Feb 1895–Sep 1917 [LY Jan 1905–Jul 1914]; \$; in New York in Gld coin); the 4% Liberty Bonds (Oct 1917–Dec 1918; \$; in the U.S. in \$); the Federal Reserve Board's 10–15 year Treasury Bond index (1919–40); 10 year bonds (1941 on).

⁴²The 3s were converted into a 1% bond in January 1881, to 1.25% in March 1882, and were converted into 4% bonds in August 1882.

Appendix D International events and integration

[NOT FOR PUBLICATION]

A number of events could have caused the time pattern of integration discovered by indices of integration and segmentation in Figures 4–6. To formulate some plausible hypotheses, I name historical events related to financial markets integration in Table D-1.⁴³ Overall, the methodology advocated in this paper matches remarkably well the country events and global crises in financial integration.

According to the evidence from the index of segmentation in Figure 6, the period between the mid-1880s and up the early 1910s experienced a number of *individual-country* events. Around the turn of the 20th century the United States experienced six major bank panics, with wild fluctuations in the U.S. gold and silver reserves. Some of these were foreign-born (in 1890, following the near insolvency of Barings bank in London), but most were largely home-grown. The most severe panic of 1893 was partially caused by a run on the gold supply and then depletion of the federal reserves. The U.S. borrowing during the time of the panic was difficult, and could only be financed by bonds with high yields. This might have caused partial segmentation of the American financial markets and the lack of comovement of the U.S. interest rates with the rest of the world as Figure 5–K demonstrates. The Spanish-American war of 1898 is another vivid example of the event affecting individual economies. The United States won the war and acquired Puerto Rico, Guam, and Philippines from Spain; Cuba gained independence, and Spain assumed the Cuban debt. Spanish defeat in the war not only caused a jump in Spain’s interest rates but largely ended its colonial rule in the Western Hemisphere. Subsequent fall of the monarchy in Spain in 1931, the weak governments of the early 1930s, and finally the civil war of 1936-39 leading to establishment of Franco’s authoritarian regime posed huge human-life and economic costs for Spanish economy. The impact of the civil war and the international isolation of Spain till mid-1950s might be the reason for the continued disconnection of Spanish financial markets seen in Figure 5–H.

⁴³The anecdotal evidence in this section draws on the works of Davies (2002), Britton (2001), Homer and Sylla (1996), Norris (1999), Kindelberger (2000), O’Rourke and Williamson (1999).

World War I disrupted all countries. The Great Depression had a similar global impact.⁴⁴ Both events are examples of the *common shock* hitting most of the in-sample economies. These shocks might be the partial reason for two spikes in the index of integration seen in Figure 4 around the mid-1910s and the late 1930s. Historical evidence suggests that the global shock could transmit across countries since the restrictions to capital flows were absent at the heyday of Gold Standard, but the impact of the Great Depression was powerful enough to hit all the countries *despite* some capital restrictions already in place. Notice that the Index of segmentation 1 in Figure 6 is low around World War I (low value means returns moved together), but it points to some market segmentation between the mid-1920s and World War II (on average two countries were negatively correlated with the world according to the Index 2).⁴⁵

Past World War II the international financial linkages, disrupted by the Great Depression and World Wars, gradually recovered. The collapse of the Bretton Woods system of fixed exchange rates, the oil shocks of 1973–74 and 1979, and the Latin American debt crisis of the early 1980s have the properties of the global crises. Figure 4 shows them as spikes along the upward trend in the index of integration; Figure 5 has no clear country-specific divergencies; and index of segmentation in Figure 6 reaches the historic low with just one spike in the late 1970s.⁴⁶ These figures also show that despite the common view it is clear that the integration reached the levels comparable to the Gold Standard era as early as the 1960s, on the verge of but before the collapse of the Bretton Woods system. Clearly during the Bretton-Woods era of tight controls and fixed exchange rates, some capital flows were possible in spite of the policies designed to keep them in check.

⁴⁴Among the possible causes are sharp fall in commodity prices in 1921, German hyperinflation of 1923, and recessions which stroke the countries, such as France and Great Britain, which returned to the Gold Standard at pre-war parity (see Britton (2001) and O'Rourke and Williamson (1999) among others). This interpretation is consistent with the evidence from Bordo and Schwartz (1999) that countries which chose to restore convertibility to gold had different economic performance than those who decided to abandon the Gold Standard.

⁴⁵Recall that the regression analysis establishes the low point in the trend of integration in 1928.

⁴⁶Out of all countries in the sample Germany in 1973–77, Britain in the late 1970s, and the Netherlands in the late 1970s and late 1980s diverged from the group, see Figure 5. The behavior of German and Dutch rates can be attributed to substantial and variable currency premiums, and of British rates to removal of capital controls in the UK in 1979 (see Frankel 1992).

Table D-1: Time line of international financial market disturbances, 1875–2002

<i>Events</i>	<i>Causes and the international impact</i>
	Turn of the 20th century, pre-World War I system
First Barings crisis in Britain (1890)	Heavy involvement in South America, especially Argentina. After a revolution in Argentina, Barings is in bankruptcy and is saved by the Bank of England and all the main London banks. Gold Standard remained robust. The interest rates generally rose to a peak.
Bank panic in the U.S. (1892-93)	A bank panic, collapse of stock market, failure of 600 banks, railroad bankruptcies. British sell American securities and withdraw gold (after UK Baring crisis). Gold Standard losing confidence in the U.S., fall in budget surplus, agitation for silver. Sherman Silver Act of 1890 repealed to reassure confidence of foreigners.
Spanish-U.S. war (1898)	Cuba gained independence from Spain. The U.S. got Guam, Puerto Rico, purchased Philippines. Sharp jump in Spanish rates.
The 1890s	Belgium is very rich and fast-growing. 4th industrial power in Europe by the end of XIX c. Germany and the U.S. catch up UK rapidly. Low long-term interest rates in all important trading nations. American returns always above British until after World War I.
International bank crisis of 1907	Emergence of the “trusts” in U.S. renders banking system vulnerable. Hundreds of American banks fail. Bank of England, Banque de France and Reichsbank transfer gold from their reserves to meet liquidity demand in the U.S. Increase of bank rates in these countries. Big crisis is prevented. The following 1908: sharp fall in commodity prices, major recession year.
	World War I
	During the war: major price inflation everywhere; Gold Standard was <i>de facto</i> suspended; fighting countries exported gold to pay for the war; tax increases; effective government regulation of all markets.
	The early 1920s – mid 1920s
Reconstruction and the end of postwar boom	Post-war boom and then slump everywhere. Monetary tightening to fight post-war inflation, resulting sharp deflation, fall in world commodity prices, cyclical downturn. Burden of reparations and political instability in Germany result in hyperinflation, collapse of savings, social unrest, attempted revolution, fall in credit rating (1922–23). Gold Standard restored in Germany (1924), UK and the U.S. (1925), France (1926), Worst problems of postwar adjustment had been overcome by the mid-1920s. Decrease in credibility of Gold Standard
	Great Depression
Stock market boom and crash in the U.S.	Fed easy money policy stoked the stock market boom (1928–29). The New York stock market crash (Oct. 1929). Fed tightens credit causing a slump in the US economy.
Cutoff of foreign lending (around 1931) and the collapse of Gold Standard	The Great Depression (1929-1930): bank failures, cutoff of lending, bankruptcies. 1931: Large withdrawals of gold from London and accumulation in the U.S. and France. Britain abandons the gold standard. Banking crises in Austria, Germany, Japan and abandonment of Gold Standard there and in Ireland, Scandinavia, and some South American countries. 1936: France leaves Gold. France continues to be the center of a Franc bloc including most of the non-German European countries south of Scandinavia until WWII.

Notes: Continued on the next page.

World War II

WWII was very similar to WWI: suspension of the market system, increase of demand (employment, inflation in most countries), increase of taxes, government debt and liquidity. Short and long interest rates had been regulated and did not reflect the supply and demand for capital.

Bretton Woods, 1950s, 1960s

Convertibility without macroeconomic coordination

Bretton Woods system of convertible currencies, fixed exchange rates, and free trade. U.S. plays a very active, dominant, role in reconstruction and stabilization.

Speculations at gold and currency markets

Cold war, the Korean war (1950-53), Suez Crisis (1957), Franco-Algerian war (1954-62) and end of the Fourth Republic (1958), Caribbean crisis (1962), Vietnam war (1964-75). Currency speculations and crises in France (1958, 1968), Italy (1963), Britain (1964). Britain devalues against the dollar (1967), crisis of confidence in Bretton Wood system. U.S. balance of payments in deficit (1968). U.S. abandons the gold pool. After 1965, slowing down of the post-World War II economic expansion, *stagflation*, and the highest interest rates in all major market economies

Collapse of Bretton Woods, oil shocks of the 1970s

Shifts to floating exchange rate regime

U.S. Nixon administration devalues dollar (1971); Germany and Japan forced to revalue. Britain leaves the EEC snake and floats the pound. Banking crisis in Britain (1973-74). U.S. suspends the convertibility of dollar to gold (1973). Formal acceptance of multilateral floating as the new regime. Watergate Scandal (1972-75). Eurodollar market crisis (1974). Stagflation with weak growth and high unemployment in OECD until the end of the 1970s. 1979: European Monetary System created; Volker's tightening of monetary policy in the U.S. drives the world interest rates up.

OPEC oil shocks (1974 and 1978-1980)

Thatcher and Reagan deregulations, Global recession of 1981-82, Debt Crisis

Movement to the lower role of government in economic life

Thatcherism in Britain (1979-1990), the Falklands war (1982). Reagan in the U.S. cuts taxes but not its expenditures (1981). Large and persistent government deficit in the 1980s and tripled national debt.

Third World debt crisis

Interest rates rise in the industrial world in an effort to curb inflation, made developing countries debts unsustainable. Mexican debt crisis: flight of capital from Mexico and other heavy Latin American borrowers: Argentina, Brazil and Venezuela (1982). 1979-82 six realignments in EMS due to non-convergent inflation rates.

Stock market panics of 1987

A record fall on Wall Street (October 1987). Hurricane over southern England and Black Monday at the London Stock Exchange.

1990s

Beginning of the 1990s

Liberalization of 1980s improved growth but did not make it sustainable. The crises of European Exchange Rate Mechanism (ERM): massive international speculation hits different European currencies and forces Britain to leave the ERM (1992). Recessions and stagnation in all major industrialized countries, with different timing.

European Integration

End of Cold War, collapse of the USSR, reforms in Eastern Europe
Maastricht Treaty on European Union (1992): economic and political integration (exchange rate stability, further political integration started from monetary policy). Introduction of a single currency (1999). ECB takes control of setting interest rates.

Notes: Sources are Davies (2002), Britton (2001), Homer and Sylla (1996), Norris (1999), Kindelberger (2000), O'Rourke and Williamson (1999).

Appendix E Comovement of real returns

[NOT FOR PUBLICATION]

Domestic investors considering returns in their own country or speculating in foreign goods (the real arbitrage) might consider real rather than nominal returns. Real long-term bond returns are most directly related to the costs of capital investments and the expected marginal yield on investment (see Obstfeld and Taylor, 2003; 2004). Convergence of real interest rates is thus a broad measure of financial integration because in an integrated economy we would observe convergence of the real rates of return on both physical assets and financial assets.⁴⁷

In principle, the PCA-based measure can be used to study comovement of real interest rates. Taylor and Sarno (2004) demonstrate that financial market efficiency, which implies that UIP holds in form (1) or even when the deviations from the UIP as in Eq. (2) are stationary, does not preclude the long-run PPP condition from holding. This result assumes a plausible dynamic equilibrium correction relationship between prices and nominal exchange rates by which a real appreciation of a country's currency has a net long-run deflationary impact on the economy. One of the conditions for this mechanism stipulates that the expected real interest rate differential is not a constant value but a stationary process, which has empirical support (see citations in Taylor and Sarno). To study comovement of real returns we need to take into account the behavior of inflation rates. Over the very long-run this analysis is complicated by the variability of development paths cross-sectionally and over time. Specifically, the less-developed at a time countries could exhibit higher inflation rates than more industrialized countries (the Balassa-Samuelson effect) and it is not obvious how such "Balassa-Samuelson trends" evolve and how the convergence of real returns will be affected. According to Lothian (2002), the advantage of UIP relative to the real-interest differential is that errors in expectations of inflation do not enter in.

I compute real bond returns using the "exact" Fischer formula $r_t = (1 + i_t)/(1 + \Pi_t^e) - 1$,

⁴⁷Lothian (2002) explains that ex ante real rates converge if either UIP and purchasing power parity (PPP) both hold perfectly (the law of one price holds perfectly in an ex ante sense in both bond markets and goods markets), or deviations from the two conditions completely offset one another (if they are due to a common cause, such as errors in forecasts of exchange rate).

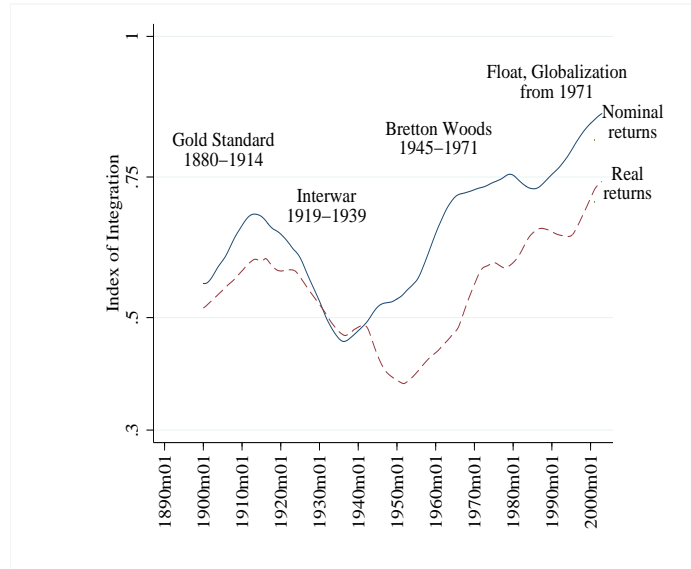
where Π_t^e is the expected inflation rate. As Obstfeld and Taylor (2004) I assume the perfect foresight and calculate Π_t^e as 12-month-forward inflation rate from the realized consumer price indices as $P_{t+12}/P_t - 1$. For some countries with only the yearly historic CPI series (before the 1930s) I use yearly inflation rate in the following year.⁴⁸ I estimate principal components for 11 bond series using 156 month forward-looking rolling window to match the forward-looking inflation forecast. Panel A of Figure E-1 reports the smoothed pattern of comovement of the inflation-adjusted returns r_t and the nominal returns i_t replicated from Figure 1.

Most of the time the first principal component explains a lower proportion of variation in real returns than in nominal returns (the index based on real returns has a lower value than the baseline index from nominal yields). This implies that inflation dynamics creates an additional reason for divergences of real returns. As stressed in the introduction, the key in describing the pattern of integration is to focus on the long-run *trend* and not the level of an index per se. Overall, the qualitative pattern of integration emerging out of real returns matches the path of the baseline index: there is a J-shape in integration with the high in the recent years. Prior to the 1940s the former follows the latter quite well. The main difference is in the timing of the all-time minimum. While the baseline index has a low in the 1930s, a historic minimum in the index computed from real returns is observed in the late 1940s, following World War II. The possible reason for this pattern is a fairly large difference in inflation performance of various countries after the war as Panel B demonstrates. From the mid-1950s inflation rates moved more in-sync, and the trend in the index based on real returns turns positive and largely follows the index based on nominal returns. I do not discuss this issue further because in this paper I am primarily concerned about financial integration and hence use the nominal returns that are relevant for international investors in financial markets.

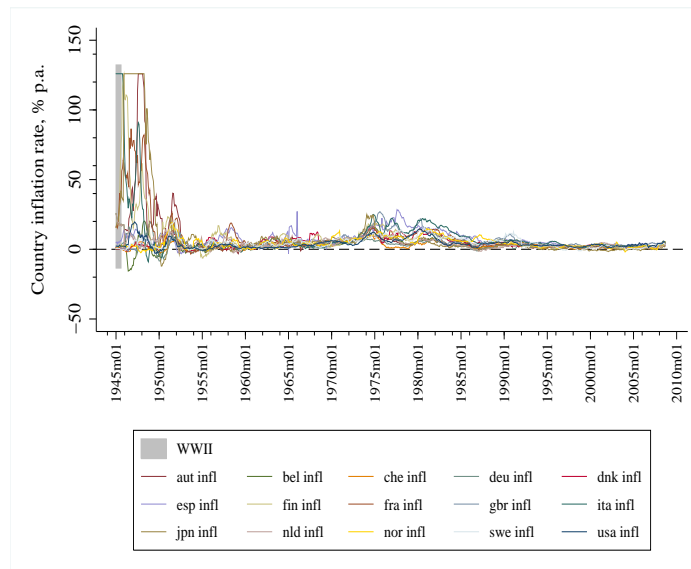
⁴⁸I also tried estimating Π_t^e from interpolated monthly CPI series for such cases with similar results.

Figure E-1: Index of integration based on nominal and real yields and country inflation rates

Panel A: Proportion of variation in bond returns explained by the 1st principal component (smoothed series), 1900–2008



Panel B: Country inflation rates, 1945–2008



Notes: Panel A: Estimates of the proportion of variation in bond returns explained by the first principal component smoothed using the uniformly weighted moving average smoother. Government bond returns are in levels. In-sample countries are Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, United Kingdom, and United States. The estimation of the component is performed by rolling window with the bandwidth of 156 months.

Panel B: Inflation rate is calculated as year-over-year changes of CPI from the GFD in percent.