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Safe Havens, Feedback Loops, and Shock Propagation in Global Asset Prices

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Do Safe Havens Make Asset Markets Safer

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Abstract

We create a network of bilateral correlations of changes in sovereign bond yields and individual bank equity price changes since 2000. We extract some stylized facts from this network of asset price correlations and document the clear differences in asset price correlations between safe havens and non-safe havens: safe havens, as commonly defined, have higher sovereign-sovereign, bank-bank, and bank-sovereign correlations than non-safe havens. In a simple shock propagation model, we illustrate how these higher correlations may turn safe havens into shock propagators. While we discuss safe havens as a group, we document how the US is in a category of its own, differing significantly from the other countries including Switzerland or Japan. Separately, we find that feedback loops amplify shocks, and those emanating from bank stress more than those emanating from sovereign stress.

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Contents Page

I. INTRODUCTION

Over the past half-decade since the onset of the global financial crisis, asset prices and capital flows have gyrated and their movements have differed strongly across different groups of countries. In particular, some countries—"safe havens"—experienced strong inflows into sovereign bond markets while others found even their most liquid markets drying up. Has the presence of these safe haven flows changed the resilience of the global financial network that was buffeted by repeated shocks since 2007? In this paper we present some stylized facts on the role of safe havens in spreading or containing contagion in asset prices.

We focus on asset price correlations rather than financial exposures for two reasons. First, asset price correlations represent proxy networks for underlying fundamental economic ties when more granular data is missing or available with a lag (Gale, 2014). For example, strong correlations between two banks' equity prices could reflect significant creditor and borrower relationships between two banks—for which quantitative data is not available. Alternatively or in addition, similar business models, comparable macro risks, and financial exposures could generate strong correlations between banks. Strong correlations between bank equity prices and sovereign bond yields could reflect large sovereign exposures of the bank or large contingent liabilities of the sovereign arising from a too-big-to-fail bank. Strong correlations between two sovereigns' bond yields could reflect a similar investor base or deeply interconnected banking systems like in the euro area. Asset price changes and their correlations are available at much higher frequency than data on these underlying exposures (many of which are not available in any case). As a result, changing asset price correlations can indicate stress well before it is reflected in available data. Second, asset price correlations matter in their own right in that they can trigger macroeconomic effects (Caceres et al. 2010). For example, an increase in sovereign bond yields is typically accompanied by an increase in domestic longterm financing cost that affect investment and consumption—even if there are no immediate adjustments in financial exposures.

A rapidly expanding literature has documented contagion across asset prices and, in particular, between sovereign and bank debt. Several authors have provided evidence of cross-country contagion in long-term sovereign bond yields (Caceres et al, 2010; Gilmore et al, 2010) or sovereign CDS spreads (Caporin et al, 2013) for euro area countries or a broader sample of European countries, the US, and Japan. While there is some concern that strong sovereign-sovereign correlations simply reflect correlations in fundamental financial factors—especially short-term interest rates (Manganelli and Wolswijk, 2007) —, Mody (2009) has shown that 2007 was a turning point in sovereign-sovereign correlations with increasing differentiation according to credit risk. In addition to sovereign-sovereign contagion, several authors have also documented sovereign-bank contagion. After bank bailout episodes and financial rescue packages in the euro area, the correlation between bank and sovereign CDS spreads increased significantly (Acharya, Drechsler, and Schnabl, 2011) and bank and sovereign CDS spreads' sensitivity to a global risk factor became more similar (Ejsing and Lemke, 2009). Also outside these narrow financial rescue episodes, correlations between sovereign and bank CDS spreads have risen (Merton et al, 2013). By estimating correlations, this literature has essentially mapped parts of the *topology* of the network of asset prices, with a heavy focus on periods of stress. Here, we will complement these estimates with broader stylized facts about the larger network of countries and banks, over a longer horizon, and for specific groups of countries. In a next step, we illustrate the implications of heightened asset price correlations for shock propagation among asset prices.

There is a growing literature on shock propagation in networks of financial exposures and lending relationships, tested in interbank markets, cross-border banking, and payment systems. Authors typically find knife-edge stability properties of these financial networks. Compared with a more sparsely interconnected network, a more densely interconnected network is more resilient to small shocks but less resilient to large shocks (Allen and Gale, 2000; Acemoglu, 2013); a more concentrated network is more fragile if there are shocks to its core rather than to shocks in its periphery (Motter and Lai, 2002). Roukny et al (2013) examine the tradeoff between the average number of links, the average node's robustness, general market conditions such as "market illiquidity" that reduce all nodes' robustness, and the shape of the network (i.e. the distribution of the number of links). They show that no single network is the least fragile under all circumstances. More centralized networks are generally more fragile than more dispersed networks, but are more robust when the most central nodes have the most buffers and are not subject to targeted shocks. In contrast to this strand of literature, we do not examine shock propagation as a function of the overall shape of the network but rather we examine shock propagation as a function of the properties of a specific subgroup of nodes within the existing shape of the asset price network.

In our exercise, we take a shock as given. There is a strand of literature, however, that argues that the shape of the network can help predict shocks. Several authors have shown network measures to be significant correlates of banking system and general financial system stress. Minoiu et al (2013) found rising interconnectedness (measured as clustering coefficients and degree centrality) in the global network of cross-border banking exposures from the BIS locational statistics to be significant predictors of systemic banking crises. So were degree and betweenness centrality in a bank-level network of syndicated loans (Caballero, 2012). At the same time, increased connectivity in the same network fostered trade (Hale, 2012). While the previous papers related mainly to the pre-crisis period, Chinazzi et al (2013) found that degree centrality in a network of cross-country debt and equity exposures was a significant predictor of the drop in growth and to stock market volatility during the crisis. The measures these authors used were country-level measures of a country's position in the network. While these are useful to predict crises or trade in any particular country, they do not explain the dynamics of contagion from a crisis. In contrast, here we do not attempt to predict a crisis or any other shock but, *contingent on a shock occurring somewhere*, trace how contagion travels through global asset price markets.

Blending elements of the literatures on asset price contagion and exposure networks, we illustrate how the stability of the global network of asset price co-movements has changed over time. We hone in on a particular group of countries with unique characteristics—safe haven countries—and their role in amplifying or slowing the spread of contagion across borders and asset classes. We document substantially higher sovereign-sovereign, bank-bank, and sovereign-bank asset price correlations in safe haven than in non-safe haven countries. This distinction comes out more clearly in our sample than in those of previous authors because we deliberately expand it to include many emerging markets (50 sovereigns) and individual banks (331 banks). To achieve this larger sample, we rely on sovereign bond yields and bank equity prices, which in many countries are more liquid than CDS spreads. By using individual bank data, we are able to distinguish sovereign-bank correlations between more and less systemic banks which are too big to fail to different degrees.

Before delving into the characteristics of safe havens, we also illustrative in a thought experiment, how the strength of correlations interacts with feedback loops in shock propagation. We show that cross-country correlations between sovereign-bond yields have been stronger than between individual bank equity prices and that these, in turn, are stronger than correlations between bank equity prices and domestic sovereign bond yields. As a result, any shock that would have reached the sovereign bond yield network would have been propagated quickly and strongly across countries. Hence, had a *bank equity price* shock raised local sovereign bond yields through bank-sovereign links, it would have triggered strong feedback loops between the two asset classes and across countries. In contrast, a *sovereign bond yield* shock, even if it had depressed local bank equity prices, would have been amplified less strongly by feedback loops from the more mildly correlated global bank equity price network.

The existing literature on safe havens has defined safe haven assets as hedges of returns on risky reference portfolios during times of financial stress or rising risk aversion. This literature has examined exchange rates (Beck and Rahbari, 2008; Habib and Stracca, 2012; Ranaldo and Söderlind, 2010), gold (Baur and McDermott, 2010), or sovereign bonds (Hartmann et al., 2006) as hedges against stock market risk. In addition, market analysts and IMF (2012) have defined safe havens based on sovereign credit ratings by rating agencies. We apply these two commonly used definitions—hedge against stock market risk and credit ratings—to our dataset to define safe havens before we proceed to examine their properties.

In our dataset, safe havens turn out to have distinctive properties. First, their sovereign bond yields are on average more strongly than non-safe havens' yields correlated with other countries' sovereign bond yields—both with other safe havens or non-safe havens. Similarly, safe havens' bank equity prices tend to be more strongly correlated with other banks' equity prices than non-safe havens' bank equity prices; however, the gap between safe havens and non-safe havens is smaller for bank-bank correlations than for sovereign-sovereign correlations. Second, sovereign bond yields in safe havens are on average more strongly *positively* correlated with their home banks' equity prices, whereas they are uncorrelated and in very few cases negatively correlated in non-safe haven countries. Were bank equity prices and sovereign bond yields mainly driven by concerns about country-level credit risk, one would expect an increase in sovereign bond yields to be associated with a fall in bank equity prices, i.e. a negative correlation. In contrast, where credit risk is of negligible concern—i.e. in safe havens—expectations about future growth and monetary policy become predominant: an improving growth outlook raises bank equity prices together with the expectation of tightening monetary policy which, in turn, puts pressure on sovereign bond yields. Reminding the reader of the pros and cons of a correlation-based dataset, we illustrate how, as a result of their higher correlations in all three dimensions, safe havens can propagate shocks to other countries faster than non-safe havens—although to varying degrees depending on the source and "recipient country" of the shock and the time period.
In the next section, we describe our data, followed by our definition of safe havens and their properties in Section III. In Section IV, we document some stylized facts of feedback loops in shock propagation. In Section V, we examine the role of the two characteristics of safe havens in

amplifying or dampening shock propagation. Several of these facts raise intriguing questions, summarized in Section VI, that are left for further research.

II. Data

We use daily changes in 5-year bond yields of 39-50 sovereigns and daily log changes in bank equity prices of 331 individual banks using Bloomberg data.[1] About one-third of the banks and one-half of the sovereigns are European, about one-quarter of both are Asian, and three quarters of the banks and one-half of the sovereigns are emerging markets. Because of limited data availability in the 1990s, the time span for our network of global bank equity prices and sovereign bond yields comprises 2000-2013. The full sample is divided into subsamples of six-month intervals from H1 2000 to H2 2013.[2]

Table 1. Regional distribution of banks and sovereigns in the sample
(Share of total number of entities)

	Banks	Sovereigns
Asia AM	7	12
Asia EM	16	16
Non-EA Europe, AM	5	9
Europe EM	17	19
EA core	5	10
EA periphery	7	9
MENA	13	3
US, Canada	2	7
Latam	10	14
Other (Africa, Central Asia, Offshore centers)	17	2

We adjust the daily data for time zones and exchange rate changes. Asian markets close before North America markets open and half-way through the trading day of European markets. Hence, a shock in a North American market can only be reflected in Asian markets on the following day and in European markets at best late in the trading day or the following day. For shocks originating in North America, we therefore match North American data with the average of the same-day and next-day data for Europe and with next-day data for Asia. Similarly, for shocks originating in Europe, we match European data with the average of same-day and next-day data for Asia.

For each bank/bank, sovereign/sovereign, and bank/sovereign pair, we calculate bilateral Pearson

1 5-year bond yields are the most widely available data. In the early 2000s, there are gaps in sovereign bond yield data for Brazil, Colombia, Croatia, Iceland, Sri Lanka, Peru, Romania, Russia, Slovakia, Ukraine, and Vietnam. However, our results are robust to using the smaller samples of 2-year or 10-year bond yields.

2 The majority of the Euro zone countries provide sovereign bond yields ranging back to 1994. Therefore, we consider this as a special case and we devote Box 1 to analyze the situation in the European Monetary Union (EMU) individually over the years 1994-2012.

correlation coefficients between bank equity price log changes and sovereign bond yield changes over each of our subperiods. Ideally, we would have used measures that explicitly incorporate causality, e.g. Granger causality or spillover coefficients as in Diebold and Yilmaz (2009), but the estimations necessary to derive these measures would typically have constrained our sample size. Therefore and in keeping with much of the rest of the asset price literature, here we begin by focusing on simple correlations and treat our shock propagation model as purely illustrative.[3] Of course, correlation coefficients could in principle reflect a common response to global shocks which one might consider stripping out of asset price correlations. However, many of our countries are large and systemic enough that it becomes difficult to disentangle global shocks from country-specific shocks. For example, a shock originating in US financial markets, even if triggered by very US-specific events, would typically be considered a global shock. Also, Forbes and Rigobon (2002) caution that simple correlation networks can suffer from volatility bias when correlations spike during crisis periods. By taking wider semi-annual windows, instead of narrow windows around crises, we remove some of this bias.[4] To eliminate spurious correlations, we set the correlations between sovereigns and banks outside their countries to zero.[5]

We call our network $G(V, E)$ a representation of a set of nodes $V = \{v_1, v_2, \dots, v_n\}$, connected by a set of edges $E \subset V \times V$. The strength of the edge between two adjacent nodes is determined by our Pearson correlation coefficient. Formally, we may represent a network G in a matrix form, denote it by $A_{n \times n}$, where all diagonal elements are equal zero, i.e. the relation between the same assets is irrelevant, and elements a_{ij} represent the correlation between assets i and j. Since we use the time adjusted data, matrix A is not symmetric, making the network directed, i.e. $a_{ij} \neq a_{ji}$ for some i and j. Formally, if we denote the number of sovereigns by n^s and number of banking sectors by n^b,one may rewrite the network as a block matrix $B_{(n^s+n^b)\times(n^s+n^b)}$, where two diagonal blocks represent the individual networks and the remaining blocks are zeros except for the instances when the sovereign and banks refer to the same country.

3 In principle, shocks can of course also jump from equity and bank stock prices to interbank money markets or foreign exchange markets. We will consider these asset classes in future research.

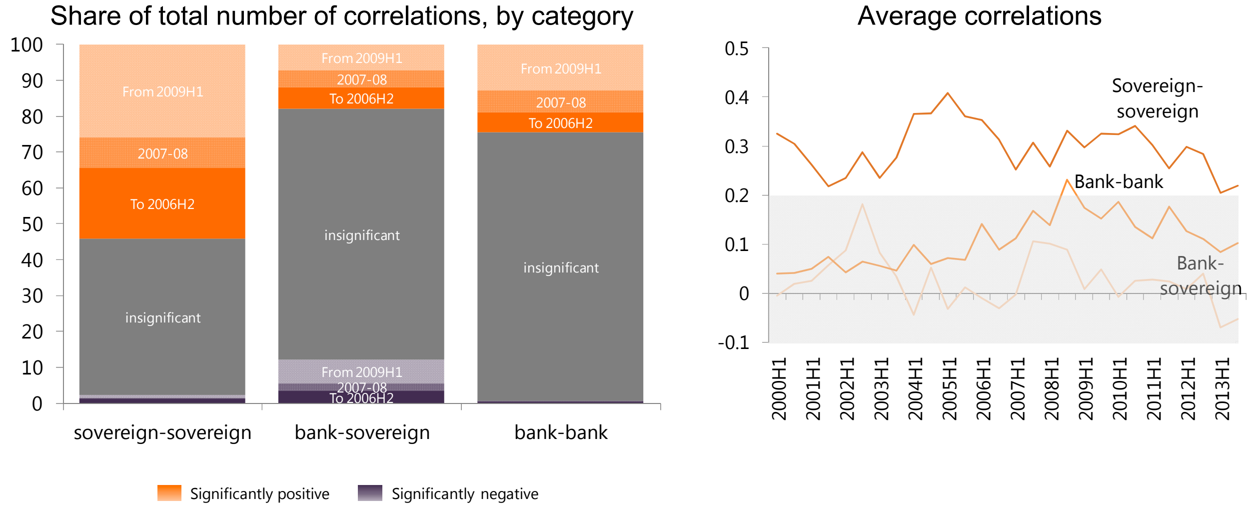
4 Alternatively, one could zoom in explicitly on the crisis periods and correct for volatility bias and common shocks by rank correlations, MR-coefficients of a quantile regression, dynamic conditional correlations (DCC GARCH), entropy-based methods (cross-entropy and "entropy correlation"), and extreme value dependence.

5 While this does mean that, e.g. the correlation between the Greek sovereign bond yield and a French bank's equity price is eliminated by assumption, it also avoids many spurious correlations, e.g. between the Finnish sovereign and Argentinian banks. Here, to avoid the many spurious correlations even if at the cost of eliminating some valid ones, we remove all sovereign/bank correlations except those within each country.

III. Stylized Facts

Figure 1 shows summary statistics for correlations between daily sovereign bond yield changes ("sovereign-sovereign"), between daily bank equity price changes ("bank-bank") and between daily changes in sovereign bond yields and same-country bank equity prices ("bank-sovereign").[6]

Figure 1. Number of and average correlations between daily changes in sovereign bond yields and bank equity price changes, 2000-2013



These summary statistics confirm five stylized facts.

First, the bulk of the correlations are inside the 95% confidence interval [-0.196, +0.196] and, hence, statistically insignificant. This is especially the case for bank-sovereign and, to a lesser extent, bank-bank correlations. In contrast, more than half of sovereign-sovereign correlations are significantly positive, with very few significantly negative ones.

Second, *sovereign-sovereign* correlations are stronger than *bank-bank* and, even more so, *bank-sovereign* correlations. At the peak of the global financial crisis in 2008H2, bank-bank correlations spiked to almost match, on average, sovereign-sovereign correlations. Since then, however, bank-bank correlations have declined. A little later, with the onset of the euro area crisis in early 2010, sovereign-sovereign correlations have also fallen.

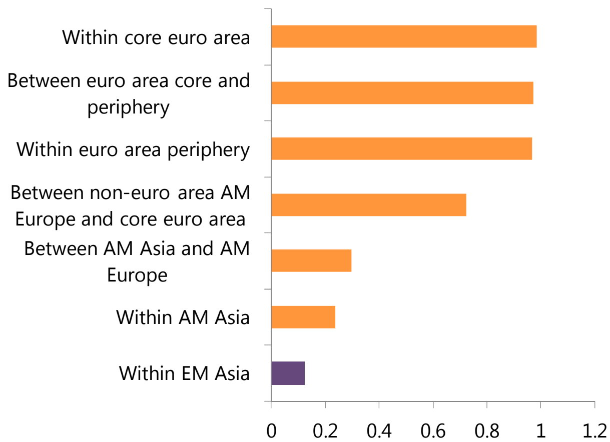
Third, the strongest positive *sovereign-sovereign* correlations (in the highest bracket above 0.8) are almost exclusively among European sovereigns, possibly reflecting the common exchange rate (Figure 2). There are only a few exceptions: Australia's and New Zealand's sovereign bond

[6] We tested these stylized facts using 2-year and 10-year correlations and found that they still apply. We also calculated correlations of *weekly* and *two-weekly* changes in bond yields and bank equity prices. Especially the number of significantly positive sovereign-sovereign correlations and negative bank-sovereign correlations rises as the window of changes widens. However, the single most important fact driving our subsequent analysis—that safe havens have higher correlations—remains correct.

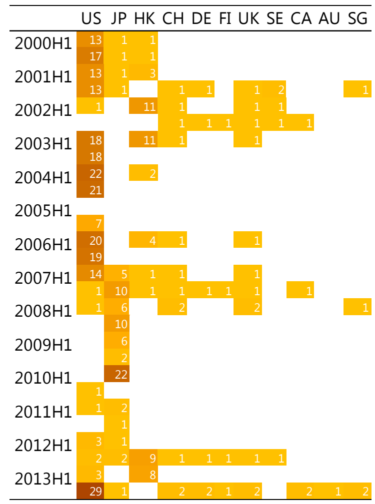
yields throughout the sample period and large emerging markets and Canada during period of stress in advanced countries had strongly positive correlations[7]. There are only very few significantly negative correlations between sovereign bond yields, predominantly with the US (2000-2007, 2013), Japan (2007-10) and Hong Kong (2002-03, 2012-13).

Figure 2. Sovereign-sovereign correlations, 2000-13
(Correlations between daily changes in sovereign bond yields)

Average correlations



Number of significantly negative correlations



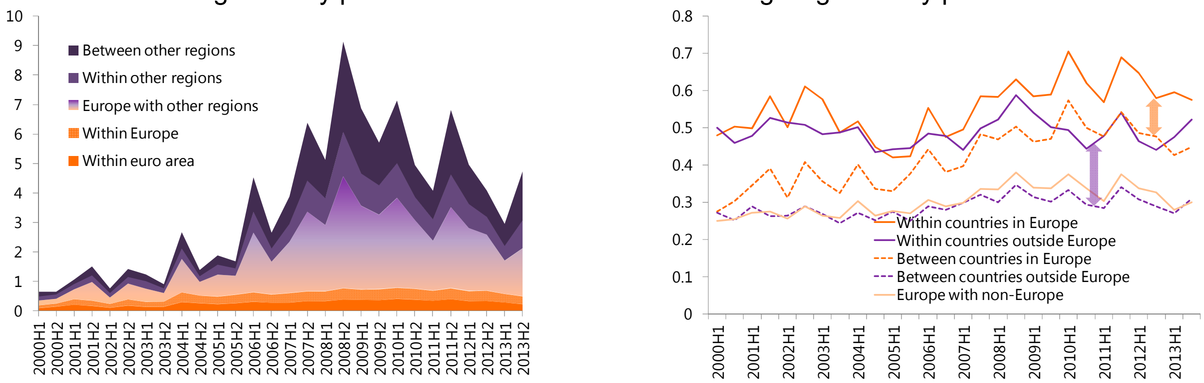
Note: Number of cross-country correlations between daily changes in sovereign bond yields that are significantly negative (excluding those with "higher-ranked" safe havens in columns further left).

Fourth, *bank-bank* correlations are also highest in Europe, although most significantly positive bank-bank correlations are found between Europe and the rest of the world (Figure 3). Even though they are significant, many of them are small. The largest correlations between bank equity price changes prevail in Europe. Both in Europe and the rest of the world, bank-bank correlations within countries tend to be larger than between countries. In Europe, the gap in average correlations between and within countries narrowed in 2004 but widened with the euro area crisis. Nevertheless, it remains smaller inside Europe than outside.

[7] Turkey/Brazil/South Africa in the second half of 2007, Brazil/Mexico/Canada/Turkey in the first half of 2010, and South Africa/Singapore/Mexico in the second half of 2011.

Figure 3. Bank-bank correlations, 2000-13
(Correlations between daily log changes in bank equity prices)

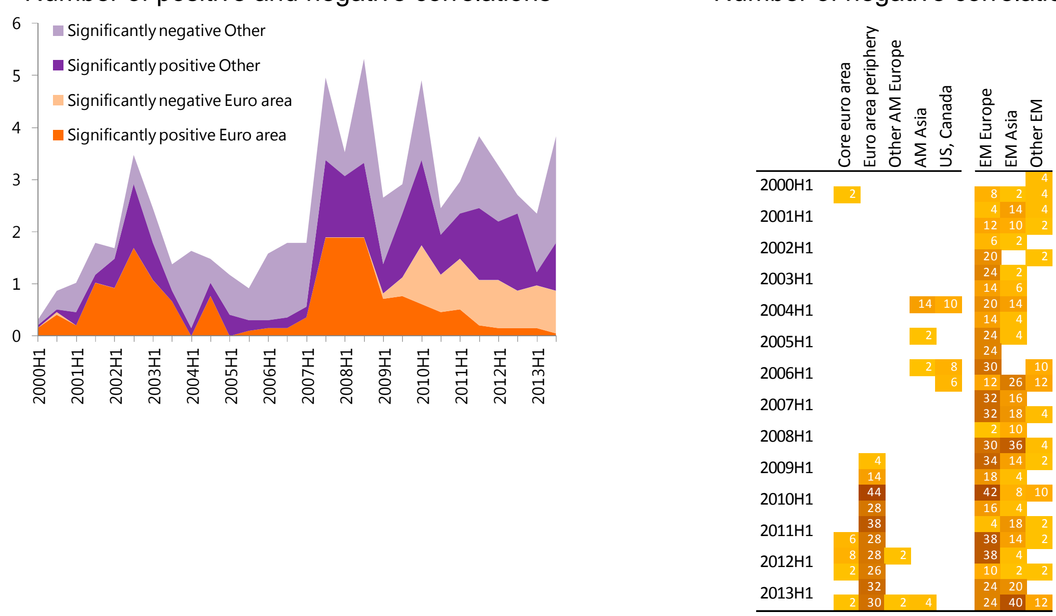
Number of significantly positive correlations | Average significantly positive correlations



Fifth, some four-fifths of *bank-sovereign* correlations are statistically insignificant. Of the few that are significantly positive about two thirds fell into the euro area before the euro area crisis (Figure 4). Even fewer bank-sovereign correlations are significantly negative. Until the euro area crisis, these were predominantly outside the euro area but have since appeared also in the euro area periphery.[8] We will return to our interpretation of positive and negative correlations when we explore the differences between safe havens and non-safe havens below.

Figure 4. Bank-sovereign correlations, 2000-13
(Number of significant correlations between daily log changes in bank equity prices and daily changes in own-country sovereign bond yields)

Number of positive and negative correlations | Number of negative correlations

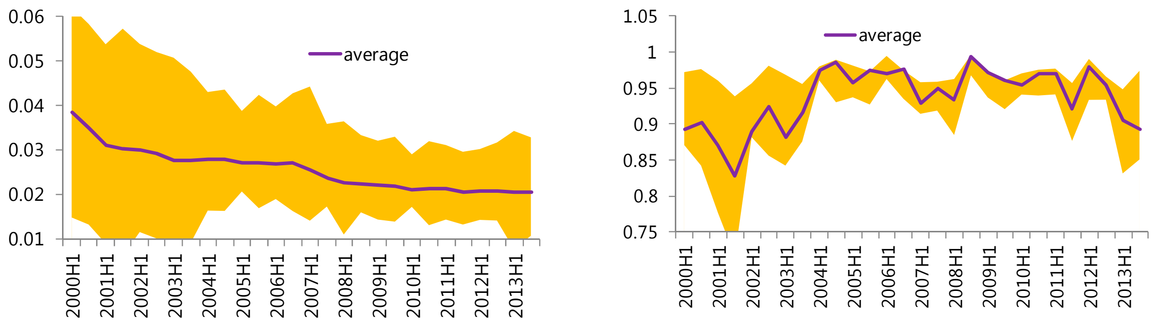


[8] These include banks in Spain, Belgium, France, Greece, Ireland, Italy, Mexico, and Russia, during 2009-13; Brazil, China, and Mexico in 2007/08; and several emerging markets throughout the sample period.

The decline in the strongest *sovereign-sovereign* correlations since 2000 is also evident in the distribution of centrality. For each country, random walk betweenness centrality (defined as in Bloechl et al, 2011) measures the probability that the country lies on any random path between any two other countries in the network. The greater a country's random walk betweenness centrality, the more frequently it "connects" other countries and, hence, the more central and important it is in the network. Figure 5 shows the average random walk centrality of the sovereign bond yield network, as well as the 25th and 75th percentiles of random walk centrality. Average random walk centrality declined noticeably in the late 2000s as some of the "most central", especially highly interconnected European countries, countries lost centrality and the centrality of the network's periphery increased.

Figure 5. Centrality and Clustering in Sovereign Bond Yield network

Random Walk Betweenness Centrality | Clustering Coefficient



High correlations may be widely dispersed or may be concentrated among small groups of countries: clusters. The clustering coefficient (here defined as in Barrat et al. 2004) measures the strength of connections among the neighbors of a country (loosely speaking, the degree of "friendship" among a country's "friends"). In the years 2000-2004, the clustering coefficient increased noticeably, consistent with similar findings by Minoiu et al (2013). From 2004-06, clustering in the sovereign bond yield network was high, with the average clustering coefficient around 97 percent (Figure 5). Since then, three episodes of "decoupling" can be distinguished. The first occurred in the 18 months of 2007 to mid-2008 and was reversed when Lehman Brothers' bankruptcy increased all correlations. The second sharp decline in clustering occurred at the height of the euro area crisis in the second half of 2011 as markets discriminated clearly between core and peripheral Europe. With the exception of a temporary reversal in the first half of 2012, clustering has weakened further.

However, in one sense at least, this decoupling was modest. Although the clustering coefficient and thus the strength of clusters have declined over time, the composition of the most important clusters has remained remarkably stable. Rosvall and Bergstrom (2008) define clusters using a random walk trap algorithm. The algorithm follows the path of a random shock around the network of correlations. It delineates clusters such that the shock is more frequently inside clusters than it jumps between clusters. Appendix Figure 1 shows the clusters of sovereign bond yields over time. Each bar corresponds to a 6-month period since 2000 and "transition bars" connect every two 6-month periods. Countries inside a cluster are stacked on top of each other, with clusters separated by a gap. The grey-shaded global cluster contained all euro area countries despite the—obviously mild by international standards—decoupling during the euro area crisis. This global cluster also included Japan (except early in the decade), the UK, Switzerland, the non-euro area Nordics, advanced country commodity exporters (except in late 2002/early 2003), and Eastern Europe (except in late 2002). Of the large countries, only the US was outside this global cluster but rejoined it at the height of global financial market stress in 2008-2012.[9] In the first half of 2008, Korea, Indonesia, India, Philippines, China, Malaysia, Thailand, Japan decoupled briefly from this global cluster (Appendix Figure 2).

The network of *bank equity prices* has been much less clustered than that of sovereign bond yields (Appendix Figure 3). With the exception of equity prices of the global banks in Western Europe (dark blue in Appendix Figure 3), Eastern Europe (light blue) and the US (orange), banking systems were essentially clustered by nationality until 2006. Especially Asian and non-US North American banking systems only began in 2006 to integrate into a widening global cluster of bank equity prices, which began to shrink again from 2010 onwards (orange in Appendix Figure 4 and green in Appendix Figure 5).

IV. Mapping the Network of Sovereign Bond Yields and Bank Equity Prices

The clusters in Appendix Figures 1-5 help us define broad groupings over time. Greater granularity can be achieved by examining individual countries within clusters for individual subperiods. Appendix Figure 6-10 show (for visual clarity, a subset of all) the pairwise links for a few distinctive intervals: 2000-06, 2007-09, and 2010-12. As discussed above, sovereign-sovereign correlations tend to be much higher than bank-bank correlations and bank-sovereign correlations tend to be the weakest. To make sure that at least some links in each dataset are represented, we select the strongest 10 percent of sovereign-sovereign, bank-bank, and bank-sovereign (negative only) links.

Appendix Figure 6 shows the characteristics of sovereign-sovereign interconnectedness. Pre-crisis (2000-06), Singapore and, less directly, Korea were the main “bridges” between Emerging Asian and European sovereign bond yields. Since the first half of 2008, sovereign bond yields in Asia (Korea, Indonesia, India, Philippines, China, Malaysia, Thailand, Japan) have become less correlated with the group of advanced country sovereign bond yield correlations. European sovereign bond yields have remained the most closely intertwined, despite some recent weakening of links with some of the periphery (see also Box 1 for euro area countries). Correlations between European sovereign bond yields and US sovereign bond yields have strengthened since the pre-crisis period.

Appendix Figure 7 shows the characteristics of bank-bank interconnectedness. Pre-crisis (2000-06), there were few strong bank-bank correlations and they were mostly confined to region Europe or individual countries. The global financial crisis (2007-09) tightened these disparate pre-crisis groups into one knot of cross-border correlations between bank equity returns. One Singaporean bank tied this tight global group to Asian-Pacific banks. Since then (2010-12) only

[9] The clusters in Figure 4 are the same as those in Figure 3. Only different countries or groups of countries are highlighted in the two Figures.

the European banks remain tightly intertwined whereas other countries' bank equity prices have drifted out of the dense global grouping. In particular, Asian and Latin American banks have decoupled from banks in other advanced economies. In Asia, two cross-country bank groupings have remained strong: one including banks in Australia, Singaporea, Korea, and Malaysia and another including banks in Hong Kong and China. In Europe, banks in Greece and Cyprus separated from the main European grouping. In this most recent episode, there were only a few strong cross-border correlations outside Europe: in Asia-Pacific (Singapore and Australia) and North America (Canada and the US).

In Appendix Figures 8-10, for individual country groups, we parse the network for cross-country chains of correlations between banks and sovereigns.

Significant (negative) correlations between sovereign bond yields and bank equity prices were present within each country in Emerging Asia (Appendix Figure 8). [10] In contrast to these *within-country* correlations, c*ross-country* sovereign-sovereign and bank-bank correlations were relatively weak prior to the global financial crisis. At the height of the global financial crisis (2007-09), sovereign-bank linkages strengthened in almost all the emerging Asian economies: shocks from European banks could now be transmitted through Singapore to other Asian banks which, though bank-sovereign feedback loops, could have propagated them to Asian sovereigns.

Like emerging Asian countries, Turkish, Polish and—to a lesser extent—Hungarian bank equity prices were highly correlated with their own countries' sovereign bond yields (Appendix Figure 9). During the global financial crisis (2007-09), both sovereign-bank links and cross-country banking sector linkages strengthened further. Stress in Turkey's tightly-linked banking sector could now affect both sovereigns and banks in Poland and Hungary through the banking channel. During the subsequent European crisis (2010-12), Turkey decoupled from Poland and Hungary which remain together in a tightly interconnected cluster. Turkey and Romania developed into two highly correlated within-country groups.

Unlike in emerging European and Asian countries, sovereign-bank interconnections in the GIIPS and Cyprus (Appendix Figure 10) were weak prior to the global financial crisis. During the global financial crisis (2007-09), Spanish and Italian banks began to be highly correlated with core European banks whereas the Greek and Cypriot banks formed a separate group of strong bank-bank correlations. Sovereign-bank linkages remained quite weak, however. As the European crisis deepened (2010-12), aside from higher interconnectedness of global banks, sovereign-bank inter-linkages also strengthened. For example, stress in bank 2 in Portugal could have travelled to Portugal's sovereign which then could have propagated it to Portuguese bank 3 which, in turn, is highly correlated with Italian bank 2, etc. Similar contagion chains can be drawn for Belgium, Spain, Italy and Austria. Greece and Cyprus remained decoupled from the other European banks and sovereigns during this period.

[10] Malaysia, Thailand, Indonesia, Philippines, China, India.

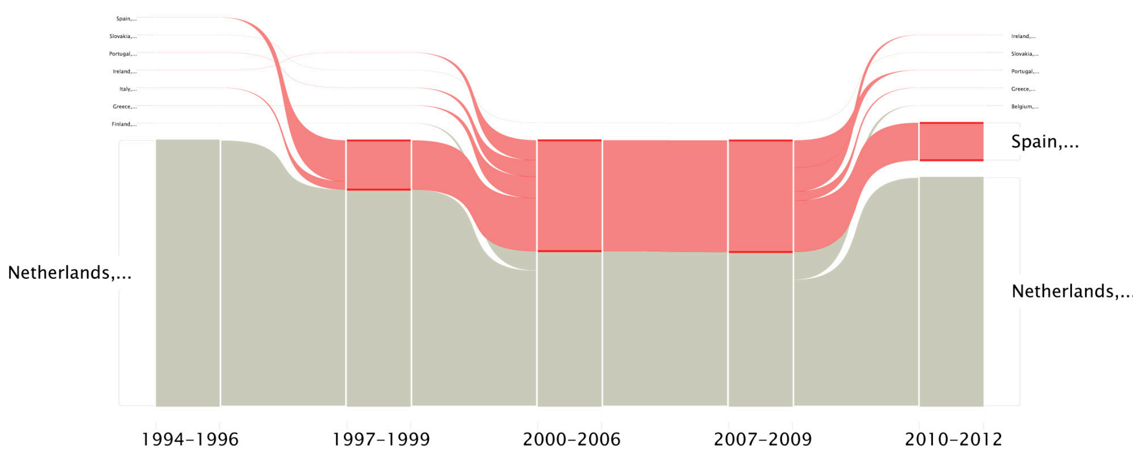
Box 1. Clustering and declustering of the Eurozone community in Sovereign Bond Yields

Since data is available from 1994, we construct a time line of the network of sovereign bond yields in 12 countries in the European Monetary Union and later euro area (Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Slovakia and Spain). We can detect a changing core community in Europe over time. By a community, we understand a part of the global network where the interconnectedness is relatively higher than to the rest of the network. In order to distinguish communities we apply the random-walk algorithm developed by Rosvall and Bergstrom (2008).

In 1994-1996 the core of the EMU—Austria, Belgium, France, Germany and the Netherlands—constituted a separate cluster from all remaining countries. In 1997-1999, Italy and Spain joined this core EMU cluster, and Greece, Ireland, Portugal, Finland joined it in 2000-2006. As might be expected from its late membership in the euro in 2009, Slovakia did not join the community.

In 2010-2012 the core cluster partly dissolved. Belgium, Greece, Ireland and Portugal separated completely whereas Italy and Spain joined a common cluster.

Box Figure 1. The evolution of the clustering structure in the Sovereign Bond Yields within the Eurozone network



Source: Graph prepared by the software delivered at a courtesy of Rosvall and Bergstrom (2008).
Note: GIIPS countries are shown in red. Lines refer to clusters. For instance in 2000-2006 all the countries joined one big cluster.

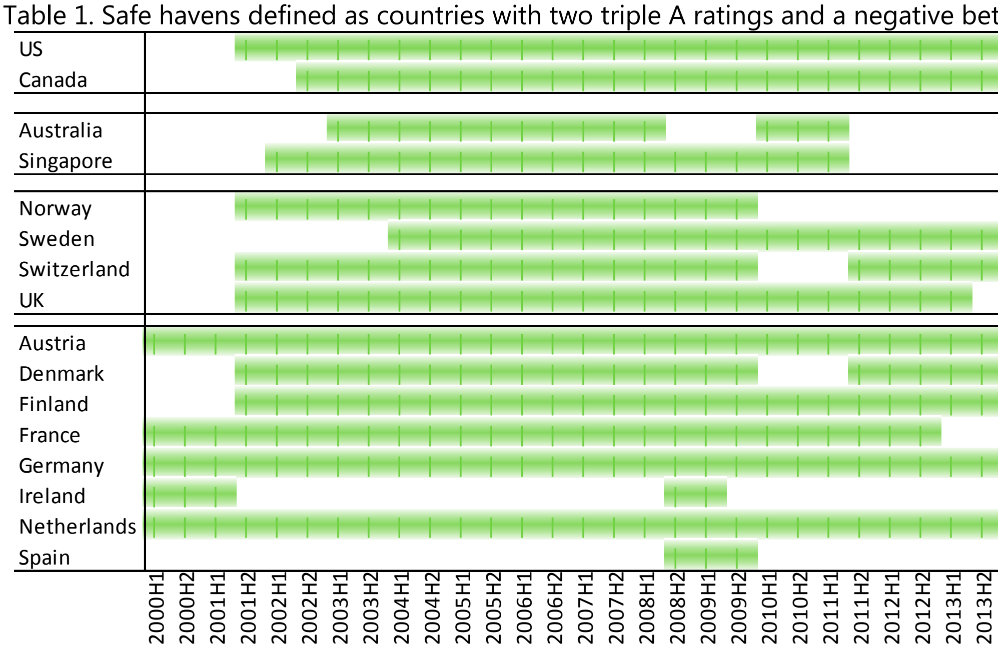
V. Defining Safe Havens

As it turns out, one group of countries is substantially different from others: safe havens. Two definitions have commonly been used to define safe assets. The first definition is one based on credit ratings, for example as in IMF (2012). A country is considered a safe haven if it has a triple AAA credit rating from at least two of the three major rating agencies (Fitch, S&P, and Moody's). This rules out Japan as safe haven since none of the three agencies rated it triple A during our sample period.

The second definition is based on "negative beta". A safe asset is an asset whose return correlates negatively with returns of riskier assets during times of stress.[11] As Habib and Stracca (2012) do for exchange rates, we define sovereign bonds as safe assets if changes in their yields correlate negatively with the returns on a risky asset during financial market stress. As our benchmark global risky asset we choose the US banking equity price index. We use the same stress events as those identified in Habib and Stracca (2012). In particular, these are Q4 2000; Q3 2001 and 2002; H2 2008; H1 2010; and Q3 2011.

We define safe havens as those countries that meet both these two criteria. They have at least two triple A ratings *and* their sovereign bond yields correlate negatively with risk assets' returns during times of stress. We deliberately choose the more restrictive intersection of the two definitions rather than their union because the mechanistic "negative beta" definition would occasionally allow in countries that do not pass the "smell test". According to the "negative beta" definition, for example, Japan would indeed qualify as safe haven during parts of the sample. So would, however, Slovakia and the Philippines. Insisting on at least two strong credit ratings introduces some judgment into the definition that ensures a plausible set of countries. We have, however, run all our exercises for the alternative definition of safe havens as countries with three triple AAA ratings *or* a negative beta and the results were robust. Table 1 shows the list of safe haven countries over time. Note that Spain and Ireland were considered safe havens in the wake of Lehman's bankruptcy. Switzerland and Denmark briefly stopped being considered safe havens until the euro area crisis regained momentum in the second half of 2011.

Table 1. Safe havens defined as countries with two triple A ratings and a negative beta



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[11] For advanced countries, including the US, the positive correlation between sovereign bond yields and prices of riskier assets has been documented by Bauer and Rudebusch (2013) and Pandl (2013). In contrast, for emerging markets, Drainville et al. (2011) show a negative correlation between bond yields and bank equity prices and speculate that this reflects strongly correlated risk premia of EM assets.

How do safe havens differ from non-safe havens? On average, safe haven correlations are well above non-safe haven correlations, both for sovereign-sovereign and bank-sovereign correlations and, to a lesser extent, bank-bank correlations (Figure 6). The higher correlations of safe havens are both with safe haven partner countries and with non-safe haven partner countries. One exception was the period 2005-07, when domestic bank-sovereign correlations were close to zero both in safe havens and in non-safe havens. Not only the mean but also the whole shape of the distribution of correlations differed between safe havens and nonsafehavens. Whereas the distributions of nonsafehavens' correlations were approximately normal, those for safehavens had very fat tails with high positive correlations.[12]

Figure 6. Average correlations of safe haven and non-safe haven countries

[12] Note that the higher correlations of safe havens are specific to safe havens—not simply to advanced countries. The average sovereign-sovereign correlation for advanced country safe havens in the sample was 0.55, the average correlation for the advanced country non-safe haven was 0.38. The average bank-bank correlation for advanced country safe havens in the sample was 0.31, the average correlation for the advanced country non-safe haven was 0.19. Finally, the average bank-sovereign correlation for advanced country safe havens in the sample was 0.17, the average correlation for the advanced country non-safe haven was 0.06.

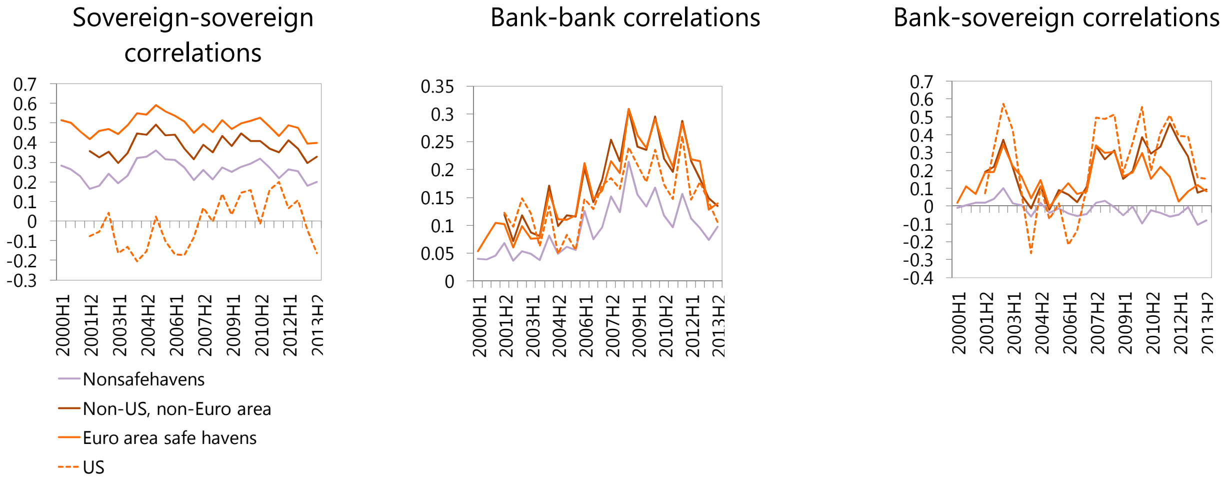
How do we interpret the positive correlation between sovereign bond yields and bank equity prices? Long term sovereign bond yields can be broadly decomposed into two components: (i) expectations of average future short-term interest rates and (ii) a premium that investors require for bearing the (e.g., credit, liquidity) risk of a long-term bond investment. The expectations component (i) is driven by inflation expectations and expectations of future real rates of return, which depend on future economic growth. The risk premium component (ii) is determined by the degree of uncertainty about these future developments and by the degree of investor risk-aversion. Similarly, bank equity prices can be decomposed into a component that reflects expectations of future profitability and a risk premium.

During a downturn, a pessimistic economic outlook drives down bank equity prices; the expectation of a loosening monetary policy response drives down sovereign bond yields. This is our expectations component (i). Separately, rising risk aversion during a downturn induces investors to turn away from riskier assets to safer ones. This reduces yields on safe assets and raises yields (i.e. reduces prices) of riskier assets. This is our risk premium component (ii). In safe haven countries, sovereign bonds are considered safe assets. Hence, both effects generate a positive correlation between bank equity prices and sovereign bond yields.

In contrast, in non-safe haven countries, sovereign bonds are not considered a "safe asset" to which investors will turn when risk aversion rises. As global risk aversion rises, therefore, investors will move out of *both* sovereign bonds and bank equity, sovereign bond yields will rise while bank equity prices fall, and—for a given economic outlook—a negative correlation between sovereign bond yields and bank equity prices will emerge. Since expectations about economic outlook and risk aversion drive the correlation between sovereign bond yields and bank equity prices into opposite directions, the sign of overall correlation is ambiguous.

In addition to differences between the average safe haven and non-safe haven country, there are also differences between the various safe haven countries. The US, for example, has exceptionally low cross-country sovereign-sovereign correlations (even below those of non-safe haven countries) and—especially in the pre-crisis period—domestic bank-sovereign correlations well above those of the average safe haven or non-safe haven country. Safe haven countries in the euro area, in contrast, have higher-than-average cross-country sovereign-sovereign and bank-bank correlations but since the financial crisis somewhat lower domestic bank-sovereign correlations (Figure 7).

Figure 7. Average correlations of safe haven and non-safe haven countries



VI. Modeling Shock Propagation

We next conduct a thought experiment to illustrate how safe havens might amplify or buffer shock propagation. We assume that shocks are propagated in this network in a simple and stylized version of a standard model from the disease-spreading literature, developed by Jammazi and Aloui (2012). Every period each node propagates the cumulative shock it has received to all adjacent nodes. The impact of the shock is weighted by the strength of the link between the nodes. To keep it simple, we make two simplifying assumptions in our use of Jammazi and Aloui (2012). First, we assume that nodes are neutral—i.e. our nodes cannot stop shock propagation—so that the propagation depends on the network structure only. Second, we do not assume any buffers—i.e. our nodes cannot slow shock propagation. The literature on shock propagation is usually based on exposure or lending networks, where buffers have an easy interpretation as liquidity ratios or capital ratios. However, in the context of asset price correlations, there are no natural buffers that come to mind. So as to not reduce by assumption the cascade effect observed in financial markets, we do not assume buffers. The details of the shock propagation mechanism are described in Appendix I.

Our illustrative shock propagation exercise inherently assumes some degree of causality: a shock is "triggered" in one country and "passed on" to others. While the correlations themselves are agnostic on the direction of causality, we posit that causality is unlikely to run from small entities to large entities. For example, the 93 percent correlation between changes of the 5-year sovereign bond yields of Ireland and Germany in 2010-12 is more likely to reflect the Irish sovereign bond market responding to shocks in Germany than vice versa. To capture this discrepancy when the source market is much smaller than the destination market, we scale the correlation between the two entities down proportionately to the relative size: We weight each correlation by the relative size of the source's and destination's total assets (for banks) or government debt (for sovereigns), capping the weight at one. (In future research, we aim to determine the direction of causality of the correlation in a less ad hoc manner, e.g. by using Diebold-Yilmaz (2009) spillover coefficients or including Granger causality measures (Granger, 1969)).

We simulate two types of shocks, one in each of our markets: a sovereign bond yield shock and a bank equity price shock. The initial shock is assumed to be a 1 percent increase in either sovereign bond yields or in daily bank equity prices. For example, in the first step, the source country's sovereign bond yield is increased by 1 percent. All the adjacent countries' (destinations') sovereign bond yields are then impacted by their (weighted) correlations with the source country sovereign bond yield. Separately, the local source country's banks' equity prices are affected by their correlation with their home sovereign bond yield. In the second step, the destination countries themselves become the countries of origins of the next round of shocks: each of them propagates the shock they received in the previous round to all their partner countries. The mechanism repeats step after step and in each step we calculate the cumulative effects of shock propagation in all the countries.[13] We simulate shocks in three subsets of countries: the average of a shock in any individual country of the network, a simultaneous shock in all the GIIPS countries (Greece, Ireland, Italy, Portugal, and Spain), or a shock in the US alone.

Three more caveats are in order. First, the results are an illustration based on the price correlation network and therefore reflect purely market-implied, price-based shock propagation. The extent to which this price-based propagation is mapped into changing exposures is beyond the scope of this paper. Second, by assumption, there is nothing in our thought experiment that stops shock propagation; in practice, of course, policy steps would (and did) contain shock propagation. Of course, these policy interventions are also implicit in our estimated correlations. Alternatively, the shock itself, if left unchecked, could change the structure of the network. Hence, we interpret our results as counterfactuals that may have occurred had modest additional shocks happened in an unchanged network and had there been no additional policy measures. Third, our thought experiment does not say anything about the speed of contagion from shocks. Since almost all sovereigns bond yields and all bank equity prices have at least some correlation—even if small—and we do not exclude any by assumption, the network is complete, i.e. a shock in any one part of the network will immediately travel to all other parts of the network. Instead of speed of contagion, our results are indicative of the size of the impact and the amplification over time of an initial shock on each country and on average. Although the steps have no time dimension, they show the path along which a shock travels around the network. Therefore, in our results below, we retain the notion of distinct steps/iterations for illustrative purposes.

A. Baseline Results

Figure 8 shows the average impact of a sovereign bond yield shock on sovereign bond yields after 5 iterations (continuous line) and after 10 iterations (dotted line) in the three scenarios.[14] Similarly, Figure 9 shows the average impact of a bank equity price shock on bank equity prices. The impacts of the various shocks differ depending on the source market and country of the shock and have changed over time and over the number iterations as shocks get amplified.

[13] To contain exploding paths, we scale each step by the number of nodes (countries and individual banks).

[14] In calculating the average, for GIIPS and US shock origins we exclude the source country of the shock in order to focus on spillovers to other countries. In the average country setting we subtract the size of the initial shock from all the nodes, focusing on the net effect of the shock propagation.

Amplification over iterations. With the exception of a sovereign bond yield shock in the US, the impact of a shock is gradually amplified as the shock reverberates around global sovereign bond and bank equity markets. This amplification—the gap between the continuous and dotted lines in Figures 7 and 8—is strongest for a sovereign bond yield shock in the GIIPS. A sovereign bond yield shock in the GIIPS is initially mainly transmitted to European bond markets and only later reaches the rest of the world.

Across source countries of shock. The amplification of a GIIPS sovereign bond shocks that raises global sovereign bond yields stands in interesting contrast to the impact of a US sovereign bond shock. We have already shown above that the US is a special safe haven, with on average mildly negative correlations with other sovereign bond yields at least until 2006 and again in 2013 (Figure 7). The initial negative impact of a shock in the US on most other sovereign bond markets would over time have been amplified by the positive correlations between other advanced market sovereign bond yields. This reversed in 2007-2012, when sovereign-sovereign correlations of the US turned mildly positive on average. As a result, the average impact was modest and changed little after 5 iterations.

Over time. The impact of a sovereign bond shock in the average country, the GIIPS, and the US peaked in the first half of 2005 and even higher in the second half of 2010 (with an additional peak for a US shock in the second half of 2002). In broad terms, the shape of the curves of the average impacts has reflected movements in average sovereign bond yield correlations (Figure 6). Similarly, broadly matching movements in bank-bank correlations over the period, the average impact of a bank equity price shock peaked in the second half of 2008.

Across source markets of shock. In contrast to the impact of sovereign bond yield shocks, the impact of bank equity price shocks in the three scenarios is very similar. Bank-bank correlations and bank-sovereign correlations are substantially more similar across countries than sovereign-sovereign correlations (Figure 7). Hence the impacts of bank equity prices shocks originating in subgroups of countries (e.g. the US and the GIIPS) are likely to be more similar than those of sovereign bond yield shocks.

Figure 8. Impact of sovereign bond yield shock on sovereign bond yields in other countries

Shock originating in average country | Shock originating in GIIPS | Shock originating in US

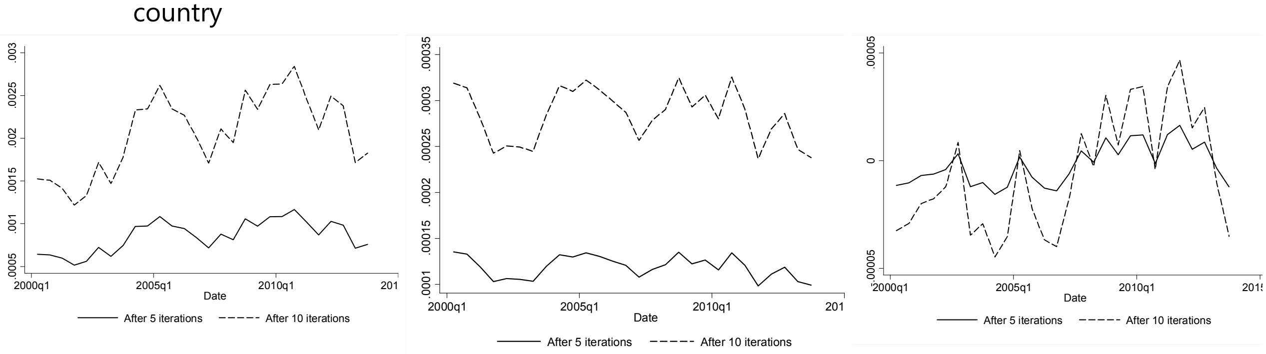


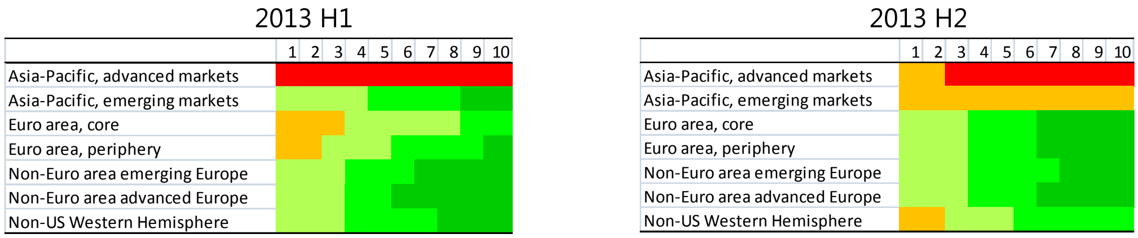
Figure 9. Average Impact of bank equity price shock on bank equity prices in other countries

Shock originating in average country | Shock originating in GIIPS | Shock originating in US

Cross-country differences in impact. We can trace the impact of a sovereign bond yield shock on sovereign bond markets and bank equity prices across the network. For example, the left panel of Figure 10 shows the heatmap of the impact in each step of a sovereign bond yield increase in the US in the *first half* of 2013 on sovereign bond yields elsewhere by quintiles. The deeper the red, the more positive the impact; the greener, the more negative the impact. A US bond yield shocks in the first half of 2013 would have initially raised sovereign bond yields in advanced Asia-Pacific (Australia, New Zealand, Singapore, Hong Kong, Japan, Korea). Since most European sovereign bond yields were mildly negatively or negligibly correlated with US sovereign bond yields, the impact of US sovereign bond yield shock would have been initially close to zero but would over time have turned negative. Emerging market sovereign bond yields in this period were mostly negatively correlated with US sovereign bond yields, hence the more negative impact in emerging market sovereign bond yields. A similar shock in the *second half* of 2013 would have taken somewhat longer to build to the same positive impact in advanced Asia-Pacific, would not have reduced sovereign bond yields of emerging Asia, but would have reduced euro area sovereign bond yields more than in the first half of 2013.

The regional averages in the heatmap in Figure 10 disguise substantial heterogeneity across countries. For example, if India and Indonesia had been isolated, India would have looked like the euro area periphery and Indonesia would have been the second darkest red throughout. Turkey and Brazil would have looked similar to the non-euro area Europe.

Figure 10. Impact of sovereign bond yield shock in the US on sovereign bond yields in other countries



Note: The deeper the red the more positive the impact, whereas the deeper the green, the more negative impact of a US sovereign bond yield shock on the particular group of countries.

B. Feedback Loops in Shock Propagation

Feedback loops—even along the relatively weak sovereign-bank correlations in our dataset—spread a shock from one asset class into another, where it can then proliferate and return to the initial asset class. We test the effect of feedback loops in sovereign bond contagion by comparing shock propagation under two scenarios: the actual network of sovereign-sovereign and bank-sovereign correlations and a counterfactual network where we assume all bank-sovereign links are zero, i.e. a counterfactual network in which feedback loops are not possible. In our counterfactual network without bank-sovereign links, a sovereign bond yield shock would not travel into the banking system at all and vice versa.

Figure 11 shows the average effect of feedback loops during a *sovereign bond yield* shock in the average country, the GIIPS, and the US.[15] Each line displays the difference between the average impact in networks with and without feedback loops of a 1 percent bond yield shock. Since all three lines are above zero, feedback loops have on average amplified the impact of sovereign bond yield shocks. Similarly, the Figure 12 shows the gap between the average impact of a *bank equity price* shock including and excluding feedback loops. The vertical scales of the same scenarios in Figures 10 and 11 are identical to facilitate the comparison of bank and bond shocks. The strength of feedback loops varies over time and across countries depending on the source of the shock.

Across source countries of shocks. Feedback loops in the event of both sovereign bond yield shocks and bank equity price shocks are by an order of magnitude stronger for the average source country than for a shock originating the GIIPS and the US. This reflects the predominance of highly-interconnected European sovereigns and banks in the sample.

Across source markets of shocks. Except in late 2002, feedback loops were on average similar for sovereign bond yield and bank equity price shocks if they originate in the average country. However, when the shock originated in the US or the GIIPS and especially since 2010, feedback loops amplified bank equity price shocks more strongly than sovereign bond yield shocks.

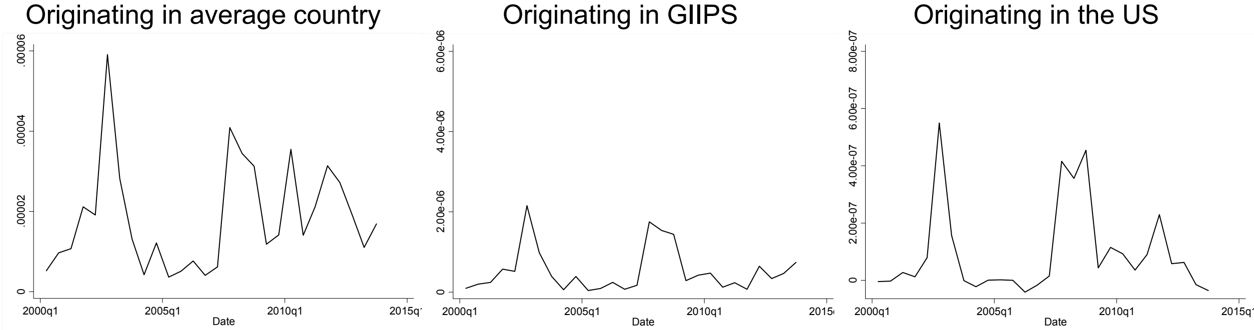
[15] Again, we exclude the source country from the average impact, in order to focus on spillover effects.

Because of their significantly negative and positive bank-sovereign correlations, respectively, GIIPS and US banks transmitted shocks into the strongly correlated sovereign bond yield network where they propagated quickly and fed back into bank equity prices.[16] In contrast, GIIPS and US sovereigns, through their bank-sovereign correlations, transmitted shocks into the only mildly correlated bank-bank network where shocks propagated more slowly. As a result, feedback loops amplified bank equity price shocks more strongly than sovereign bond yield shocks.

Over time. Developments in feedback loops over time for bank equity price shocks and sovereign bond yield shocks in the average country broadly match the movements over time in average bank-sovereign correlations in safe havens (Figure 6), which are greater shock propagators than non-safe havens because of their greater average correlations. An exception are the weakening feedback loops triggered by s*overeign bond yield* shocks in the *GIIPS* and, to a lesser extent, the *US*. These are caused by movements in bank-sovereign correlations that have begun to dampen shock propagation of sovereign bond yield yields: around 2008, from near-zero, bank-sovereign correlations turned significantly negative in the GIIPS and significantly positive in the US. The drop in bank equity prices following a sovereign bond yield spike in the GIIPS and transmitted across borders through (mildly correlated) bank equity price networks, muted sovereign bond yield spikes elsewhere, possibly by making room for monetary policy loosening. Conversely, the drop in bank equity prices associated with a drop in US sovereign bond yields and transmitted outside the US, would have dampened the rise in sovereign bond yields elsewhere.

Figure 11. Average impact of bond market shock on global sovereign bond yields, Difference between impact with and without feedback loops

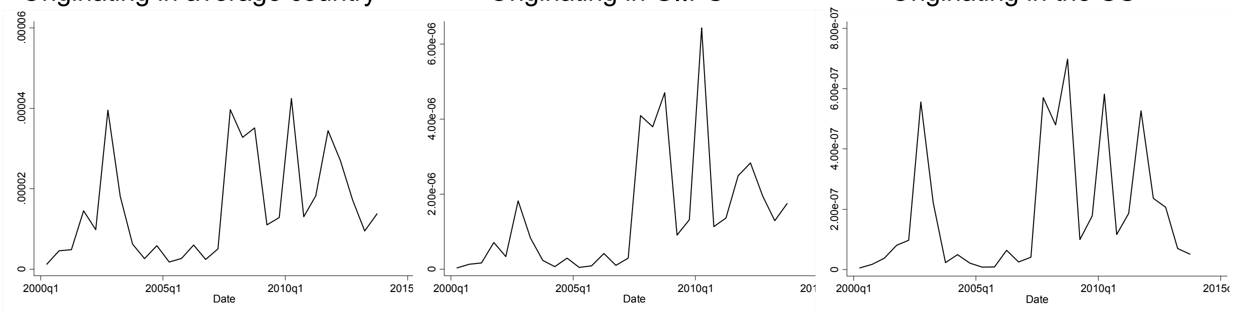
Originating in average country | Originating in GIIPS | Originating in the US



[16] This contrasts with bank-sovereign correlation outside the US and GIIPS many of which are insignificant in size.

Figure 12. Average impact of a bank equity price shock on global bank equity prices,
Difference between impact with and without feedback loops

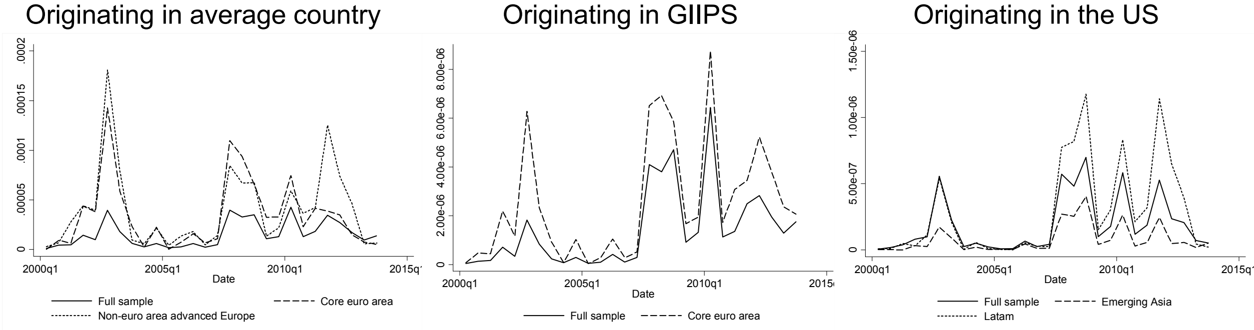
Originating in average country Originating in GIIPS Originating in the US



Across recipient countries of shocks. Feedback loops have amplified external shocks to varying degrees for different recipient countries. Figure 13 shows how the amplification by feedback loops has changed over time for different country groups. At different times during the sample period, feedback loops from bank equity price shocks in the *average country* were strongest for different country groups. In 2008-09, feedback loops were strongest for the highly-correlated core euro area, whereas more recently they were strongest in non-euro area advanced Europe. A GIIPS bank equity price shock would have been most amplified by feedback loops in the euro area; a US bank equity price shock in Latin America.

Figure 13. Average impact of a bank equity price shock on global bank equity prices,
Difference between impact with and without feedback loops

Originating in average country Originating in GIIPS Originating in the US



C. The Role of Safe Havens in Shock Propagation

Our next exercise is focused on safe havens as defined in Section V. In our sample, the average safe haven has a key characteristic that distinguishes it from the average non-safe haven: the average safe haven has stronger sovereign-sovereign, bank-bank, and (since 2007) bank-sovereign correlations than the average non-safe haven. With the exception of the US, this applies not only to European but also to non-European safe havens (see Section V).

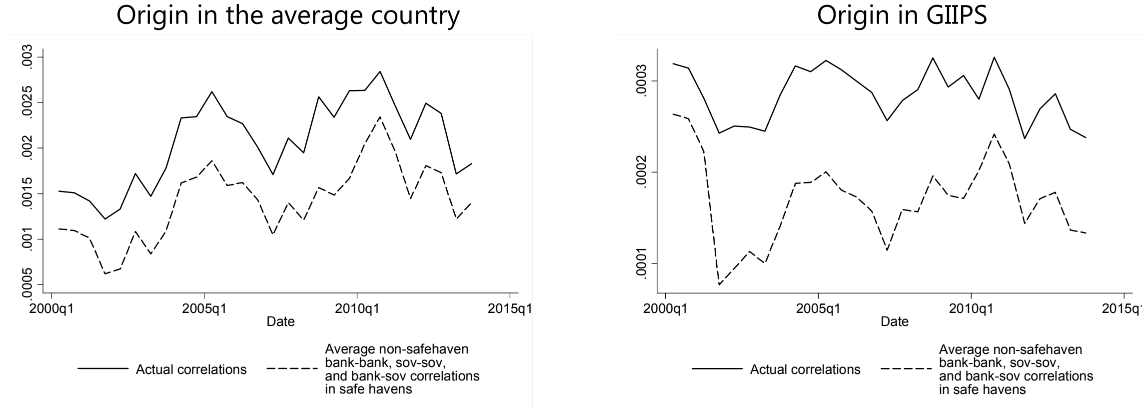
In our next thought experiment, we will show how these stronger correlations can make safe havens act as shock propagators in global asset price networks—both within each asset class and across asset classes. Consider, for example, a bond yield shock that originates in a non-safe haven and arrives in a safe haven. Because of safe havens' strong sovereign-sovereign correlations with both non-safe havens and other safe havens, the shock raises safe haven sovereign bond yields and is transmitted to third sovereigns. Because of significantly positive bank-sovereign correlations in safe havens (in contrast to virtually zero correlations in non-safe havens), the rise in safe haven sovereign bond yields would have been accompanied by rising bank equity prices, possibly by generating the expectation of monetary policy loosening. These, in turn, would have been transmitted through bank-bank correlations to other safe havens where bank-sovereign correlations would have triggered feedback loops into sovereign bond yields.

To distill the unique role of safe havens, we need to construct a "no-safe havens" counterfactual network that we can compare against our actual network. For our "no-safe havens" counterfactual network, we replace all the safe havens' correlations with average correlations of non-safe haven countries (for sovereign-sovereign, bank-bank, and bank-sovereign links) as if they were the average non-safe haven country. Then we compare these impacts with the baseline results in the actual network.

Sovereign bond yield shock in average country and GIIPS. Figure 14 shows the role of safe havens in the propagation of sovereign bond shocks in the average country and in the GIIPS (non-safe haven countries). The impact of a shock in a network without safe havens—one in which *all* safe haven correlations have been replaced with non-safe haven average correlations—is shown in the dotted line and the impact in the actual network of correlations in the continuous line. Since the dotted line is below the continuous line, shocks propagate *more strongly* in a network *with* safe havens than in one without safe havens. Not surprisingly, the shrinking group of safe havens since 2011 has resulted in a narrowing gap between the impacts in the actual and the counterfactual networks.

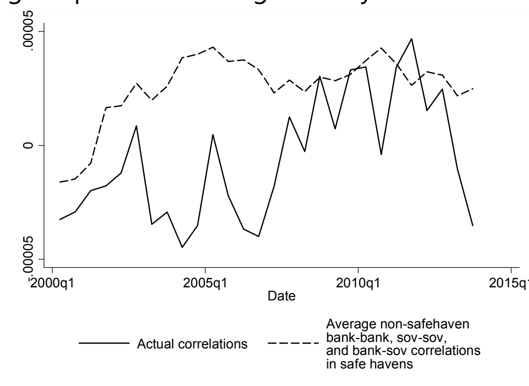
Figure 14. Bond market shock in different source countries:
Shock propagation with and without safehaven country correlations
(Average impact on sovereign bond yields after 10 steps)

Origin in the average country | Origin in GIIPS



Sovereign bond yield shock in US. Consider next a sovereign bond yield shock in the US, by our definition a safe haven since 2001. We have already shown that the US is an unusual safe haven: until 2006 and in 2013, it had mildly negative bond yield correlations with other sovereigns—in absolute terms well below those of the average non-safe havens—and low domestic sovereign-bank correlations (Figure 7). As a result, in our illustrative thought experiment, a pre-crisis sovereign bond yield shock originating in the US was actually propagated more slowly than if the US were the average non-safe haven country (Figure 15). Since the crisis, bank-sovereign correlations in the US have increased sharply and sovereign-sovereign correlations have approached those of non-safe haven countries. As a result, the two curves have approached each other.

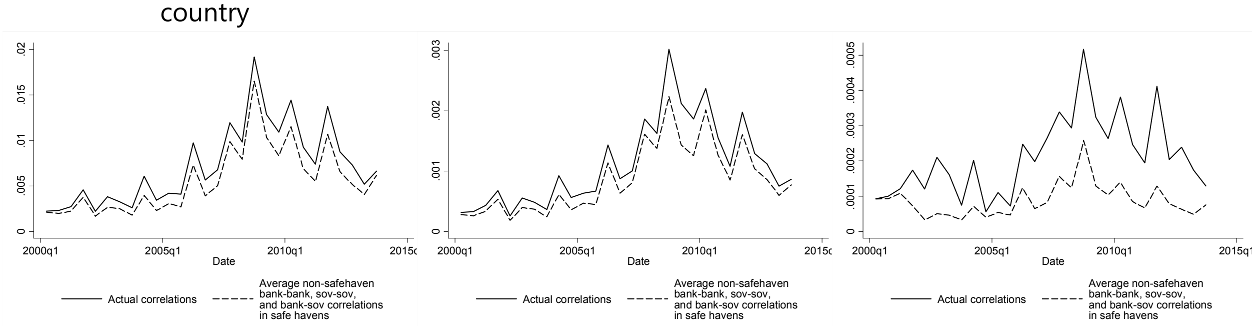
Figure 15. Bond market shock in the US:
Shock propagation with and without safehaven country correlations
(Average impact on sovereign bond yields after 10 steps)



Bank equity price shock. In Figure 16, we conduct the same experiment for a bank equity price shock in the average country, the GIIPS, and the US. In all three cases, the presence of safe havens accelerates shock propagation. In contrast to a sovereign bond yield shock, this applies also—and strongly—in the event of a shock in the US. Like other safe havens, bank-bank correlations in the US are above the average in non-safe havens. As a result, US banking shocks also propagate faster in the actual network than in one without safe havens.

Figure 16: Impact of bank equity price shock on average bank equity prices

Originating in the average country | Originating in GIIPS | Originating in the US



VII. Conclusions and Issues for Further Research

In this paper we lay out stylized facts that we can link to shock propagation among sovereign bond yields and bank equity prices.

First, we document how cross-country correlations between sovereign-bond yields have been stronger than between individual bank equity prices and how these, in turn, are stronger than correlations between bank equity prices and domestic sovereign bond yields. As a result, any shock that would have reached the sovereign bond yield network would have been propagated quickly and strongly across countries. Hence, had a *bank equity price* shock raised local sovereign bond yields through bank-sovereign links, it would have triggered strong feedback loops between the two asset classes and across countries. In contrast, a *sovereign bond yield* shock, even if it had depressed local bank equity prices, would have been amplified less strongly by feedback loops from the more mildly correlated global bank equity price network.

Second, we describe the stronger sovereign-sovereign, bank-bank, and bank-sovereign correlations in safe haven countries than non-safe haven countries. As a result of these higher correlations, we illustrate in a thought experiment how safe haven countries could have acted as shock propagators by accelerating and strengthening the propagation both of sovereign bond yield and bank equity price shocks. We also highlight that the US is a very unusual safe haven with negative sovereign-sovereign correlations until the mid-2000s which would have slowed the propagation of sovereign bond yield shocks in the US during that period.

Third, we illustrate how changes in the distribution of correlations within and across asset classes can map into shock propagation. For example, our thought experiment suggests that the peak in bank equity price correlations in the second half of 2008 and subsequent fall would also have been reflected in shock propagation of bank equity price shocks. No such trends are evident in sovereign bond yield correlations.

Our results raise some intriguing follow-on questions for further research. The role of safe havens probably changes depending on their “neighborhood” in the network. Safe havens in deeply interconnected Europe may well play a different role than safe havens in Asia. The role of policy actions is also not addressed in this paper. It is likely that announced policies altered the shape of the correlation network and changed shock propagation.

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Appendix I: Shock Propagation Mechanism

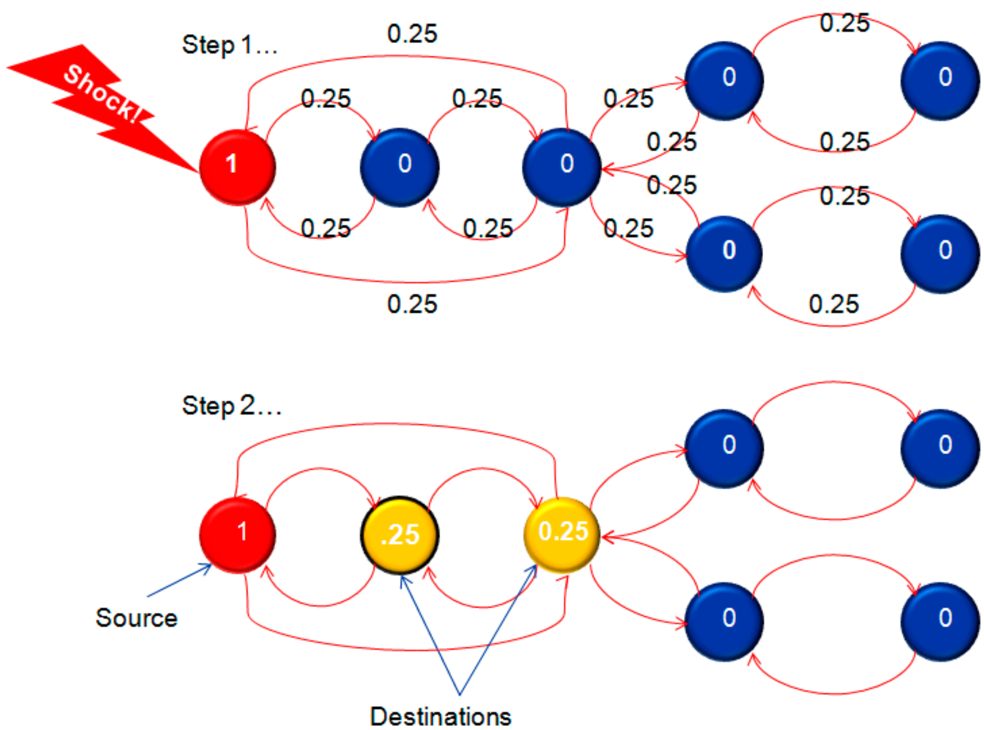
For illustration purposes, imagine a very simple network structure, consisting of 7 nodes connected by links of equal weights 0.25. Before the shock, none of the nodes is affected so that all of them are 0. Imagine now, that in step 1 node A is hit by a shock of magnitude one.

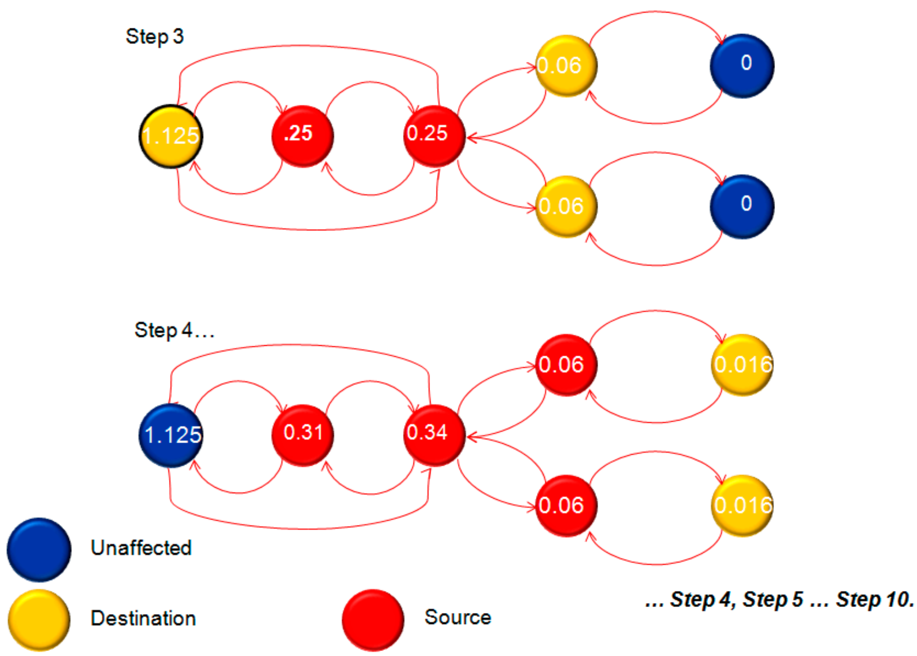
The leftmost node is now a source of the shock to the adjacent nodes, propagating 25% of its initial magnitude with an appropriate sign.

In the second step, there are three sources of the shock, i.e. the three left-most nodes, propagating each 25% of the initial shock accumulated.

All nodes except the two rightmost ones become shock propagators in the third step.

We repeat the process for an arbitrary number of steps. After each step, we calculate the cumulative impact in each of the nodes.



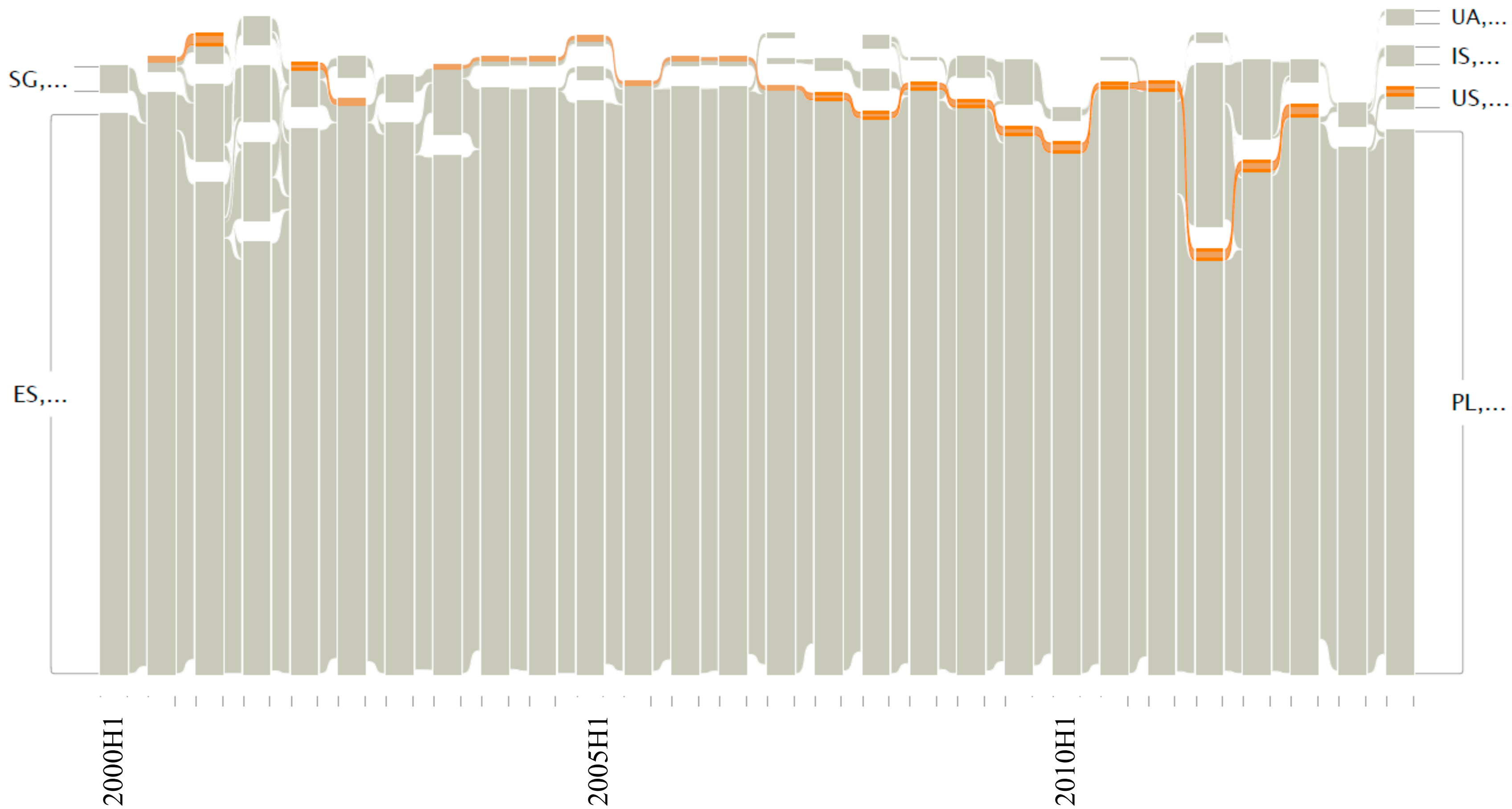

Step 3
1.125
.25
0.25
0.06
0
0.06
0
Step 4…
1.125
0.31
0.34
0.06
0.016
0.06
0.016
Unaffected
Destination
Source
… Step 4, Step 5 … Step 10.

Appendix Table 2. List of all countries and banks used in the analysis, available in different periods. The number of banks for a particular country is given in brackets.

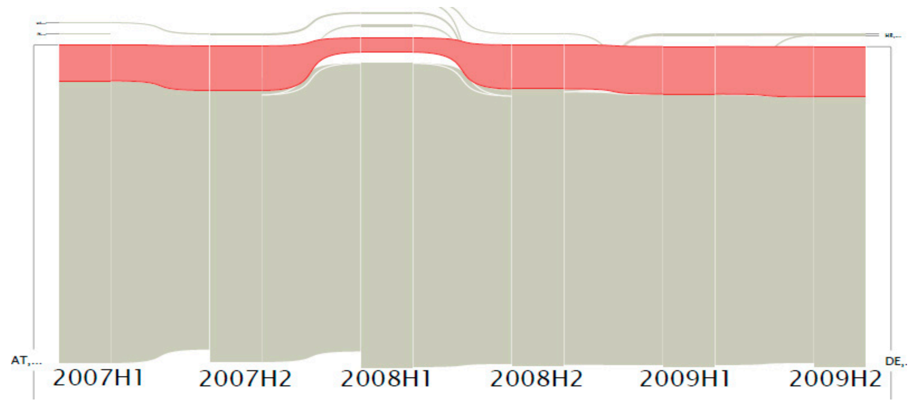
2000-2006		2007-2009		2010-2012		2013	
Sovereigns	Banks(#)	Sovereigns	Banks(#)	Sovereigns	Banks(#)	Sovereigns	Banks(#)
Austria	Argentina(6)	Austria	Argentina(7)	Austria	Argentina(7)	Austria	Argentina(7)
Australia	Austria(5)	Australia	Austria(5)	Australia	Austria(5)	Australia	Austria(5)
Belgium	Australia(5)	Belgium	Australia(5)	Belgium	Australia(5)	Belgium	Australia(5)
Canada	Belgium(3)	Canada	Belgium(4)	Canada	Belgium(4)	Canada	Belgium(4)
Switzerland	Bulgaria(3)	Switzerland	Bulgaria(5)	Switzerland	Bulgaria(5)	Switzerland	Bulgaria(5)
China	Bahrain(7)	China	Bahrain(7)	China	Bahrain(7)	China	Bahrain(7)
Colombia	Brazil(4)	Colombia	Brazil(4)	Colombia	Brazil(4)	Colombia	Brazil(4)
Czech Republic	Canada(6)	Czech Republic	Canada(6)	Czech Republic	Canada(6)	Czech Republic	Canada(6)
Germany	Switzerland(4)	Germany	Switzerland(5)	Germany	Switzerland(5)	Germany	Switzerland(5)
Denmark	Chile(7)	Denmark	Chile(7)	Denmark	Chile(7)	Denmark	Chile(7)
Spain	China(6)	Spain	China(6)	Spain	China(7)	Spain	China(7)
Finland	Colombia(7)	Finland	Colombia(7)	Finland	Colombia(8)	Finland	Colombia(8)
France	Cyprus(3)	France	Cyprus(3)	France	Cyprus(3)	France	Cyprus(3)
United Kingdom	Czech Republic(1)	United Kingdom	Czech Republic(1)	United Kingdom	Czech Republic(1)	United Kingdom	Czech Republic(1)
Greece	Germany(5)	Greece	Germany(5)	Greece	Germany(5)	Greece	Germany(5)
Hong Kong	Denmark(4)	Hong Kong	Denmark(4)	Hong Kong	Denmark(4)	Hong Kong	Denmark(4)
Indonesia	Egypt(11)	Croatia	Egypt(11)	Croatia	Egypt(11)	Croatia	Egypt(11)
Ireland	Spain(5)	Indonesia	Spain(6)	Indonesia	Spain(7)	Indonesia	Spain(7)
Israel	Finland(2)	Ireland	Finland(3)	Ireland	Finland(3)	Ireland	Finland(3)
India	France(5)	Israel	France(5)	Israel	France(5)	Israel	France(5)
Italy	United Kingdom(6)	India	United Kingdom(6)	India	United Kingdom(6)	India	United Kingdom(6)
Japan	Greece(7)	Italy	Greece(7)	Italy	Greece(7)	Italy	Greece(7)
Korea (South)	Hong Kong(4)	Japan	Hong Kong(4)	Japan	Hong Kong(4)	Japan	Hong Kong(4)
Mexico	Croatia(5)	Korea (South)	Croatia(5)	Korea (South)	Croatia(5)	Korea (South)	Croatia(5)
Malaysia	Hungary(1)	Sri Lanka	Hungary(1)	Sri Lanka	Hungary(1)	Sri Lanka	Hungary(1)
Netherlands	Indonesia(6)	Mexico	Indonesia(6)	Mexico	Indonesia(6)	Mexico	Indonesia(6)
Norway	Ireland(3)	Malaysia	Ireland(3)	Malaysia	Ireland(3)	Malaysia	Ireland(3)
New Zealand	Israel(6)	Netherlands	Israel(6)	Netherlands	Israel(6)	Netherlands	Israel(6)
Philippines	India(6)	Norway	India(6)	Norway	India(6)	Norway	India(6)

2000-2006		2007-2009		2010-2012		2013	
Sovereigns	Banks(#)	Sovereigns	Banks(#)	Sovereigns	Banks(#)	Sovereigns	Banks(#)
Pakistan	Iceland(4)	New Zealand	Iceland(4)	New Zealand	Iceland(4)	New Zealand	Iceland(4)
Poland	Italy(6)	Peru	Italy(7)	Peru	Italy(7)	Peru	Italy(7)
Portugal	Japan(3)	Philippines	Japan(3)	Philippines	Japan(3)	Philippines	Japan(3)
Sweden	Korea (South)(7)	Pakistan	Korea (South)(7)	Pakistan	Korea (South)(8)	Pakistan	Korea (South)(8)
Singapore	Sri Lanka(7)	Poland	Sri Lanka(7)	Poland	Sri Lanka(7)	Poland	Sri Lanka(7)
Thailand	Luxembourg(2)	Portugal	Luxembourg(2)	Portugal	Luxembourg(2)	Portugal	Luxembourg(2)
Turkey	Morocco(5)	Sweden	Morocco(5)	Russian Federation	Morocco(5)	Russian Federation	Morocco(5)
Taiwan	Mexico(4)	Singapore	Mexico(4)	Sweden	Mexico(5)	Sweden	Mexico(5)
United States	Malaysia(8)	Slovakia	Malaysia(8)	Singapore	Malaysia(8)	Singapore	Malaysia(8)
South Africa	Netherlands(2)	Thailand	Netherlands(2)	Slovakia	Netherlands(2)	Slovakia	Netherlands(2)
	Norway(2)	Turkey	Norway(2)	Thailand	Norway(2)	Thailand	Norway(2)
	New Zealand(1)	Taiwan	New Zealand(1)	Turkey	New Zealand(1)	Turkey	New Zealand(1)
	Peru(5)	United States	Peru(5)	Taiwan	Peru(5)	Taiwan	Peru(5)
	Philippines(9)	South Africa		United States	Philippines(9)	United States	
	Pakistan(9)		Philippines(9)	Viet Nam	Pakistan(11)	Viet Nam	Philippines(9)
	Poland(10)		Pakistan(11)	South Africa	Poland(11)	South Africa	Pakistan(11)
	Portugal(4)		Poland(11)		Portugal(5)		Poland(11)
	Qatar(7)		Portugal(4)		Qatar(7)		Portugal(5)
	Romania(3)		Qatar(7)		Romania(3)		Qatar(7)
	Russia (3)		Romania(3)		Russia (5)		Romania(3)
	Sweden(4)		Russia (5)		Sweden(4)		Russia (5)
	Singapore(3)		Sweden(4)		Singapore(3)		Sweden(4)
	Slovenia(1)		Singapore(3)		Slovenia(3)		Singapore(3)
	Slovakia(5)		Slovenia(3)		Slovakia(5)		Slovenia(3)
	Thailand(8)		Slovakia(5)		Thailand(8)		Slovakia(5)
	Turkey(8)		Thailand(8)		Turkey(9)		Thailand(8)
	Taiwan(9)		Turkey(9)		Taiwan(10)		Turkey(9)
	Ukraine(1)		Taiwan(10)		Ukraine(2)		Taiwan(10)
	United States(5)		Ukraine(1)		United States(4)		Ukraine(2)
	Venezuela(7)		United States(5)		Venezuela(8)		United States(4)
	South Africa(3)		Venezuela(8)		Viet Nam(7)		Venezuela(8)
			Viet Nam(6)		South Africa(3)		Viet Nam(7)
			South Africa(3)				South Africa(3)

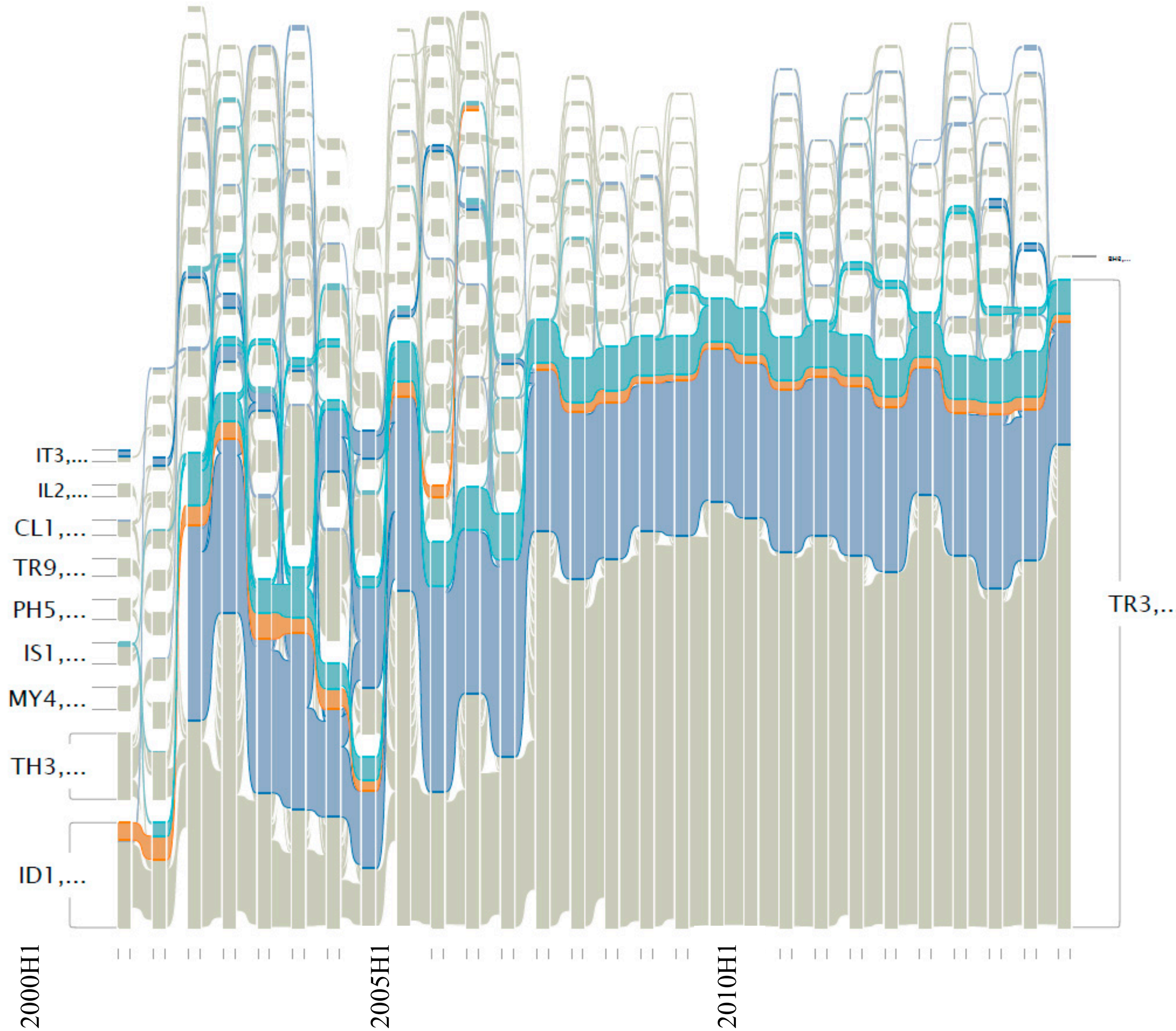
Appendix Figure 1. US in sovereign bond yield clusters



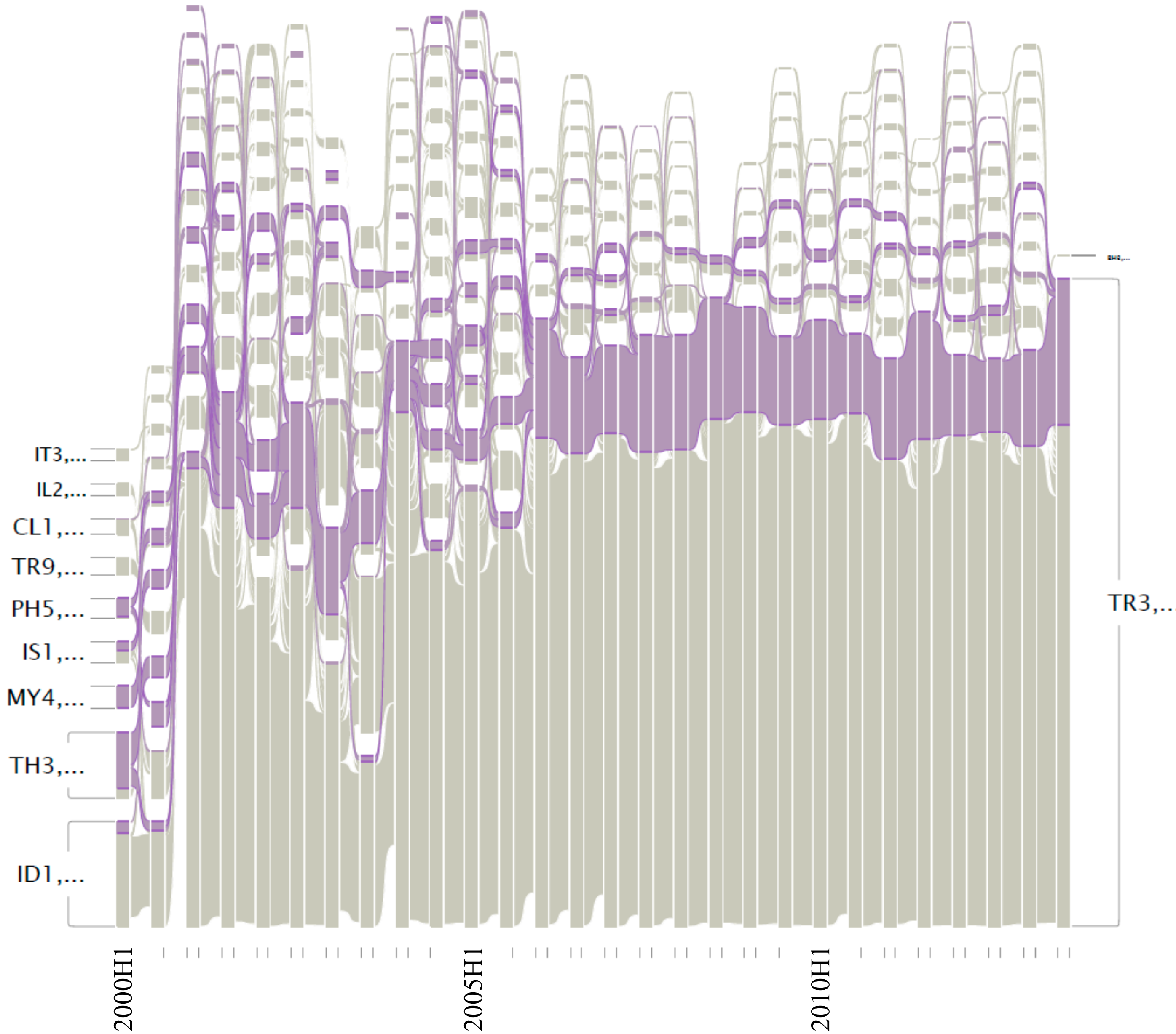
Appendix Figure 2. Asia in sovereign bond yield cluster, 2007-2013



Appendix Figure 3. European and US banks in bank equity price clusters



Appendix Figure 4. Asian banks in clusters of bank equity prices



Appendix Figure 5. Non-US American banks in clusters of bank equity prices

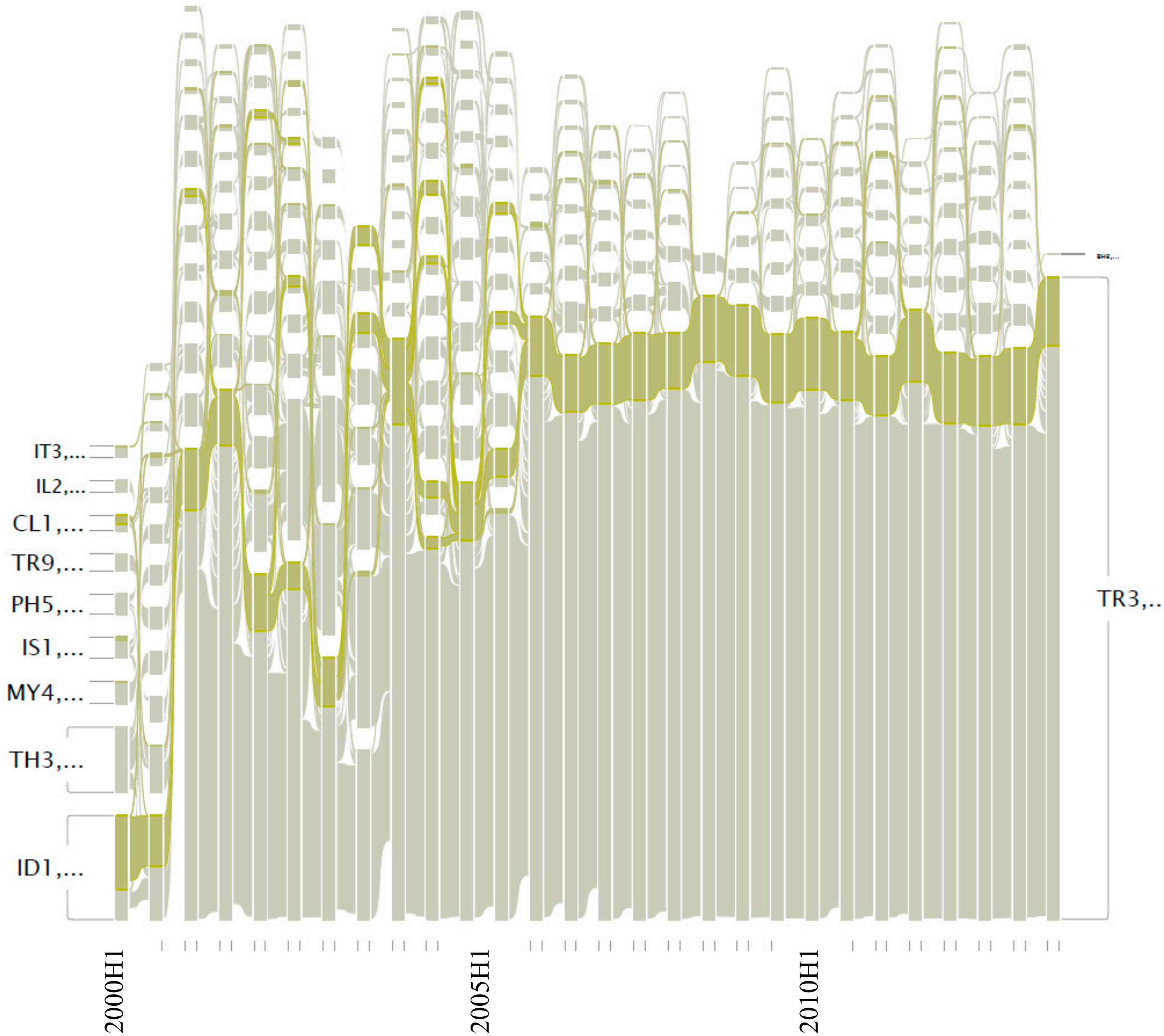
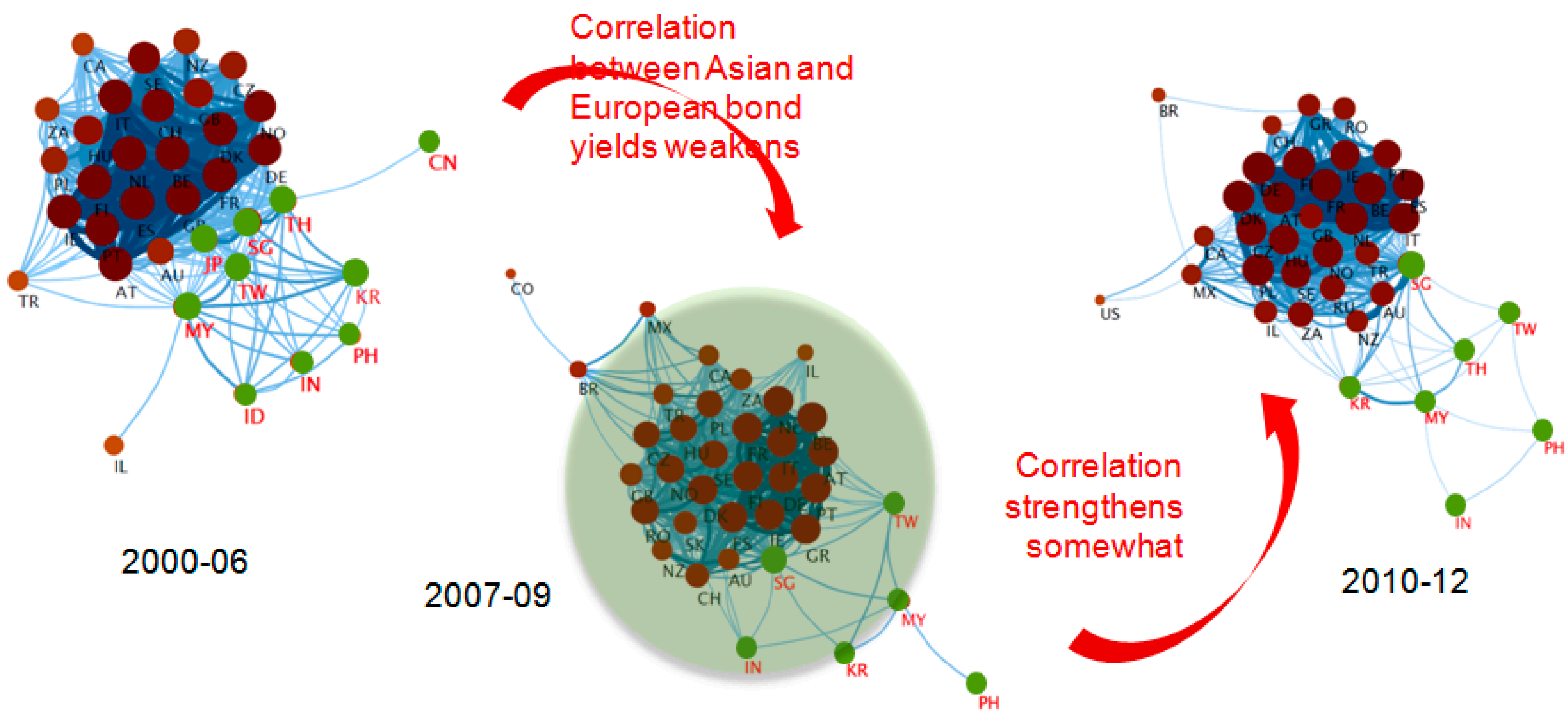
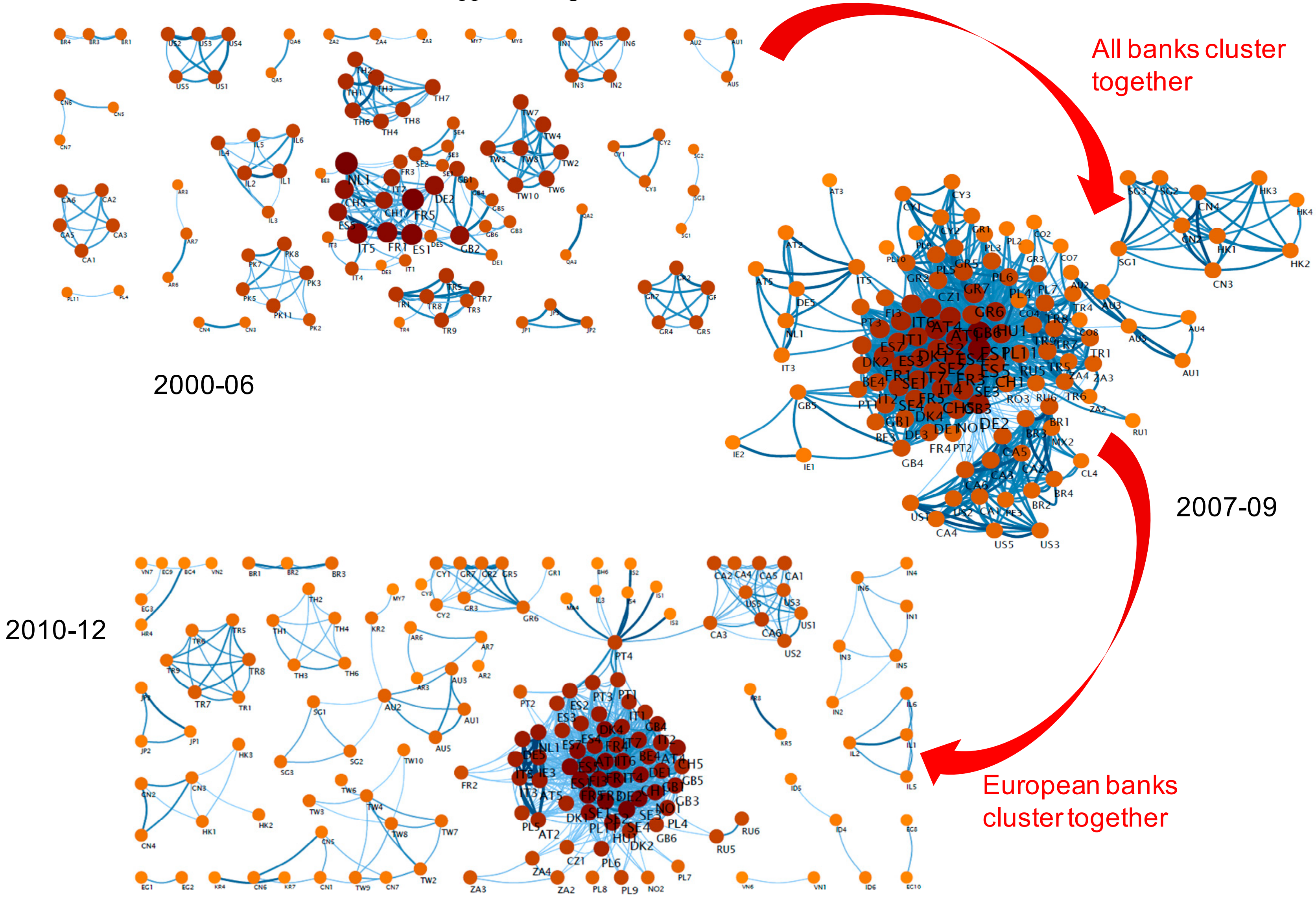


Figure 6. Sovereign Interconnectedness



Appendix Figure 7. Bank Interconnectedness



Appendix Figure 8. Sovereign-Bank Correlations in Emerging Asia

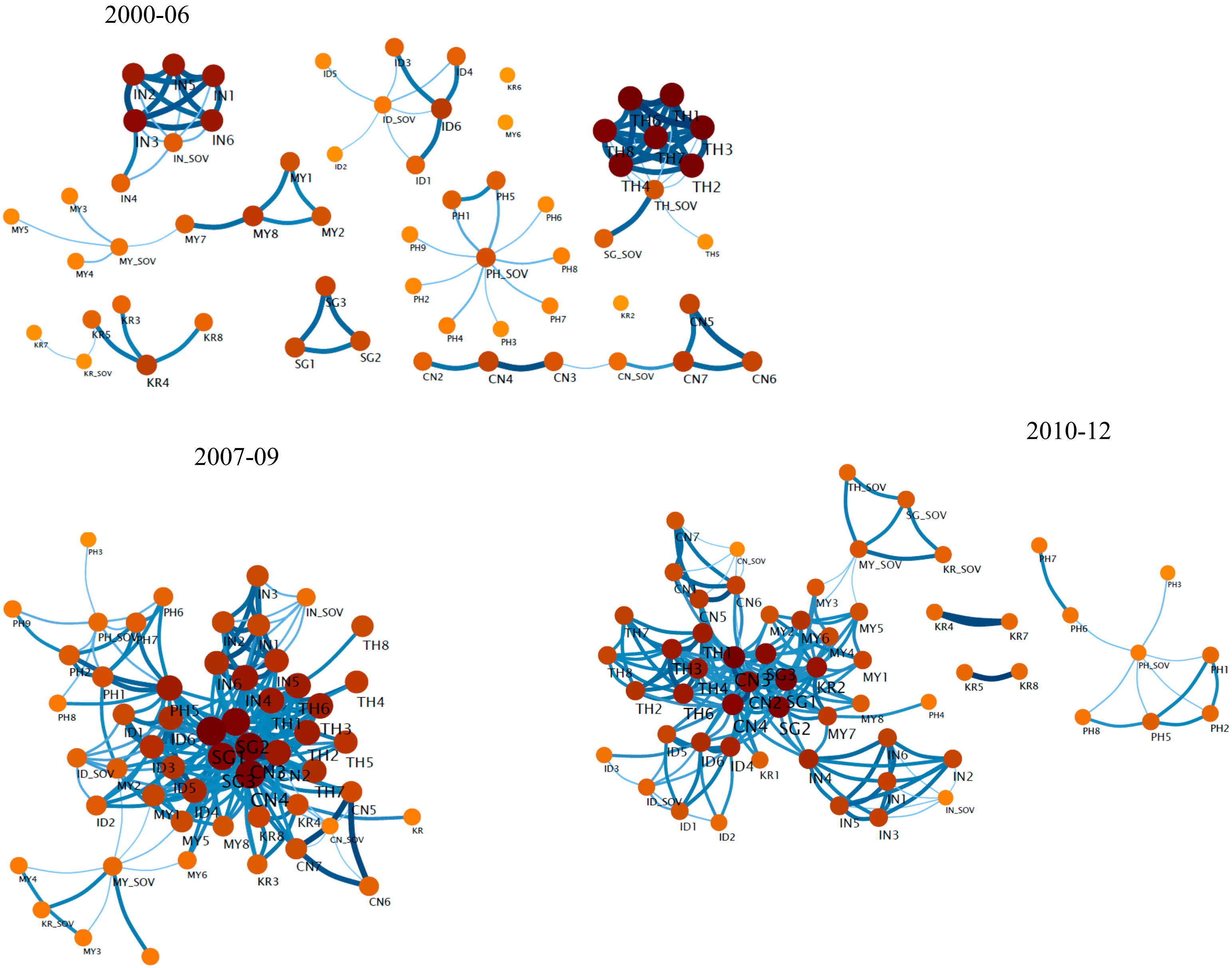


Figure 9. Sovereign-Bank Correlations in Emerging Europe

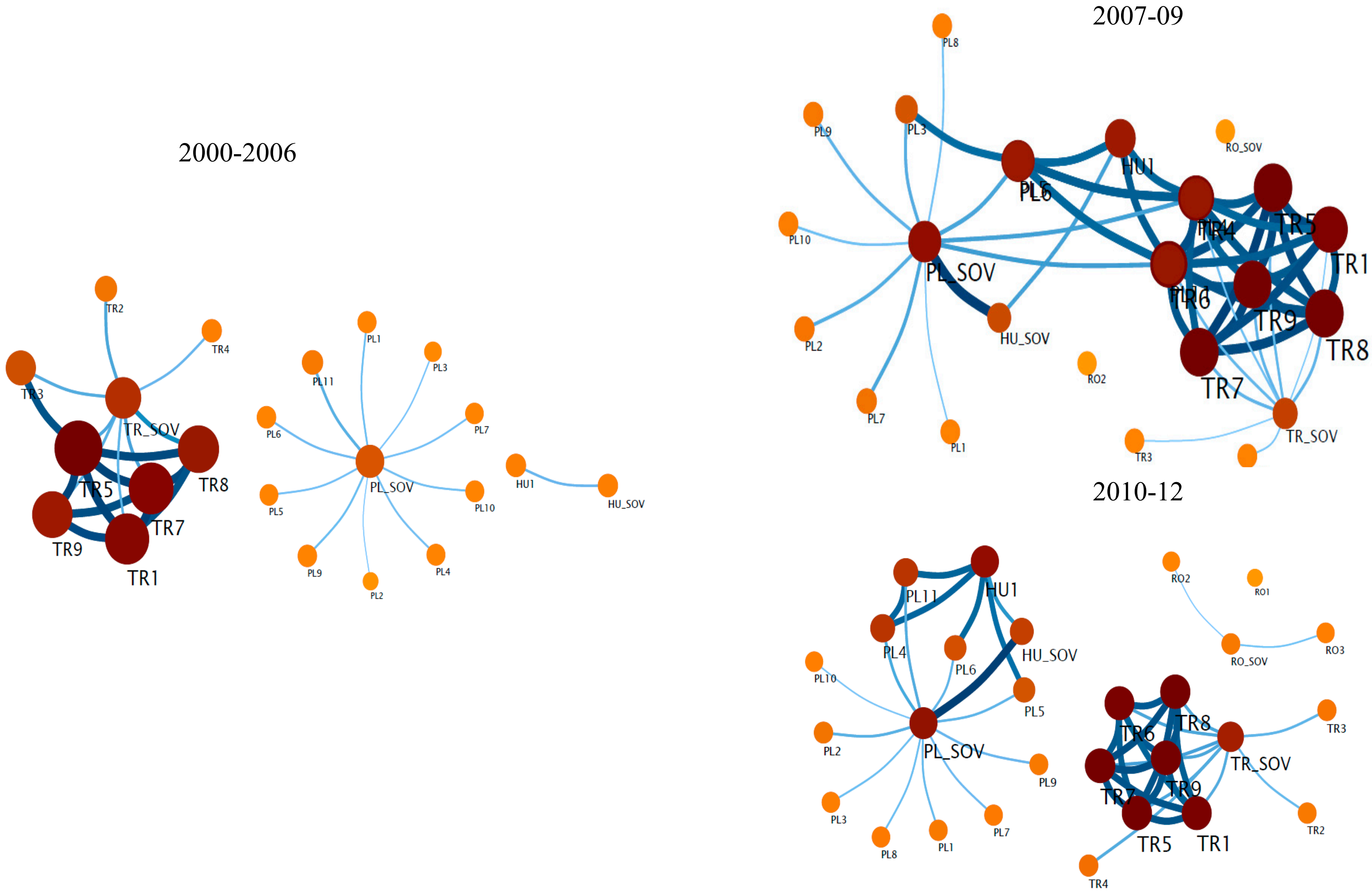


Figure 10: Sovereign-Bank Correlations in Euro Area