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* Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank.

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De Nederlandsche Bank NV
P.O. Box 98
1000 AB AMSTERDAM
The Netherlands

Hazardous tango: Sovereign-bank interdependencies across countries and time*

Jack Bekooij[a], *Jon Frost*[a,b], *Remco van der Molen*[a] *and Krzysztof Muzalewski*[c]

[a] *De Nederlandsche Bank, Amsterdam, The Netherlands*
[b] *VU University, Amsterdam, The Netherlands*
[c] *Unibail-Rodamco, Schiphol, The Netherlands*

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Abstract

Sovereign-bank feedback loops have been at the heart of the euro area crisis and many previous debt crises. We regress a market measure of interdependency – the correlation between sovereign and bank credit default swaps (CDS) – against various fundamental indicators of interlinkages and risk for 65 banks from 23 countries from Q1 2006 to Q4 2015. We find evidence that direct sovereign debt holdings of banks, implicit contingent liabilities of the government to banks and market volatility are significantly linked to higher correlations. While such CDS correlations are generally higher for banks in countries bank-based financial systems, we do not find these channels to be stronger in these countries than market-based systems. Finally, we find that bank CDS levels perform better in explaining sovereign CDS levels in periods of high volatility. Overall, these results support the notion of non-linear effects and spillovers in CDS markets.

Keywords: sovereign debt, banking crises, financial stability, CDS markets.
JEL classifications: G01, G21, H63.

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1. Introduction

The outbreak of the European sovereign debt crisis in 2010 underscored the danger of interdependencies between sovereigns and the banking sector. In Ireland, stress in the banking sector led the government to provide large-scale support in the form of capital injections and guarantees – a "pyrrhic victory" which ultimately compelled the government to request external EU/IMF support (Acharya, Drechsler and Schnabl, 2014). The fiscal stress and ultimate restructuring of the Greek government, meanwhile, led to the insolvency and restructuring of the Greek and Cypriot banking sectors (Zettelmayer, Trebesch and Gulati, 2013).

Since then, the so-called "doom loop" (Gros, 2013), "diabolic loop" (Cooper and Nikolov, 2015), "deadly embrace" (Farhi and Tirole, 2015) or "hazardous tango" (Merler and Pisani-Ferry, 2012; DNB, 2015) between banks and sovereigns has become the topic of intensive policy and academic discussions.[1] The research of Bolton and Jeanne (2011), Blundell-Wignall and Slovik (2011) and Alter and Schüler (2012) underscores the relevance of these interdependencies in the recent global financial crisis. Yet such links have also played a role in a number of earlier advanced economy and emerging market crises, from the sovereign defaults and banking crises in Denmark in 1813 to Russia in 1998 and Argentina in 2002 (Reinhart and Rogoff, 2009; 2011).

Despite these contributions, Gray and Jobst (2013) point out that the ultimate impact of such interdependencies on the economy is not entirely understood. Specifically, the impact may be different during normal times than during periods of stress. There may also be important differences between countries based on their market structures. As long as these issues remain unclear, credit risk and pro-cyclical tail risks may remain mispriced and there may be volatile swings in perceptions of the debt sustainability of sovereigns and the banking sector (De Grauwe and Ji, 2013). Only once the relationship between sovereign and banking risk is better understood can effective policies and regulatory measures be implemented to reduce the probability and impact of financial crises. Consequently, in-depth analysis of sovereign-bank interdependencies is essential from a supervisory, financial stability and monetary policy perspective.

This paper investigates which factors drive interdependencies between the credit risk of sovereigns and domestic banks across countries. To tackle this question, we draw on existing theory and empirical work on sovereign risk, banking crises and credit market frictions to distinguish between four potential channels of risk transfer: (i) direct bank-to-sovereign risk transfer; (ii) direct sovereign-to-bank risk transfer; (iii) indirect links through the real economy; and (iv) credit market frictions. The first three channels can be considered fundamental factors of banking and sovereign risk, while the fourth can be considered the result of market inefficiencies.

Our empirical analysis focuses on the level of sovereign-bank interdependencies and the drivers

[1] Throughout the paper, we use "interdependency" to mean a bidirectional relationship between the risk profile of a government and of domestically owned banking groups. A "feedback loop" is a special case of such interdependencies, when risk factors for either banks or sovereigns lead to a self-reinforcing deterioration of credit risk.

of these links over a broad sample of countries and over the past decade. To assess interdependency, a market measure is applied: the Spearman rank correlation between credit risk returns as given by daily changes in credit default swap (CDS) spreads of individual banks and their home sovereign. This correlation measures whether the risk premiums of banks and sovereigns hit extreme levels simultaneously. As an identification strategy, we analyze time series changes and cross-sectional differences in this correlation measure against the independent variables intended to proxy the four channels sketched above. We complement this with estimations of the *level* of CDS spreads of banks and sovereigns. These regressions are estimated for 65 banks in 23 countries with quarterly data over the period Q1 2006-Q4 2015. Our multivariate panel regressions make it possible to determine which factors play the most important role in sovereign-bank interdependencies, based on their statistical and economic significance. The innovation of our analysis is to assess these links not only for a specific stress period, but for a broad range of countries and banks over the period before and after the global financial crisis.

The results of these exercises show that both the exposures by a bank to sovereign debt and the contingent liabilities of the sovereign toward banks are positively and significantly linked to higher correlations between bank and sovereign CDS. While such CDS correlations are generally higher for banks in bank-based financial systems, we do not find these channels to be stronger in these countries than market-based systems. Among control variables, we find that sovereign-bank interdependency is higher in periods of low output growth and greater financial market volatility. Based on a second set of regressions, we find that sovereign CDS levels are explained by (lagged) bank CDS levels to a greater extent in periods of high volatility. Bank CDS levels show a strong link with lagged sovereign CDS levels across all periods, with no significant additional effect when volatility is high. From these results, we infer that sovereign and bank risks may spill over to one another through direct financial links, both in bank-based systems and market-based financial systems, and that bank-to-sovereign risk transfer is especially important during high volatility in financial markets.

This paper is structured as follows. Section 2 describes the emerging theory of sovereign-bank interlinkages based on the relevant literature, and derives testable hypotheses. Section 3 introduces the data, our estimation methodology and some broad trends in the data. Section 4 provides the empirical results in terms of interdependency analysis, regression results and the robustness checks. Finally, section 5 concludes.

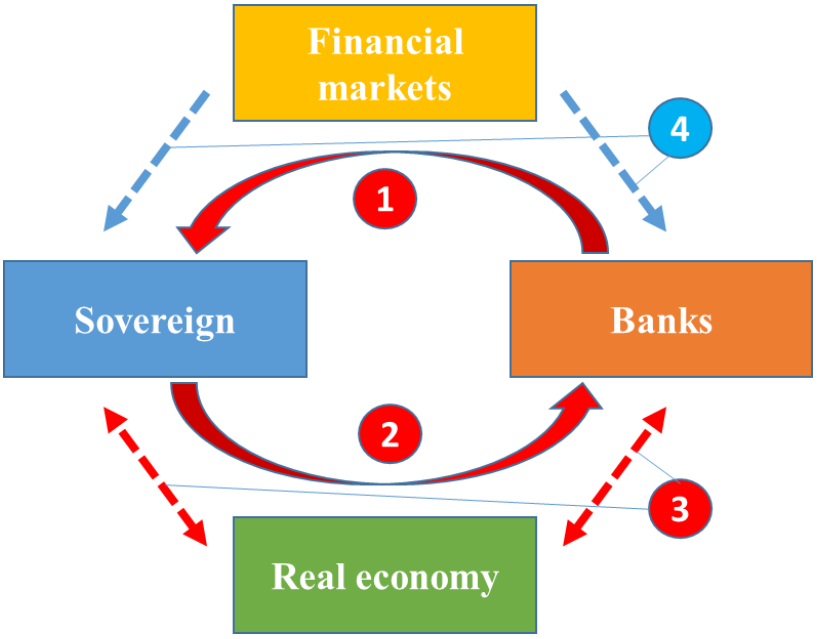
2. Literature and hypotheses on sovereign-bank interlinkages

In order to structure the growing literature on sovereign-bank interdependencies, this section divides the theoretical models based on the channels that they emphasize. Where relevant, examples from the empirical literature are also given. It concludes by deriving testable hypotheses.

Figure 1 gives a schematic overview on the different channels through which sovereigns and

banks are interlinked, and shows how these different channels may result in feedback-loops between sovereigns and banks. In general, we can distinguish between: (i) direct bank-to-sovereign risk transfer, such as explicit and implicit government guarantees; (ii) direct sovereign-to-bank risk transfer, such as direct holdings of sovereign debt, correlations in the cost and availability of funding, and the credibility of government support to banks; (iii) indirect links, for example through credit risk in the real economy; and (iv) credit market frictions, which can lead prices of credit risk for both banks and sovereigns to persistently diverge from fundamental values.[2]

Figure 1 – Transmission channels of sovereign and bank risks



Note: solid arrows refer to direct transmission channels, while dashed arrows are indirect links. Red denotes fundamental factors, while the blue channel is the result of credit market frictions.

The size and relative importance of these channels may differ significantly across countries and over time. For example, we expect differences between countries where credit to the private sector is dominated by bank lending ("bank-based financial systems"), and where non-bank players and capital markets play a larger role ("market-based financial systems;" see Goldsmith, 1969; Levine, 2002; Gambacorta et al., 2014). In bank-based systems, the government may be more likely to bail out banks, given their importance in financing of the real economy, and may also depend to a greater extent on banks as investors in domestic sovereign debt markets. Moreover, there may be important differences between normal times and more volatile periods, such as financial crises. In normal times, the interdependencies are not problematic: the government can act as a safety net for individual banks, and government debt plays an important role as a safe asset. In periods of high

[2] For further description, see BIS (2011), ESRB (2015), Gray, Merton and Bodie (2008) and Acharya, Drechsler and Schnabl (2014). For a theoretical model on the interplay of bank equity and resolution, see Cooper and Nikolov (2015).

volatility, the interdependencies may become more problematic, as the different channels may result in a vicious circle, feedback loops or non-linear "cliff effects." These ultimately lead to higher financing costs and a greater risk of systemic crises. Particularly problematic are so-called "twin crises" with defaults by the sovereign and the banking sector, which may be larger and more costly than independent crisis events (see Panizza and Borenzstein, 2009; Reinhart and Rogoff, 2011; and Balteanu and Erce, 2014). Finally, when there is strong financial integration, for example in the euro area, there may be important cross-border effects of sovereign debt holdings by foreign banks (Bolton and Jeanne, 2011).[3] Due to data limitations, we will only focus on domestic effects and cross-border contagion will be outside the scope of our analysis.

2.1 Direct bank-to-sovereign links

The experience of financial crises over the past decades and the large-scale support provided to financial institutions has given impetus to work on the effects of state support on the affected banks and sovereigns. In these cases, both explicit support to banks (direct capital and liquidity support, deposit insurance) and implicit guarantees (expectations of bail-out) can improve bank solvency, but may erode the solvency of the government. A key study is Gray, Merton and Bodie (2008) who show with contingent claims analysis (CCA) that the interdependencies are determined by the amount of *explicit* and *implicit* guarantees of the sovereign to banks. Acharya, Drechsler and Schnabl (2014) develop a theoretical model which describes the sovereign-bank relationship. Similarly to Gray, Merton and Bodie, they find that large support packages provided by sovereigns to the banking sector increase the degree of spillovers from banks to sovereigns.

Meanwhile, Bénassy-Quéré and Roussellet (2014) develop a micro-based measure of implicit contingent liabilities of the sovereign to the banking sector. This is calculated as the difference between the risk-weighted assets (RWA) and the core Tier I capital held by banks, i.e. the amount of risky assets not covered by a bank's own funds. A proxy of this measure, when consistent data on core Tier I capital is not available, is the RWA minus total equity. This can in turn be scaled relative to GDP, which approximates the government's carrying capacity; this measure will be used in our empirical estimations. A large literature including Panetta et al. (2009) and King (2009) examines the impact of state support on banks, and generally finds that interventions lower credit spreads for supported institutions. Yet they do not provide an analysis of the effects of support on the sovereign or on the degree of sovereign-bank interdependencies.

2.2. Direct sovereign-to-bank links

The most straightforward channel through which banks can be affected by sovereign risk is

[3] Relatedly, Breckenfelder and Schwaab (2015) show that in the euro area, expectations of state support can extend across borders, as new information on banks from the ECB's 2014 Comprehensive Assessment affected not only the governments of stressed banks, but also non-stressed governments. Mink and De Haan (2013) show that news about Greece in 2010 had little impact on the equity prices of other European banks, while news about a potential bail-out had a large impact, perhaps due to its signal about future bank bailouts.

through direct holdings of sovereign debt. When government bonds make up a significant portion of banks' assets, changes in the price of sovereign securities – or sovereign default – directly affect bank balance sheets. Losses may cause a decrease in bank's profits, consequently decreasing equity and leading to investor concerns about the solvency of the bank. Moreover, the use of government bonds for liquidity purposes, e.g. as high-quality collateral in private transactions and in central bank liquidity operations, will be impaired by changes in sovereign risk measures.

Gennaioli, Martin and Rossi (2014) model such holdings and the risk of government default. They show that large-scale bank holdings of sovereign debt may be a key reason why advanced economy sovereigns do not default more often – but also why defaults are extremely costly when they do occur. Their theoretical predictions are that sovereign defaults should cause a contraction in private credit, and that this effect should be larger in countries where financial institutions are more developed and banks hold more government bonds. This is confirmed empirically with a panel of emerging and developing countries over 1980-2005. Similarly, D'Erasmo and Mendoza (2016) show theoretically that governments may be able to sustain higher levels of domestic public debt when they have a bias in favor of domestic bondholders.

Among applied empirical work, Blundell-Wignall and Slovik (2011) show that the scale of (domestic) sovereign exposures by Greek and Cypriot banks, as well as some Northern European banks (e.g. Hypo Real Estate) in early 2010 was so large relative to Tier I capital that these banks would not be able to absorb various potential haircuts to the value of such debt. Asonuma, Bakhache and Hesse (2015) show from a large panel of advanced and emerging market economies that greater home bias in the sovereign debt holdings of domestic banks can reduce the cost of borrowing for the sovereign, but can also allow governments to sustain higher deficits and to delay fiscal consolidation until public debt reaches dangerously high levels. Balteanu and Erce (2012) show that, as compared to isolated banking crises, "twin" bank and sovereign debt crises tend to feature a high level and strong growth of exposures by the banking sector to the sovereign.

Banks may increase government bond holdings during a crisis for a variety of reasons. Acharya and Steffen (2015) argue that purchases by euro area banks of peripheral bonds during 2007-2012 can be understood as "carry trade" behavior, or an attempt by "large, under-capitalized banks to exploit government guarantees, arbitrage regulatory risk weights, and access central-bank funding." Ongena, Popov and van Horen (2016) show that banks in stressed euro area countries tended to purchase more bonds than foreign banks in months of strong issuance, particularly when they had received state support – a finding linked by the authors to moral suasion. Alternatively, Castro and Mencía (2014) relate such increases to macroeconomic factors, such as industrial production and unemployment, which may indicate a lack of private credit demand.

In addition to the risks to banks after a sovereign default, banks' sovereign exposures may crowd out private credit, through various channels. Bottero, Lenzu and Mezzanotti (2015) find that the Greek bailout in 2010, which led to a reassessment of the riskiness of sovereign exposures of

banks, also led to a tightening in the credit supply of banks to firms. They estimate that the drop in bank lending by Italian banks to firms reached 2 percent over the subsequent year. Similarly, Popov and van Horen (2012) find significant effects of sovereign debt degradation on the real economy via the bank lending channel and the quality of the banking sector.

2.3. Indirect links

Sovereigns and banks can also be interdependent through their joint reliance on the real economy. Theoretically, Di Iasio and Pierobon (2013) show how the creditworthiness of the sovereign can affect bail-out expectations and liquidity risk of private intermediaries, including shadow banks. When creditworthiness deteriorates, this could force deleveraging pressures through financial markets, which can have significant effects on the real economy. Empirically, Angelini, Granda and Panetta (2014) find that the correlations between sovereign and bank CDS are not higher than correlations between sovereigns and non-financial companies in the euro area. They interpret this as evidence that "country risk seems to be a key factor underlying the sovereign-bank relationship." This issue will be returned to in an extension to our baseline model in section 4.3, where we examine differences between the sovereign-bank and "sovereign-corporate" nexus.

2.4. Credit market frictions

Finally, both sovereign and bank risk may be affected by frictions in credit markets, e.g. due to information asymmetries or to coordination failures, particularly during periods of stress. In this vein, Broner, Erce, Martin and Ventura (2014) develop a theoretical model in which domestic and foreign investors can trade sovereign debt in the secondary market, but where creditor discrimination leads to a higher expected return for domestic investors when default risk rises. At the same time, due to financial frictions, such purchases crowd out private borrowing, thus displacing productive investment and reducing growth and welfare.

There is a large empirical literature seeking to explain movements in credit market spreads (see for example, Collin-Dufresne, Goldstein and Martin, 2001 and Haugh, Ollivaud and Turner, 2009). For the euro area crisis, De Grauwe and Ji (2013) argue that the lack of explanatory power of debt-to-GDP ratios before the crisis, and the dramatic (non-linear) increase in spreads since 2008, is evidence of such mispricing in the euro area CDS market. Yet as de Haan, van den End and Hessel (2013) show, estimations of credit spreads may be heavily influenced by modelling choices such as sample selection, inclusion of financial variables and whether coefficients are allowed to change across countries and over time. For this reason, such estimations must be approached with the proper care, and while some developments may appear to result from market frictions, it is difficult to isolate these definitively in practice.

2.5. Testable hypotheses

With these channels now described, we develop two testable hypotheses. Our first hypothesis exploits variation in our market measure of interdependency, namely Spearman correlations. One reason why the CDS premiums of banks and sovereigns would move together is because the assets and liabilities of domestic banks and the sovereign are directly linked, either through exposures of the banks to their sovereign, e.g. holdings of sovereign debt, or through (potential) commitments of the sovereign to domestic banks, e.g. explicit or implicit guarantees (sections 2.1 and 2.2 above). The higher these *direct* exposures, the more the riskiness of the sovereign and the banks will be related. An increase in the (perceived) riskiness of the one would lead to a higher (perceived) riskiness of the other. Yet the impact of direct mutual exposures on the sovereign-bank interdependency may not be the same for all countries, and – in addition to indicators of the real economy (section 2.3) – may also depend on market structure. For example, in countries where the banking sector provides a larger share of overall credit and is thus more systemically important, the government is more likely to guarantee banking sector liabilities in stress periods. Similarly, when banks are more dominant in private credit provision, they may also be a more important segment of the investor base for government debt. Hence, we would expect to see higher sovereign-bank interdependencies in these countries than in countries where the banking sector is less dominant:

H_1: Higher exposures of banks to sovereigns and higher implicit contingent liabilities are tied to a higher market perception of sovereign-bank interdependencies (i.e. higher Spearman correlations), and these effects are larger in countries with bank-based financial systems.

Of course, it is possible that the direct exposure channels only affect short-term market correlations but not actual *levels* of risk premiums. Our second hypothesis seeks to exclude this possibility. Specifically, we investigate how CDS spreads of sovereigns spill over to banks and vice versa. We expect that the CDS premiums of banks will be higher when the sovereign is under strain, and that sovereign CDS rise when banks are in distress. Moreover, we would expect these spillovers to be especially large in periods of financial volatility. This yields our second hypothesis:

H_2: Sovereign credit spreads are a stronger determinant of bank credit spreads, and bank spreads are a stronger determinant of sovereign spreads, in periods of high market volatility.

This hypothesis can best be tested by estimating the level of sovereign and bank credit spreads directly. If the explanatory power of lagged sovereign (bank) credit spreads on bank (sovereign) spreads rises when volatility is high, this is further evidence of non-linear effects, such as a feedback loop. Moreover, because higher credit spreads for sovereigns lead to a greater fiscal burden, and higher spreads for banks tend to be passed on to private borrowers, examining the level of spreads

allows us to make a more direct link to potential welfare effects.

3. Data, methodology and trends

To investigate sovereign-bank interdependencies across countries and time, we introduce our data sources and our market measure of bank-sovereign links, namely the Spearman correlation between CDS premiums of a banking group and its home sovereign. Next, we empirically test which factors are the most important in explaining such links, by regressing our measure on specific bank, sovereign and country characteristics.

3.1. Data sources

The analysis on sovereign-bank interdependencies is performed on a panel data set of 65 banks in 23 countries at quarterly frequency over the course of 10 years (Q1 2006-Q4 2015). The country choice and the period for the analysis were restricted largely by data availability of the CDS series. For most countries and banks the series start in January 2006. The resulting data set spans the global pre-crisis (2006-2007), in-crisis (2007-2009) and recovery periods (2010-2015), and also the euro area sovereign debt crisis (2010-2012). For each of the 23 countries, daily CDS spreads of the sovereign and the largest banks by market capitalization were selected.[4] The use of large banks is based on data availability, but this choice should provide a good basis for sovereign-bank interdependencies, since especially bank-to-sovereign risk transfer (expectations of state support) relates mostly to large, systemically important institutions. The list of selected countries and the included banks is presented in the annex.

The total assets of banking groups and their exposure to governments are taken from Bankscope. Because these variables are only available at annual frequency, they are interpolated within a year using quarterly data on the total claims and exposures of the full national banking sector from the IMF's International Financial Statistics (IFS). The underlying assumption is that quarterly changes in total assets and exposures by each individual bank are comparable with the changes of the aggregate national banking sector.[5] Quarterly macroeconomic variables are taken from the IMF, and sovereign and bank ratings come from Moody's. For the level of CDS and the VIX, which are available on daily basis, quarterly averages are used. For the correlations, quarterly values are obtained by taking the correlation between changes in daily spreads within the quarter (see below).

[4] For most countries, there are at least three banks in the sample. For some countries (Germany, Ireland, Switzerland and Turkey) only two banks were selected due to unavailability of CDS data or illiquidity of CDS series (e.g. for Deutsche Postbank and Anglo Irish Bank). For China, Denmark and Norway, CDS data were available for only one domestic bank.

[5] The IFS data refer to the domestic banking sector on a locational basis, whereas the Bankscope banking group data are on a consolidated basis. The in-quarter adjustments are between -10% and 16% relative to a linear trend between annual values from Bankscope. While it is likely that individual banking groups diverge from the behavioral patterns of the entire banking sector within individual years, these differences are by definition short-term and in any case will not have been known publicly or by investors in bank CDS within individual years.

3.2. Measure of sovereign-bank interdependencies

Our measure for the degree of interdependencies between sovereigns and the domestic banking sectors is derived from the co-movement of the relevant CDS series. In particular, the CDS series of each bank is compared with its domestic sovereign's CDS series. In order to capture co-movement (i.e. the timing of large increases and decreases in credit risk, rather than the scale of such changes), the Spearman's rank correlation was employed. Since CDS spreads tend to be non-stationary, the degree of co-movement between returns instead of levels is measured. For each series, daily returns were calculated by taking differences between two end-of-the-day spreads.[6] The returns in each series are assigned ranks according to their values. Once the ranking process is completed, the linear correlations between the rankings of sovereign and bank CDS are computed according to the standard Pearson's formula:

$$\rho_{CDS_B,CDS_S}=\frac{Cov_{(CDS_B,CDS_S)}}{\sigma_{CDS_B}*\sigma_{CDS_S}}$$

where $Cov_{(CDS_B,CDS_S)}$ is the covariance of the bank and sovereign CDS spreads and σ_{CDS_B} and σ_{CDS_S} are the standard deviation of each series. The resulting daily values are averaged out to produce quarterly data.[7] Although we also use other correlation measures to test the robustness of our results, an advantage of the Spearman rank correlation is that it does not assume a linear relationship between the two series.

3.3. Explanatory variables

In order to determine the factors underlying the level of sovereign-bank interdependencies several measures representing the sovereign to bank and bank to sovereign exposures were developed. The preferred measures are the following two measures:

- *Sovereign exposures of banks* – the claims on governments by a bank relative to its total assets. This series is on a consolidated basis. A key limitation is that it captures holdings of all government debt, rather than just the debt of the domestic sovereign. While domestic sovereign exposures are available for the entire banking sector in most EU countries (and are used in the robustness checks), they are not consistently available for individual banks, or for other regions. However, in most non-EU countries, domestic debt is a majority of banks' sovereign debt portfolios, making this a reasonable proxy.[8] Larger holdings of

[6] For example, the return on 1 May is the end of day price for 1May minus end of day price for the 30 April.

[7] For alternative approaches, such as co-exceedance, see Baur and Schulze (2005) and Forbes and Rigobon (2002).

[8] In the EU, domestic exposures make up 52% of overall government bonds holdings on a consolidated basis, and 75% on a locational basis. There are higher values in the larger countries, such as the UK, Spain, Italy, France and Germany. International supervisory data sources suggest that this share is much higher outside the EU.

sovereign debt should be associated with higher sovereign-bank interdependency.

- *Implicit contingent liabilities of the sovereign* – in line with Bénassy-Quéré and Roussellet (2014), the amount of implicit liabilities is proxied by the RWA minus total equity of each bank, divided by the domestic country's GDP.[9] Even though not contracted by law, there is an expectation of sovereign support to domestic banks in times of distress. Consequently, a larger and riskier banking sector with a lower equity cushion increases the amount of potential support. An increase in this measure should lead to increasing levels of sovereign-bank interdependencies.[10]

In addition to sovereign-bank exposures, bank and sovereign risk determinants are incorporated into the model. This relates to the notion that the state of the banking sector is an important determinant of sovereign CDS and vice versa (Dieckmann and Plank, 2011). As a result, sovereign and bank ratings can influence the level of sovereign-bank interdependencies. Furthermore, macroeconomic and financial market variables also partially account for the sovereign's and banking sector's common exposure to the same economy and the perception of risk. Consequently, two risk determinants, one macroeconomic variable and one financial market control were included in the baseline model. The risk determinants are:

- *Sovereign Ratings* – sovereign credit ratings transformed into numbers with a linear numerical scale (AAA=25, intervals of 1 unit per notch). This variable represents an overall measure of sovereign creditworthiness. The sovereign credit rating is based on the Long Term Issuer rating of Moody's Investor Service. A higher rating represents greater sovereign creditworthiness, which may reduce sovereign-bank interdependencies.
- *Bank Ratings* – the average of Moody's Long Term Deposits (Domestic currency) for each of the 65 banks, again transformed into numbers with a linear numerical scale (AAA=25, intervals of 1 unit per notch). Again, a higher rating represents a safer bank which poses less risk to the sovereign.

The macroeconomic and financial market controls are:

- *Output growth* – year-on-year change in real GDP, taken from the OECD. High economic growth generally entails an improving risk outlook and a greater capacity to pay down a nominal debt burden. This decreases the risk of future default and at the same time has a positive effect on overall creditworthiness of both banks and the sovereign.

[9] Data sources: SNL Financial and IMF International Financial Statistics. An additional advantage of the Bénassy-Quéré measure over alternative indicators is that it does not include sovereign exposures, due to the zero risk weighting of sovereigns in the capital requirement framework in various global jurisdictions.

[10] An avenue for future analysis would be to look at *explicit* contingent liabilities from banking sector support programs, and at any changes due to recent reforms to encourage bail-in.

- *Volatility* – the Chicago Board Option Exchange volatility index ("VIX"), accessed from Datastream. The VIX is the most commonly used index of market volatility. Since it is a measure of global market volatility, the same index was used for every country in the sample. Daily index values were averaged over each quarter to match the rest of the sample. Controlling for volatility in the markets helps to isolate changes in CDS which are a result of common market movements (or the level of financial frictions) as opposed to a result of changes in fundamental variables.
- *Bank share of credit* – the percentage share of banks in overall credit to the domestic private sector, taken from the BIS. This share is a relatively direct measure of financial structure, and allows for a classification of countries into relatively bank-based versus market-based financial systems.[11]

3.4 Regression methodology

Our market-based measure of the perceived interdependency between the sovereign and banks is compared across countries and time, and regressed against relevant financial and macroeconomic variables. For our baseline regression, used to test the first hypothesis, this takes the form of:

$$\rho_{CDS_B,CDS_S\,i,t} = \alpha + \beta_1 X_{i,t-1} + \beta_2 Y_{i,t-1} + \beta_3 Z_{i,t-1} + \beta_4 \sigma_t + \gamma_i [+\rho_{CDS_B,CDS_S\,i,t-1}] + \epsilon_{i,t} \qquad (1)$$

where $\rho_{CDS_B,CDS_S\,i,t}$ denotes our correlation measure for bank *i* and quarter *t*, $X_{i,t-1}$ is a proxy of direct sovereign-to-bank risk transfer channels, lagged by one quarter; $Y_{i,t-1}$ is a proxy of direct bank-to-sovereign risk transfer; $Z_{i,t-1}$ is a vector with bank and sovereign ratings and output growth; and $\sigma_{,t}$ is overall financial market volatility, proxied by the VIX, which is included contemporaneously (i.e. in the same quarter).[12] The variables α, γ, and ε are, respectively, the constant, the bank fixed effects term and an error term. The variables β_1, β_2, β_3, and β_4 denote our estimated coefficients. These equations are estimated using ordinary least squares (OLS). A Hausman test confirms the choice of fixed effects, as random effects would be inconsistent. Due to some autocorrelation in the quarterly data, we also show the baseline regressions with the lagged dependent variable, $\rho_{CDS_B,CDS_S\,i,t-1}$. Throughout the regressions, we use clustered standard errors.

To better test the differences between bank-based and market-based systems, we use simple interaction terms, such that the estimation becomes:

[11] Countries with relatively bank-based systems are those where the average share of bank credit in total credit is above the sample median, while market-based systems have bank credit shares below the median. Note that some traditionally bank-based countries, such as Germany and Japan, have seen a growing role of non-bank credit in the past decade, such that they are now relatively market-based. Emerging market economies generally have a large bank share of credit. Alternative data sources, such as the OECD, yield a similar relative ranking of countries, but do not have data on the bank share of credit for all countries over the full sample period.

[12] The independent variables are lagged by one quarter as a simple means of addressing reverse causality. The VIX is shorter-term and less likely to be influenced by individual countries in the sample.

$$\rho_{CDS_B,CDS_S\,i,t} = \alpha + \beta_1 X_{i,t-1} + \beta_2 (X_{i,t-1} * S_{i,t-1}) + \beta_3 Y_{i,t-1} + \beta_4 (X_{i,t-1} * S_{i,t-1}) + \beta_5 S_{i,t-1}$$
$$+\beta_6 Z_{i,t-1} + \beta_7 \sigma_t + \gamma_i + \epsilon_{i,t} \quad (2)$$

where $S_{i,t-1}$ is the financial structure of the country (i.e. the share of bank credit in overall credit), and $X_{i,t-1} * S_{i,t-1}$ and $Y_{i,t-1} * S_{i,t-1}$ are, respectively, the products of this measure and direct sovereign-to-bank and bank-to-sovereign risk transfer channels.

In line with our second hypothesis, we would like to exclude the possibility that correlations only concern short-term co-movement. Hence, in a second step, we estimate the levels of banks CDS and sovereign CDS spreads directly. These regressions take the form of:

$$CDS_{B\,i,t} = \alpha + \beta_1 X_{i,t-1} + \beta_2 Y_{i,t-1} + \beta_3 Z_{i,t-1} + \beta_4 \sigma_t + \beta_5 CDS_{S\,i,t-1} + \gamma_i + \epsilon_{i,t} \quad (3)$$

$$CDS_{S\,j,t} = \alpha + \beta_1 \bar{X}_{j,t-1} + \beta_2 \bar{Y}_{j,t-1} + \beta_3 \bar{Z}_{j,t-1} + \beta_4 \sigma_t + \beta_5 CDS_{\bar{B}\,i,t-1} + \gamma_j + \epsilon_{j,t} \quad (4)$$

where $CDS_{B\,i,t}$ denotes the quarterly average of 5-year CDS spreads for bank *i* in quarter *t*, $CDS_{S\,j,t}$ is the quarterly average 5-year CDS spreads of sovereign *j* in quarter *t*, and the other variables are the same as in equation (1). The key difference in equation (4) is that all variables are now at the country level, such that the sovereign-to-bank and bank-to-sovereign risk transfer indicators are a total for the entire banking sector (from IMF IFS). Meanwhile, $CDS_{\bar{B}\,i,t-1}$ denotes an average for all of the banks from country *j* in the sample, and γ_j are now country fixed effects.

3.5. Descriptive statistics

Table 1 shows key characteristics of all of the variables used in the regressions. The correlation measure is usually positive, with a mean around 33%. Sovereign CDS spreads (5-year, expressed in basis points, bp) vary from a level close to 0 up to a level of 1294 bp for sovereigns (Portugal, Q1 2011) and 1698 bp for banks (Banco Commercial Portugues, Q4 2011). Sovereign and bank ratings have been converted to a number between 0 (lowest) and 25 (highest ratings). The implicit contingent liabilities average 77% of GDP, but with large heterogeneity between bank-country pairs. The maximum is 273% by Allied Irish Bank in Q1 2009. Bank exposures to sovereigns average at 8.2% of total assets, and are generally higher in emerging markets, e.g. the 44.7% recorded by Akbank in Q4 2009. The bank share of private credit averages at about 66% across all countries, but is much lower in countries like the US, Ireland and Luxembourg, and much higher in emerging markets like Brazil. Real GDP growth averages 3.4% across the sample, and the VIX averages at 20 bp, with a maximum level of 59 bp in Q4 2008, after the failure of Lehman Brothers.

Table 1: Descriptive statistics of dependent and independent variables

Variable	Observations	Mean	Std. Dev.	Min	Max
Spearman correlation (in %)	2,040	33.2%	24.8%	-33.6%	93.7%
Sovereign CDS (in bp)	2,438	110.2	136.7	1.4	1294.7
Bank CDS (in bp)	2,442	168.9	188.2	3.6	1698.7
Implicit CL (RWA-TE, % of GDP)	2,225	77.4%	56.7%	1.4%	272.8%
Bank exposures to sovereigns (% total assets)	2,127	9.2%	7.6%	0.1%	44.7%
Bank share in private sector credit (BIS)	2,600	65.6%	17.3%	16.7%	95.3%
Sovereign rating (in notches)	2,600	21.62	4.03	13.00	25.00
Bank rating (in notches)	2,577	20.45	3.12	7.00	25.00
GDP growth (in %)	2,600	2.1%	3.4%	-13.1%	13.3%
VIX (in bp)	2,600	20.39	9.13	11.03	58.61

Note: unbalanced panel, as CDS data are missing for some countries in the early part of the sample period.

All variables have been tested for stationarity with the Levin-Lin-Chu (2003) panel unit root test. A unit root can be ruled out for all variables at the 95% confidence level, except for sovereign ratings. All variables have also been tested for multicollinearity (table 2). The correlation between the quarterly average levels of bank and sovereign CDS (80%) is much higher than the average of within-quarter Spearman correlations of daily changes, which are used in the regressions. The high correlation between sovereign and bank ratings (70%) calls for some caution in interpreting the effects of regressions that include both variables. The high (negative) correlation between sovereign ratings and sovereign CDS, and between bank ratings and bank CDS is in line with expectations, as more creditworthy banks and sovereigns have lower financing costs. In the second step, ratings will thus form an important control variable on the right-hand side of regressions on CDS spread levels.

Table 2: Correlations between the dependent and independent variables

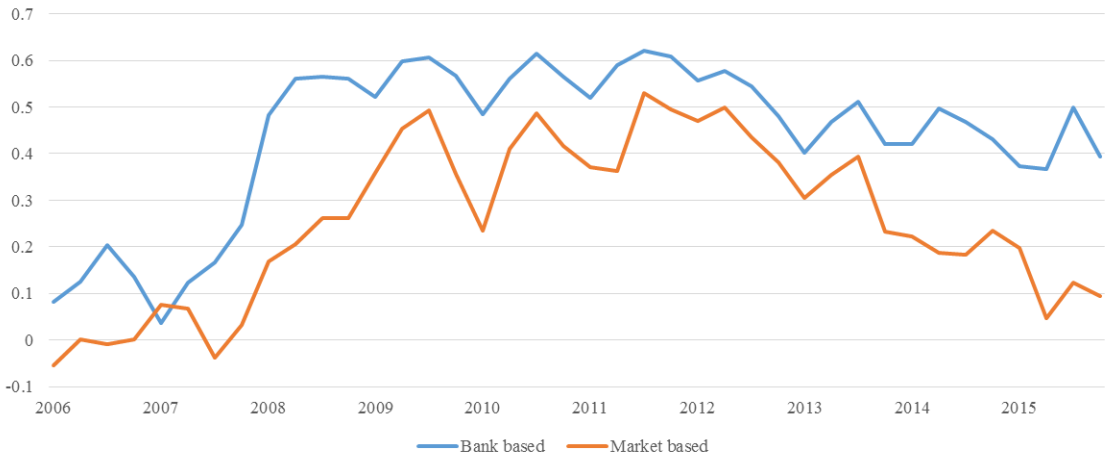
	Spearman correlation	Sovereign CDS	Bank CDS	Implicit CL	Bank exp. to sovereigns	Bank share	Sovereign rating	Bank rating	GDP growth
Sovereign CDS	0.33								
Bank CDS	0.26	0.80							
Implicit contingent liabilities	-0.05	0.00	-0.04						
Bank exposures to sovereigns	0.06	0.12	0.13	-0.28					
Bank share in private credit	0.28	0.24	0.09	-0.20	0.03				
Sovereign rating	-0.31	-0.60	-0.48	0.32	-0.40	-0.54			
Bank rating	-0.17	-0.53	-0.53	0.26	-0.22	-0.31	0.72		
GDP growth	-0.09	-0.18	-0.23	-0.25	0.17	0.30	-0.29	-0.10	
VIX	0.19	0.19	0.21	0.10	-0.03	0.01	0.06	0.16	-0.37

Note: pairwise correlations, i.e. linear correlations considering all available observations per pair of variables.

3. 6. Trends in the data

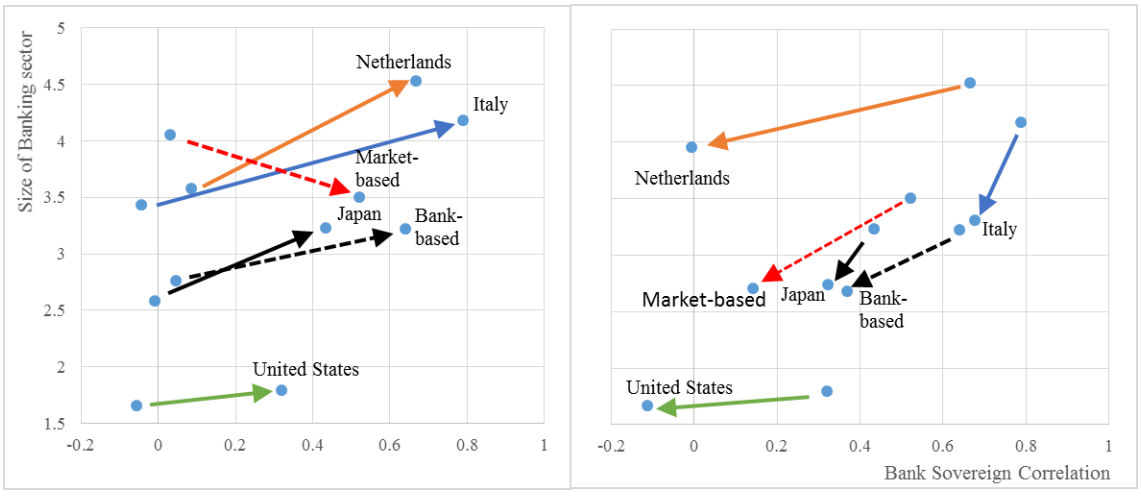
Figure 2 shows the correlation of sovereign and bank CDS premiums over time, split by countries with relatively bank-based versus relatively market-based financial systems. The strong increase in the correlation measures between 2007 and 2009 is striking. This is unlikely to be the result of changes in fundamental factors alone, but could rather be interpreted as evidence of a repricing of risk through feedback loops. Moreover, we find that the sovereign-bank interdependency is generally higher for banks in countries with a bank-based financial system than in countries with a market-based financial system. Also, the decline in the correlation in the post-crisis period has been more pronounced in in countries with a market-based financial system.

Figure 2: Spearman rank correlations for different countries over time



Note: Countries with a ratio of bank credit to total credit above the sample-wide median as of Q3 2015 are defined as bank-based, while those with such ratios below the median are defined as market-based.

Figure 3: Spearman rank correlations for different countries before and after 2011



Note: In the left figure we show the movement of correlations in relation to the size of the banking sector in the period 2007Q1 to 2011Q3. In the right the same movement is presented for the period 2011Q3 to 2015Q4.

Figure 3 shows the change in banking sector size and correlation in sovereign and bank CDS throughout the sample period. Especially bank-based countries saw the size of the banking sector relative to GDP increase in the period through 2011, at the same time that the market measure of the sovereign-bank nexus for the largest banks was increasing. Relatively market-based countries saw the relative size of the banking sector decline, but correlations increase. Since the peak of the euro area crisis in 2011, the euro area countries (e.g. Italy and the Netherlands) have seen a decline in the overall size of the banking sector, and correlations have again decreased. Yet this is not exclusive to Europe: a similar pattern can be seen in the United States and Japan, which have also experienced bank deleveraging and a declining sovereign-bank nexus, and in the average of bank-based and market-based countries generally. Also note the different patterns for the United States and the Netherlands, on the one hand, and for Italy and Japan, on the other. The first two countries, where markets are sanguine about public debt sustainability, basically moved back to their old position after 2011. Italy and Japan, two countries with very high public debt levels, now have a bank-sovereign correlation substantially higher than before the crisis. This suggests that markets have paid more attention to the sovereign-bank nexus since the crisis.

4. Empirical results and robustness checks

4.1. Regression results

To test our first hypothesis we regress the correlation between bank and sovereign CDS premiums on banks' holdings of sovereign debt and the contingent liabilities of the sovereign to the bank. While our hypothesis focuses on the direct risk transfer channels (1 and 2 in figure 1), we also control for indirect links in the regressions. Common exposures to economic shocks can be captured with GDP growth, while financial shocks should be captured with the VIX. We also include bank fixed effects to take into account unobserved bank-specific characteristics.

The results are shown in table 3. For the first regression (column 1) with only the direct risk transfer channels and the VIX, we find that larger sovereign exposures are associated with a significantly higher correlation between the CDS premiums of banks and their sovereign. In economic terms, an increase in sovereign exposures by 4% of total assets (one standard deviation in Italy during the sample) is associated with a sovereign-bank CDS correlation that is 5.9 percentage points higher. Higher contingent liabilities, as measured by the Bénassy-Quéré and Roussellet (2014) measure, are also associated with a tighter sovereign-bank link. The economic significance is generally smaller: an increase in this measure by 7.5% of GDP (one standard deviation in Brazil or Turkey) is associated with an increase by 1.3 pp in the sovereign-bank CDS correlation. To test whether this effect depends on the riskiness of the sovereign holdings of banks, we include the sovereign rating and its interaction with sovereign exposures as explanatory variables (column 2). We find that these variables are not significantly related to the sovereign-bank CDS correlation. This suggests that higher sovereign exposures are associated with stronger

bank-sovereign interdependencies, irrespective of the riskiness of these exposures. Together, these results suggest that across all the banks and countries under analysis, both bank-to-sovereign links and sovereign-to-bank links are tied to higher interdependency. Moreover, these interdependencies are higher when financial market stress, as measured by the VIX, is high.

Table 3: Estimations of Spearman rank correlation between sovereign and bank CDS

	(1)	(2)	(3)	(4)	(5)
	Full sample				
Sovereign to Bank risk transfer					
Bank exposures to sovereigns (% total assets)	1.468***	1.439**	1.399***	0.604***	0.004
	(0.401)	(0.605)	(0.388)	(0.196)	(1.025)
Exposures to sovereigns * sovereign rating		-0.016			
		(0.082)			
Exposures to sovereigns * bank share					2.309
					(1.744)
Bank to Sovereign risk transfer					
Implicit CL (RWA-TE, % of GDP)	0.175***	0.174***	0.142**	0.083**	0.435***
	(0.061)	(0.059)	(0.066)	(0.036)	(0.149)
Implicit CL * bank share					-0.463*
					(0.250)
Risk measures					
Sovereign rating		-0.007	-0.002	-0.007**	
		(0.008)	(0.009)	(0.003)	
Bank rating			-0.001	0.006	
			(0.010)	(0.004)	
Macroeconomic controls					
GDP growth			-0.010***	-0.002	
			(0.003)	(0.001)	
Bank share					0.03
					(0.509)
Financial market volatility					
VIX	0.006***	0.006***	0.006***	0.004***	0.006***
	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)
Autocorrelation					
Spearman (lag1)				0.534***	
				(0.031)	
Number of observations	1602	1602	1598	1549	1602
Number of groups	65	65	65	64	65
R-sq within	0.103	0.105	0.117	0.401	0.114
R-sq between	0.008	0.000	0.010	0.700	0.010
R-sq overall	0.008	0.017	0.014	0.496	0.032

Note: * significance at 90%; ** significance at 95%; *** significance at 99%. Bank fixed effects and clustered standard errors are used throughout. Constants are not reported.

When adding further control variables, i.e. credit ratings agencies' risk assessments of banks and GDP growth (column 3), we find that neither the sovereign nor bank rating has a significant

impact on the sovereign-bank link. However, and as expected, the coefficient of GDP growth is strongly negative and significant. Financial market stress remains associated with significantly higher correlations between the CDS premiums. As a simple means of testing for potential autocorrelation, the lagged dependent variable can be included (column 4). In this specification, the direct sovereign-to-bank and bank-to-sovereign risk transfer channels and VIX remain significant.

If correlations between CDS premiums are tied primarily to implicit guarantees of the sovereign, we expect this effect to be stronger in countries where the government is more likely to finance a bail-out of the banking system, and where banks are larger relative players in the financial system and sovereign debt markets. This could be the case in bank-based financial systems, i.e. those countries where the banking system is more important for aggregate private credit (Gambacorta et al., 2014). Thus, we test the second part of our first hypothesis by interacting our measure of implicit guarantees with the share of bank credit in total credit to the economy. Column (5) of table 3 shows the results of this regression. While the coefficient of the interaction term between exposures and the bank share in credit is positive, it is not statistically significant (t-value of 1.32). The coefficient of implicit liabilities is now much larger, but the negative interaction term implies that this effect is *decreasing* in the share of bank credit. This means that, ceteris paribus, higher implicit contingent liabilities are tied to greater interdependencies primarily in market-based financial systems, and not in highly bank-based systems.[13] Overall, we can only confirm the first half of our first hypothesis. Higher exposures of banks to sovereigns and a larger banking sector are indeed tied to a higher market perception of sovereign-bank interdependencies, but we cannot confirm that this effect is larger in bank-based financial systems.

The empirical testing of our second hypothesis goes more deeply into the feedback mechanism between banks and sovereigns, as we analyze how direct risk transfer channels, sovereign fundamentals and sovereign credit spreads influence bank credit spreads, and how these links, bank fundamentals and bank credit spreads influence sovereign spreads. We analyze how these effects are manifested in both stressed and tranquil market conditions by interacting the CDS premiums of the other sector with financial market volatility (the VIX).

We start with bank CDS (table 4). First, we find that without controlling for sovereign fundamentals, there is a statistically significant link between the level of bank CDS spreads and the scale of bank exposures to sovereigns (column 1). The measure of implicit contingent liabilities, which could measure the uplift from expectations of sovereign support, is not significant. Second, moving on to the risk measures, we confirm that CDS premiums of banks are not only affected by their own risk characteristics, but also by the riskiness of the home sovereign. We find that the link between a bank's CDS spread and its sovereign exposures seems to be particularly strong when the domestic sovereign has a *higher* credit rating (column 2). This may imply that the value of (implicit)

[13] Separately, we have found that when splitting the sample into relatively bank-based versus relatively market-based systems, bank exposures are separate in both sub-samples, while implicit contingent liabilities are significant in neither.

sovereign support is higher in countries with a relatively creditworthy sovereign. The sovereign rating, itself, has a significant negative coefficient, with each one notch upgrade being associated with a roughly 29 bp improvement in spreads (column 3). When the lagged sovereign CDS spread is included as an independent variable (column 4), this has a coefficient close to 1. In this specification, sovereign exposures become insignificant, but the implicit liabilities do show up with the expected negative sign, implying sovereign uplift.

Finally, and most importantly for our second hypothesis, we are interested in how the significance of the sovereign CDS and sovereign rating for bank spreads during depends on market volatility. We find that the relation between the level of sovereign CDS and bank CDS is not significantly affected by the VIX (column 5). In other words, while lagged sovereign CDS levels are a (highly) important determinant of bank CDS levels, the sovereign-to-bank risk transfer does not appear to differ between low and high-volatility periods.

Table 4: Estimations of bank CDS with fixed effects

	(1)	(2)	(3)	(4)	(5)
	Full sample				
Sovereign to Bank risk transfer					
Bank exposures to sovereigns (% total assets)	765.114**	775.413*	-61.1	76.909	26.926
	(289.847)	(400.412)	(199.703)	(137.161)	(152.092)
Exposures to sovereigns * sovereign rating		-133.601**			
		(56.479)			
Bank to Sovereign risk transfer					
Implicit CL (RWA-TE, % of gdp)	-38.868	-24.89	-28.634	-110.814**	-108.698*
	(77.738)	(46.443)	(52.683)	(50.600)	(56.259)
Risk measures					
Sovereign rating		-52.480***	-28.921**	-3.675	
		(10.096)	(11.993)	(8.005)	
Bank rating			-11.771**	-1.075	
			(5.120)	(5.019)	
Macroeconomic controls					
GDP growth			-10.989***	-0.743	
			(2.567)	(1.958)	
Financial market sentiment					
VIX	4.211***	5.520***	4.790***	3.676***	2.545***
	(0.641)	(0.656)	(0.641)	(0.526)	(0.659)
Sovereign sentiment					
Sovereign CDS				0.973***	1.169***
				(0.073)	(0.196)
Sovereign CDS * VIX					-0.007
					(0.005)
Number of observations	1832	1832	1828	1772	1776
Number of groups	65	65	65	65	65
R-sq within	0.063	0.264	0.292	0.623	0.598
R-sq between	0.012	0.333	0.475	0.388	0.384
R-sq overall	0.022	0.246	0.337	0.524	0.514

Note: * significance at 90%; ** significance at 95%; *** significance at 99%. Constants are not reported.

For sovereign CDS (table 5), on the other hand, we do find a positive interaction effect, i.e. higher spillovers when the VIX is high. These regressions, which are performed at the country level, again begin with only the direct risk transfer channels (columns 1 and 2). Here, the coefficient for the total banking sector's exposures to sovereigns (now from IMF IFS, at quarterly frequency and on a locational basis) is positive but insignificant. When including the sovereign rating and the interaction of this rating and the sovereign exposures of the banking sector, we find a significantly negative coefficient for the sovereign rating, as expected, but no effect of the rating on the significance of sovereign exposures (column 2). The implicit liabilities measure, which is a sum for all of the banks in sample and should be associated with higher sovereign CDS spreads, is not significant. When the bank rating is added (columns 3 and 4), it has a significant negative sign, with a one-notch upgrade of any major bank being associated with a decline in the sovereign CDS spread of 18 bp. Note that the coefficient of the bank rating is higher than that of the sovereign rating, with the sovereign rating even becoming insignificant after adding the lagged average CDS spread of the banks in sample (weighted by total assets) as an explanatory variable. As expected, higher output growth is also linked to lower sovereign CDS spreads in the respective quarter.

Finally, and again important for our second hypothesis, we consider the role of market volatility in the relation between (lagged) banking CDS spreads and the sovereign CDS (column 5). Here, we find that market volatility is associated with a significantly stronger link between the banking CDS and sovereign CDS. This shows that the riskiness of the banking sector matters more for market perceptions of sovereign creditworthiness during stressed market conditions.

Table 5: Estimations of sovereign CDS with fixed effects

	(1)	(2)	(3)	(4)	(5)
	Full sample				
Sovereign to Bank					
Bank exposures to sovereigns (% total assets)	404.845	-77.253	-487.335	-519.300	52.346
	(453.884)	(663.953)	(570.003)	(550.387)	(262.582)
Exposures to sovereigns * sovereign rating		-86.157			
		(57.301)			
Bank to Sovereign					
Implicit CL (RWA-TE, % of gdp)	22.291	41.286	31.84	62.074	68.754
	(30.332)	(30.648)	(24.093)	(44.761)	(47.381)
Risk measures					
Sovereign rating		-43.446***	-16.143*	-3.954	
		(14.253)	(9.194)	(5.837)	
Bank rating			-17.944***	-15.973***	
			(3.752)	(4.851)	
Macroeconomic controls					
GDP growth			-5.212***	-2.950*	
			(1.773)	(1.575)	
Financial market sentiment					
VIX	2.125***	2.817***	3.316***	2.642***	-2.060*
	(0.664)	(0.777)	(0.750)	(0.775)	(1.079)
Banking sentiment					
Banking CDS				0.165	-0.044
				(0.098)	(0.075)
Banking CDS * VIX					0.014***
					(0.003)
Number of observations	737	737	737	732	732
Number of groups	23	23	23	23	23
R-sq within	0.037	0.242	0.267	0.354	0.390
R-sq between	0.107	0.646	0.750	0.244	0.134
R-sq overall	0.051	0.376	0.421	0.254	0.215

Note: * significance at 90%; ** significance at 95%; *** significance at 99%. Constants are not reported.

4.2 Robustness checks

The above results have been subjected to a number of tests in which we alter the model specifications and the way the variables are constructed. These tests generally support the key results of our baseline regressions, though statistical significance (particularly of implicit contingent liabilities) sometimes changes. The results of several tests on the correlations are presented in table 6.

One possible criticism of our baseline regression is that the VIX, as a global variable, may not be equally appropriate for each country in the sample. One alternative measure that has recently become available for major economies is the economic policy uncertainty index of Baker, Bloom and Davis (2015). This index, based on the frequency of key words regarding economic policy uncertainty in international newspapers, is positively correlated with the VIX, but is more sensitive

to national specificities. The first column of table 6 shows the results when using the economic policy uncertainty index. The sample size is lower due to lower country coverage. Bank exposures remain significant, while implicit contingent liabilities are insignificant.

Table 6: Alternative estimations of correlations between bank and sovereign CDS

	Bank level			Country level	
	(1) Baker / Bloom / Davis index	(2) Euro area countries	(3) Non-Euro area	(4) Exposures EU	(5) Exposures EU
Sovereign to Bank					
Bank exposures to sovereigns (% total assets)	1.046*	1.178***	0.466***	4.772**	-13.243
	(0.534)	(0.306)	(0.170)	(1.666)	(9.249)
Exposures to sovereigns * bank share					26.995*
					(13.925)
Bank to Sovereign					
Implicit CL (RWA-TE, % of GDP)	0.157	0.123***	0.075	0.063**	-0.143
	(0.231)	(0.040)	(0.055)	(0.022)	(0.097)
Implicit CL * bank share					0.392*
					(0.194)
Risk measures					
Sovereign rating	-0.004	-0.008*	0.033***	0.018	
	(0.012)	(0.005)	(0.008)	(0.016)	
Bank rating	0.02	0.009*	0.015**	-0.019	
	(0.014)	(0.005)	(0.007)	(0.018)	
Macroeconomic controls					
GDP growth	-0.018***	-0.003	-0.002	-0.017***	
	(0.005)	(0.002)	(0.002)	(0.005)	
Bank share					-2.007*
					(0.926)
Financial market sentiment					
Economic policy uncertainty	0.091***				
	(0.016)				
VIX		0.004***	0.004***	0.008***	0.008***
		(0.001)	(0.001)	(0.001)	(0.001)
Autocorrelation					
Spearman (lag1)		0.574***	0.449***		
		(0.044)	(0.043)		
Number of observations	976	691	858	389	389
Number of groups	37	26	38	11	11
R-sq within	0.114	0.472	0.355	0.240	0.207
R-sq between	0.017	0.447	0.102	0.125	0.036
R-sq overall	0.003	0.471	0.017	0.177	0.063

Note: * significance at 90%; ** significance at 95%; *** significance at 99%.

A second potential criticism is that the effects may be different across jurisdictions, and in particular in the members of a currency union – particularly the euro area – than in countries with their own currency (De Grauwe and Ji, 2013; Van Loon and De Haan, 2015). When dividing our sample (columns 2 and 3) we can confirm that both bank exposures and contingent liabilities have a stronger association with CDS interdependency for banks inside the euro area. Sovereign exposures are also highly significant for non-euro area banks, while contingent liabilities are not.

Moreover, for euro area banks, higher sovereign ratings are tied to a lower interdependency, while higher bank ratings are associated with a tighter sovereign-bank link. These results warrant further investigation, ideally taking into account further institutional characteristics, such as regulatory regimes for sovereign debt and state aid rules in the various countries.

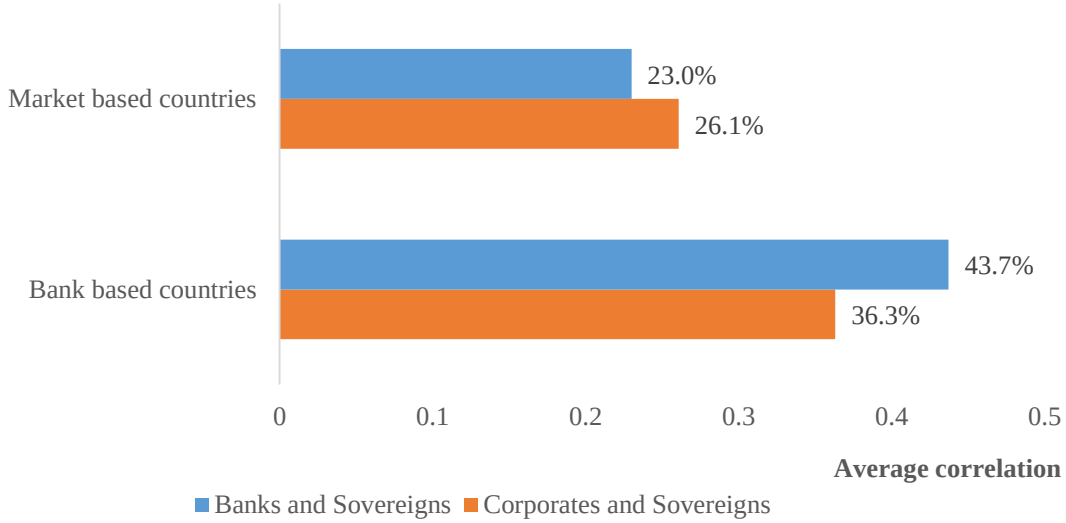
Where available, we use information on bank exposures to the domestic sovereign rather than the broader class of sovereign exposures (including Sweden, but with the exception of the UK). Although this is a more precise test of our hypotheses, the information is only available for EU countries. Moreover, we define the bank-sovereign correlations at the country level, i.e. the correlations between the domestic sovereign and an index of the banks in sample from that country, weighted by total assets (columns 4 and 5). Here, we find that bank exposures to the domestic sovereign (from ECB) and the level of implicit liabilities are highly significant. When we interact these variables with the bank share in total credit, we find that both bank exposures to the domestic sovereign and the level of implicit liabilities are more strongly related to the CDS correlation if the share of bank credit is higher. While this exercise has a number of caveats (including fewer observations and aggregation of important bank-specific indicators), these results are fully in line with the first hypothesis. Again, this suggests there may be potential for further investigating the differences between bank-based and market-based economies, and for the specific characteristics of the euro area.

Finally, additional checks have confirmed that the results are robust to using a simple Pearson's correlation as the dependent variable, and to alternative definitions of implicit contingent liabilities, including the size of the banking sector, leverage ratios or the largest banks in percent of GDP. The sign and significance of coefficients are comparable to the baseline regressions. These results are omitted for brevity but are available upon request.

4.3 Extensions

In general, we would expect to find positive correlations between the sovereign CDS and that of other domestic counterparties, both financial institutions and non-financial corporates. Both sovereigns and private borrowers are subject to shocks in the domestic economy, and the riskiness of the sovereign is an important determinant of the credit rating of domestic borrowers. However, implicit in our analysis is the idea that the relationship between banks and sovereigns is "special." Banks are typically large holders of sovereign debt, whereas the government is more inclined to use large amounts of financial support for the banking sector than for other sectors in the economy. (By way of illustration: governments bail out banks, like ING, but are much less likely to bail out large corporates, like Royal Dutch Shell). So even though the risk premiums of the sovereign and a wide range of domestic borrowers may be correlated, we would expect this to be the result of the (indirect) links through dependence on the real economy and, to a lesser extent, financial markets (channels 3 and 4 in figure 1).

Figure 4: The sovereign-bank nexus versus the "sovereign-corporate nexus"



Note: Bars show the average correlation for country groups in sample. The correlation between corporate and sovereign CDS spreads uses the same calculation method as for the sovereign bank-correlation: a Spearman rank correlation calculated with daily data, based on the data within the respective quarter.

When we compare the level of correlation of sovereign and bank CDS premiums to that of sovereign and corporate CDS premiums, we find no large differences on average. But when we divide the sample into countries with a bank based versus a market based financial system, we find that the difference between the two sub-samples is substantially larger for the sovereign-bank correlation (figure 4). Moreover, when rerunning the above regressions at the country level with the correlation between sovereign CDS and average corporate CDS premiums as the dependent variable (not reported), we find a stronger effect for changes in GDP growth and a weaker effect for our direct risk transfer channels than for our baseline regressions with bank CDS premiums. This illustrates that the existence of direct feedback mechanisms is especially important for sovereigns and banks, and is again an invitation for further analysis.

5. Conclusions

In this study, we have investigated four types of channels which may impact sovereign-bank interdependencies across countries and time. With our empirical analysis, we can confirm that the two direct channels of risk transfer – through sovereign debt holdings of banks, which expose banks to sovereign risk shocks, and risk-weighted assets minus total equity relative to GDP, which measure implicit contingent liabilities to banks – are linked to higher correlations between sovereign and bank CDS. Thus, the market perception of interdependency between sovereign and banking credit risk does respond to fundamental factors. These relationships are present when controlling for changes in sovereign and bank ratings, macroeconomic factors and market volatility. Yet somewhat surprisingly, we do not find these effects to be stronger in bank-based than in market-

based financial systems. We can thus confirm the importance of direct risk transfer channels, but not the expectation of a stronger effect in bank-based systems, at least when the analysis is done at the level of individual banks.

From a systemic risk perspective, such correlations are relevant primarily if they lead to higher financing costs for banks or sovereigns, particularly in periods of stress. Our second hypothesis, which relates to the impact of sovereign (bank) credit premiums on the level of bank (sovereign) credit premiums, offers a more complete picture. When volatility is high, markets are more likely to consider the riskiness of banks as relevant for sovereign risk and to charge higher financing costs. Banks with higher sovereign exposures may also pay higher spreads, but the impact of sovereign premiums does not appear to be higher in periods of high volatility. This appears to underscore the importance of sovereign-to-bank risk transfer.

Overall, our results show that market data across countries and time may hold important clues to how systemic risk is manifested. Especially CDS markets hold great potential for empirical analysis. It is perhaps tempting during bouts of high market volatility to claim that markets are overreacting and that credit spreads in the financial markets do not correspond to fundamentals. While this may or may not be true and objectively measurable, it has to be recognized that market prices do matter for the liquidity and solvency of both sovereigns and banks, and do have real effects on overall macroeconomic outcomes. From a systemic risk perspective, it is thus important to consider how policy choices – such as the preferential treatment of sovereign debt in prudential regulation, large and undercapitalized banking sectors, or expectations of state support to banks – may influence the probability and severity of financial shocks and "twin crises." Policies such as the zero risk weighting for sovereign exposures in Basel III, the lack of large exposure limits and numerous other exemptions for banks' holdings of sovereign debt seem particularly relevant in this context. Overall, our results at the least provide grounds for caution when considering the retention of such policy measures which strengthen sovereign-bank interdependencies.

Annex: Countries and banks in sample

Table A1 shows the list of countries and banks included in this study. Our sample of 23 countries is determined largely by the availability of CDS data, i.e. the presence of an active CDS market, and reliable macroeconomic and bank balance sheet data. Our sample includes 15 countries categorized by Laeven and Valencia (2013) as having systemic banking crisis over 2007-2010, and 8 countries without.[14] Moreover, we have 13 EU members and 5 emerging economies as classified by the IMF. Banks are selected based on the existence of an active CDS market, with prices that change on at least 5 trading days within a single quarter. In general, these are the most systemically important institutions within their respective jurisdictions.

Table A1: Countries and banks used for estimations

Country	Banks
Australia*	Commonwealth Bank of Australia, Westpac Bank, ANZ Bank
Austria*	Raiffeisen Zentralbank, BAWAG, Erste Group, UniCredit Bank Austria
Belgium*	KBC, Dexia
Brazil	Banco do Brasil, Brasil Bradesco, BNDES
China	Bank of China
Denmark	Danske Bank
France*	BNP Paribas, Société Générale, Crédit Agricole
Germany	Commerzbank, Deutsche Bank
India	Bank of India, Exim Bank of India, ICICI Bank, IDBI Bank, State Bank of India
Ireland*	Bank of Ireland, Allied Irish
Italy	Intesa Sanpaolo, UniCredit, Mediobanca
Japan*	Mitsubishi, Sumitomo Mitsui, Mizuho
Netherlands*	ABN Amro Bank, ING Bank, Rabobank
Norway*	DNB Norway Bank
Portugal	Banco Commercial Portugues, Banco Espirito Santo, Caixa Geral
Republic of Korea	Industrial Bank of Korea, Kookmin Bank, Shinhan Bank, Woori Bank
Russian Federation	Alfa Bank, Bank of Moscow, VTB Bank, Sberbank
Spain	Santander, BBVA, Sabadell
Sweden*	SEB, Svenska Handelsbanken, Swedbank, Nordea
Switzerland	UBS, Credit Suisse
Turkey	Akbank, Türkiye Iş Bankası
United Kingdom*	Barclays, Lloyds, HSBC
United States*	Wells Fargo, Citigroup, JPMorgan Chase

* Countries classified as relatively market-based economies based on a ratio of bank credit in total private credit that is below the sample median.

[14] The countries without recent banking crises are Japan, Turkey, China, Brazil, India, Korea, Norway and Australia.

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