INSTITUTE
OF ECONOMICS

Scuola Superiore
Sant'Anna

LEM | Laboratory of Economics and Management

Institute of Economics
Scuola Superiore Sant'Anna

Piazza Martiri della Libertà, 33 - 56127 Pisa, Italy
ph. +39 050 88.33.43
institute.economics@sssup.it

LEM
WORKING PAPER SERIES

Bank-sovereign ties against interbank market integration: the case of the Italian segment

Susanna Saroyan [a]
Lilit Popoyan [b]

[a] Department of Banking and Finance, University of Zürich, Switzerland
[b] Institute of Economics, Scuola Sant'Anna, Pisa, Italy

2017/02 January 2017
ISSN(ONLINE) 2284-0400

Bank–sovereign ties against interbank market integration: the case of the Italian segment

Susanna Saroyan *　　Lilit Popoyan †

Abstract

This paper investigates interbank market fragmentation that results from the bank–sovereign risk nexus. We focus on the Italian market fragmentation before and within the European sovereign debt crisis. By using Italian bank and GIPSI country CDS spread changes, we suggest a new measure of sovereign/bank spillovers, based on partial correlations. Then, we examine the relationship between the sovereign-to-banks contagion risk variable and interbank market fragmentation in rates using the e-MID market data. We find that the bank–sovereign nexus is a significant source of fragmentation during the most acute phase of the sovereign debt crisis. Our findings suggest that even if the home country/bank ties impact interbank market integration seriously, the risk from other distressed countries is not negligible.

Keywords: Money market fragmentation; sovereign risk; sovereign–bank spillover, contagion, bank regulation.

JEL Classification Numbers: E42; E58; G21; G28.

*Department of Banking and Finance, University of Zürich, Andreasstrasse 15, 8050 Zürich; E-mail address: `susanna.saroyan@uzh.ch`.

†Institute of Economics (LEM), Scuola Superiore Sant'Anna, Piazza Martiri della Libertá 33 - I-56127 Pisa (Italy); E-mail address: `lilit.popoyan@santannapisa.it`.

1 Introduction

The two-way link between the conditions of sovereign states and banks has been a key threat during the recent financial turmoil. Concerns about the bank–sovereign nexus increased, when the bond yields of some peripheral euro zone governments reached unprecedented high levels following massive bank bailouts. Since then, bank–sovereign interlinkages and channels of two-way contagion have been examined by a few outstanding studies that shed light on the portfolio reshuffling of European banks towards risky sovereign bonds, especially for banks resident in troubled GIPSI (Greece, Ireland, Portugal, Spain, Italy) countries (see Battistini et al. 2014, Acharya & Steffen 2015). In its turn, this growing phenomenon provoked a fragmentation of money markets in the euro area and impaired the smooth monetary policy transmission within the money union.

This paper aims at investigating the relationship between the Italian interbank money market fragmentation (using e-MID data) and the risk nexus that relates Italian banks to distressed EU sovereigns. We provide an empirical analysis in two steps. First of all, we provide evidence for the presence of the bank–sovereign nexus between the Italian banking sector and GIPSI countries during the period between September 2008 and December 2012. We borrow methods both from the factor-model (De Bruyckere et al. 2013) and the network spillover literature (Kenett et al. 2010, 2015, Schwendner et al. 2015), to compute a new excess correlation-driven measure of sovereign-to-bank contagion using CDS premiums. At the second stage, we use this new measure to provide empirical evidence on the connection between market fragmentation and sovereign–bank ties during the European sovereign debt crisis. We focus on the Italian interbank segment mainly because our fragmentation indicator is computed using daily rates from the e-MID.[1] Our findings stress the importance of reforms that target severing bank–sovereign ties in the EU.

Banks' increasing preference for stressed sovereign debt in times of sovereign crisis finds several explanations in the literature. The first one is the "carry trade" behavior of European banks, which involves strategically investing in long term GIPSI sovereign bonds using short term refinancing from repo markets, where French and German bonds are accepted as reliable and liquid collateral with small haircuts. Acharya & Steffen (2015) argue that European banks increased their exposures to peripheral sovereign bonds even when yield spreads (GIPSI-German bund) were very wide. Moreover, the authors highlight that those purchases were partly financed by earnings from selling core country bonds (i.e. Germany, France). Thus, European banks have bet on a future drop in GIPSI sovereign bond yields, by expecting to gain both on the differences in interest rates today, and on the revaluation of risky sovereign assets tomorrow. The European Central Bank's (ECB) accommodating haircut policy for high yield sovereign bonds that serve as collateral for primary refinancing repo operations probably contributed to support this carry trade behavior of banks.

The second explanation of the increasing sovereign exposure is the home bias motivated by the moral hazard that drives GIPSI banks to continue buying home country bonds (Battistini et al.

[1] e-MID is a Milan based electronic market for interbank deposits in the euro area. It was founded in Italy in 1990 for Italian Lira transactions and denominated in Euros in 1999. The market represents 17 % of overall European interbank unsecured transactions, but is especially representative for the Italian banking sector.

2014). Banks are aware that even in the framework of a unique monetary union, like the euro area, resolution schemes will probably be national and banks will be recapitalized by their own sovereigns in case of difficulties. The case of Fortis in September 2008, when the three Benelux sovereigns (Belgium, Netherlands, and Luxembourg) bailed out their respective domestic parts of the cross-border entity, came to support the common belief that European banks become "national" once in trouble. This "implicit guarantee" (Acharya et al. 2012, De Bruyckere et al. 2013, Acharya, Drechsler & Schnabl 2014) induces banks in stressed countries to take excessive positions on distressed sovereign assets. The moral hazard mechanism that aggravates the home bias in distressed countries operates as follows: banks think that if their country goes bankrupt, their bank will collapse as well, so they can ignore the risk of their own sovereign (Battistini et al. 2014). The home bias might also result from the "moral suasion" (Acharya & Steffen 2015, Battistini et al. 2014) each member state supervisory authority exercises on its national banking system. National supervisory bodies promote home debt purchase in order to decrease their bond yield and, therefore, continue borrowing at a low price. In the European Union (EU), the regulatory power at the national level has enhanced these perverse incentives and reinforced the diabolic loops between banks and their home countries.

The application of Basel II capital adequacy rules under the EU jurisdiction supplied a favorable ground for the development of the sovereign–bank nexus during the crisis. The EU authorities have allowed supervisors to permit large banks following the IRB (Internal Rating Approach) to stay on the Standardized Approach for their sovereign exposures.[2] Under the Standardized Approach, the Capital Requirements Directive (CRD) of the European Union stipulates a zero risk weight for exposures to the European Central Bank and to member states' sovereign debt issued in the domestic currency of that member state (in Euro). This weakness of the regulatory framework makes high yield sovereign bonds costless (in terms of regulatory capital) for undercapitalized GIPSI banks and came to enhance the carry trade behavior of European banks. A similar side-effect also carries liquidity and capital requirement of the new Basel III regulatory framework (see **?**).

The main findings of this paper can be summarized as follows. In line with the sovereign–bank spillover literature (De Bruyckere et al. 2013), we provide evidence that sovereign–bank contagion risk increased during the GIPSI sovereign crisis. By observing contagion dynamics, we identify that our sovereign–bank spillover measure is closely related to both adverse events and policy interventions. The measure seems to be particularly sensitive to country's rating downgrades. We find that the bank/home country (here Italy) intertwined risks positively and significantly impact market fragmentation during the last two quarters of 2011, which corresponds to Italy's economic and political crisis. We go beyond the studies that discuss fragmentation in the context of sovereign–bank interlinkages only from the perspective of home country risk (de Andoain et al. 2014, Mayordomo et al. 2015). This paper differs from them as it investigates the extent to which

[2]The Internal Rating Based (IRB) approach allows banks to assess their credit risk using their own models with granular rating scale. The Standardized Approach prescribes external rating based positive risk weights to all except the highest rated sovereigns (AAA to AA-).

bank–sovereign ties, both with home and foreign distressed countries, are menacing for interbank market integration in terms of interest rates. We provide evidence that market fragmentation in rates is also determined by the contagion risk between the Italian banking sector and other GIPS countries.

The remainder of this paper is structured as follows: Section 2 briefly reviews the literature on sovereign–bank spillovers and wholesale money market fragmentation. In Section 3 we present data, methodology and dynamics of our original measure of the sovereign–bank dependency. Section 4 introduces variables and methods for the regression analysis of interbank market segmentation and discuss empirical results. Section 5 concludes and discusses policy implications.

2 Related literature

Notwithstanding the rapidly growing body of literature on financial contagion, there is still no consensus on the definition and identification methodologies of contagion.[3] Hence, the way it is measured varies with regard to its definition. More specifically, the existing studies dealing with financial contagion can be broadly grouped into two groups. The first group of studies defines contagion as a structural break in transmission of shocks based on increased bivariate cross-country/cross-market correlation of stock returns and/or volatility during financial distress. They try to uncover financial contagion both via linear estimation methods (i.e., Forbes & Rigobon 2002, Favero & Giavazzi 2002, Bae et al. 2003, Corsetti et al. 2005, Mink & De Haan 2013) and by introducing non-linearities (i.e., Longin & Solnik 2001, Hartmann et al. 2004, Rodriguez 2007). The second group of contributions, to whom we belong to, addresses financial contagion (spillover) as additional co-movements over and above market fundamentals during crisis periods with respect to tranquil times. To capture the excess co-movement, empirical papers predominantly use Vector Autoregressive techniques (such as contributions by Bekaert et al. 2005, Boschi 2005, Guo et al. 2011, Alter & Beyer 2014) or Factor model specifications (i.e., Corsetti et al. 2005, Dungey & Martin 2007, De Bruyckere et al. 2013). Contagion, in their view, appears due to changes in one financial market in response to changes in factors in other markets. Essentially it reflects co-movement of market returns and spillover effects are transmissions due to links between markets.

The existing empirical literature investigates various forms of spillovers, but focuses mainly on spillovers (i) between sovereign states and financial sectors (such as Ejsing & Lemke 2011, Alter & Schüler 2012, De Bruyckere et al. 2013, Acharya, Drechsler & Schnabl 2014, Alter & Beyer 2014, Angelini et al. 2014), (ii) between sovereign states (for seminal contributions see De Santis 2012, Kalbaska & Gkatkowski 2012, Metiu 2012, Aizenman et al. 2013, Beirne & Fratzscher 2013, Caporin et al. 2013), and (iii) across markets (see Blanco et al. 2005, Zhu 2006, Ammer & Cai 2011, Delatte et al. 2012). Our paper contributes to the literature on spillovers between sovereigns and the banking sector. Studies on links between sovereign and bank default (credit) risks in times of distress were rather scarce, but have grown since the onset of the Eurozone debt crisis.

[3] See contributions of Dornbusch et al. (2000), Claessens & Forbes (2001), Pericoli & Sbracia (2003), Dungey et al. (2005) and Pesaran & Pick (2007) for surveys on definition and methodologies of financial contagion.

Among those studies, Alter & Schüler (2012) provide evidence on default risk transfer between the sovereigns and their domestic banks before and after the bank bailout programs (see also Ejsing & Lemke 2011). They argue that bank bailout programs changed both the composition of banks' and sovereign balance sheets, and affected the linkage between the default risk of governments and their local banks. They found that in the period before the bank bailouts the direction of contagion was from bank credit spreads to the sovereign CDS market, and the opposite path was in operation after the bailouts. Carrying the same line of research, Alter & Beyer (2014) examine spillovers between sovereigns and banks in the euro area for a time span between October 2009 and July 2012. They find growing interdependence between sovereigns and the bank component of the spillover index only around some important EU policy interventions. They also show that in the contagion index, banks–to–sovereigns and sovereigns–to–banks components increase during the period of analysis, which provide evidence for intensifying feedback loops between euro area banks and sovereigns. Acharya, Drechsler & Schnabl (2014) and Angelini et al. (2014) provide empirical evidence of two-way interactions between sovereign and financial risk in the banks-sovereign nexus. Using credit default swap (CDS) rates on European sovereigns and banks, Acharya, Drechsler & Schnabl (2014) show that bank bailouts trigger the rise of sovereign credit risk in Eurozone countries. They also argue that post-bailout changes in sovereign CDS explain changes in bank CDS, even after controlling for aggregate and bank-level determinants of credit spreads, thereby confirming the sovereign–bank loop. In the same vein of the empirical study, Angelini et al. (2014) provide evidence on the sovereign–bank linkage based on the correlation between the CDS premiums for the sovereign and banks. They point out that the risk of a government's insolvency is a factor that spreads to the entire economy, including banks. They also highlight that the increasing home bias observed during the distress is a consequence and not a cause of the crisis.

But how can a risk from one sovereign/bank spill over into another bank/sovereign? The literature mainly emphasizes the connection between the balance sheet items of contract counterparties. In particular, they highlight the asset holding and collateral channels (see in particular BIS 2011, Angeloni & Wolff 2012, De Bruyckere et al. 2013) of risk transmission that mainly works through banks being exposed to sovereigns by holding debt, or by holding collateral in the form of sovereign debt.[4] The hypothesis of asset holding channel has been tested by De Bruyckere et al. (2013) who find that the factor model-extracted excess correlation between banks and foreign sovereigns are significantly affected by the level of direct exposures to sovereign bonds. In their recent contribution, Beltratti & Stulz (2015) provide evidence that the correlation between banks' stock prices and peripheral countries' positive or negative risk shocks are higher in the presence of direct exposures to the given sovereign. They attribute this shock transfer to a systemic contagion channel. Moreover, differently from existing bank/sovereign nexus literature, they evidence that significant risk transfer is directed from sovereigns to banks. Having this results in mind if one supposes that balance sheet exposures are the basis of the observed sovereign–bank spillovers, then the interbank

[4]Asset and collateral channels in work could be found in contributions by Caruana et al. (2012) and De Bruyckere et al. (2013).

market fragmentation that results from the stress of foreign member states could be attributed to a higher informational gap that exists between domestic and foreign lenders. From this perspective this paper joins the theoretical and empirical literature that explains the post-crisis cross-border interbank inactivity by even more pronounced informational asymmetries between foreign financial institutions (see Freixas & Holthausen 2005, Cassola et al. 2008, Abbassi et al. 2015).

Lastly, but importantly, our paper contributes to the empirical studies on financial fragmentation of euro area money markets during the European sovereign debt crisis (see seminal contributions by Manna 2011, de Andoain et al. 2014, Vari 2014, Abbassi et al. 2015, Mayordomo et al. 2015, among others). Studies on EU financial market disintegration predominantly disentangle the measurement, the determinants, and the impact of macro policy-driven interventions on fragmentation. In particular de Andoain et al. (2014) examine the degree of fragmentation of the euro area overnight unsecured money market for a time span between June 2008 and August 2013. They identify fragmentation episodes based on analysis of risk-adjusted borrowing rates and banks' ability to satisfy their funding needs, controlling for resort to short-term central bank liquidity.[5] Their contribution suggests that non-standard measures, such as long-term liquidity operations, were broadly effective in dampening market fragmentation. Following the same stream of literature Mayordomo et al. (2015) argue that bank-specific global factors (that is, financing costs and counterparty risk) and country-specific factors (that is, debt-to-GDP ratio, the economic sentiment, bank sector openness) are among the most significant factors that contributed to the high levels of fragmentation observed in the European interbank market. They also document a significant temporary decrease in fragmentation immediately after the implementation of the Securities Market Program (SMP) and the 3 year Long Term Refinancing Operation (LTRO) by the ECB. Another contribution focusing on fragmentation issues in interbank market is Vari (2014) who documents the disruptive effects of fragmentation on monetary policy transmission mechanism. His theoretical model explains how excess liquidity arises endogenously in the banking system and causes the short term interest rate to partially escape the control of the monetary authority. Moreover, Abbassi et al. (2015) show that the fragmentation during the crisis is not only a result of the elevated sovereign default risks or break-up expectations. In line with the aforementioned contributions, they argue that unconventional monetary policy measures mitigate this geographical fragmentation.

3 Measuring Sovereign–bank dependency

A Data and Methodology

An extensive literature on financial crises and propagation of shocks across countries/markets used observed increases in correlation between the returns as a measure of financial contagion.[6] Subsequently, this approach was challenged by Forbes & Rigobon (2001, 2002) who showed the

[5] Manna (2011) uses another approach and defines the fragmentation in interbank market as a domestication tendency in volumes.

[6] For early contributions see Lee & Kim (1993), Frankel & Schmukler (1996).

presence of omitted variables and heteroscedasticity in data, which may cause correlation coefficients to be biased upwards during periods of financial distress. Recent literature has examined the contagious nature of financial shocks depending on whether or not the observed degree of co-movement in returns is "excessive". For our analysis, "excess co-movement" is defined as co-movement beyond the degree that is justified by economic fundamentals. The latter method goes through computing the excess correlations between the two returns (see Bekaert et al. 2005, Kallberg & Pasquariello 2008, Bunda et al. 2009, Anderson 2012, De Bruyckere et al. 2013).[7]

In order to capture spillovers that could set a financial contagion in motion between the Italian banking sector and sovereign states across the euro area, we set up a factor model with the structure proposed by De Bruyckere et al. (2013). We do so to account for excess correlation among economic fundamentals between Italian banks and GIPSI countries, based on daily sovereign and bank CDS spread changes. In particular, we decompose CDS differentials of the Italian banking system and GIPSI sovereigns for common fundamental factors and other latent factors. It is worth mentioning that by defining the factor model we avoid the above-mentioned problem with the upward bias correction for correlations that Forbes & Rigobon (2001, 2002) propose. Moreover, due to the factor model, we effectively take a stand on the global, regional, and country-specific fundamentals, as well as the mechanism that transfers fundamentals into correlation.

As in the seminal contribution of De Bruyckere et al. (2013), for the beginning of our analysis we consider a four-factor model of CDS spread changes on individual GIPSI countries and the Italian banking sector. We adopt this model because estimated errors and thus excess correlations are expected to be more conservative compared to single-factor (iTraxx)-based models. The model controls for more possible commonality sources. We want to see if the co-movements of CDS spread changes between the Italian banking system and GIPSI countries are attributable to common factors or if there is excess co-movement due to contagion. Our factor model, given by Equation 1-2, aims to shed light on spillover effects in the bank–sovereign nexus.

$$\Delta CDS_{ITb,t} = \alpha_0 + \sum_{k=1}^{n} \alpha_k f_{k,t} + \epsilon_{ITb,t}, \qquad k = 1,..,4 \tag{1}$$

$$\Delta CDS_{c,t} = \beta_0 + \sum_{k=1}^{n} \beta_k f_{k,t} + \epsilon_{c,t}, \qquad k = 1,..,4 \tag{2}$$

In Equation 1 $\Delta CDS_{ITb,t}$ stands for daily change in CDS premiums of the Italian banking sector. To reflect the credit risk of the overall Italian banking sector, we compute average CDS spreads of Italian banks for which CDS quotes are available.[8] $\Delta CDS_{c,t}$ is a specified GIPSI country CDS spread change and reflects the default risk for each GIPSI country separately.[9] $f_{k,t}$ denotes fundamental factors, and $\epsilon_{ITb,t}$ and $\epsilon_{c,t}$ are the corresponding error terms.

[7]Essentially, it is the correlation between the residuals of the factor model.

[8]While computing the average CDS spread of Italian Banking sector the following banks are considered: Unicredit, Banca Monte dei Paschi di Siena, Intesa Sanpaolo, Banco Popolare - Societa Cooperativa, Banca Popolare di Milano, Banca Nazionale del Lavoro, Mediobanca, and Banca Italease.

[9]Index c stands for GIPSI sovereign states, namely Greece, Italy, Portugal, Spain, and Italy.

The factor model specification requires a strong stance on fundamentals, as well as the form by which fundamentals affect changes in CDS spreads. Prior research has already uncovered several factors that determine changes in banks' CDS spreads (see in particular Berndt & Obreja 2010, De Bruyckere et al. 2013, Angelini & Di Febo 2014).[10] We base the factor model specification on the contribution of De Bruyckere et al. (2013), and hence conditioned the change in CDS spread on four factors. With $f_{1,t}$, we control for the general market risk in the euro area by using the *iTraxx Europe* index, which refers to 125 European investment grade corporate CDSs (including financials), reflecting the overall credit performance of the Eurozone's real economy.[11] The second factor $f_{2,t}$ is the *VSTOXX.* volatility index, which is based on the EURO STOXX 50 real time options prices. It is designed to reflect the market expectations of near-term to long-term volatility by measuring the square root of the implied variance across all options of a given time to expiration. The *VSTOXX* index is a barometer measuring market sentiment of participants on volatility in the European market. As a third factor $f_{3,t}$ we include the *Total market index* for the EU, which consists of approximately 1950 EU stocks including non-financials and through which we control for business climate change in EU. Finally, with factor $f_{4,t}$, we control for market expectations about future conditions in the financial market, measured with the *Term Spread.* The *term spread* is measured as the difference between the yield on a 10-year euro area GIPSI country government bond and the 1-month Euribor rate expresses in basis points. All fundamental factors and CDS spread changes related data are obtained from the *Thomson Reuters Datastream* database.[12] Table 1 below displays summery statistics for CDS spread changes and for state variables used for computing error correlations in this first stage of the analysis.

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
$\Delta CDS_{ITb,t}$	0.184	8.381	-42.447	50.687	1160
$\Delta CDS_{IT,t}$	0.164	11.203	-79.984	89.367	1175
$\Delta CDS_{GR,t}$	1.77	25.147	-277.775	173.25	847
$\Delta CDS_{IR,t}$	0.088	15.423	-137.214	101.177	1175
$\Delta CDS_{SP,t}$	0.167	10.909	-75.244	61.305	1175
$\Delta CDS_{PT,t}$ in %	0.303	24.969	-199.905	187.605	1175
TermSpread_IT in bp	291.369	137.151	-92.83	581.24	1161
TermSpread_IR in bp	439.153	220.687	-123.36	976.58	1161
TermSpread_GR in bp	1185.274	1089.72	-90.31	5740.440	1161
TermSpread_SP in bp	299.665	155.903	-120	647.17	1161
TermSpread_PT in bp	537.463	367.631	-109.08	1453.84	1161
iTraxx Europe	125.514	33.99	65.3	215.917	1175
Total market index	1338.969	192.038	803.170	1855.48	1175
VSTOXX	30.128	10.426	15.65	87.510	1175

Table 1: Summary statistics for state variables and CDS spread chnages

[10] In factor models that tend to explain the changes in CDS premia, models with the iTraxx index dominate.

[11] We choose the iTraxx Europe index because it tracks the European risk more closely than other commonly used measures of general risk, such as VIX (CBOE volatility index) and the Bank of America BBB spread.

[12] We miss data for CDS premiums for Greece sovereign between May 2011 and September 2012 because CDS on Greek debt stopped being traded in the market (for more on this issue see Martin & Waller 2012).

B A measure of sovereign–bank dependency

In order to investigate the influence of a specified GIPSI country credit risk on the Italian Banking sector and to disentangle credit risk spillover effects in sovereign–bank pairs, we use two notions of co-movements in CDS spreads computed on a month-by-month basis: (i) The partial correlations between the Italian banking sector and individual GIPSI country CDS changes, given fundamental factors ($\hat{\rho}_{IT,c:f}$)[13] and (ii) partial correlation between the Italian banking sector and a specified country of CDS changes, given fundamental factors and the CDS change of a third country z different from the specified country c ($\hat{\rho}_{ITb,c:f,z}$).[14] Note that partial correlations $\hat{\rho}_{ITb,c:f}$ and $\hat{\rho}_{ITb,c:f,z}$ between variables $\Delta CDS_{ITb,t}$ and $\Delta CDS_{c,t}$ are excess correlations or so called residual correlation coefficients of $\Delta CDS_{ITb,t}$ and $\Delta CDS_{c,t}$ that are not correlated with f and $\Delta CDS_{z,t}|z \neq c$. Hence, $\hat{\rho}_{ITb,c:f}$ is the same as the correlation between the error terms $\epsilon_{ITb,t}$ and $\epsilon_{c,t}$ from Equations 1 and 2: To compute $\hat{\rho}_{ITb,c:f}$ we make a monthly regression with daily frequency data. A small value of $\hat{\rho}_{ITb,c:f}$ may imply that fundamental factors strongly affect the correlation between $\Delta CDS_{ITb,t}$ and $\Delta CDS_{c,t}$. Accordingly, jumps in correlations are fundamental factor driven. On the contrary, a large value of $\hat{\rho}_{ITb,c:f}$ may account for a small contribution of fundamental factors f to the correlation between $\Delta CDS_{ITb,t}$ and $\Delta CDS_{c,t}$ implying that either $\Delta CDS_{ITb,t}$ and $\Delta CDS_{c,t}$ influence each other directly or that the correlation is by virtue of some other factors. Note, however that this variable does not give an unambiguous answer regarding whether there is a spillover or not, since a small value of $\hat{\rho}_{ITb,c:f}$ can be due to a small third-order partial correlation coefficient included in the computation of $\hat{\rho}_{ITb,c:f}$.

Analyzing the magnitude of the impact of factors that are not related to economic fundamentals f (that is, contained in residuals) make sense only if we make a comparison with the simple correlation (see more on comparison of simple and excess correlation in the seminal paper of Bunda et al. 2009). The partial correlation above shows the correlation that is not attributed to fundamentals, but it does not give information as to what extent non fundamentals factors are important in explaining the correlations as compared to fundamental factors.

Using the theoretical background proposed by Kenett et al. (2010) and Kenett et al. (2015), we disentangle spillover effects in the bank–sovereign nexus by using the partial (excess) correlation concept. Based on this methodology, we can quantify the net influence of a particular sovereign's credit risk on the risk of the Italian banking sector, excluding the impact of economic fundamentals. In our study, credit risk is manifested in the changes in bank and sovereign CDS spreads. The new measure allows for the isolation of the influence of a third company's stock return on correlation of the returns of two different companies, once the impact of fundamental factors are already removed from the correlation between those two variables. Analogously, to assess the influence of the $\Delta CDS_{z,t}$ on the $\Delta CDS_{ITb,t}$ and $\Delta CDS_{c,t}$ pair, we compute the quantity $d_{ITb,c:z}$, which allows for the isolation of the impact of common fundamental factors and assesses the effect of $\Delta CDS_{z,t}$

[13]For the sake of notational convenience we denote with f the presence of all fundamental factors in partial correlation formula, e.g. $\hat{\rho}_{ITb,c:f} = \hat{\rho}_{ITb,c:f_1,f_2,f_3,f_4}$.

[14]The theoretical basics of computation of the partial correlation can be found in Appendix A.

on the residual correlation dynamics:

$$d_{ITb,c:z} = \hat{\rho}_{ITb,c:f} - \hat{\rho}_{ITb,c:f,z}. \tag{3}$$

The first component of Equation 3 $\hat{\rho}_{ITb,c:f}$ stands for the excess correlation or residual correlation driven from the factor model described by Equations 1 and 2. While the second, less familiar, component $\hat{\rho}_{ITb,c:f,z}$ represents the partial correlation between the CDS changes of the Italian banking sector and a country c given fundamentals, and the risk of a third country z.[15] Variable $d_{ITb,c:z}$ is large when a significant fraction of the partial correlation $\hat{\rho}_{IT,c:f}$ can be explained in terms of $\Delta CDS_{z,t}$. On the contrary, a small value of $d_{ITb,c:z}$ indicates a small contribution of $\Delta CDS_{z,t}$ to the partial correlation $\hat{\rho}_{IT,c:f}$. At this juncture, $d_{IT,c:z}$ can be viewed either as the partial correlation dependency of $\hat{\rho}_{ITb,c:f}$ on $\Delta CDS_{z,t}$, or as the correlation influence of $\Delta CDS_{z,t}$ on the partial correlation $\hat{\rho}_{ITb,c:f}$.

Further, we follow the methodology introduced by Kenett et al. (2010) and define the average influence $d_{ITb:z}$ of the series $\Delta CDS_{z,t}$ on the correlation between $\Delta CDS_{ITb,t}$ and GIPSI country c CDS change series by summing up the partial correlations $d_{ITb,c:z}$ of every pair of the Italian banking sector and GIPSI country CDS change:

$$DmeanZ = \mid d_{ITb:z} \mid \equiv \langle \mid d_{ITb,c:z} \mid \rangle_{c \neq z} \tag{4}$$

It approximates the monthly net influence of country z's risk on the risk of the Italian banking sector, excluding the impact of common factors. For the sake of simplicity, we use the absolute value of $d_{ITb,c:z}$ for Equation 4. Such a choice is motivated by the nature of $DmeanZ$ variable. Being a measure to assess the impact of individual country risk on residual correlation dynamics $DmeanZ$ is composed of the sum of linear differences ($d_{ITb,c:z}$). The latter, in its turn, can provide also negative values (even if in the majority of cases the values are positive) and in the sum can be canceled out.

C Dynamics of the dependency measure

Focusing on $DmeanZ$ as the quantitative measure to identify potential spillovers between GIPSI sovereigns and the Italian banking system (see Equation 4), we analyze the impact of country-specific and euro zone-wide economic/policy events on the spillover dynamics through the time span of July 2008 – December 2012. We treat the procedure to be a preliminary but important qualifying check for the measure $DmeanZ$ to fit the data with historical events. Note that a $DmeanZ$ significantly different from 0 reflects a high influence of specified GIPSI country z CDS spread change on the correlation structure of the Italian banking sector and all remaining GIPSI countries not considering z itself. Essentially, it will provide evidence for high excess co-movement

[15]The risk of Greece might determine the co-movements of CDSs of the Italian banking sector and another country in the system, via concerns about the common currency (euro) or via overlapping portfolio exposures. If, for example, Spanish banks and Italian banks are commonly exposed to Greek sovereign debt, then changes in Greek CDSs can impact both the CDS of Spain (via its banking sector) and the CDS of the Italian banking sector.

(spillover) from a GIPSI sovereign to Italian banks due to the impact of country z and, on the contrary, if $DmeanZ$ is close to 0, it provides evidence for a relative absence of spillovers from GIPSI country z to Italian banks.

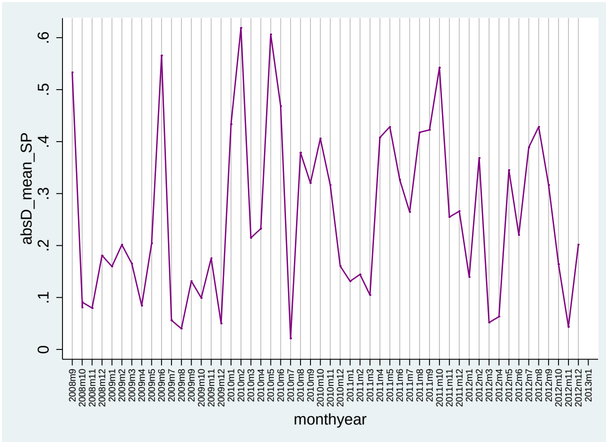
Due to the financial turmoil triggered by the Lehman Brothers bankruptcy in September 2008, a majority of governments in EU countries and the ECB were forced to take actions on crisis events to support failing financial institutions. This has triggered a partial transfer of credit risk in the sovereign–bank nexus, thus allowing the problems to foster spillovers to banking structures of other countries. Figure 1 and Figure 2 present the overall picture of spillover dynamics from GIPSI sovereigns (including domestic sovereign) to Italian banks through the measure of $DmeanZ$. The European policy and country-specific events we are interested in are summarized in Table 3. It is worth mentioning that the dynamics of $DmeanZ$ display similar pattern as the excess correlation measure developed by De Bruyckere et al. (2013), but the magnitude of the spillovers are notably smaller.

The dynamics of $DmeanZ$ documents risk spillover from GIPSI sovereigns to the Italian banking system in response to sovereign rating news, such as downgrades. The literature on spillovers is already familiar with the contagious nature of downgrades in European financial market through both the "wake-up call" and hedging channels (see in particular Arezki et al. 2011, Afonso et al. 2012, Giordano et al. 2013). Our measure $DmeanZ$ appears to be very sensitive to rating downgrades, showing an appearance of risk spillovers when rating companies announce a downgrade on any of GIPSI countries sovereign or credit rating. Particularly, a transmission of Greece rating downgrade news to the Italian banking system is more evident when at the end of December 2009 Fitch, S&P, and Moody's simultaneously cut Greek debt rating and, subsequently, at the end of April, S&P downgraded Greek debt to BB+ and Portuguese debt to A-. If we look at the impact of Spain's downgrades, $DmeanZ$ documents increasing risk transfer after S&P and later on Fitch and Moody's announced Spain rating downgrades during April, May, and September of 2010, respectively. During October of 2011, Spain was downgraded both by S&P and Fitch finding upwards dynamics in the measure of $DmeanZ$. If we look at the impact of the Portuguese sovereign on the Italian banking sector, downgrades in January 2009 by S&P and further rating cuts by Fitch (March, 2010) and S&P (April, 2010) generated an increasing level of $DmeanZ$.[16]

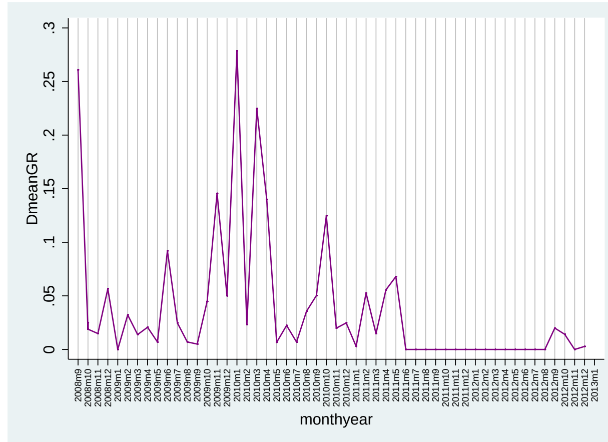
A potential channel through which "unfavourable news" on sovereign ratings may spill over across countries and across financial markets passes through the asset side of banks' balance sheet.[17] One channel is the holding of foreign sovereign debt by domestic banks. A sovereign rating downgrade in a given GIPSI country is likely to affect the profitability of banks in other countries where banks are holding this debt making the balance sheet more vulnerable. This is the case in Europe where banks hold, at times, substantial amounts of sovereign debt in both their trading and banking books (see also Blundell-Wignall & Slovik 2010, Angeloni & Wolff 2012). Another channel

[16]Detailed information on rating downgrades of GIPSI countries are presented in Table 3 together with the date of event and the description.

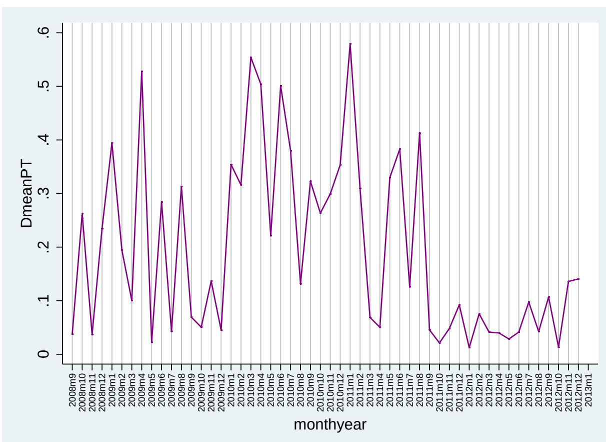
[17]For more comprehensive discussion of the channels through which sovereign credit rating announcements may spill over to other markets see the seminal work of Sy (2009).



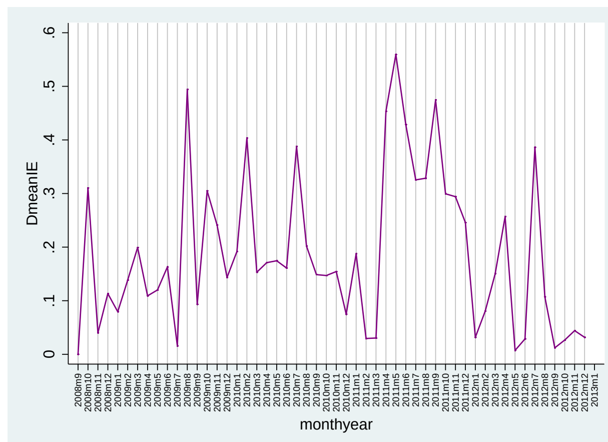
(a) Impact of Spain on IBS and GIPSI countries CDS change correlations



(b) Impact of Greece on IBS and GIPSI countries CDS change correlations



(c) Impact of Portugal on IBS and GIPSI countries CDS change correlations



(d) Impact of Ireland on IBS and GIPSI countries CDS change correlations

Note: Closer the measure DmeanZ $=\mid d_{ITb:z} \mid$ *is to 0, the weaker is the impact of the second country CDS change on correlation between the Italian banking system average CDS change and specified GIPSI country pair. The absence of data in Figure (b) is due to the fact that CDS on Greek debt stopped trading when markets gave Greece a 50% percent chance of default.*

Figure 1: Impact of specified country on the Italian banking system and GIPSI country CDS change correlation structure

through which sovereign rating news may spill over across countries and markets is when banks in one country hold claims on banks in other countries and are thus exposed to one another. This cross-holding feature is at the core of the European financial market convergence process in Europe.

Except the sovereign downgrades, our results document increasing spillover dynamics during key financial market adverse events and policy interventions. We started from Lehman's collapse in September 2008, and we detect the first common spillover from all the GIPSI sovereigns to the Italian banking system, which amplifies during the European debt crisis taking place since the end of 2009. In particular, an increasing spillover dynamic leaking from the distressed Greek sovereign

Date	Event
21 Jan 2009	S&P Downgrades Portugal sovereign credit rating from AA- to A+ with negative outlook.
30 Mar 2009	S&P downgrades Ireland to AA+ from AAA.
8 Jun 2009	S&P downgrades Ireland sovereign dept.
8 Dec 2009	Fitch cuts Greece debt rating to BBB+ from A1, a day after S&P warned of a downgrade.
16 Dec 2009	S& P cuts Greece debt rating to BBB+ from A-.
22 Dec 2009	Moody's downgrades Greece debt to A2 from A1.
24 Mar 2010	Fitch cut Portugal's sovereign credit rating by one notch to AA-.
27 Apr 2010	S&P downgrades Greece (to BB+) and Portugal (to A-).
28 Apr 2010	S&P downgrades Spain (to AA-).
28 May 2010	Fitch downgrades Spain from AAA to AA+.
30 Sep 2010	Moody's downgrades Spain to Aa1.
15 Dec 2010	Moody's puts Spain on review for a possible downgrade.
9 May 2011	S&P downgrades Greece's sovereign credit rating from BB- to B.
13 Jun 2011	Greek credit rating is downgraded to CCC by S&P.
5 Aug 2011	S&P downgrades U.S debt to AA+ from AAA.
21 Sep 2011	S&P have downgraded 7 Italian banks after they have dropped Italy's sovereign rating 2 days ago.
7 Oct 2011	Fitch cuts Italy's credit rating from AA- to A+ and Spain's rating to AA- from AA+.
13 Oct 2011	S& P cut Spain's long-term credit rating by one notch from AA to AA- with negative outlook.
8 Dec 2011	Fitch cuts Greece rating to BBB + from A-, with a negative outlook.
22 Dec 2011	Moody's cuts Greece rating to A2 from A1.
13 Jan 2012	S&P downgrades France, Austria (from AAA), Spain, Italy and five other Eurozone members.
14 Fab 2012	Moody's Downgrades Six European Sovereigns including Italy, Portugal, Slovakia, Slovenia and Spain.
16 Jan 2012	S&P downgrades EFSF from AAA to AA+.

[a] ***Source:*** *BIS, Financial Times, Bloomberg, Thomson Reuters*

Table 2: Timeline of rating events

to Italian banks are documented first, during October-November 2009, after the Greek government revealed a revised budget deficit of 12.7% of GDP for 2009 (which was double the previous estimate) and then in January 2010, after the critical report of the European Commission on the Greek debt and deficit. The measure *DmeanZ* detects increasing spillovers from GIPSI sovereigns during rescue packages concerning Greece (first one in May 2010, and the second in June 2011), Ireland (December 2010), and Portugal (May 2011). Moreover, *DmeanZ* is sensitive to the rise and fall of the ECB refinancing rate. Notably, the upward spillover dynamic is detected on April 2011 when ECB raised its refinancing rate by 25 basis points to 1.25% and then raised the rate by another 25 basis points to 1.50% in July, being more focused on inflation risks.

The results reveal several policy-related actions to have had a decreasing impact on spillover dynamics. In May 2009, the ECB announces the European Financial Stabilization Mechanism (EFSM) together with liquidity-providing longer-term refinancing operations (LTROs) with full allotment and a maturity of one year (1Y LTRO), which brings a decline in risk transfer from the GIPSI sovereigns to Italian banks. The severe stress in the European banking system finally started to subside when Mario Draghi took over as ECB president on November 1, 2011. Two days after he became ECB president, the ECB cut its refinancing rate by 25 basis points to 1.25%. Then, in December, the ECB cut the refinancing rate by another 25 basis points to 1.00%. More importantly, the ECB at its meeting on December 8 (2011), announced that it would conduct two 36-month longer-term refinancing operations (LTROs), one in late December and one in February.

Date	Event
15 Sep 2008	Lehman Brothers bankruptcy.
5 Nov 2009	The Greek government reveals a revised budget deficit of 12.7% of GDP for 2009.
12 Jan 2010	The European Commission publishes a report criticizing the Greek budget deficit.
2 May 2010	Greek bailout of 110 billion EU-IMF support package is announced.
9 May 2010	The European Financial Stabilization Mechanism (EFSM) is announced.
28 Nov 2010	The Irish government accepts a 68 billion EU-IMF support package.
3 May 2011	The Portuguese government accepts a 78 billion EU-IMF support package.
7 Apr 2011	ECB raises its main refinancing rate by 25 bps to 1.25%.
7 Jul 2011	ECB raises its main refinancing rate by 25bps to 1.50%.
21 Jul 2011	Eurozone officials agree on a second rescue package for Greece.
8 Dec 2011	ECB cuts refinancing rate by 25 bps to 1.00% and announces two (LTROs) with full allotment.
21 Dec 2011	ECB decided on 1st longer-term refinancing operations (LTROs) with a maturity of 36 months.
29 Feb 2012	ECB launched the 2nd longer-term refinancing operations (LTROs) with a maturity of 36 months.
18 Apr 2012	Italy's government revises its 2012 GDP forecast downward to -1.2% from -0.5%.
5 Jul 2012	ECB cuts its main refinancing rate by 25 basis points to 0,75%.
26 Jul 2012	Mario Draghi's famous speech.

[a] ***Source:*** *BIS, Financial Times, Bloomberg, Thomson Reuters*

Table 3: Timeline of financial market and policy intervention events

These two LTROs provided a total of 1.019 trillion euros worth of 36-month loans to more than 800 European banks. The LTROs gave the banks the funding they could not easily obtain in the interbank or bond markets and greatly reduced the chances of a European bank failure. In addition, many European banks used the cash they borrowed at 1.00% to buy European sovereign bonds at much higher yields, thus locking in a guaranteed spread as long as the sovereign did not default. Finally, the implementation of the 25 basis point cut in the refinancing rate to 0.75% by the ECB (July 5, 2012) and Mario Draghi's famous speech on 26 July 2012 decreased the spillover dynamics from sovereigns to Italian banks.[18] The ECB also cut its deposit rate to zero, which meant that banks holding reserves on deposits with the ECB would no longer receive any interest on those deposits. The purpose of the cut in the deposit rate to zero was to encourage banks to find more useful outlets for their cash, such as lending it to other banks in the interbank lending market, to buy fixed-income securities to bring down interest rates on sovereign and corporate bonds, or to make new loans to businesses and consumers to stimulate the economy.

If we focus on the impact of rating downgrades and policy events that are directly connected only to the Italian sovereign, we see the following picture (see Figure 2). Italian sovereign rating downgrades produced increasing risk transfer from the domestic sovereign to the Italian banks. In particular during September–October of 2011, when S&P downgraded 7 Italian banks after they dropped the Italian sovereign rating one day ago. In the same month, Fitch also cut Italy's rating from AA+ to AA-. An important indicator of the situation was the record high price of Italy's 5-year credit default swap (the price of insuring against a sovereign default) on a daily basis (591basis points). Afterwards, in January 2012, S&P downgraded France, Austria, Spain, Italy and five other Eurozone members dropping Italy's rating to BBB+, finding an increasing spillover

[18]This level of refinancing rate was the lowest level in the ECB's history and even lower than the 1.00% rate seen in the immediate aftermath of the 2008/2009 financial crisis.

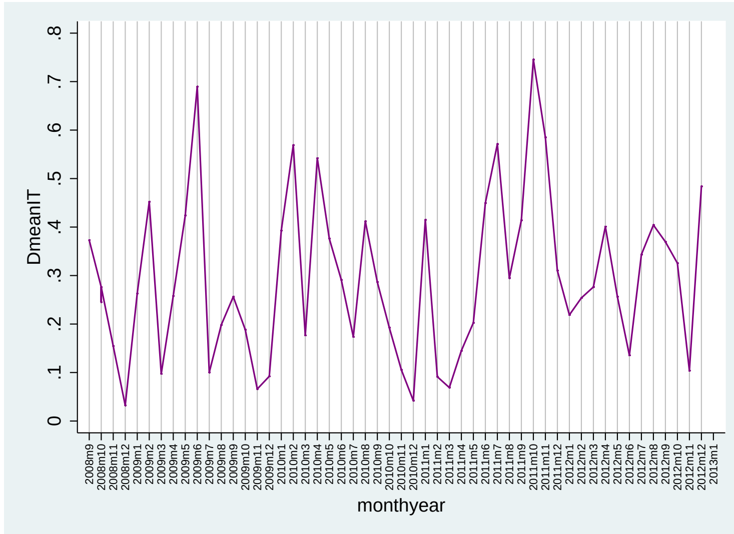


Figure 2: Impact of Italian sovereign on the Italian banking system and GIPSI country CDS change correlation structure

dynamic in risk transfer from Italian sovereign to the domestic banking system. An increasing spillover is also detected during April 2012, when Italy's government revised its 2012 GDP forecast downward to -1.2% from -0.5%. Consequently, Italy delayed its balanced budget by two years, from 2013 to 2015. Italy raised its 2013 deficit target to +0.5% of GDP from +0.1%.

4 Interbank market fragmentation

A Regression analysis and variables

In this section we try to understand to what extent sovereign–bank ties impair the integration of the Italian interbank market. Thus, we run a simple bank fixed effect regression model, with $FragRateIT_{i,t}$ as a variable to explain both by our contagion variables $DmeanZ_t$ and macroeconomic control variables $Controls_t$ that have been already used in the existing literature (see Mayordomo et al. 2015). We run an interaction term only fixed effect regression model specified as follows:

$$FragRateIT_{i,t} = \alpha + \beta_{Z,T} \times DmeanZ_t \times D_T + \gamma_{Z,T} \times Controls_t \times D_T + \sigma * Bank_i + \epsilon_{i,t} \quad (5)$$

A.1 Dependent variable: Interbank market fragmentation

The dependent variable in the Equation 5 above represents the level of fragmentation of the Italian banking sector from the overall European interbank market. $FragRateIT_{i,t}$ is computed for each Italian borrowing bank i as a monthly spread that represents the level at which cross-border and domestic interbank rates diverge. We compute $FragRateIT_{i,t}$ as follows:

$$FragRateIT_{i,t} = RateFORtoIT_{i,t} - minRateITtoIT_t \quad (6)$$

$FragRateIT_{i,t}$ is the difference between the weighted average cross-border borrowing rate each domestic bank i pays within the month t (denoted as $RateFORtoIT_{i,t}$) and a benchmark $minRateITtoIT_t$, which is the minimum domestic borrowing rate of the given month t. The higher is $FragRateIT_{i,t}$, the smaller is Italian segment's integration to the overall European interbank market.

To compute our measure of fragmentation, we use daily overnight borrowing rates from e-MID micro-data. e-MID is a Milan-based trading platform that enables European banks to match their daily liquidity needs. It was considered a representative market for European overnight interbank transactions, at least until the Italian debt crisis of summer 2011 (see Beaupain & Durre 2012, Arciero et al. 2014). Our dataset comprises e-MID overnight transactions spanning from October 2008 to December 2012. We conduct our analysis centralizing the Italian banks forming approximately 68% of the banks and 84% of total volume turnover under the considered period. However, as emphasized by Brossard & Saroyan (2016), e-MID also exhibited significant domestication tendencies in volumes, at the end of 2009.[19] The authors mention that this period coincides with the unprecedentedly high correlation coefficients between CDS spreads of European banks and stressed peripheral sovereigns (see also Panetta et al. 2011). The disintegration of the European wholesale money market both in rates and volumes is not limited to e-MID, as studies using Target 2-extracted interbank data show similar patterns in the overall European market (see Abbassi et al. 2015, de Andoain et al. 2014).

We compute $FragRateIT_{i,t}$ for the period of acute European sovereign/bank stress, ranging from October 2008 to December 2012, for 109 Italian banks borrowing cross-border. Figure 3 below displays the monthly average $FragRateIT_{i,t}$.

Note, that evident breakpoints are observable in this variable's movements. Figure 3 shows high fragmentation during the post-Lehman period which decreased progressively after the ECB's intervention in October 2008.[20] However, the market became fully integrated only after May 2009, when the ECB first announced its 1 year Long Term Refinancing Operations (1Y LTROs). Since May 2010, when the sovereign debt crisis officially started with the bailout of Greece, Italian cross-border rates started to diverge from domestic ones again. One can distinguish two rounds of fragmentation during the GIPSI crisis period. The first phase covers the first bailouts of Greece and Ireland, between *June 2010 to March 2011*. Fragmentation in rates on the e-MID market became even higher during the second phase of the sovereign crisis, ranging from April 2011 (including Portugal's bailout) to December 2012. Within this subperiod of the sovereign crisis, markets assigned Greece 50% of default chance on its debt, and other, less suffering peripheral countries,

[19] Note that Greek government communicated the country's fiscal difficulties in October-November 2009. See the event timeline in Table 3.

[20] On October 8, 2008, the ECB announces the passage to the Fixed Rate Full Allotment MROs (Main Refinancing Operations) and enlarges the list of eligible collaterals for MROs.

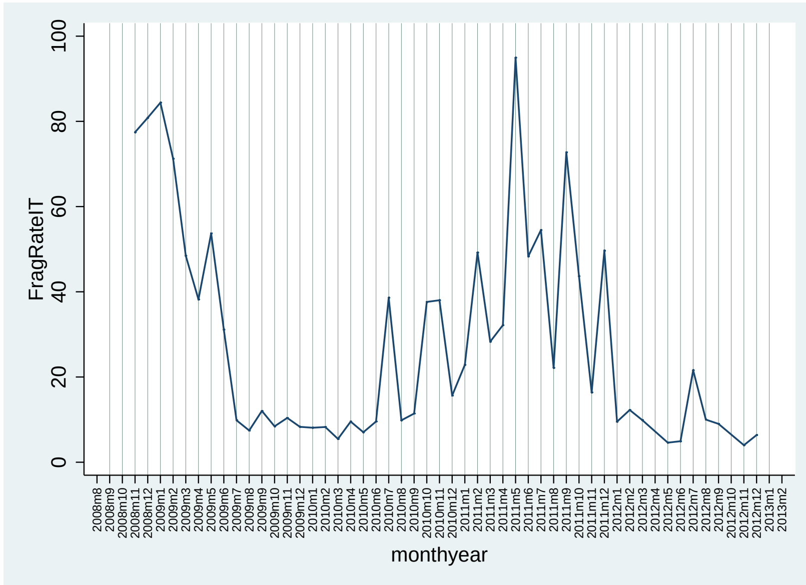


Figure 3: Monthly average fragmentation in rates

like, Italy and Spain entered into fiscal and political crisis as well (for Italian case see Zoli 2013). The e-MID market became relatively integrated again starting from January 2012, after the ECB announced its three year LTROs. This dynamic is in line with the findings of Mayordomo et al. (2015), who provide evidence of an improvement in integration following the announcements of some of the ECB's interventions, especially the 3 year LTRO.

A.2 Explanatory variables

We expect the sensitivity of fragmentation to sovereign–bank contagion risk to become stronger during the bank/sovereign crisis and subsequently smaller with the ECB's policy communications and interventions in 2012. Therefore, we regress $FragRateIT_{i,t}$ over contagion variables $DmeanZ$ (defined in Section 3) and other macroeconomic variables $Controls_t$ (discussed below) crossed with a set of time dummies denoted as $D_T = D_1, D_2, D_3, D_4$. The first period dummy D_1 is equal to 1 during the period running from October 2008 to May 2010, and 0 otherwise. D_1 controls for the pre-sovereign crisis sub-period. The second dummy D_2 is equal to 1 for the sub-period running from June 2010 to March 2011, and 0 otherwise. This sub-period corresponds to the first phase of the European sovereign debt crisis which incorporates Greek and Irish first bailouts. The third dummy D_3 captures more acute stage of sovereign debt crisis and market fragmentation and is equal to 1 for the time interval running from April 2011 to November 2011, and 0 otherwise. During this second phase of sovereign debt crisis, Greece and Ireland were in deep fiscal and political stress (implying consecutive bailouts for both countries), and new countries, such as Italy and Spain, were encountering fiscal difficulties. Finally, we define D_4 that takes the value 1 for the sub-period running from *December 2011 (when the ECB announced its 3 year LTROs) to December 2012*, and

0 otherwise. Within this time span, precisely in June 2012, Mario Draghi made his famous London speech by showing the ECB's determination to maintain a harmonized monetary union and to dampen concerns about the euro.

Equation 5 below includes also macroeconomic control variables $Controls_t$ which are crossed with the set of time dummies D_T. $Controls_t$ is a set of four control variables including the debt-to-GDP ratio ($Debt-to-GDP$), the economic sentiment index (ESI),the banking sector openness ($BSOpen$), and the size of the financial sector in Italy ($SizeFS$). Most of these variables are only available on the quarterly basis, whereas our dependent fragmentation measure is computed monthly (see equation). Thus, we chose to use one-quarter lags for all $Controls_t$ variables.

We obtained some of the control variables, such as $Debt-to-GDP$ and ESI from Eurostat database in pure basis. We treat the debt-to-GDP to be a valid indicator of solvency and credit-worthiness for an individual country, and hence we expect the sign to be positive. Using the same data source, we measure the size of the financial sector as a part of Italy's GDP attributable to country's financial sector. We use the natural logarithm of the variable denoted as $SizeFS$ in our regression model. Lastly, our variable of banking sector openness $BSOpen$ is constructed using the BIS locational banking statistics data.[21] It is measured as a ratio of aggregated external loans and deposits of Italian domestic (BIS reporting) banks to the country's GDP. The summary statistics for both control- and spillover- variables are displayed in Table 4 below.

In order to account for bank specific permanent effects, we incorporate borrower dummies $Bank_i$ in our fixed effect regression. However, as emphasized by Petersen (2009) and Thompson (2011), in panel form data adding fixed bank effects might not be sufficient to obtain unbiased standard errors, if temporary firm effects are present. Temporary firm effects imply that within-bank correlation of standard errors changes (dies) over time. Thus, we run regressions both with heteroskedasticity-robust standard-errors (without clustering) and with standard-errors clustered at borrower level. We find that standard errors are more conservative in the second case. Therefore, further, in Section B we chose to report regression results with standard errors adjusted for borrower level clustering.

Variable	**Definition**	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**N**
$FragRateIT_{i,t}$	I-b market fragmentation	0.313	0.314	0.01	1.569	1087
$DmeanGR_t$	Spillover between GR sov.and IT banks	0.038	0.064	0	0.279	1117
$DmeanIT_t$	Spillover between IT sov.and IT banks	0.293	0.168	0.032	0.746	1117
$DmeanIE_t$	Spillover between IE sov.and IT banks	0.187	0.144	0	0.560	1117
$DmeanSP_t$	Spillover between SP sov.and IT banks	0.258	0.163	0.021	0.619	1117
$DmeanPT_t$	Spillover between PT sov.and IT banks	0.197	0.166	0.012	0.579	1117
$Debt-to-GDP$	Debt-to-GDP ratio	117.83	6.036	104.7	127	1131
$SizeFS$	Size of financial sector	23.661	0.046	23.562	23.751	1131
$BSOpen$	Banking sector openness	0.409	0.034	0.364	0.528	1131
ESI	Economic sentiments index	92.496	8.999	74.2	105.2	1131

Note: Interbank market fragmentation and spillover variables are computed on monthly bases. Instead, the mac-mroeconomic control variables are included on quarterly bases.

Table 4: Summary statistics of the whole sample

[21] https://www.bis.org/statistics/bankstats.htm

B Regression results

In this subsection we present empirical results about the impact of our spillover measure on interbank market integration in rates. As discussed in Section 2, existing works show that during the last bank/sovereign crisis, contagion took place in two directions: first from banks to sovereigns, and then the reverse, when sovereigns were fiscally weakened after rescuing international banks (Acharya, Drechsler & Schnabl 2014). Often, two-sided contagion is present simultaneously, as shown by Alter & Beyer (2014) and Gómez-Puig et al. (2015). Moreover, authors talk about negative feedback effects that generate contagion loops.[22] Our spillover measure computed at a monthly frequency approximates the influence of individual GIPSI sovereign credit risk on Italian banks. Results from our fixed effect interaction-term specification are displayed in Table 5 below.[23] Estimated coefficients of $DmeanZ_t$ (in rows) crossed with time dummies D_T (in columns) present the sensitivity of the spread $FragRateIT_{it}$ to sovereign–bank spillovers given the time period.

As expected, the positive sign and the significance of $DmeanIT_t \times D_3$ signal that sovereign–bank interlinkages menaced the integration of the Italian interbank market during the second stage of the sovereign debt crisis ($D_3 = 1$), when Italy itself was in trouble. In terms of magnitudes, our results suggest that when the spillover variable (which is less than one) increases by one standard deviation (see Table 4 for summery statistics), then the average $FragRateIT_{it}$ grows by 20 basis points ($1.159 * 0.168(SD) \approx 0.2\%$). Our findings are in line with de Andoain et al. (2014), who show that Italian banks have started to pay a significantly high home premium since summer 2011, which increased even more in fall 2011. More specifically, the sign and the significance of the estimated coefficient of $DmeanIE_t \times D_3$ (see Table 5), shows that during this most acute stage of debt crisis (for $D_3 = 1$), the average fragmentation of the Italian interbank sector is about three times more sensitive to the changes in $DmeanIE_t$ than to those in $DmeanIT_t$. Precisely, one standard deviation increase in the variable $DmeanIE_t$ would imply on average an increase of 67 basis points ($4,618 * 0,114(SD) \approx 0.67\%$) of the $FragRateIT_{it}$ spread.

According to the estimated coefficients of $DmeanIE_t \times D_2$ and $DmeanGR_t \times D_2$, within the first period of sovereign debt crisis (i.e. $D_2 = 1$), the integration of the Italian banking sector deteriorates when spillovers from Ireland and Greece get higher. Unfortunately, we were unable to compute the $DmeanGR_t$ variable for further periods when the default risk of Greece was so high that Greek CDS stopped being traded. According to our dataset, the CDS market for Greek debt has dried up at least until August 2012. Our findings concerning the presence of contagion risk between foreign sovereigns and Italian banks are in line with De Bruyckere et al. (2013). De Bruyckere et al. (2013) show that asset/exposure channels are determinant for contagion, regardless of whether banks' are exposed to their home country or other stressed sovereigns. The link between the risk of peripheral

[22]The direction of spillover or a loop should be very sensitive to the time span chosen for studying contagion. We think that the longer the subperiod under study, the higher is the probability of finding two-way contagions. The dominance of one direction or another should be pronounced if we reduce the time span of contagion. We compute spillovers on a monthly basis.

[23]Note, we present the table of results in a matrix form for a sake of simplicity and readability. We put the main spillover and control variables in rows and interaction dummies in columns.

countries and non-resident banks has also been evidenced by Beltratti & Stulz (2015), who attribute those spillovers to two possible channels: systemic and exposure based. Those authors also provide evidence that banks are asymmetrically sensible to positive and negative shocks coming from foreign countries. They argue that banks' benefits in case of positive shocks in peripheral countries are higher than their losses when the choc is negative. Our study goes a step forward and provides evidence, for the first time, that sovereign–bank risk spillovers not only exist but also impact interbank market integration in Europe, whenever the contagion risk is driven from own or foreign stressed countries.

In order to understand the mechanism of bank/sovereign spillovers and include it in a further analysis, we attempted to have a preliminary look at the cross-border exposure data from the BIS consolidated banking statistics. Unfortunately, we did not always find sector based breakdown (i.e. bank, government, the private sector, etc.) and thus, we were unable to distinguish government exposures from others. However, we found data about Italian banks' exposures to the Irish economy and its government available only for the fourth quarter of 2010. Actually, during this period Italian banks' were effectively exposed both to the whole Irish economy and its government. We also observed that BIS reporting Irish banks' were themselves significantly exposed to Italian economy during the period under the study.[24] These facts point out the importance to explore different mechanisms of sovereign-bank contagion in further research, which remains, however, a challenging task because of the scarcity of cross-border bank-sovereign exposure data.

The significance of coefficients of some of country specific $Controls_t$ suggests that spillovers are not the single variables that impact Italian banks' cross-border spreads. Our results are globally comparable to those from Mayordomo et al. (2015) and show that the impact of those control variables changes depending on the period. Their influence becomes significant and economically important especially when Italy has been in distress (for $D_3 = 1$). It is the case for the economic sentiment index $ESI \times D_3$ which becomes statistically significant and much more important in times of stress. This result suggests that a stronger economic sentiment about Italian economy would on average imply a smaller level of fragmentation.

The sign and the significance of the coefficient of $BSOpen \times D_3$ shows that when the domestic sovereign, Italy, is in distress the market fragmentation decreases with the banking openness. The impact of $BSOpen \times D_3$ is not surprising. Note, that BIS aggregated statistics we use to compute $BSOpen$ also include interbank exposures. Thus, cross-border interbank rates and by consequence cross-border spreads (the measure of fragmentation in this paper) should be decreasing in $BSOpen$. Moreover, this relationship should hold particularly when cross-border trades become scarcer because of the high home country risk. However, we find the opposite effect for variables $BSOpen \times D_1, BSOpen \times D_2, BSOpen \times D_4$.

Finally, we find that the estimated coefficient of the Debt-to-GDP ratio impacts negatively and significantly the $FragRateIT_{it}$ before the debt crisis (see the coefficient of $Debt - to - GDP \times D_1$) and becomes positive and very strong during the second stage of the sovereign debt crisis ($Debt -$

[24]Italy was the 3rd biggest foreign exposure for Irish banks.

$to - GDP \times D_3 = 1$).

Var. Crossed With	$\times D_1$	$\times D_2$	$\times D_3$	$\times D_4$
D_mean_GR	0.513*	2.413***		
	(0.209)	(0.633)		
D_mean_IE	-0.245	1.235***	4.618***	0.227
	(0.165)	(0.329)	(0.513)	(0.135)
D_mean_IT	0.135	-0.490	1.159***	-0.066
	(0.176)	(0.268)	(0.216)	(0.166)
D_mean_SP	0.255	-0.233	0.641	0.106
	(0.146)	(0.293)	(0.331)	(0.212)
D_mean_PT	-0.113	-0.196	0.280	1.047
	(0.127)	(0.177)	(0.206)	(0.532)
Size FS	1.302*	1.200	-0.713	0.874
	(0.616)	(0.591)	(0.837)	(0.547)
BSOpen	3.735***	4.627***	-39.200***	5.783**
	(0.747)	(1.027)	(10.384)	(2.059)
ESI	-0.008	0.023	0.058***	0.021
	(0.004)	(0.030)	(0.010)	(0.011)
Debt-to-GDP	-0.040***	-0.047	0.433***	0.018
	(0.006)	(0.054)	(0.097)	(0.019)
Observations			1074	
Constant			-26.849	
			(14.590)	
R^2			0.855	

Note: Standard errors clustered at borrower level are in parentheses. * $p < 0.05$, ** $p < 0.01$,*** $p < 0.001$

Table 5: Main specification: interaction term fixed effect model
This table reports the impact of sovereign-bank risk spillover measure on the interbank market integration in rates. This impact is estimated by a fixed-effect interaction terms specification with standard errors clustered at borrower level. The data used spans from October 2008 to December 2012. The first column contains the coefficients of the fixed effect specification crossed with time dummy D_1 which includes the period from October 2008 to May 2010. Second, third and fourth columns of the table are coefficients where spillover and macro variables are crossed with time dummies D_2, D_3 and D_4 responsible for the time periods June 2010 to March 2011, April 2011 to November 2011 and December 2011 to December 2012, respectively. Fragmentation is estimated according to Eqs. (6). Standard errors are reported between brackets.

5 Conclusions, policy implications and future extensions

In this paper, we suggest a new measure of sovereign–bank contagion that differs from the classical factor model driven excess correlation. Apart from common fundamentals, a third country (or a third banking sector) might indirectly impact this excess correlation (correlation between residuals). Thus, our measure first permits for the quantification of the role that any GIPSI country play in the correlation between Italian banks and remaining GIPSI sovereigns, excluding the impact of common financial factors. Then, we compute the average impact of each country on the Italian banking sector.

We study the dynamics of contagion using a rigorously constructed event table and illustrate that the measure is particularly sensible to the downgrades of the given sovereign debt and to some interventions of the ECB.

Finally, this paper provides empirical evidence that sovereign–bank contagion risk impacts interbank market fragmentation in rates. We illustrate that during the most acute, second round, of the sovereign debt crisis, fragmentation in rates of the Italian banking sector, measured via e-MID data, is positively and significantly correlated with bank–sovereign ties. We find that the home country effect is important, but it is not the sole factor responsible for fragmentation: Italian banks' risk correlations with Ireland scares foreign lenders even more during this period.

We provide evidence for the effectiveness of policy interventions. We show that Italian banks' risk dependence from the home sovereign is no more a source of divergence in rates in 2012 when the ECB announces its 3 year LTROs and its President Mario Draghi made his speech demonstrating his determination to save the euro. Ireland remains, however, a source of rate divergence, but magnitudes have decreased considerably as compared to 2011.

Our modest findings focusing on Italy have some policy implications in the current framework of euro zone-wide reforms aiming to durably homogenize the monetary union. Our results suggest that if the ultimate objective of the policymaker is market integration, then measures focusing on breaking only bank/home country ties would not suffice to achieve it. As mentioned previously and evidenced by a number of studies, banks have incentives to increase their exposures to both home and non-home GIPSI countries in times of crisis (carry trade). Thus reforms that target integration would be effective only if they, in general, manage to dampen banks' incentives to take excessive positions on risky sovereign bonds.

One of the most apparent flaws in banking regulation is the general application of zero risk weights for sovereign exposures (Acharya, Engle & Pierret 2014) thus giving privileged positions to sovereign bonds.[25] In general, Basel capital requirements (both in Basel II and in Basel III) stipulate that banks have to hold capital for all asset classes either based on a given regulatory risk weight or based on internally modeled default probabilities. However, this key idea of the Basel Accord has not been followed in the Capital Requirements Directive (CRD) of the European Union.

Consequently, EU banks usually employ a zero risk weight for sovereign debt and thus do not hold capital against any of the sovereign exposures to EU member states (Acharya & Steffen 2015). This regulatory treatment of sovereign debt (disregarding any ratings or diversification in risk weights) is counterproductive for overcoming the interlinkages between banks and sovereign debt that has been a primary cause of the economic problems Europe faces today.More importantly, it makes investments in risky sovereign debt particularly attractive (Battistini et al. 2014, Acharya & Steffen 2015). If sovereign risk materializes (as happened in the European sovereign debt crisis), banks might experience a substantial capital shortfall and might even require capital backstops by their domestic sovereigns.

We suppose that adequate capital requirements for risky sovereign assets combined with the

[25]Following the Capital Requirements Directive (CRD) of the European Union, both in Basel II and Basel III bank regulators' sovereign bonds are weighted under 0% risk weight, and the liquidity coverage ratio (LCR) of Basel III is included in the first level of high-quality liquidity assets.

supranational banking regulation would also resolve the home bias problem, which was particularly pronounced for banks from peripheral distressed countries. The application of positive risk weights for sovereign exposures, as suggested in CDR IV of Basel III, could be a major weapon against fragmentation, as it fights excessive exposures to all kind of risky sovereigns. However, in the current context of home bias of European banks' balance sheets, the sovereign risk control by capital requirements threatens the policymaker, because of its pro-cyclical nature. Another prudential tool, namely the large exposure limit, is an ideal alternative to excessive capital requirements in times of crisis. This rule, from which sovereign assets have been exempted due to the EU's CRR (Capital Requirement Regulations), suggests a maximum concentration rate (25% of equity) for exposures to the same entity or sector. This measure will resolve the home bias problem, but will not neutralize banks' incentives to buy high yielded risky sovereign bonds with short-term funding (carry trade). For example, any bank, which is constrained to a large exposure limit for sovereign exposures can diversify its assets and comply with the rule, by buying GIPSI bonds issued by five different countries. In that case, the sovereign risk will continue menacing banks' health.

To break the bank–sovereign nexus, the Banking Union proposed a project including SSM (Single Supervisory Mechanism) and SRM (Single Resolution Mechanism) bodies to ensure consistency and efficiency of supervision across the Eurozone. The SRF, which will be operational in 2016, is a mutualized resolution fund financed by the EMU banks themselves. The SRF is an ambitious project, which will allow for the transferring of the recapitalization burden from the public to the private sector. However, the efficiency of the SRF on severing bank–sovereign ties remains debatable. First, the SRM only envisages a progressive total mutualization. The SRM will start by setting up NRFs (National Resolution Funds), which will gradually (within 8 years) transfer their funds to the common SRF. Secondly, in case of systemic defaults of banks, the SRF will be too small to recover all losses. The ESM (European Stability Mechanism), which is expected to become the institution that provides the SRF with a credit line in case of large losses, does not have the sufficient capacity to play this role of a common backstop. Moreover, as long as the recapitalization of banks by the ESM passes through sovereigns and is not directed to banks, the perverse ties between banks and their home countries would persist.

Acknowledgements

We are grateful for helpful comments and discussions by Dror Kenett, Giorgio Fagiolo, Olivier Brossard, John V. Duca, Andrea Roventini, Alessio Moneta, Irena Vodenska and several participants at seminars and conferences where the paper has been presented and in particular WEHIA 2016 (Castellòn de la Plana, Spain). Susanna Saroyan acknowledges European Commission for the Horizon 2020 - Marie Sklodowska Curie Action (MSCA) Individual Fellowship (IF) Grant: No. 704936 - FINREALNETS project. Lilit Popoyan acknowledges financial support from European Unions Horizon 2020 grant: No. 640772 – Project Dolfins. All usual disclaimers apply.

References

Abbassi, P., Bräuning, F., Fecht, F. & Peydró, J. L. (2015), 'Cross-border liquidity, relationships and monetary policy: Evidence from the euro area interbank crisis', *Deutsche Bundesbank Discussion Paper* (45).

Acharya, V., Drechsler, I. & Schnabl, P. (2014), 'A pyrrhic victory? bank bailouts and sovereign credit risk', *The Journal of Finance* **69**(6), 2689–2739.

Acharya, V., Engle, R. & Pierret, D. (2014), 'Testing macroprudential stress tests: The risk of regulatory risk weights', *Journal of Monetary Economics* **65**, 36–53.

Acharya, V. V., Drechsler, I. & Schnabl, P. (2012), 'A tale of two overhangs: the nexus of financial sector and sovereign credit risks', *Financial Stability Review* (16).

Acharya, V. V. & Steffen, S. (2015), 'The greatest carry trade ever? understanding eurozone bank risks', *Journal of Financial Economics* **115**(2), 215–236.

Afonso, A., Furceri, D. & Gomes, P. (2012), 'Sovereign credit ratings and financial markets linkages: application to European data', *Journal of International Money and Finance* **31**(3), 606–638.

Aizenman, J., Hutchison, M. & Jinjarak, Y. (2013), 'What is the risk of european sovereign debt defaults? fiscal space, cds spreads and market pricing of risk', *Journal of International Money and Finance* **34**, 37–59.

Alter, A. & Beyer, A. (2014), 'The dynamics of spillover effects during the european sovereign debt turmoil', *Journal of Banking & Finance* **42**, 134–153.

Alter, A. & Schüler, Y. S. (2012), 'Credit spread interdependencies of european states and banks during the financial crisis', *Journal of Banking & Finance* **36**(12), 3444–3468.

Ammer, J. & Cai, F. (2011), 'Sovereign cds and bond pricing dynamics in emerging markets: Does the cheapest-to-deliver option matter?', *Journal of International Financial Markets, Institutions and Money* **21**(3), 369–387.

Anderson, M. (2012), 'Contagion and excess correlation in credit default swaps', *SSRN Working Paper Series* .

Angelini, E. & Di Febo, E. (2014), 'CDS spreads: an empirical analysis on the determinants', *Journal of Empirical Economics* **2**(2), 70–87.

Angelini, P., Grande, G. & Panetta, F. (2014), 'The negative feedback loop between banks and sovereigns', *Bank of Italy Occasional Paper* (213).

Angeloni, C. & Wolff, G. B. (2012), 'Are banks affected by their holdings of government debt?', *Bruegel working paper* (07).

Arciero, L., Heijmans, R., Heuver, R., Massarenti, M., Picillo, C. & Vacirca, F. (2014), 'How to measure the unsecured money market? the eurosystem's implementation and validation using target2 data', *The Eurosystem's Implementation and Validation Using TARGET2 Data (April 23, 2014). Bank of Italy Occasional Paper* (215).

Arezki, R., Candelon, B. & Sy, A. N. R. (2011), 'Sovereign rating news and financial markets spillovers: Evidence from the European debt crisis', *IMF working papers* (11/68).

Bae, K.-H., Karolyi, G. A. & Stulz, R. M. (2003), 'A new approach to measuring financial contagion', *Review of Financial studies* **16**(3), 717–763.

Battistini, N., Pagano, M. & Simonelli, S. (2014), 'Systemic risk, sovereign yields and bank exposures in the euro crisis', *Economic Policy* **29**(78), 203–251.

Beaupain, R. & Durre, A. (2012), 'Nonlinear liquidity adjustments in the euro area overnight money market', *ECB Working Paper* (1500).

Beirne, J. & Fratzscher, M. (2013), 'The pricing of sovereign risk and contagion during the european sovereign debt crisis', *Journal of International Money and Finance* **34**, 60–82.

Bekaert, G., Harvey, C. R. & Ng, A. (2005), 'Market integration and contagion', *Journal of Business* **78**(1).

Beltratti, A. & Stulz, R. M. (2015), Bank sovereign bond holdings, sovereign shock spillovers, and moral hazard during the european crisis, Technical report, National Bureau of Economic Research.

Berndt, A. & Obreja, I. (2010), 'Decomposing European CDS returns', *Review of Finance* **14**(2), 189–233.

BIS (2011), 'The impact of sovereign credit risk on bank funding conditions', *CGFS Papers* (43).

Blanco, R., Brennan, S. & Marsh, I. W. (2005), 'An empirical analysis of the dynamic relation between investment-grade bonds and credit default swaps', *The Journal of Finance* **60**(5), 2255–2281.

Blundell-Wignall, A. & Slovik, P. (2010), 'The EU stress test and sovereign debt exposures'.

Boschi, M. (2005), 'International financial contagion: evidence from the argentine crisis of 2001–2002', *Applied Financial Economics* **15**(3), 153–163.

Brossard, O. & Saroyan, S. (2016), 'Hoarding and short-squeezing in times of crisis: Evidence from the euro overnight money market', *Journal of International Financial Markets, Institutions and Money* **40**, 163–185.

Bunda, I., Hamann, A. J. & Lall, S. (2009), 'Correlations in emerging market bonds: The role of local and global factors', *Emerging markets review* **10**(2), 67–96.

Caporin, M., Pelizzon, L., Ravazzolo, F. & Rigobon, R. (2013), 'Measuring sovereign contagion in europe', *NBER Working Paper* (18741).

Caruana, J., Avdjiev, S. et al. (2012), 'Sovereign creditworthiness and financial stability: an international perspective', *Banque de France Financial Stability Review* **16**, 71–85.

Cassola, N., Holthausen, C. & Duca, M. L. (2008), The 2007/2008 turmoil: a challenge for the integration of the euro area money market, *in* 'Conference on Liquidity: Concepts and Risks, CESifo Conference Centre, Munich', pp. 23–17.

Claessens, S. & Forbes, K. (2001), International financial contagion: An overview of the issues and the book, *in* 'International financial contagion', Springer, pp. 3–17.

Corsetti, G., Pericoli, M. & Sbracia, M. (2005), 'some contagion, some interdependence: More pitfalls in tests of financial contagion', *Journal of International Money and Finance* **24**(8), 1177–1199.

de Andoain, C. G., Hoffmann, P. & Manganelli, S. (2014), 'Fragmentation in the euro overnight unsecured money market', *Economics Letters* **125**(2), 298–302.

De Bruyckere, V., Gerhardt, M., Schepens, G. & Vander Vennet, R. (2013), 'Bank/sovereign risk spillovers in the european debt crisis', *Journal of Banking & Finance* **37**(12), 4793–4809.

De Santis, R. A. (2012), 'The euro area sovereign debt crisis: safe haven, credit rating agencies and the spread of the fever from greece, ireland and portugal', *ECB working paper* (1419).

Delatte, A.-L., Gex, M. & López-Villavicencio, A. (2012), 'Has the cds market influenced the borrowing cost of european countries during the sovereign crisis?', *Journal of International Money and Finance* **31**(3), 481–497.

Dornbusch, R., Park, Y. C. & Claessens, S. (2000), 'Contagion: How it spreads and how it can be stopped', *World Bank Research Observer* **15**(2), 177–197.

Dungey, M., Fry, R., González-Hermosillo, B. & Martin, V. L. (2005), 'Empirical modelling of contagion: a review of methodologies', *Quantitative Finance* **5**(1), 9–24.

Dungey, M. & Martin, V. L. (2007), 'Unravelling financial market linkages during crises', *Journal of Applied Econometrics* **22**(1), 89–119.

Ejsing, J. & Lemke, W. (2011), 'The janus-headed salvation: Sovereign and bank credit risk premia during 2008–2009', *Economics Letters* **110**(1), 28–31.

Favero, C. A. & Giavazzi, F. (2002), 'Is the international propagation of financial shocks non-linear?: Evidence from the erm', *Journal of International Economics* **57**(1), 231–246.

Forbes, K. J. & Rigobon, R. (2002), 'No contagion, only interdependence: measuring stock market comovements', *The journal of finance* **57**(5), 2223–2261.

Forbes, K. & Rigobon, R. (2001), Measuring contagion: conceptual and empirical issues, *in* 'International financial contagion', Springer, pp. 43–66.

Frankel, J. A. & Schmukler, S. L. (1996), 'Crisis, contagion, and country funds: Effects on East Asia and Latin America'.

Freixas, X. & Holthausen, C. (2005), 'Interbank market integration under asymmetric information', *Review of Financial Studies* **18**(2), 459–490.

Giordano, R., Pericoli, M. & Tommasino, P. (2013), 'Pure or wake-up-call contagion? another look at the EMU sovereign debt crisis', *International Finance* **16**(2), 131–160.

Gómez-Puig, M., Sosvilla Rivero, S. & Singh, M. K. (2015), 'Sovereigns and banks in the euro area: a tale of two crises', *Manish Kumar, Sovereigns and Banks in the Euro Area: A Tale of Two Crises (January 07, 2015)* .

Guo, F., Chen, C. R. & Huang, Y. S. (2011), 'Markets contagion during financial crisis: A regime-switching approach', *International Review of Economics & Finance* **20**(1), 95–109.

Hartmann, P., Straetmans, S. & De Vries, C. G. (2004), 'Asset market linkages in crisis periods', *Review of Economics and Statistics* **86**(1), 313–326.

Kalbaska, A. & Gkatkowski, M. (2012), 'Eurozone sovereign contagion: Evidence from the cds market (2005–2010)', *Journal of Economic Behavior & Organization* **83**(3), 657–673.

Kallberg, J. & Pasquariello, P. (2008), 'Time-series and cross-sectional excess comovement in stock indexes', *Journal of empirical finance* **15**(3), 481–502.

Kenett, D. Y., Huang, X., Vodenska, I., Havlin, S. & Stanley, H. E. (2015), 'Partial correlation analysis: applications for financial markets', *Quantitative Finance* **15**(4), 569–578.

Kenett, D. Y., Raddant, M., Zatlavi, L., Lux, T. & Ben-Jacob, E. (2012), Correlations and dependencies in the global financial village, *in* 'International Journal of Modern Physics: Conference Series', Vol. 16, World Scientific, pp. 13–28.

Kenett, D. Y., Tumminello, M., Madi, A., Gur-Gershgoren, G., Mantegna, R. N. & Ben-Jacob, E. (2010), 'Dominating clasp of the financial sector revealed by partial correlation analysis of the stock market', *PloS one* **5**(12), e15032.

Kenett, Y. N., Kenett, D. Y., Ben-Jacob, E. & Faust, M. (2011), 'Global and local features of semantic networks: Evidence from the hebrew mental lexicon', *PloS one* **6**(8), e23912.

Lee, S. B. & Kim, K. J. (1993), 'Does the october 1987 crash strengthen the co-movements among national stock markets?', *Review of Financial Economics* **3**(1), 89.

Longin, F. & Solnik, B. (2001), 'Extreme correlation of international equity markets', *Journal of Finance* pp. 649–676.

Madi, A., Kenett, D. Y., Bransburg-Zabary, S., Merbl, Y., Quintana, F. J., Boccaletti, S., Tauber, A. I., Cohen, I. R. & Ben-Jacob, E. (2011), 'Analyses of antigen dependency networks unveil immune system reorganization between birth and adulthood', *Chaos: An Interdisciplinary Journal of Nonlinear Science* **21**(1), 016109.

Manna, M. (2011), 'Home bias in interbank lending and banks resolution regimes', *Bank of Italy Temi di Discussione (Working Paper) No* **816**.

Martin, F. M. & Waller, C. J. (2012), 'Sovereign debt: a modern greek tragedy', *Federal Reserve Bank of St. Louis Review* **94**(September/October 2012).

Maugis, P. (2014), 'Event conditional correlation: Or how non-linear linear dependence can be', *arXiv preprint arXiv:1401.1130* .

Mayordomo, S., Abascal, M., Alonso, T. & Rodriguez-Moreno, M. (2015), 'Fragmentation in the european interbank market: Measures, determinants, and policy solutions', *Journal of Financial Stability* **16**, 1–12.

Metiu, N. (2012), 'Sovereign risk contagion in the eurozone', *Economics Letters* **117**(1), 35–38.

Mink, M. & De Haan, J. (2013), 'Contagion during the greek sovereign debt crisis', *Journal of International Money and Finance* **34**, 102–113.

Panetta, F., Correa, R., Davies, M., Di Cesare, A., Marques, J.-M., Nadal de Simone, F., Signoretti, F., Vespro, C., Vildo, S., Wieland, M. et al. (2011), 'The impact of sovereign credit risk on bank funding conditions'.

Pericoli, M. & Sbracia, M. (2003), 'A primer on financial contagion', *Journal of Economic Surveys* **17**(4), 571–608.

Pesaran, M. H. & Pick, A. (2007), 'Econometric issues in the analysis of contagion', *Journal of Economic Dynamics and Control* **31**(4), 1245–1277.

Petersen, M. A. (2009), 'Estimating standard errors in finance panel data sets: Comparing approaches', *Review of financial studies* **22**(1), 435–480.

Rodriguez, J. C. (2007), 'Measuring financial contagion: A copula approach', *Journal of Empirical Finance* **14**(3), 401–423.

Schwendner, P., Schuele, M., Ott, T. & Hillebrand, M. (2015), 'European government bond dynamics and stability policies: Taming contagion risks'.

Sy, A. N. R. (2009), 'The systemic regulation of credit rating agencies and rated markets', *IMF working paper* (09/129).

Thompson, S. B. (2011), 'Simple formulas for standard errors that cluster by both firm and time', *Journal of Financial Economics* **99**(1), 1–10.

Vari, M. (2014), 'Implementing monetary policy in a fragmented monetary union', *Banque de France Working Paper* (529).

Zhu, H. (2006), 'An empirical comparison of credit spreads between the bond market and the credit default swap market', *Journal of Financial Services Research* **29**(3), 211–235.

Zoli, E. (2013), 'Italian sovereign spreads: Their determinants and pass-through to bank funding costs and lending conditions'.

Appendix A Partial Correlations

A partial (or residual) correlation measures how much a given variable, say *f*, affects the correlations between another pair of variables, say x and y. Thus, in this *(x, y)* pair, the partial correlation value indicates the correlation remaining between x and y after the correlation between x and f and between y and f have been subtracted. Defined in this way, the difference between the correlations and the partial correlations provides a measure of the influence of variable f on the correlation *(x, y)*.[26] Therefore, we define the influence of variable f on variable x, or the dependency of variable x on variable *f*, as *D(x,f)*, to be the sum of the influence of variable f on the correlations of variable x with all other variables. This methodology has originally been introduced for the study of financial data (Kenett et al. 2010, 2012, Maugis 2014), and has been extended and applied to other systems, such as the immune system (Madi et al. 2011), and semantic networks (Kenett et al. 2011).

Whereas the simple correlation is a measure describing the linear association between two variables, a partial correlation coefficient measures the association between two variables after controlling for or adjusting for the effects of one or more additional variables. Partial correlation has an order coinciding with the quantity of variables it is conditioned. According to this logic, a simple correlation coefficient has a 0-order.

Suppose we want to calculate the association between x and y after removing the effect of a common explanatory variable f_1 both from x and y. The formula for the above relationship passes through the first-order partial correlation:

$$\hat{\rho}_{x,y:f_1} = \frac{\rho_{x,y} - \rho_{x,f_1}\rho_{y,f_1}}{\sqrt{[1-\rho^2_{x,f_1}][1-\rho^2_{y,f_1}]}}, \tag{7}$$

where each ρ of the right side is a normal correlation coefficient.

Although the above-mentioned example considers only three variables (x, y and f_1), there is no theoretical need for such a limit. Suppose, we are now interested in determining determine the relationship between x and y when the effects of variation in f_1 and f_2 factors are removed from both x and y. Second order partial correlation solves the problem:

$$\hat{\rho}_{x,y:f_1,f_2} = \frac{\hat{\rho}_{x,y:f_1} - \hat{\rho}_{x,f_2:f_1}\hat{\rho}_{y,f_2:f_1}}{\sqrt{[1-\hat{\rho}^2_{x,f_2:f_1}][1-\hat{\rho}^2_{y,f_2:f_1}]}}, \tag{8}$$

where each term on the right side of the equation is a first-order partial correlation coefficient.

As already mentioned, the partial correlation concept is not limited to any finite number of variables; hence, one could calculate a third-order or fourth-order partial correlation based on three second-order and third-order partial correlations accordingly.

Third-order partial correlation:

$$\hat{\rho}_{x,y:f_1,f_2,f_3} = \frac{\rho_{x,y:f_1,f_2} - \rho_{x,f_3:f_2,f_1}\rho_{y,f_3:f_2,f_1}}{\sqrt{[1-\rho^2_{x,f_3:f_2,f_1}][1-\rho^2_{y,f_3:f_2,f_1}]}}. \tag{9}$$

Fourth-order partial correlation:

$$\hat{\rho}_{x,y:f_1,f_2,f_3,f_4} = \frac{\rho_{x,y:f_1,f_2,f_3} - \rho_{x,f_4:f_3,f_2,f_1}\rho_{y,f_4:f_3,f_2,f_1}}{\sqrt{[1-\rho^2_{x,f_4:f_3,f_2,f_1}][1-\rho^2_{y,f_4:f_3,f_2,f_1}]}} \tag{10}$$

[26] Note that in case we have a partial correlation conditioned on one variable, the influence measure is the difference between a simple and a first order partial correlations. If the partial correlation is conditioned on two or more variables, the influence measure becomes a difference of the two different order partial correlations.