PANOECONOMICUS, 2014, 3, pp. 331-348
Received: 01 January 2013; Accepted: 09 July 2013.

UDC 336.143.232
DOI: 10.2298/PAN1403331S
Original scientific paper

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How Are Interbank and Sovereign Debt Markets Linked? Evidence from 14 OECD Countries, the Euro Area and Russia

Summary: The paper explores causal linkages between interbank and sovereign bond markets in 14 OECD countries, the Euro area and Russia during the 2008-2009 crisis and post-crisis period. The analysis has been carried out for individual countries and in a multivariate framework. It enables to identify systemically important countries in both markets. The USA, Switzerland, Australia, South Korea and Russia are of particular significance in the interbank lending market. Switzerland, the UK, Poland, Australia and Canada play a pivotal role in the public debt market. The analysis under the multivariate framework reveals substantial heterogeneity in the network structure of both markets. Only 12% of causal relationships coincide, which may fuel financial contagion. Volatility spillovers underlie the causal linkages. They are estimated by means of dynamic volatility indices based on rolling correlation matrices and help identify the transformation of the international banking turmoil into the sovereign debt crisis.

Key words: Interbank lending markets, Public debt, Granger causality, Diks-Panchenko test, Rolling correlations.

JEL: G17, G21, H6.

Sovereign indebtedness in developed economies remains an overriding challenge for theorists and policymakers. It may take years, if not more, to resolve the problem. Thus, Carmen Reinhart and Kenneth Rogoff (2011a) who argued that the period following the Great Recession could be called "a decade of debt" may be right.

It is important to bear in mind that the current situation has largely arisen from the attempts to ameliorate the effect of the 2008-2009 financial crisis. National governments had to bail out financial institutions, which in some cases seriously undermined their fiscal balances. In this paper I focus on the interaction between interbank lending and sovereign bond markets in 14 OECD countries, the Euro area and Russia during the 2008-2009 crisis and post-crisis period. Disruptions in interbank lending are reliable predictors of systemic banking crises primarily due to its network nature (Andreas Krause and Simone Giansante 2012). However, to the best of my knowledge, the crisis transmission from an interbank to a public debt market remains insufficiently explored. First I analyze it for individual countries and then, in a multivariate framework. A significant heterogeneity in the network structure of the two markets is found. Moreover, they are characterized by separated incomplete networks which seem to spur crisis propagation. I proceed by constructing dynamic volatility indices for both markets based on rolling correlations. The two indices help identify the transformation of the banking crisis into the public debt crisis, i.e. the moment of the credit transfer, which, according to the estimations, occurred in October-November 2009.

The paper is organized as follows. Section 1 briefly surveys relevant literature. In Section 2 the data, methodology and results of causality analysis between inter-bank and public debt markets for individual countries in the sample are presented. Section 3 examines the interrelations for both markets within the sample, pointing to possible contagion effects. Section 4 assesses volatility dynamics underlying these effects in each of the markets. Section 5 concludes.

1. Literature Review

Financial crises, in particular, banking ones, help predict sovereign debt crises. According to Reinhart and Rogoff (2011b), government debts rise about 86 percent in the three years following a systemic financial crisis. Davide Furceri and Aleksandra Zdzienicka (2012), and Athanasios Tagkalakis (2013) similarly report significant post-crisis upswings in public debt to GDP ratios in advanced economies. Irina Balteanu and Aitor Erce (2012) analyze twin bank-public debt crises in 117 developing and emerging economies in an event-study framework and find that they are preceded by high banking sector leverage and involve boom-bust growth patterns and a build-up of government debt.

From the public finance perspective, banking crises may turn very costly as Patrick Honohan (2008), and Luc Laeven and Fabian Valencia (2012) assert. It is due to contingent liabilities assumed by public authorities and materialized during financial crises. These liabilities may both be explicit (e.g. loan and export guarantees, government insurance programs, etc.) and implicit. Though the relative importance of various types of contingent liabilities is country-specific, implicit liabilities have generally been the most burdensome, with bailouts being their main ingredient (Aliona Cebotari 2008).

However, contingent liabilities don't warrant any panacea for a country engulfed by financial instability. During severe banking crises contingent liabilities, such as blanket guarantees on bank liabilities may be insufficient and should be complemented with massive liquidity injections. Using a sample of 42 banking crises, Laeven and Valencia (2008) figure out that blanket guarantees are successful in mitigating liquidity pressures arising from deposit withdrawals, whereas banks' foreign liabilities appear irresponsive to this type of guarantees. Agnes Benassy-Quere and Guillaume Roussellet (2012) assess the effect of contingent liabilities stemming from systemically important EU banks on fiscal sustainability in a tax-gap framework. They find that every percentage point rise in the differential between interest and growth rate after the banking crisis raises the tax gap by 1% of GDP. Therefore, an excessive use of contingent liabilities may exacerbate moral hazard problems in the banking sector and eventually precipitate the transformation of a banking turmoil into a public debt crisis.

In addition to direct fiscal disruptions, banking crises affect the post-crisis real growth dynamics, making the fiscal sustainability rebound more complicated. Giovanni Dell'Ariccia, Enrica Detragiache, and Raghuram Rajan (2008) present the evidence that they are especially detrimental to the industrial sectors heavily reliant on external finance and/or populated by small firms. Consequently, the transmission channel from banking to public debt crises should be carefully studied.

To quantify this spillover, Serkan Arslanalp and Yin Liao (2012) explore the link between contingent liabilities and sovereign credit default swap (CDS) spreads for 32 countries and find that one percent GDP increase in these liabilities results in 24 basis points (bps) rise of CDS spreads of developed economies and in 75 bps for emerging markets. Other papers consider sovereign credit default spreads together with a selection of bank CDS series from the countries in question (Jacob Ejsing and Wolfgang Lemke 2011; Viral V. Acharya, Itamar Drechsler, and Philipp Schnabl 2012; Adrian Alter and Yves S. Schuler 2012). Their major finding is consonant: a credit risk transfer between banking sectors and sovereign bonds has been underscored, with causality running from banks to sovereigns till bail-outs are announced, and vice versa afterwards.

2. Causality Issues between Interbank and Public Debt Markets

The relationship between interbank and public debt markets is studied for 14 OECD countries, the Euro area and Russia from September 2008 till August 2012. Three monthly data series for each country are used: 3-month interbank interest rates or their equivalents (*INTB_RATE*), secondary market yields of 10-year sovereign bonds (*LONGT_RATE*) and main central bank rates. Monthly data are business daily averages. The data on interbank rates and sovereign bond yields come from the OECD Statistics (*Monthly monetary and financial statistics*) while main central bank rates are retrieved from respective central bank sites. The sample composition is entirely determined by data availability: all the countries with missing values in one of the series are excluded. For the Euro area, 3-month Euro Interbank Offered Rate (EURIBOR) is used as an interbank market indicator and weighted sovereign bond yields as a public debt indicator. Descriptive statistics are given below (Table 1).

Granger tests have been carried out to uncover causality directions between interbank and public debt markets for each country. To properly specify lag length of these tests, I rely on an optimal lag number of VARs where interbank rates and sovereign bond yields enter as endogenous variables and main central bank rates as exogenous ones. The inclusion of the central bank rates in the VARs appears relevant as they may have a significant impact on interbank rates and sovereign bond yields through the channel of monetary transmission. Thus, by explicitly modeling this effect I minimize the risk of finding a spurious co-movement between the interbank and sovereign bond markets caused by a third factor.

As no cointegration is found in pairwise framework, unrestricted VAR rather than VECM should be applied. Prior to making VARs, these time series are subject to unit root tests (Augmented Dickey-Fuller tests) and the first differences of the data are taken in case of non-stationarity. The overall VAR stability is checked by means of inverse roots of AR characteristic polynomial. If they lie inside a unit circle, a

Table 1 Descriptive Statistics for *INTB_RATE* and *LONGT_RATE*

Country / variables	Min	Max	Mean	Std. dev.	Jarque-Bera test statistic	Jarque-Bera test *p*-value
Australia						
INTB_RATE	3.10	7.27	4.37	0.81	10.30	0.005
LONGT_RATE	2.89	5.80	4.82	0.79	6.10	0.047
Target cash rate	3.00	7.00	4.20	0.81	9.03	0.011
Canada						
INTB_RATE	0.38	3.29	1.10	0.66	58.57	0.000
LONGT_RATE	1.65	3.68	2.92	0.60	5.71	0.058
Target rate	0.25	3.00	0.85	0.56	45.92	0.000
Czech Republic						
INTB_RATE	1.00	4.24	1.70	0.85	37.35	0.000
LONGT_RATE	2.38	5.45	4.00	0.70	0.27	0.870
Lombard rate	1.50	4.50	2.12	0.69	76.14	0.000
Denmark						
INTB_RATE	-0.12	5.26	1.39	1.31	46.27	0.000
LONGT_RATE	1.10	4.39	2.90	0.85	2.92	0.230
Discount rate	0.00	4.44	1.25	1.02	48.22	0.000
Iceland						
INTB_RATE	4.00	18.57	7.88	4.50	16.45	0.000
LONGT_RATE	4.99	15.01	7.13	1.98	87.01	0.000
Current rate	3.25	17.50	7.18	4.17	7.48	0.023
Japan						
INTB_RATE	0.33	0.89	0.45	0.16	17.07	0.000
LONGT_RATE	0.78	1.49	1.16	0.19	2.13	0.340
Policy rate	0.05	0.50	0.09	0.08	511.47	0.000
South Korea						
INTB_RATE	2.41	6.03	3.22	0.84	52.76	0.000
LONGT_RATE	3.09	5.99	4.61	0.69	1.60	0.450
Base rate	2.00	5.25	2.70	0.72	13.83	0.000
New Zealand						
INTB_RATE	2.59	7.95	3.22	1.15	215.68	0.000
LONGT_RATE	3.40	6.02	5.09	0.80	5.22	0.073
Official cash rate	2.50	7.50	3.02	1.21	161.01	0.000
Norway						
INTB_RATE	1.87	6.92	2.87	1.11	136.99	0.000
LONGT_RATE	1.73	4.49	3.37	0.75	4.93	0.084
Key policy rate	1.25	5.25	2.13	0.97	118.67	0.000
Poland						
INTB_RATE	3.81	6.85	4.59	0.72	28.43	0.000
LONGT_RATE	4.88	6.35	5.85	0.35	3.52	0.170
Reference rate	3.50	6.00	4.10	0.68	11.43	0.003
Sweden						
INTB_RATE	0.15	4.49	1.14	0.93	29.18	0.000
LONGT_RATE	1.33	3.90	2.74	0.71	4.39	0.110
REPO rate	0.25	4.67	1.31	1.03	25.32	0.000
Switzerland						
INTB_RATE	0.01	2.96	0.34	0.57	503.40	0.000
LONGT_RATE	0.56	2.76	1.64	0.62	2.82	0.240
Swiss average rate overnight	-0.05	1.73	0.10	0.26	2147.18	0.000
UK						
INTB_RATE	0.56	6.18	1.27	1.22	209.17	0.000
LONGT_RATE	1.64	4.58	3.28	0.77	4.07	0.130
Official bank rate	0.50	5.00	0.79	0.94	360.98	0.000
USA						
INTB_RATE	0.19	4.32	0.59	0.82	311.60	0.000
LONGT_RATE	1.53	3.85	2.90	0.70	4.16	0.120
Federal funds target rate	0.13	2.00	0.21	0.32	1037.53	0.000
Euro area						
INTB_RATE	0.33	5.11	1.35	1.04	114.10	0.000
LONGT_RATE	3.01	4.66	3.96	0.39	1.62	0.440
Euro area REPO rate	0.75	4.25	1.31	0.72	164.49	0.000
Russia						
INTB_RATE	4.20	27.83	8.55	5.22	56.49	0.000
LONGT_RATE	7.55	10.58	8.52	0.86	9.68	0.010
Refinancing rate	7.75	13.00	9.19	1.79	10.10	0.006

Source: Author's estimations.

VAR satisfies the stability condition. The optimal lag length selection is primarily based on LR test statistic which is complemented with a set of information criteria - final prediction level (FPE), Akaike (AIC), Schwarz (SC) and Hannan-Quinm (HQ). The results of pairwise Granger causality / block exogeneity Wald test are summarized in Table 2.

Table 2 Granger Causality between Interbank and Public Debt Markets

Country	Lag length	*INTB_RATE* does not cause *LONGT_RATE*		*LONGT_RATE* does not cause *INTB_RATE*	
		Chi-squared-statistic	*p*-value	Chi-squared-statistic	*p*-value
Australia	1	2.23	0.14	1.26	0.26
Canada	2	0.32	0.85	4.94	0.08
Czech Republic	2	4.46	0.11	3.58	0.17
Denmark	3	1.75	0.63	7.19	0.06
Iceland	1	2.25	0.13	16.40	0.00
Japan	1	2.72	0.09	0.77	0.38
South Korea	1	1.40	0.24	2.07	0.15
New Zealand	**3**	18.31	0.00	8.67	0.03
Norway	2	2.65	0.27	2.83	0.24
Poland	2	1.30	0.52	1.36	0.51
Sweden	1	2.26	0.13	0.01	0.92
Switzerland	1	3.58	0.06	1.71	0.19
UK	1	2.15	0.14	2.45	0.12
USA	**1**	2.94	0.09	8.49	0.00
Euro area	1	0.34	0.56	0.25	0.62
Russia	1	0.05	0.83	14.33	0.00

Source: Author's estimations.

In 8 cases causal linkages between interbank and public debt markets during the 2008-2009 crisis and post-crisis period are found. In Japan and Switzerland interbank lending markets Granger cause public debt markets. The relationship is bidirectional in the USA and New Zealand. In Canada, Denmark, Iceland and Russia sovereign debt markets unidirectionally influence interbank lending markets. However, it is surprising that no linkage is found in case of the major economies (the UK, the Euro area).

A possible explanation is that the linkages may be of nonlinear nature. For example, up to a certain level of interbank rates, government bond rates may remain irresponsive but after the threshold has been reached, they may overshoot. Standard Granger causality (or, to be precise, non-causality) tests do not account for this nonlinearity.

Consequently, the next step in the analysis is to find out if there is nonlinearity in the examined bi-variate relationships. To this end, BDS test is carried out for the VAR residuals (William A. Brock et al. 1996). Its null hypothesis states that the residuals are independent and identically distributed (*ibid*). If it is rejected, nonlinear linkages between interbank and public debt markets may indeed be present for a given country. As the complete output of the BDS test is bulky, I only enlist countries with possible nonlinear causal relationships, but the results of the test are available from the author upon request. BDS test points to the possible nonlinearity for a vast majority of the sample: Australia, Canada, Czech Republic, Iceland, Japan, Norway, Poland, South Korea, Sweden, Switzerland, the UK, the US, the Euro area and Russia. The null hypothesis holds for Denmark and New Zealand, meaning that linear Granger causality tests are sufficient to adequately capture the causal relationship between interbank and public debt markets in these countries. For the first subsample linkages should additionally be tested by means of a nonlinear causality test.

Over the past 20 years several nonlinear causality tests have been proposed, e.g. Ehung G. Baek and Brock (1992), and Craig Hiemstra and Jonathan D. Jones (1994). I resort to the nonparametric test by Cees G. H. Diks and Valentin Panchenko (2006). This test tends to outperform Hiemstra-Jones test as the latter looks spurious due to the rejection probabilities under the null hypothesis converging to one with the rising sample size. Diks and Panchenko replaced the global test statistic with an average of local conditional dependence measures and formulated practical guidelines for choosing an optimal bandwidth depending on the sample size. The test has been applied to estimate causal relationships between exchange rates (Stelios D. Bekiros and Diks 2008a), stock prices and trading volumes (Shyh-Wei Chen 2008), spot and future commodity prices (Bekiros and Diks 2008b), finance-growth nexus (Henryk Gurgul and Lukasz Lach 2012), fiscal policy and economic growth (Stella Karagianni, Maria Pempetzoglou, and Anastasios Saraidaris 2012).

In this paper the test has been applied to VAR residuals and run in both directions for the lag number from 1 to 5 and for the bandwidth equal to 1.5, taking into account the time series length. Its null hypothesis resembles that of Granger causality test, namely, X does not help predict Y and Y does not help predict X. T-statistic is calculated to check the null (Table 6, Appendix).

The test underscores the nonlinear bidirectional causality for Russia significant at 5% level and weak evidence of causality running from the public debt market to the interbank lending one for Japan, Poland, Switzerland, the Euro area and the UK. In a nutshell, after controlling for nonlinear causality, there are 11 countries with linkages between the two markets. For Canada, Iceland, Denmark, Poland, the Euro area and the UK the causal relationship is running from the public debt market to the interbank one. In case of Japan, New Zealand, Switzerland, the USA and Russia the causality is bidirectional. There is no evidence in favor of any causal relationship for Australia, Czech Republic, South Korea, Norway and Sweden.

3. Multiple Causal Relationships in Interbank and Public Debt Markets

I estimated the relationship between interbank and public debt markets in a bi-variate VAR framework for each of the countries in the sample. For a number of important economies no statistically significant causal linkage has been underscored. Notwithstanding this empirical result, it doesn't necessarily mean that such relationship is indeed non-existent. It may be of high-order moments that are difficult to capture even by means of nonparametric causality tests.

Additional information could have been obtained by means of other econometric techniques such as multivariate GARCH models. They are not aimed at addressing causality issues but help figure out if there is any volatility spillover between markets which can be treated as a necessary, but insufficient prerequisite for causal linkages. However, in our case it is problematic to construct stable GARCH models even in a bi-variate framework due to a relatively small length of the time series.

Recently introduced measures, such as CoVaR (Tobias Adrian and Markus K. Brunnermeier 2011), equi-correlations (Robert F. Engle and Bryan T. Kelly 2012) or metrics built from pieces of variance decompositions (Francis X. Diebold and Kamil Yilmaz 2011) that shed light on financial connectedness can hardly be applied either as they do not deal with causality issues.

Linkages may be transmitted from interbank to public debt markets in a roundabout way. For example, country *A* is characterized by bidirectional causality between the markets and at the same time is closely connected with country *B* in each of them, say, being Granger-caused by *B* in the interbank market and Granger-causing *B* in the public debt one. Then, an impulse generated by country *B*'s interbank market will ultimately affect this country's public debt rates through several transmission stages. Consequently, it may arrive both amplified and weakened. This hypothetical example justifies the necessity to study multiple causal relationships between the countries in both markets.

To this end, multivariate VAR methodology has been applied. Two VARs for interbank and public debt markets are estimated. All the 16 country variables are treated as endogenous. Again it is necessary to control for changes in main central bank rates. Instead of fitting the entire set of these rates in the equation that would result in VAR identification problems, I first apply principal components analysis (PCA) and use three most important components as exogenous variables. They cumulatively explain 79% of the variation in the main central bank rates. They are selected on the basis of Kaiser criterion (their eigenvalues should exceed 1) and the corresponding scree plot, which is a standard approach for the PCA (Table 7 and Figure 2 in Appendix).

Then I specify an appropriate lag length on the basis of LR test statistic complemented with a set of information criteria. The optimal lag length is equal to 1 and the models satisfy the stability condition, judging by inverse roots of AR characteristic polynomial lying within a unit circle. Then Granger causality / block exogeneity Wald tests are carried out. All the linkages that are significant at least at 10-percent level are denoted with 1 and inserted into causality matrices. The linkages are marked in columns, with Granger causing variables being in the upper horizontal line. The results are presented in Tables 3 and 4.

Table 3 Multiple Causal Relationships between Interbank Markets

	Australia	Canada	Czech Republic	Denmark	Iceland	Japan	Korea	New Zealand	Norway	Poland	Sweden	Switzerland	UK	USA	Euro area	Russia	**RECEIVE**
Australia																	**0**
Canada				1			1										**2**
Czech Republic						1										1	**2**
Denmark	1					1											**2**
Iceland			1			1							1			1	**4**
Japan								1				1	1	1		1	**5**
Korea											1						**1**
New Zealand					1												**1**
Norway														1			**1**
Poland			1				1						1			1	**4**
Sweden												1	1	1			**3**
Switzerland					1												**1**
UK	1					1	1				1	1				1	**6**
USA							1										**1**
Euro area																	**0**
Russia		1		1				1		1							**4**
GIVE	**2**	**1**	**2**	**2**	**2**	**4**	**4**	**2**	**0**	**1**	**2**	**3**	**4**	**3**	**0**	**5**	
NSI	**1.00**	**-0.33**	**0.00**	**0**	**-0.33**	**-0.11**	**0.60**	**0.33**	**-1.00**	**-0.60**	**0**	**0.50**	**-0.20**	**0.50**	**N/A**	**0.11**	

Source: Author's estimations.

Table 4 Multiple Causal Relationships between Public Debt Markets

	Australia	Canada	Czech Republic	Denmark	Iceland	Japan	Korea	New Zealand	Norway	Poland	Sweden	Switzerland	UK	USA	Euro area	Russia	**RECEIVE**
Australia		1	1							1			1				**4**
Canada							1			1			1		1		**4**
Czech Republic	1			1												1	**3**
Denmark	1	1															**2**
Iceland							1				1	1					**3**
Japan		1		1						1							**3**
Korea													1			1	**2**
New Zealand	1		1			1				1	1						**5**
Norway	1	1	1							1			1				**5**
Poland	1	1			1											1	**4**
Sweden		1								1							**2**
Switzerland																	**0**
UK	1									1							**2**
USA	1	1				1						1	1				**5**
Euro area					1					1							**2**
Russia					1		1			1							**3**
GIVE	**7**	**7**	**3**	**2**	**3**	**2**	**3**	**0**	**0**	**9**	**2**	**2**	**5**	**0**	**1**	**3**	
NSI	**0.27**	**0.27**	**0**	**0**	**0.00**	**-0.2**	**0.20**	**-1**	**-1.00**	**0.38**	**0.00**	**1.00**	**0.43**	**-1.00**	**-0.33**	**0.00**	

Source: Author's estimations.

The tables also include the sum of cases when this or that country Granger causes others (the last but one horizontal line denoted as "*GIVE*") and the sum of cases when it is Granger caused (the last right hand column "*RECEIVE*"). A composite indicator called "Net Spillover Index (*NSI*)" is computed for each country (European Banking Federation - EBF 2011):

$$NSI = \frac{GIVE - RECEIVE}{GIVE + RECEIVE}. \qquad (1)$$

The indicator accounts for the net impact of a country in the interbank or public debt market networks. By definition, *NSI* takes on values from -1 to 1. The closer it is to 1, the more countries are Granger caused by the country in question, or similarly, the latter is less vulnerable to an external influence.

Judging by *NSI*s, the USA, Switzerland, Australia and South Korea primarily Granger cause others in the interbank lending markets. Switzerland, the UK and Poland constitute a pool of most influential countries in the sovereign debt market. It is also instructive to consider the total number of causal linkages for a country (both outgoing and incoming, i.e. *GIVE+RECEIVE*). This indicator describes how central the role of a particular country in the network is (Sanjeev Goyal 2009). In the interbank lending market the UK, Japan and Russia top the list, whilst in the public debt market Poland, Australia and Canada lead. This analysis is instrumental in revealing systemically important countries in international finance.

The estimation of multiple causal relationships underscores two unexpected findings which are to be additionally examined: an almost negligible role of the Euro area in the markets (both as an originator and recipient of causal linkages) and the position of the USA receiving rather than generating causal linkages in the sovereign debt market.

A possible explanation for the first phenomenon is that the risk of the contagion from the Euro area to other regions may be overestimated. This view is line with the "wake-up-call" hypothesis of contagion when only countries with weak macroeconomic fundamentals and having close economic ties with an originator are subject to the direct transfer of instability. The "wake-up-call" contagion should be distinguished from "pure" contagion when financial distress is virtually a random walk process with little dependence on fundamentals. If analyzed from this perspective, the situation inside the Euro area can be assessed as a "wake-up-call" contagion, with the other economies in the sample relatively unaffected so far due to more resilient macroeconomic fundamentals. Though not claimed as totally correct, this view is consonant with earlier findings on moderate propagation effects of the European crisis (Tamim Bayoumi and Francis Vitek 2011; Rafaella Giordanno, Marcello Pericolli, and Pietro Tommasino 2013).

The USA may be Granger caused in the public debt market owing to the status of a safe haven in terms of the crisis. Foreign investments in the US long-term government bonds are largely irresponsive to moderate shifts in their yields and tend to grow even when they shrink. Thus, inelastic demand for US public debt fueled by the massive reallocation of funds from other advanced economies' sovereign debt during the crisis may be accountable for this unexpected position of the USA in multiple causal linkages in the sovereign debt market.

The structure of the causality matrices is also helpful in assessing the propensity to contagion. The overall density of causal relationships in the interbank and public markets is 15.4 and 20.4% of the total number (16^2 - 16 = 240) of potential linkages. It is also interesting to compare the structure of causal relationships in both markets, picking up overlapping elements of causality matrices. There is little commonality in them: only about 12.2% of causal relationships coincide. On the one hand, the findings enable to assert that the propagation velocity of contagion between the interbank and public debt markets is likely to be moderate. On the other hand, "thin" and structurally heterogeneous causal relationships may exacerbate the situation as more countries are engulfed by contagion, while under such network structures they are much less incentivized to work out mechanisms for rapid liquidity reallocation to bail out each other. This view seems to prevail in the literature on financial networks and contagion. Such "thin" and heterogeneous network structures reflecting causal relationships in both markets fall under the category of separated incomplete networks which are more prone to contagion (Franklin Allen and Douglas Gale 2000, 2007).

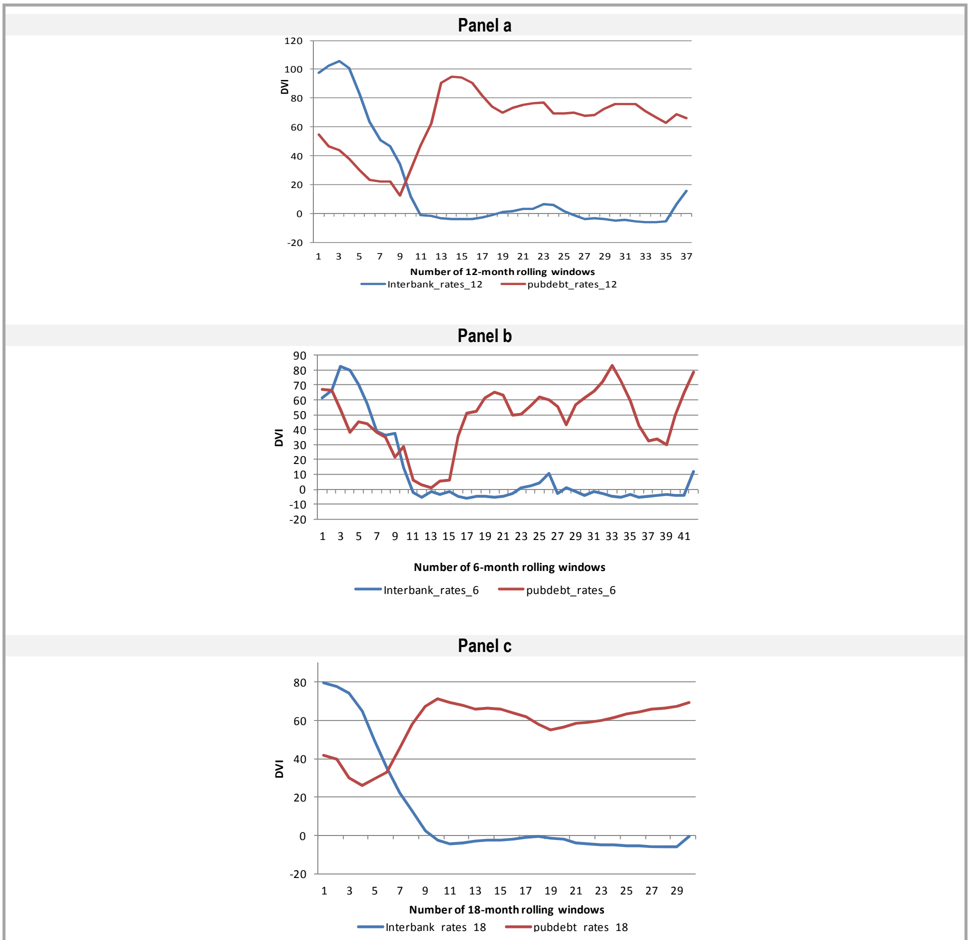
4. Dynamic Volatility Indices in Interbank and Public Debt Markets

It is important to shed light on the mechanics of the underscored causal linkages. It is natural to assume that it hinges around volatility spillovers. As pointed above, due to a limited time series length, multivariate GARCH models cannot be applied to track them. To overcome the difficulty, I resort to a simpler, yet an established approach - computing rolling correlations. For example, they are used to model financial integration (Jan Babecky, Luboc Komarek, and Zlatuse Komarkova 2008) and contagion (Srobona Mitra and Elena Duggar 2007).

The overall volatility dynamics in September 2008 - August 2012 is to be tracked, so I actually calculate rolling correlation matrices. The baseline rolling window is set to 12 months. To ensure robustness of the results, 6- and 18-month rolling windows are also applied. Dynamic volatility indices (*DVI*) are the sums of correlation ratios in the rolling correlation matrices which have 16x16 dimension and are computed for a given rolling window *t* as:

$$DVI_t = \frac{\sum_{i=1}^{16}\sum_{j=1}^{16} r_{ij} - 16}{2}. \quad (2)$$

This simple metric builds on the well-known premise that in the periods of financial turmoil asset prices tend to co-move, whereas in tranquil times their changes are less correlated, giving more opportunities for portfolio diversification. Therefore, higher values of *DVI*s are indicative of deteriorating financial conditions in the interbank or public debt market. By comparing the dynamics of the *DVI*s, one can judge about a possible volatility spillover as well as detect the transformation of the international banking crisis into the public debt one with more precision (Figure 1, panel a, b, c).



Source: Author's estimations.

Figure 1 Dynamic Volatility Indices in the Interbank and the Public Debt Market for: (a) 12-Month; (b) 6-Month; (c) 18-Month Windows

In the interbank market the threshold is the period November 2008 - October 2009 for the 12-month window; November 2008 - April 2009 for the 6-month window, and September 2008 - February 2010 for the 18-month window. The middle points of the periods are used to narrow down the determination of structural breaks. The analysis reveals a volatility shrinkage starting from the yearly 2009 (January-April) in the interbank market. Then *DVI*s converge to a near-zero level. As for the public debt market, its volatility leaps in October-November 2009 and remains high up to August 2012. Thus, October-November 2009 is considered as the time of the credit risk transfer from the interbank to public debt markets. This timing of the transfer corresponds to the first manifestations of the Euro area public debt fragility (Ireland and Greece) in the late 2009. For example, Constantin Gurdgiev et al. (2011) present a detailed account of how speculative lending and disproportionate external borrowing by Irish banks undermined the fiscal balance of the "Celtic tiger". Similar evidence on all the PIGS referring precisely to the late 2009 is reported in Abel L. Costa Fernandes and Paulo R. Mota (2011).

Additionally, I examine if the *DVI*s are sensitive to changes in the sample composition. To this end, additional *DVI* series are generated: first, when the USA data are excluded and, second, when the Euro area data are eliminated. Judging by the correlation ratios between the new and full sample *DVI*s which are very close to 1 (Table 5), the indicators used to track the timing of the credit transfer appear robust to the exclusion of major economies.

Table 5 A Sensitivity Test Results for *DVI*s

Variable	Rolling window	*DVI* (USA excluded)	*DVI* (Euro area excluded)
Interbank_rate		0.992	0.994
Pubdebt_rate	12	0.984	0.985
Interbank_rate		0.986	0.987
Pubdebt_rate	6	0.978	0.994
Interbank_rate		0.995	0.996
Pubdebt_rate	18	0.983	0.985

Source: Author's estimations.

The dynamic volatility indices not only help identify the transformation of one crisis into another, they may also be relevant in assessing systemic risk build-ups in the interbank and public debt markets. They may appear useful as components of composite financial conditions indices as well.

5. Conclusions

The paper explores causal linkages between interbank and public debt markets in 14 OECD countries, the Euro area and Russia. The analysis has been implemented for individual countries and in a multivariate framework. For 11 countries the causal relationships have been underscored. In case of Japan, New Zealand, Switzerland, the USA and Russia they are bidirectional.

The multivariate analysis identifies systemically important countries in the interbank and public debt markets. The USA, Switzerland, Australia, South Korea and Russia are of particular significance in the interbank lending market. Switzerland, the UK, Poland, Australia and Canada play a pivotal role in the public debt market. The minor role of the Euro area in both markets and that of the USA in the public debt one have been found and explained.

As for the analysis of multiple causal linkages, substantial heterogeneity in the network structure of both markets has been revealed: only about 12% of causal relationships coincide. The relationships in both markets constitute separated incomplete networks which exhibit higher proneness to crisis propagation if compared with tightly connected structures.

Volatility spillovers are likely to underlie the causal linkages. They are estimated by means of dynamic volatility indices based on rolling correlation matrices and help identify the transformation of the international banking crisis into the public debt one. It is dated as of October-November 2009. The dynamic volatility indices can also be helpful in tracking systemic risk build-ups in both markets.

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Appendix

Table 6 Results of Diks-Panchenko Nonparametric Causality Test

Lag number	*INTB_RATE does not cause LONGT_RATE*		*LONGT_RATE does not cause INTB_RATE*	
	T-statistic	*p*-value	*T*-statistic	*p*-value
Australia				
1	-2.38	0.99	-0.98	0.84
2	-2.39	0.99	-0.35	0.64
3	-1.79	0.96	-0.77	0.78
4	-0.35	0.63	1.10	0.14
5	-0.23	0.59	0.34	0.37
Canada				
1	-1.07	0.86	-1.13	0.87
2	-1.10	0.86	-1.27	0.90
3	0.76	0.22	0.90	0.18
4	1.00	0.16	-0.01	0.50
5	0.32	0.37	-1.04	0.85
Czech Republic				
1	-0.17	0.57	-1.07	0.86
2	-0.10	0.54	0.82	0.21
3	-0.95	0.83	0.63	0.26
4	-0.35	0.63	1.25	0.11
5	-1.06	0.86	0.83	0.20
Iceland				
1	1.12	0.13	0.80	0.21
2	-1.04	0.85	-0.98	0.84
3	-0.50	0.69	1.18	0.12
4	-1.07	0.86	1.03	0.15
5	-0.98	0.84	0.75	0.23
Japan				
1	-0.40	0.65	0.63	0.26
2	-0.09	0.54	**1.40**	**0.08**
3	-0.42	0.66	1.05	0.15
4	-0.69	0.75	1.03	0.15
5	0.86	0.20	0.97	0.17
South Korea				
1	0.23	0.41	-0.95	0.83
2	-0.45	0.67	0.90	0.19
3	0.20	0.40	0.42	0.34
4	1.00	0.16	0.22	0.41
5	0.67	0.25	0.47	0.32
Norway				
1	-0.86	0.80	0.27	0.39
2	-1.09	0.86	0.76	0.22
3	0.27	0.39	0.93	0.18
4	0.83	0.20	-0.19	0.57
5	-0.17	0.57	0.28	0.39
Poland				
1	-0.43	0.67	**1.37**	**0.09**
2	-1.86	0.97	1.26	0.10
3	-1.57	0.94	**1.41**	**0.08**
4	-1.96	0.98	1.02	0.16
5	-1.39	0.92	0.32	0.37
Sweden				
1	0.95	0.17	0.38	0.35
2	0.51	0.30	0.86	0.20
3	0.70	0.24	0.97	0.17
4	1.03	0.15	1.04	0.15
5	0.60	0.28	1.07	0.14

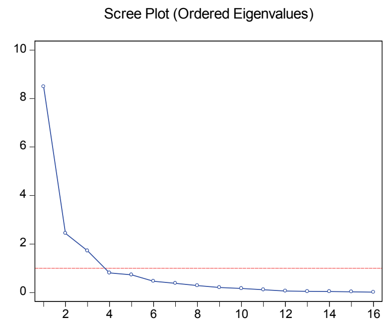
		Switzerland		
1	0.90	0.18	**1.34**	**0.09**
2	-0.35	0.64	0.36	0.36
3	0.31	0.38	0.17	0.43
4	0.55	0.29	-0.20	0.58
5	1.24	0.11	-0.23	0.59
		Euro area		
1	-1.14	0.87	-0.04	0.52
2	-1.18	0.88	-1.05	0.85
3	-1.31	0.90	0.30	0.38
4	-1.30	0.90	-0.31	0.62
5	-0.74	0.77	**1.46**	**0.07**
		UK		
1	-1.62	0.95	-1.59	0.94
2	-0.70	0.76	**1.32**	**0.09**
3	-0.68	0.75	0.17	0.43
4	-0.54	0.71	-0.55	0.71
5	0.21	0.42	-0.87	0.81
		USA		
1	0.45	0.33	0.61	0.27
2	0.18	0.43	1.08	0.14
3	-0.69	0.75	0.84	0.20
4	-0.08	0.53	1.07	0.14
5	0.58	0.28	0.83	0.20
		Russia		
1	**1.96**	**0.02**	**2.21**	**0.01**
2	1.19	0.12	**1.44**	**0.07**
3	**1.43**	**0.08**	0.85	0.20
4	0.80	0.21	**1.44**	**0.07**
5	0.53	0.30	**1.39**	**0.08**

Source: Author's estimations.

Table 7 Results of Principal Components Analysis for Main Central Bank Rates

Number of principal component	Eigenvalue	Variance proportion explained	Cumulative variance proportion explained
1	8.49	0.53	0.53
2	2.44	0.15	0.68
3	1.72	0.11	0.79
4	0.81	0.05	0.84
5	0.73	0.05	0.89
6	0.46	0.03	0.92
7	0.38	0.02	0.94
8	0.29	0.02	0.96
9	0.21	0.01	0.97
10	0.17	0.01	0.98
11	0.11	0.01	0.99
12	0.06	0.00	0.99
13	0.05	0.00	0.99
14	0.04	0.00	1.00
15	0.03	0.00	1.00
16	0.01	0.00	1.00

Source: Author's estimations.



Source: Author's estimations.

Figure 2 Selection of the most Informative Principal Components on the Basis of the Scree Plot