Macroprudential policies: transmission channels and impact on systemic risk

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Abstract

We investigate the impact of regulatory interventions on systemic risk measured by SRISK and CoVaR indicators. We look into the impact of prudential tools on systemic risk at the country level. We check for the average policy impact as well as the differential between the groups of countries. We apply the spatial econometric approach to decompose the policy impact into direct and indirect impact. Our estimations confirm the importance of macroprudential policies for systemic risk reduction. Importantly most of the reduction comes from the indirect effect of the network capturing 85 percent of total impact. Once we split the country-level indicators into banking and non-banking sectors the results still hold. However as expected policy impact is typically more relevant (and sizeable) for the banking sector. The network relevance however is important for both sectors.

Keywords: systemic risk, macroprudential policy, banking regulation, networks, spatial econometrics

1 Introduction

Recent financial crisis has revealed the evil side of financial innovations and deregulation - aggressive risk-taking behaviour of the agents and possible spillovers due to interconnectedness. As the aftermath of the crisis contagion of financial distress and systemic risk build-up became an important topic on the regulatory and research agenda. There are multiple ways to define systemic risk and measure it [1]. In general it reflects the risk in the economy stemming from the interconnections between the financial institutions as opposed to the risk inherent to each one of them individually. The policies aimed at systemic risk regulation are accordingly referred to as macroprudential (as opposed to

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[1] see Bisias et al. (2012) and Benoit et al. (2016) for the surveys on the matter

microprudential regulation targeting individual banks). Starting from 2000 policymakers have introduced a number of macroprudential tools aimed at detecting the build-up of systemic risk and/or stabilizing the financial system.

Our paper considers the issue of systemic risk build-up and uses a spatial econometric methodology to identify the impact of macroprudential policy tools on the banking network. In a nutshell we see how the country-level systemic risk measures react to the policy changes and decompose the impact into direct and indirect parts. First one measures the own country indicator's response to the policy, second considers the risk spillovers from/to the connected countries. We evaluate the relation using the country-level systemic risk indicators, their lagged values, weighted indicators of other countries' risk levels and the instances of tightening and loosening of macroprudential policies.

Baseline approach considers the average direct and indirect effects for the selected countries. Our analysis is done for the major European countries[2], Australia, Canada and the USA. As an extension we plan to evaluate the differences between different country groups (core and periphery European countries vs the other three players), different parts of the financial sector (banks and non-banks) and countries which are net borrowers/net lenders with respect to the rest.

While the question of macroprudential policy impact has always been of great importance to the policymakers, there are certain issues which explain why there is still a room for further analysis.

First issue is related to systemic risk measurement and the distinction to be made between the two groups of institutions: systemically important (those whose default is relevant for the others) and systemically fragile (including the ones vulnerable to defaults of other banks). The measurement metrics should ideally reflect the type of systemicity. They should also be available on a basis frequent enough to match the frequency of regulatory shocks. We rely on the CoVaR Adrian & Brunnermeier (2016) and SRISK Acharya et al. (2017) indicators which reflect the two abovementioned definitions[3]. The metrics are based on the data on institutions' characteristics (size and leverage) and its co-movement with the overall market. They have the benefit of relying on open data sources and allow for fast computations and frequent updates. However, they leave aside the mechanisms by which the build-up of risk occurs.

Second issue concerned the data on policy changes. The datasets on regulatory changes used in the literature beforehead included the measures introduced for single countries (e.g. Aiyar et al. (2012) with UK analysis of capital requirements or Jiménez et al. (2017)) or cross-sectional snapshots (e.g. Barth et al. (2013)) which limited the options for the analysis and interpretation of results. Recent improvements in the field involved the construction of consistent cross-country databases spanning the extended time periods.

[2]we include Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Ireland, Luxembourg, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom

[3]Current version of the paper uses SRISK for the baseline calculations with planned extension based on the CoVaR metric

Examples of those include Cerutti et al. (2016), Cerutti et al. (2015), Reinhardt & Sowerbutts (2015) and Akinci & Olmstead-Rumsey (2017)[4]. We use a quarterly database of macroprudential tools of Cerutti et al. (2016). This is a country-level database including the instances of tightening and/or loosening the macroprudential policy with the set of tools including capital and liquidity ratios, counter-cyclical capital buffers, leverage ratios, limits to the concentration of exposures of financial institutions. Acess to the quarterly data on systemic risk indicators and policy interventions gives us both the time-series variation and the option to analyze the spillovers from one country to another.

Another typical issue was the proper evaluation of country-to country links. Exposures to common risk factors and/or bilateral contractual obligations may generate a spillover of idiosyncratic shocks endangering the whole financial system. Some of the relevant studies use simulation methods to generate the various types of networks and model the propagation of shocks in each of them (see e.g. Hałaj & Kok (2013)). Others rely on the combination of the balance sheet data and simulation to calibrate the networks (Aldasoro & Alves (2016) and Montagna & Kok (2016)). Finally, a group of connectedness measures relies on CDS and stock market returns.

We evaluate the linkages basing on the IMF Coordinated Portfolio Investment Survey dataset covering the country-level bilateral portfolio investments (debt and equity securities). We compute the set of weights showing the shares of investment into each of the counterparty countries. The dataset allows to assess the interlinkages between countries, though ideally we would like to use the data on loans as well given that the policies are targeting the banking systems[5]. In the end we chose to use the large panel of countries without restricting the sample to countries for which the cross-border loans data is available.

Finally, it was often difficult to find a proper estimation methodology which would take into account all the potential interconnections, but not suffer from the "curse of dimensionality". Including multiple countries in the estimation sample typically leads to a boost in number of parameters to be estimated. At the same time the frequency of available data limits the sample size. Spatial econometrics methodology allows to avoid the "curse of dimensionality" by combining the data for all counterparty countries into one factor and thus reducing the number of parameters to be estimated. Nevertheless, it still captures the interdependencies and allows to separate the direct and indirect policy impacts. Finally it allows for both static and dynamic analyses in the panel models.

The use of macro-prudential policy is especially important in the Eurozone because of significant difference across economic and financial conditions across its member states. As mentioned by Vitor Constancio, Vice-President of the ECB, at the Financial Stability Conference, Berlin, 28 October 2015: "We are, of course, very much aware that side effects

[4]The former two have different country coverage (64 and 119 countries) driven by the data availability (quarterly vs yearly data)

[5]We do the robustness check on the flows of loans dataset from the BIS, hower this makes us cut several countries from the analysis due to the data gaps

are also possible, in particular in the form of excessive asset valuations or excessive risk-taking by market operators." Our anallysis allows to shed light on those side effects and includes the major world players as well not to omit the important fraction of the financial market. While it's important to show that macro-prudential policy interventions indeed limit the systemic risk, an equally important questiion is to what extent region-specific policy may amplify though the international network.

Our initial findings are the following. Country-level policy interventions result in economically and statistically significant reduction in systemic risk outcomes. We find that policy tightening (loosening) typically leads to a decrease (increase) in systemic risk with indirect effect playing a major role. 85% of the impact is in fact coming from the network while 15% is attributable to the direct effect. This holds for the SAR specification (which we estimate using the SUR technique) including and excluding the lagged values of the baseline dependent variable - changes of country-level systemic risk measure scaled by the market capitalization. The results are robust to inclusion of year fixed effects and to running the analysis on the indicators for the banking/non-banking parts of the financial system.

2 Literature

2.1 Mechanisms behind systemic risk

The types of events inducing the systemic risk realization (panic-based runs, fundamental-based runs, currency mismatches in the banking system and contagion) are reviewed in Allen & Carletti (2013). Allen & Carletti (2010) emphasized the role of real estate bubbles in crisis formation. The related phenomenon of rapid expansion of credit was studied by Allen & Gale (2000) andAllen & Gale (2009). Liquidity shocks were covered in Allen & Gale (2009), Allen et al. (2009) and Allen et al. (2010). Finally, potential fundamental shocks include sovereign defaults with spillover both across countries and between sovereign debt and banking sectors (see Panizza & Borensztein (2008), Acharya et al. (2014), Acharya & Steffen (2015), Gennaioli et al. (2014)).

Financial contagion is perhaps the most widely cited source of systemic risk. It typically occurs due to the existence of linkages between banks. Freixas et al. (2000) consider the financial network formed by the bilateral operations in the payments' system, the interbank market and the derivatives' market. Following this paper a large part of literature connecting systemic risk and network analysis has evolved. Financial system is viewed as a set of nodes connected via the links representing the various types of interconnections. One group of studies (see e.g. Hałaj & Kok (2013)) uses simulation methods to generate the various types of networks and analyze the shocks' propagation in each of them. Others rely on the combination of the balance sheet data and simulation to calibrate the links (Aldasoro & Alves (2016) and Montagna & Kok (2016)). Specific mechanisms of shock propagation were seen in Arciero et al. (2014) and Gabrieli et al. (2015) basing on the data on overnight interbank loans inferred from the TARGET 2 database. The more widely used connectedness measures rely on CDS and stock market returns which are based on the readily available data. Billio et al. (2012) use the principal component analysis to capture changes in returns' correlation among four groups of financial institutions: banks, brokers, hedge funds and insurance companies. The direction of the relationship is then determined using the Granger causality tests.

2.2 Macro-prudential policy impact

When studying the impact of macroprudential policies several important choices have to be made.

First one relates to the source of data on policy adjustments. The datasets used in the literature beforehead included the cross-sectional snapshots (e.g. Barth et al. (2013)) which limited the options for the analysis and interpretation of results. Given the low frequency of available datasets (yearly basis) the studies usually cover large cross sections of countries. Various country groups (e.g. developped and devolopping) are pooled together though certain studies concentrate on particular regions (Ongena et al. (2013) for the EU and Vandenbussche et al. (2015) for the Central and Eastern Europe), or particular countries (Aiyar et al. (2012) with UK analysis of capital requirements or Jiménez et al. (2017) evidence on changes in dynamic provisioning rules). Recent improvements in the field involved the construction of consistent cross-country databases spanning the extended time periods. Examples of those include Cerutti et al. (2016), Cerutti et al. (2015), Reinhardt & Sowerbutts (2015) and Akinci & Olmstead-Rumsey (2017) [6].

A special case is a paper of Buch & Goldberg (2016) summarizing a series of country-level studies done basing on the Cerutti et al. (2016) dataset. The uniqueness and consistency of both instrument definitions and empirical approach makes the study quite important. Results turned out to be mixed. The authors documented the policy spillovers in terms of bank lending. However they saw heterogeneity across instruments and banks' characteristis (balance sheet conditions and business models). The economic significance of policy impact for the loan growth turned out to be quite limited and could be driven by few country-specific policy implementations.

The analysis in the literature is typically done on a country level with possible subdivision into bank and non-bank borrowers/lenders data. Instruments are typically split into groups according to their essence and the objects of policy application. Cerutti et al. (2016) include five types of instruments: capital buffers, interbank exposure limits, concentration limits, loan to value (LTV) ratio limits, and reserve requirements. We would further elaborate on this database when we discuss our dataset. Cerutti et al. (2015)

[6] The former two have different country coverage (64 and 119 countries) driven by the data availability (quarterly vs yearly data)

add to those the data on the leverage ratio for banks; dynamic loan-loss provisioning, tax on financial institutions and capital surcharges on SIFIs. Elliott et al. (2013) split the tools into two major groups: demand side (limits on loan-to-value ratios, loan maturities, margin requirements) and supply side (limits on deposit rates, limits on lending rates, restrictions on banks' portfolios, reserve requirements, capital requirements and supervisory guidance). Bakker et al. (2012) group the policies into capital and liquidity requirements, asset concentration and credit growth limits and loan eligibility criteria. Similarly Reinhardt & Sowerbutts (2015) looks into three groups of instruments: capital regulations (capital requirements and risk-weights changes), lending standards (LTV and DTI ratios) and reserve requirements. Finally Cizel et al. (2016) split the measures into those aimed at price and quantity of lending activity. Examples of price-based policies include dynamic provisioning requirements and taxes on banks. Examples of quantity-based include the exposure limits. This subdivision is in fact parallel to the final important decision - outcome to analyze.

There is no consensus in the literature as well as among policymakers about the objective of macro-prudential policy. However, many papers argue that the financial stability is primary motivation. The typical study in the field looks into the loan volumes and growth rates (with emphasis on changes in geography and type of exposures). As mentioned by Buch & Goldberg (2016) "bank lending as the key transmission channel running from banks to the real economy is the dependent variable".

Cerutti et al. (2016) analyze the evolution of key variables such as credit, policy rates, and house prices. They find low correlation between the instrument changes and the credit and policy rates as well as house prices. Correlation with credit growth demonstrates the counter-cyclicality of policies (tightening in the moments of credit booms). The correlations with respect to house prices are mostly not statistically significant across most countries. LTV caps are found to be complementary for monetary policy actions (measured by policy rates). Reserve requirements are also used as a tool complementary to the monetary policy in the emerging countries and several developped (EU) countries. Cerutti et al. (2015) use a bigger panel of countries (119) and a greater number of instruments (12) combined into a unique index. They find macroprudential policies to be less effective in relatively open economies (which have a greater potential for spillover effects). As a supporting fact they find positive association between the policy usages and the share of cross-border credit.

Bakker et al. (2012) study the relation between macroprudential policies and credit booms. Overall the measures are effective in alleviating the credit booms i.e. they reduce the risk of boom ending up with crisis. However they did not prevent the booms from starting and did not shorten the periods of booms.

Reinhardt & Sowerbutts (2015) perform the analysis for the BIS bank flows data. They found tightening capital requirements in a country to be associated with an increased aggregate borrowing from abroad (including the lending from the affiliates of the foreign banks). They also found no impact of changes in lending standards and mixed evidence on the impact of reserve requirements. Impact is expectedly reduced if foreign countries have a comparable tightening of policy. Akinci & Olmstead-Rumsey (2017) study the 2000-13 of changes in macroprudential policy with certain focus on instruments affecting the housing market (LTV and DTI ratios). They find that overall real domestic bank credit declines if prudential measures are tightened. Mortgage lending and house prices are affected only by macroprudential instruments related to the housing market which outperform the non/targeted measures in terms of effectiveness.

Ongena et al. (2013) cover a sample of multinational banks and assess the impact of regulation in one country on the same bank's lending standards in host country. They consider two alternatives: stricter home regulation leading to a more conservative lending in all markets or risk-reduction in home country accompanied by a transfer of risky activity to the foreign markets. Empirical evidence was in favor of the second argument.

Cizel et al. (2016) emphasized the phenomenon of risk shifting across sectors in addition to risk-shifting to foreign jurisdictions. Specifically they document the presence of cross-sector substitution effects from bank to non-bank lending activity. They find evidence of substitution effects towards nonbank credit in advanced economies with strongest impact from quantity restrictions when compared to the price-related ones.

According to Galati & Moessner (2013), one of the main objectives of macro-prudential policy is limiting systemic risk and negative externalities on financial system. As to our best knowledge our paper is the first one to look into the policy consequences using the systemic risk indicators and to decompose the policy impact into the direct home country effect and the indirect (spillover) effect coming from the network of connected countries. The paper which is close to ours in terms of the outcomes is Nistor Mutu & Ongena (2015) looking into the impact of bailout events on systemic risk in 2008-2014. The impact turned out to depend on the type of operation, bank characteristics and length of the period. Recapitalizations had only a short term risk-reducting impact while liquidity injections produced a systemic risk increase for risky or low-profitable banks. The measures considered represent the types of policy interventions aimed at saving the institutions which are insolvent or close to insolvency. Our paper instead focuses on the cases of ex-ante policies used to reduce the system-wide levels of systemic risk and/or to prevent its build-up. Similarly to Cizel et al. (2016) we split country systemic risk into bank and non-bank parts. In this way we see whether there is in fact a risk transfer from one part of the financial system to the other.

2.3 Systemic risk: indicators and assessment of interconnections

The indicators we use are SRISK and CoVaR based on the stock market data. While multiple ways of the measurement are present in the literature the two measures have certain advantages we discuss below[7]. First of all both measures rely on the stock market data and thus can be obtained and/or recomputed with reliance on multiple data sources. This also allows to get the series at a daily frequency.

SRISK measure was introduced by Acharya et al. (2017) which it as the amount of capital a bank needs to raise in case of market distress (with distress being a 40% drop in the market index).

$$\begin{aligned} SRISK_{i,t} &= E_{t-1}(CapShortfall_{i,t} \mid Crisis) = E(k(Debt_{i,t} + Equity_{i,t}) - Equity_{i,t}|Crisis) = \\ &= kDebt_{i,t} - (1-k)(1 - LRMES_{i,t})Equity_{i,t}, \end{aligned} \tag{1}$$

where $Debt_{i,t}$ and $Equity_{i,t}$ - stand for the book levels of debt and equity, k refers to the capital requirement (8% Basel requirements lowered to 5.5% for the non-US countries given the existing accounting differences).

Long run marginal expected shortfall ($LRMES_{i,t}$) is defined as the equity loss of a bank i in case of a crisis: $LRMES_i, t = -E(R_{i,t} \mid R_{S,t} < Q_S^{\alpha})$ ($R_{i,t}$ stands for the return of a given institution, $R_{S,t}-$ for the system return). It is estimated using the bivariate daily time series model characterizing the dynamics of daily bank's and stock market returns. Resulting measure depends on individual stock volatility, its correlation with the market, bank's size and leverage.

Adrian & Brunnermeier (2016) introduce $\Delta CoVaR$ defined as a change in the value at risk of the system if a given institution is in distress and estimated using the daily data on equity returns. They define $CoVaR$ via the following equality:

$$P(X^j \leq -CoVaR_{\alpha}^{j|C(X^i)}\ C(X^i)) = \alpha \tag{2}$$

$CoVaR$ indicates the value at risk of object j conditional on object i being at its VaR level. The related measure of $\Delta CoVaR$ is computed as:

$$DeltaCoVaR_{\alpha}^{j,i} = CoVaR_{\alpha}^{j|X^i=-VaR_{\alpha}^i} - CoVaR_{\alpha}^{j|X^i=Median^i} \tag{3}$$

measuring the change in $\alpha-$level VaR of j conditional on i moving from its median state to its own $\alpha-$level VaR.

[7] We refer to Bisias et al. (2012) and Benoit et al. (2016) for more extensive surveys on systemic risk measurement.

$CoVaR$ and SRISK allow us to illustrate the important issue in systemic risk evaluation. Choosing the risk indicator we need to define institution's systemicity. First definition would include "systemically important financial institutions" (SIFIs) whose failure is expected to bring substantial losses to the interlinked institutions. Systemic importance might be measured using the $CoVaR$ methodology. Alternatively It's also important to consider the group of systemically fragile institutions which are mostly vulnerable to defaults of other banks or to the shocks to the system as a whole. This is better achieved using the SRISK methodology. We describe the ways we obtained the measures in the following section.

3 Dataset

3.1 Systemic risk measures

We obtain the SRISK measure from the VLab database. To ensure comparability between countries we are scaling each country by the market capitalization of each market. We use average monthly values, but as a robustness check we pick the end of month values of SRISK.

Figures 1 below show the evolution of SRISK for the period of interest and the scaled measure trajectory for each of the countries. We use the quarterly data to match the frequency of regulatory interventions. Descriptive statistics for SRISK levels in each country are shown in Table 1

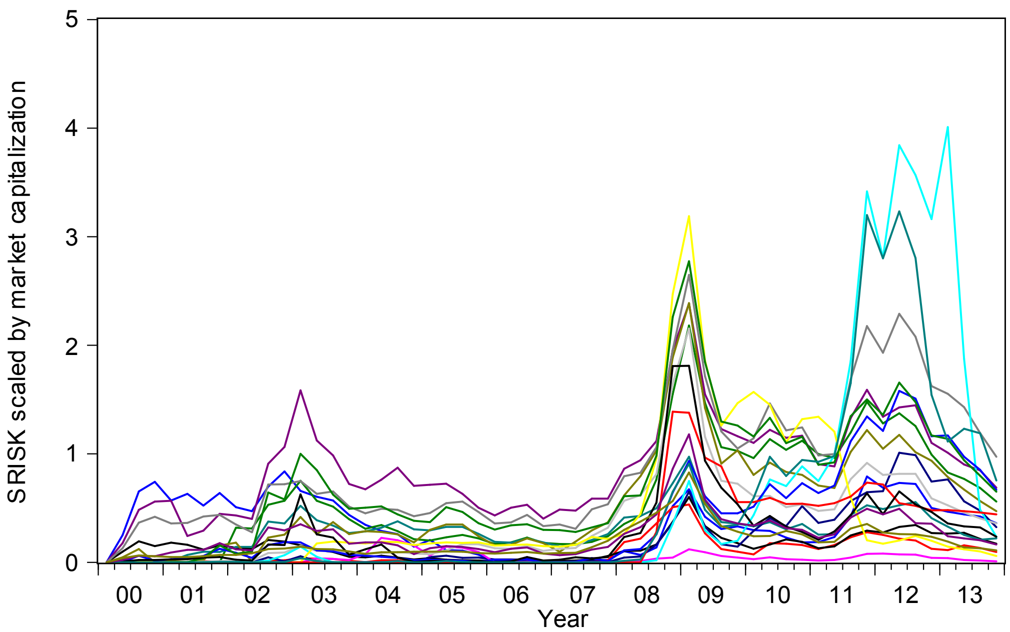

Figure 1: Systemic risk evolution over 2000-14

Table 1: Descriptive statistics for SRISK indicators

Variable	n	Mean	St. Deviation	Min	P25	P50	P75	Max
Australia	60	0.07	0.09	0	0	0.02	0.12	0.4
Austria	60	0.27	0.18	0	0.1	0.25	0.41	0.63
Belgium	60	0.43	0.37	0	0.16	0.28	0.73	1.64
Canada	60	0.11	0.08	0	0.04	0.11	0.15	0.45
Denmark	60	0.39	0.36	0	0.14	0.26	0.6	1.79
Finland	60	0.03	0.04	0	0	0.01	0.04	0.17
France	60	0.67	0.45	0	0.32	0.54	0.9	1.99
Germany	60	0.64	0.33	0	0.41	0.56	0.84	1.79
Greece	60	0.41	0.8	0	0	0.01	0.36	3.01
Ireland	60	0.32	0.5	0	0.03	0.13	0.19	2.39
Italy	60	0.28	0.33	0	0.02	0.09	0.48	1.18
Luxembourg	60	0.19	0.26	0	0	0	0.39	1.04
Netherlands	60	0.54	0.43	0	0.25	0.43	0.84	2.08
Norway	60	0.2	0.27	0	0.02	0.12	0.26	1.36
Portugal	60	0.37	0.61	0	0	0.01	0.58	2.43
Spain	60	0.15	0.2	0	0	0.03	0.26	0.76
Sweden	60	0.18	0.15	0	0.09	0.13	0.25	0.88
Switzerland	60	0.22	0.13	0	0.14	0.22	0.28	0.73
United Kingdom	60	0.28	0.31	0	0.06	0.15	0.43	1.62
United States	60	0.13	0.11	0	0.06	0.09	0.19	0.62

3.2 Country-level linkages

Country-level links are coming from an IMF Coordinated Portfolio Investment Survey (CPIS). The CPIS's important feature is the requirement for all participants to provide the amounts of their portfolio investment assets (debt and equity securities) split by the issuers' country of residency. It is undertaken from 2001 on an annual basis and presently and covers about 70 countries. For each country we pick the amounts invested into the counterparty country's securities and divide by the overall investment. Portfolios related to countries in our list cover 66 to 95 percent of overall portfolio investment. Appendix presents the splits of investment for each country across time. With several exceptions the weights are quite stable hence we focus on the 2003 weights for our analysis[8].

[8] We've also made a cross check for major European countries by comparing the geographical exposure split fsumming up the exposures of top banks within each country. Those exposures include the loans and the geographical split does not diverge with our CPIS data. Hence we consider our weights to be representative of the country-level loan exposure splits as well.

3.3 Macroprudential policy tools

For the purpose of this study we use the IMF data from Cerutti et al. (2016). It covers a broad range of macro-prudential measures for 64 countries during the period between 2000 and 2014 and has decent data quality[9].

Primary source for the dataset is Cerutti et al. (2015), national authorities information provided either through the IBRN or the IMF. Dataset includes five types of macroprudential instruments recorded as 1 or -1 entry, depending on whether the prudential tool was tightened or loosened in a given quarter. The index is coded as 0 in those quarters when no change occurs[10]. We concentrate on the financial-based tools aimed at financial institutions' assets or liabilities (general capital requirements, sector specific capital buffers, reserve requirements, concentration limits and interbank exposure limits).

- The general capital requirements index is based on the regulatory changes introduced in the Basel Accords. And it records an implementation date of policy changes.
- The sector specific capital buffer index is another bank-capital based indicator. This instrument adjusts with risk-weights of specific bank exposures and it gets tighter and looser with financial cycle. In the dataset index of sector specific capital buffer may take values higher than 1 and lower than -1, since it represent a sum of prudential instruments across different categories of credit, such as real estate credit, consumer credit and other credit.
- Reserve requirements might be used as both monetary policy instrument and macroprudential instrument, however, the index of reserve requirement is included in the dataset only for prudential objectives. It also takes values below -1 and above 1 to capture the intensity of changes. Dataset captures both foreign and local reserve requirements.
- Limits on concentrated exposures and on exposures to other banks are policies that affect claims between banks and their borrowers. They might be changed due to change in several characteristics, for example definition of large exposure, the level of limit, differentiation across counterparties, aggregate limits and sectors and assets that are covered by regulation. Importantly, the variable concentration limits and interbank exposure limits is coded as policy tightened (policy loosened), if on net, taking into account change in all characteristics is policy tightened (policy loosened).

While general capital requirements have the most changes from the cross-country perspective, reserve requirements (as well as borrower-based LTV ratio limits) have the

[9] Cerutti et al. (2016) claim that consistency of the dataset was the result of feedback received directly from country regulator on the accuracy of the policy changes recorded in the database

[10] The instrument is coded as missing if policymakers cannot use a tool, in other words if the tool has not been enacted and until time the rule implementation period has passed

Table 2: Macroprudential policy changes

Country	2000-05(L)	2000-05(T)	2006-10(L)	2006-10(T)	2011-14(L)	2011-14(T)
Australia	0	3	1	0	0	2
Austria	1	0	0	0	1	2
Belgium	1	0	0	0	0	1
Canada	0	0	0	0	0	2
Denmark	0	0	0	0	0	2
Finland	1	0	0	0	0	1
France	1	1	0	2	1	3
Germany	0	0	0	1	0	2
Greece	1	0	0	0	0	1
Ireland	1	0	0	2	0	1
Italy	1	0	0	1	0	1
Luxembourg	1	0	0	0	1	3
Netherlands	1	0	0	1	0	2
Norway	1	1	1	1	0	2
Portugal	1	0	0	1	1	2
Spain	1	0	0	1	1	2
Sweden	0	1	0	0	0	6
Switzerland	0	0	0	1	0	4
United Kingdom	0	0	0	1	0	2
United States	0	0	0	0	0	2

L stands for loosening of policies, T stands for tightening episodes

largest number of tightening and loosening episodes. The early period is characterized by frequent policy actions in emerging economies, advanced economies have been more proactive since the global financial crisis.

4 Empirical strategy

4.1 Static Models

4.1.1 Baseline Static Model

We use static spatial econometric model (SAR) to capture the direct and spillover effects from the macroprudential policies. Baseline specification may be described by the following equations:

$$y_{it} = \alpha_i + \rho y^*_{it} + \beta x_{it} + u_{it} \tag{4}$$

$$y_{it}^{*} = \sum_{i^{*} \neq i} \omega_{i^{*}j} y_{i^{*}t} \tag{5}$$

where y is $N \times 1$ vector of country-specific dependent variables, α_i captures non-spatial fixed effects, y^{*} is $N \times 1$ vector of foreign variables specific to country i, ω_{ij} is i, j element of matrix of weights W, x_{it} - stands for the country-specific macro-prudential tools. Finally, u_{it} is a vector of country-specific idiosyncratic shocks with

$$\begin{aligned} E(u_{it}u_{jt}^{'}) &= \Sigma_{ij} \\ E(u_{it}u_{jt'}^{'}) &= 0, \forall i, j \text{ and } t \neq t^{'} \end{aligned} \tag{6}$$

This model allows us to decompose the overall reaction of country-level systemic risk to macro-prudential policy into direct and indirect effects.

In current specification the global variable for country i is a weighted sum of systemic risks of other countries $j \neq i$, where weights capture the investment of country i into the other countries (i.e. how much other countries $j \neq i$ need to repay to country i). Hence we expect the tightening of policy in a given country to have a risk-reducing effect for the investor-countries.

The weighting matrix has zero diagonal which is typical for the standard spatial models which typically base the weights on the geographic distance between the units of observation. However, our matrix is asymmetric (investment of country i into assets of country j does not have to match the investment of country j into country i)

As a baseline model we use the specification, allowing for heterogeneity across countries only in terms of the fixed effects. In this way we save degrees of freedom. Such a restriction does not pose a problem for the evaluation of average direct and indirect effects.

The country-specific effects of macroprudential policy can be computed as:

$$\frac{\partial \Delta \mathbf{y}_i}{\partial u_i} = (I - \rho \cdot W)^{-1} \cdot \mathbf{1} \cdot \beta$$

given estimates for ρ and β the matrix $(I - \rho \cdot W)^{-1}$ become observable, and therefore the overall, direct and indirect effect of macroprudential policy can be computed as follows:

- *Average direct effect:* the average of the diagonal elements of $(I - \rho \cdot W)^{-1}$
- *Average total effect:* the sum across the ith row of $(I - \rho \cdot W)^{-1}$ represents the total impact on country i from the macroprudential policy shock. There are n sums like this. The average of this sums is an average total effect.
- *Average indirect effect*: the difference between the average total effect and the average direct effect.

In further steps, by relaxing restrictions and by allowing for cross - country heterogeneity also in terms of other parameters as ρ_i and β_i, we will be able to answer richer set of important questions. For example, what is the direct effect of country i macroprudential policy on the systemic risk in country i? This effect should be captured by the coefficient β_i. What is the effect of this policy on the systemic risk of other countries $\forall$ i^*, such that $i^* \neq i$? It should be captured by the set of coefficients $\rho_{i^*}, i^* \neq i$. What is the indirect effect of policy applied in country i on the systemic risk of country i, that spreads through the systemic risk of other countries? This one should be captured by the coefficient ρ_i.

4.1.2 Spatial Vector Autoregressive Model

Static model of the previous subsection considers global variable, as well as all the other variables at time t. This might indirectly generate a problem of reverse causality (if country i's systemic risk is significant enough to affect the contemporaneous systemic risk measures in related countries). We adress this issue by using instrumental variable approach. Laged value of a global variable is the most natural instrument for global variable. So our next specification is the following:

$$y^*_{it} = \gamma + \delta y^*_{it-1} + \epsilon_{i,t} \tag{7}$$

$$y_{it} = \alpha_i + \rho \widehat{y^*_{it}} + \beta x_{it} + u_{it} \tag{8}$$

where

$$y^*_{it} = \sum_{i^* \neq i} \omega_{i^*j} y_{i^*t} \tag{9}$$

and where $\widehat{y^*_{it}}$ is a fitted value from the first stage regression.

4.2 Dynamic Models

4.2.1 Baseline Dynamic Model

Up to now we were using static models of spatial econometrics. However, since the data we use is a time series data, it is natural to consider also time dependence between main variables. This will allows us to caputre effects of maroprudential policy also dynamically. To obtain dynamic model we employ spatial vector autoregressive model with temporal lags of the dependent variable. We call this model baseline dynamic model.

$$y_{it} = \alpha_i + \mu y_{it-1} + \rho y^*_{it} + \beta x_{it} + u_{it} \tag{10}$$

where

$$y^*_{it} = \sum_{i^* \neq i} \omega_{i^*j} y_{i^*t} \tag{11}$$

μ - is autoregressive coefficient from the standard VAR literature.

4.2.2 Dynamic Spatial Vector Autoregressive Model

Following the same logic as with static models, one might argue that there might be a reverse causality issues and in order to avoid this problem we also use IV approach for the dynamic model. We call this model dynamic spatial vector autoregressive model or DSpVAR further on. Our econometric specification goes as follows:

$$y^*_{it} = \gamma + \delta y^*_{it-1} + \epsilon_{i,t} \tag{12}$$

$$y_{it} = \alpha_i + \mu y_{it-1} + \widehat{\rho y^*_{it}} + \beta x_{it} + u_{it} \tag{13}$$

where

$$y^*_{it} = \sum_{i^* \neq i} \omega_{i^*j} y_{i^*t} \tag{14}$$

5 Results

We employ SUR methodology for the estimation of all the models to take into account heteroskedasticity and contemporaneous correlation in the error terms across country-level equations. Table 3 presents estimation results for all above mentioned specifications[11].As can be seen from the Table 3 (Panel A) signs of the coefficient as one would expect. Tightening of macroprudential policy leads to the systemic risk reduction (negative and significant coefficient) while the spatial variable gets a positive sign (i.e. the reduction of systemic risk in related countries is associated with risk reduction in the country of interest). Put it differently, whenever there is a macroprudential policy that is applied in country i, there is a decrease of a systemic risk in this country and this decrease is also amplified through the network effect of other countries. Positive autoregressive coefficient suggests the outcome's dependence on past realizations. Panel B confirms the initial findings via the first robustness check. Each country model is complemented with a set of year fixed effects which ensures that our results are not driven by the time trends. We proceed with the decomposition of total effect into direct and indirect effects. Results are shown in Table 5[12]. As before, panels A and B contain the results withot/with year fixed effects.

[11]We do not report the estimates of the fixed effects. They are available upon request

[12]Simulations are done using the bootstrap procedure with resampled residuals in 10000 iterations.

In the baseline static specification, total effect of macroprudential policy on the systemic risk is -2.53, however effect becomes even stronger ones IV approach with lagged dependent global variable is applied, it becomes -5.77. It is interesting to notice that not only the size of the effect changes, but also the effect become more significant. Looking at the decomposition the direct effect of macroprudential policy is rather small, while indirect effect account for roughly 85% of the total impact.

To see the evolution of the impact effect we consider dynamic spatial vector autoregression model. Main results are inthe form of impulse response functions presented in Figures 2 and 3. Confidence bounds are constracted with 10000 bootstrap simulations.

Table 3: Macroprudential Policy and Systemic Risk (country level)

	Panel A				Panel B			
Variables	(1) Static	(2) SpVAR	(3) Dynamic	(4)DSpVAR	(5) Static	(6) SpVAR	(7) Dynamic	(8) DSpVAR
Autoregressive Term (μ)	-	-	0.039***	0.076***	–	–	0.031*	0.078***
			[0.009]	[0.029]			[0.012]	[0.029]
Global Variable (ρ)	1.1066***	0.632***	1.082***	0.319***	1.079***	0.354***	1.057***	0.086
	[0.0035]	[0.106]	[0.01]	[0.09]	[0.012]	[0.129]	[0.017]	[0.128]
Macroprudential Policy (β)	−0.317**	−0.865***	−0.294	−0.848***	−0.600**	−0.848***	−0.500*	−0.846***
	[0.135]	[0.298]	[0.249]	[0.305]	[0.257]	[0.296]	[0.281]	[0.305]
Country Fixed Effects	yes	yes	yes	yes	yes	yes	yes	yes
Year Fixed Effects	no	no	no	no	yes	yes	yes	yes
Observations	1180	1180	1160	1160	1180	1180	1160	1160
Countries	20	20	20	20	20	20	20	20

Systemic risk variable is in log percentage change.

*** - p-value is below 0.01, ** - p-value is between 0.01 and 0.05, * - p-value is below 0.1

Estimation is done by SUR with fixed effects. The estimation period is 2000Q1 - 2013Q4. Standard errors are in brackets

Table 4: Macroprudential Policy and Systemic Risk (country level-by type of institution)

	Banks				Non-banks			
Variables	(1) Static	(2) SpVAR	(3) Dynamic	(4)DSpVAR	(5) Static	(6) SpVAR	(7) Dynamic	(8) DSpVAR
Autoregressive Term (μ)	-	-	-0.036^{***}	-0.180^{***}	–	–	-0.050^{***}	-0.190^{***}
			[0.008]	[0.027]			[0.012]	[0.033]
Global Variable (ρ)	1.109^{***}	0.695^{***}	1.116^{***}	0.389	0.783^{***}	0.940^{***}	0.935^{***}	2.143^{***}
	[0.005]	[0.191]	[0.009]	[0.259]	[0.002]	[0.005]	[0.012]	[0.638]
Macroprudential Policy (β)	-0.758^{**}	-1.215^{***}	-1.018^{**}	-1.412^{**}	-0.072^{**}	-0.054	-0.291^{*}	-0.571^{**}
	[0.307]	[0.502]	[0.403]	[0.491]	[0.035]	[0.116]	[0.212]	[0.279]
Country Fixed Effects	yes	yes	yes	yes	yes	yes	yes	yes
Year Fixed Effects	no	no	no	no	no	no	no	no
Observations	1180	1180	1160	1160	1180	1180	1160	1160
Countries	20	20	20	20	20	20	20	20

Systemic risk variable is in log percentage change.

*** - p-value is below 0.01, ** - p-value is between 0.01 and 0.05, * - p-value is below 0.1

Estimation is done by SUR with fixed effects. The estimation period is 2000Q1 - 2013Q4. Standard errors are in brackets

Table 5: Macroprudential Policy Effects Decomposition - country level

		Panel A		Panel B	
Variables		(1)Static	(2)SpVAR	(3)Static	(4)SpVAR
Total Effect	*Mean*	−3.1033	−3.9143	−4.9921	−4.3754
	P	0.0769	0.0603	0.0266	0.0317
Direct Effect	*Mean*	−0.4501	−0.5661	−0.7985	−0.8071
	P	0.0769	0.0603	0.0266	0.0317
Indirect Effect	*Mean*	−2.6532	−3.3482	−4.1936	−3.5682
	P	0.0769	0.0603	0.0266	0.0317

Notes: Systemic risk variable is in log percentage change. Estimation is done by SUR with fixed effects Panel A and by SUR with fixed and year effects in Panel B. The estimation period is 2000Q1 - 2013Q4. Simulations are done using bootstrap with resampling for 10 000 iterations. P stands for the probability for the average effect to be higher than zero, taking into account the total bootstrap distribution.

Table 6: Macroprudential Policy Effects Decomposition - country level

		Banks		Non-banks	
Variables		(1)Static	(2)SpVAR	(3)Static	(4)SpVAR
Total Effect	*Mean*	−7.736	−5.139	−0.169	−0.670
	P	0.066	0.167	0.346	0.113
Direct Effect	*Mean*	−1.081	−0.746	−0.056	−0.223
	P	0.066	0.167	0.346	0.113
Indirect Effect	*Mean*	−6.556	−4.393	−0.113	−0.447
	P	0.066	0.167	0.346	0.113

Notes: Systemic risk variable is in log percentage change. Estimation is done by SUR with fixed effects. The estimation period is 2000Q1 - 2013Q4. Simulations are done using bootstrap with resampling for 10 000 iterations. P stands for the probability for the average effect to be higher than zero, taking into account the total bootstrap distribution.

6 Conclusions

We have evaluated the impact of financial-based macroprudential policies on the systemic risk outcomes for a sample of 20 countries. We have shown that policy interventions are relevant for systemic risk outcomes. Risk reduction can be decomposed into the direct effect - policy impact in a country where it is introduced - and the indirect effect - coming throught the network of connected countries. On a country-level we have estimated that on average 85% of policy impact is coming from the network and only 15% are the result of a direct relation. This relation is observed both in static and dynamic specifications. It also holds when we perform the analysis on bank and non-bank levels. However the effects stay significant (with similar proportion) only for the bank segment consistently with the policy targeting the banking sector.

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Figure 2: Impulse responses to policy shock

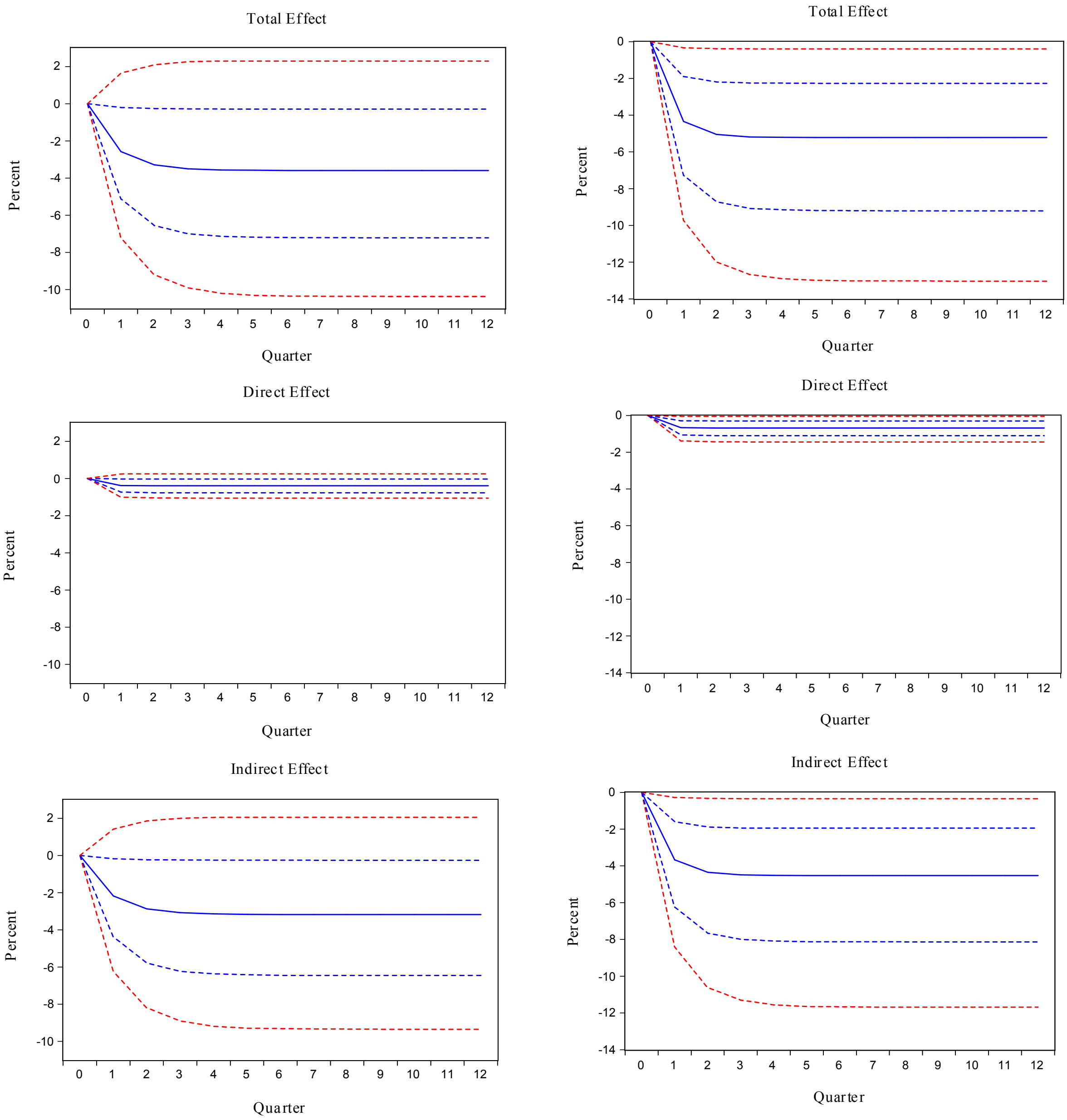

Figure 3: Impulse responses to policy shock - banks - w/o and with IV

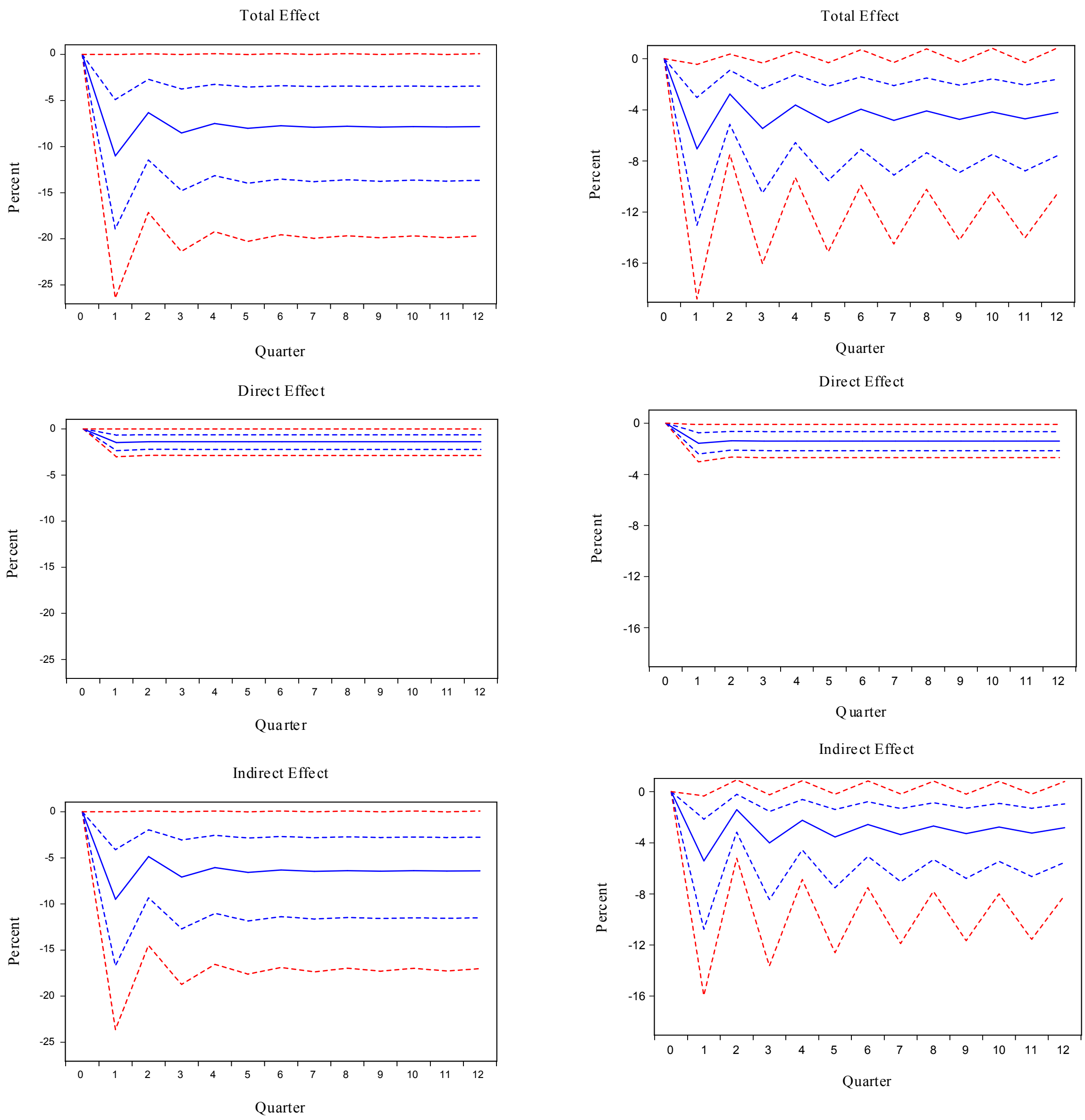

Figure 4: Impulse responses to policy shock - non-banks - w/o and with IV