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# **Drivers of Systemic Risk: Do National and European Perspectives Differ?\***

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**Very preliminary draft. Please do not quote. Comments are welcome!**

## **Abstract**

Mitigating the negative externalities that systemic risk can create for the financial system is the goal of macroprudential supervision. In Europe, macroprudential supervision is conducted both, at the national and at the European level. In principle, national regulators are responsible for macroprudential policies. Since the establishment of the Banking Union in 2014, the largest banks in the Euro Area are under the direct supervision of the European Central Bank (ECB). In this capacity, the ECB can tighten macroprudential measures implemented at the national level. In this paper, we ask whether the drivers of systemic risk differ when applying a national versus a European perspective. We use market data for about 100 listed European banks to measure each bank's contribution to systemic risk (SRISK) at the national and at the Euro Area level. Our research has three main findings. First, on average, systemic risk has increased during the financial crisis. The difference between systemic risk at the national and the European level is not very large but there is a considerable degree of heterogeneity both across countries and banks. Second, we explore the drivers of systemic risk. A bank's contribution to systemic risk increases in bank size, in bank profitability, and in the share of banks' nonperforming loans. It decreases in the share of loans to total assets and in the importance of non-interest income. Third, the qualitative determinants of systemic risk are similar at the national and at the European level while the quantitative importance of some factors differs.

**Keywords:** Systemic risk, bank regulation, Banking Union

**JEL codes:** G01, G21, G28

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# 1 Motivation

Systemic risk can create negative externalities for the financial system which individual banks do not internalize.<sup>1</sup> Banks experiencing a negative shock to capital cut down credit or sell assets. In reacting to an individual capital shortage, they fail to anticipate that other banks may have capital shortages, too. Systemic risk thus leads to an aggregate shortage of capital in the financial sector such that a reduction in lending by one bank cannot be offset by other financial institutions (Acharya and Steffen 2012). The externality that generates systemic risk is the propensity of a financial institution to be undercapitalized when the whole system is undercapitalized. Internalizing systemic risk by supervising financial institutions and, if needed, imposing additional capital requirements on banks is the task of macroprudential supervision.

In Europe, macroprudential powers rest both, at the national and at the European level. National supervisors are responsible for macroprudential oversight and for imposing macroprudential regulations. Under the Single Supervisory Mechanism (SSM), the European Central Bank (ECB) directly supervises the largest 130 European banks, representing almost 85% of total banking assets in the Euro Area. Provided that the ECB identifies systemic risks which are not adequately addressed by the national regulator, it can impose stricter regulations than the national regulator.<sup>2</sup> This division of power between the national and the European level may have implications for the stringency of macroprudential regulation. On the one hand, the degree of regulatory forbearance and “inaction bias” may be stronger at the national level if political considerations influence decision-making. On the other hand, European supervisors may fail to act if systemic risk is deemed to be contained to national financial markets.

In this paper, we ask and try to answer two main questions. First, what is a bank’s contribution to systemic risk at the national in contrast to the European level? Second, do the drivers of systemic risk differ at the national and at the European level? While there is a large and growing literature on systemic risk in banking, most previous studies do not take into account that contributions to systemic risk may differ at the national and at the European level. Prima facie, banks which are important and thus “systemic” for the national financial system may be less “systemic” for the European financial system simply because the relevant market is larger. But systemic risk is not only driven by market size. The correlation of risk

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<sup>1</sup> “Systemic” risk is different from “systematic” risk (Hansen 2013). Systematic risk is defined as macroeconomic or aggregate risks that cannot be diversified away. It is also known as market, non-diversifiable, or beta risk.

<sup>2</sup> Note that the ECB’s ability to tighten national regulation is restricted to those instruments available under the Capital requirements regulation and directive (CRR/CRD IV).

across banks, the exposure of banks to macroeconomic shocks, and the degree of connectedness of financial institutions are likewise drivers of systemic risk. If the impact of negative externalities caused by a bank at home differs from the contribution to systemic risk abroad, a national regulator might fail to take this cross-border externality into account. To the best of our knowledge, the drivers of systemic risk at the national versus the international, European level have not been analyzed before.

In this paper, we thus combine stock market data for European banks with balance sheet data. Our data cover the years 2002-2013. To measure the systemic risk emerging from a specific bank, we follow Brownlees and Engle (2012) and calculate a systemic risk measure – SRISK – which captures a bank's contribution to an aggregate capital shortfall. It is calculated based on stock market data. Overall, our dataset covers 97 European banks listed on the stock market. Given that not all explanatory variables of interest are available for all of these 97 banks, we analyze the determinants of systemic risk for 67 of these banks.

The SRISK measure has been used in several previous studies. The one closest to ours is the one by Benoit (2014) who extends the SRISK measure to distinguish the contribution to systemic risk at different levels – global, supranational, or national. While the absolute values of the SRISK can vary substantially across different regional levels, the ranking of banks according to SRISK is very similar for the different levels. Acharya and Steffen (2012) apply the SRISK concept to European banks during the recent debt crisis. They find that sovereign debt holdings have a significant impact on systemic risk whereas systemically risky banks obtained most of the government support after 2008.

We apply the SRISK measure to all banks in the Euro Area that are listed on the stock market, including those which fall under the supervision of the SSM. As in Benoit (2014), we compute the contributions of these banks to systemic risk at the national and the Euro Area level. We find that, on average, the SRISK measures of the 97 listed banks included in this study are similar at the national level and at the Euro Area level. However, at the level of the individual bank, we do find heterogeneity across banks and over time.

In a second step, we analyze the determinants of systemic risk. Finding that the drivers of systemic risk at the national level differ from those at the European level might have implications for incentives of regulators to impose macroprudential regulations and thus for the level at which banks should be supervised. From a theoretical point of view, for example, externalities generated by national banks abroad due to cross-border activities will be more effectively internalized by a supranational supervisor (Beck and Wagner 2013). National supervisors in countries with fragile banks that cause negative externalities abroad might have an incentive to shift the financial burden on to other countries. As a result, national supervision may be inefficient and induce social costs from a European perspective.

Empirical studies show that a national approach to supervision and regulation might lead to distortions in integrated markets. Agarwal et al. (2014), for instance, exploit the fact that supervision of US commercial banks alternates between the state and federal regulator. They find that federal regulators are less lenient. Beck et al. (2013) analyze trade-offs regarding the intervention of supervisors into the activities of distressed banks with cross-border activities. They show that national regulators intervened at a later stage the larger the share of foreign deposits and assets. This supports the theoretical finding that national regulators are less likely to internalize costs or benefits arising in other countries.

As regards the impact of size, our study shows that large banks contribute more to systemic risk than smaller banks, and this result holds irrespective of the regional level considered. “Size” is thus an important variable to identify globally, systemically important financial institutions (G-SIFIs), i.e. banks with a high contribution to systemic risk. But there are additional bank-level factors which drive the contribution of banks to systemic risk. More profitable banks, banks with a lower share of loans to total assets and thus a less “traditional” business model, and banks with a higher share of bad loans on their balance sheet contribute more to systemic risk. These effects gain in economic magnitude the larger a bank is.

In qualitative terms, the determinants of systemic risk are similar at the national and the Euro Area level. In quantitative terms, the impact of some factors differs. The weakening impact of a high share of traditional loans in total assets for systemic risk, for instance, is stronger at the national than at the European level.

Our analysis is linked to two strands of previous literature. A first set of previous studies proposes different measures for systemic risk. An alternative measure of systemic risk is the CoVaR model by Adrian and Brunnermeier (2011). According to this model, systemic risk is measured through the financial system's Value-at-Risk, conditional on the state of a particular financial institution. An institution's contribution to systemic risk is the difference between the CoVaR, conditional on the financial institution being in distress, and the CoVaR with the financial institution being at its median state. The reason why we prefer SRISK over the CoVaR measure is that the former has frequently been used in related studies (Acharya and Steffen 2012, Benoit 2014, Bostandzic and Weiss 2013, Laeven et al. 2014, Weiss et al. 2014). This ensures comparability to our results. Also, Brownless and Engle (2015) show that the pre-crisis SRISK is a good predictor for capital injections by the Fed during the recent financial crisis and performs well in contrast to related systemic risk measures. Furthermore, it can be easily adapted to the regional level. While this holds also true for the CoVar, the derived values are more difficult to compare across regional levels (Benoit 2014).<sup>3</sup>

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<sup>3</sup> Bisias et al. (2012) provide a detailed survey of measures for systemic risk; Brownless and Engle (2015) discuss how SRISK is related to other measures of systemic risk discussed in the literature.

We contribute to the literature on systemic risk in banking by analyzing the drivers behind banks' contribution to systemic risk at different regional levels. Previous evidence on the determinants of banks' contribution to regional systemic risk is scarce. De Jonghe (2010) studies the effect of bank-specific characteristics on tail betas, which is the probability of a sizeable decline in a bank's stock price given that a stock market crash occurs. The main focus is on the effect of "revenue diversity", resulting from a diversified portfolio, on systemic stability. Laeven et al. (2014) regress measures of idiosyncratic risk (stock returns) and of systemic risk (SRISK) of banks during the crisis on pre-crisis bank characteristics. They find that larger banks contribute more to systemic risk if they have low capital and liquidity ratios and if they have complex and more market-based business models. However, these authors neither distinguish different regional levels when analyzing systemic risk nor have a specific focus on the Euro Area, as we do here. For the sample of Euro Area banks, we confirm their result that larger banks are more systemically important. We also document that banks with a more traditional business model contribute less to systemic risk.

By identifying the determinants of systemic risk across different regions, our paper contributes to an assessment of the determinants of systemic risk embedded in existing regulations. The Basel Committee of Banking Stability (BCBS 2011), for instance, proposes measuring the systemic importance of financial institutions based on five equally-weighted criteria: size, interconnectedness, substitutability, complexity, and cross-jurisdictional activity. Each of these five criteria (excluding size) is composed of various sub-indicators which again receive equal weights. For example, the measure "cross-jurisdictional activity" considers cross-jurisdictional claims and cross-jurisdictional liabilities. This measure was adopted by the Financial Stability Board (FSB) to identify G-SIFIs, i.e. systemically important institutions at the global level.

A second set of previous studies analyzes the costs and benefits of allocating regulatory or supervisory power to the supranational level from a theoretical point of view (Dell'Ariccia and Marquez 2006, Kahn and Santos 2005, Morrison and White 2009). Regulation at the supranational level is more likely to internalize cross-country interdependencies. For example, Dell'Ariccia and Marquez (2006) show that a supranational regulator is more likely to take into account beneficial effects of higher capital requirements on the stability of banks in other countries. However, regulation becomes less flexible because uniform regulatory standards apply across countries. This might be costly if banking systems are heterogeneous across countries.

The paper is structured as follows. In the second part, we describe the institutional background for macroprudential supervision and regulation in the Euro Area. In part three, we explain the definition and measurement of systemic risk using the SRISK concept. In part

four, we present our data capturing possible drivers of systemic risk, and in part five we present regression results relating systemic risk to these determinants. Part six concludes.

## **2 Institutional Background**

Macroprudential supervision and regulation is a relatively new policy field. In Europe, the legislation establishing the European Systemic Risk Board (ESRB) went into force in the year 2010, based on a recommendation of the de Larosière report of 2009 to establish a European body with a mandate to oversee risks in the financial system as a whole. The ESRB has no direct regulatory power, but it can issue warnings and recommendation to national regulators or to other authorities.

A recommendation of the ESRB issued in 2011 requires EU member states to establish or designate an authority entrusted with the conduct of macro-prudential policy. In addition, the new EU-wide prudential requirements for credit institutions (CRD IV / CRR) require that member states set up an authority which can take measures to mitigate systemic risk posing a threat to financial stability *at the national level* (On details, see the ESRB recommendation of April 4, 2013, on intermediate objectives and instruments of macroprudential policy, ESRB/2013/1). With the European Banking Union that came into force in November 2014, the Single Supervisory Mechanism (SSM) confers to the ECB the right to impose higher capital requirements than the national authorities.

The choice of banks which are supervised under the SSM has been based on several criteria. The ECB<sup>4</sup> chooses the following factors that define a systemically important financial institution: (i) total value of assets, (ii) importance of the bank for the economy, (iii) significance of cross-border activities and (iv) requested ESM/ EFSF financial assistance. In our empirical analysis, we will include variables which measure these factors in order to check whether they are related to the systemic risk of individual banks according to the SRISK concept.

## **3 Defining and Measuring Systemic Risk**

### ***3.1 The Marginal Expected Shortfall and Systemic Risk***

We define systemic risk as the vulnerability of the entire financial system to adverse shocks and are interested in how individual financial institutions contribute to it. Vulnerability reflects an aggregate capital shortfall in the banking system, and we compute a bank's marginal contribution to this shortfall. SRISK is thus a market-based systemic risk measure

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<sup>4</sup> See the online reference <http://www.ecb.europa.eu/ssm/html/index.en.html>.

based on banks' capital shortfall (Brownless and Engle 2012, 2015). It describes the expected capital need, conditional on a systemic event:

$$SRISK_{it} = E_t \left( Capital\ Shortfall_{it+h} \mid R_{mt+1:t+h} < C \right), \quad (1)$$

where  $R_{mt+1:t+h}$  is a multi-period market return between period  $t+1$  and  $t+h$ .  $C$  is an extreme threshold loss. Hence,  $SRISK_{it}$  which gives the expected capital shortfall depends on the systemic event  $\{R_{mt+1:t+h} < C\}$ . Applying this definition of systemic risk requires assumptions on the systemic event and on a bank's capital shortfall. Previous work assumes that a financial system is in a crisis whenever the market index falls by 40 percent over the next six months (Acharya et al. 2012). So the extreme threshold loss  $C$  is set to -40%.

In order to interpret SRISK in an meaningful way and to capture the capital shortfall of an institution conditional on a systemic event, the amount by which the market index falls has to be large enough and the period during which it falls has to be long enough (Brownless and Engle 2015). However, they show that SRISK provides similar rankings of banks at the top position even if these parameters are modified.

Equation (1) shows that SRISK is based on the accuracy with which market participants anticipate the capital need of an individual bank in times of crisis. Any mechanism that might lead to an under- or overestimation of risk would affect the accuracy of this proxy for systemic risk. Similar problems beleaguer alternative measures of systemic risk based on market data such as CoVaR models. Given that our focus is on differences in banks' contribution to systemic risk at the national and at the European level, the possible mispricing of risk would be problematic if the degree of mis-pricing would vary across regions.

A financial institution experiences a capital shortfall if the value of its equity capital drops below a given fraction  $k$  of its assets:  $Capital\ Shortfall_{it+h} = k(Assets_{it+h}) - Equity_{it+h}$ . The minimum capital requirement  $k$  is set by the microprudential regulator restricting each institution to maintain equity capital as a fraction of its assets. Substituting this into equation (1) gives:

$$\begin{aligned} SRISK_{it} &= E_t \left( Capital\ Shortfall_{it+h} \mid R_{mt+1:t+h} < C \right) \\ &= E_t \left( k(Assets_{it+h}) - Equity_{it+h} \mid R_{mt+1:t+h} < C \right) \\ &= E_t \left( k(Debt_{it+h} + Equity_{it+h}) - Equity_{it+h} \mid R_{mt+1:t+h} < C \right) \\ &= kE_t \left( Debt_{it+h} \mid R_{mt+1:t+h} < C \right) - (1-k)E_t \left( Equity_{it+h} \mid R_{mt+1:t+h} < C \right). \end{aligned} \quad (2)$$

Assuming that there is sufficient equity capital to cover potential losses (hence no bail in of creditors is needed in case of distress), the book value of debt will be relatively constant. So



$Debt_{it+h}$  cannot be renegotiated in the midst of a financial crisis, and the expression  $E_t(Debt_{it+h}|R_{mt+1:t+h} < C)$  simplifies to  $E_t(Debt_{it+h}|R_{mt+1:t+h} < C) = Debt_{it}$ :

$$\begin{aligned} SRISK_{it} &= kDebt_{it} - (1-k)E_t(Equity_{it+h}|R_{mt+1:t+h} < C) \\ &= kD_{it} - (1-k)E_t(E_{it+h}|R_{mt+1:t+h} < C), \end{aligned} \quad (3)$$

where  $D_{it}$  is the book value of total liabilities and  $E_{it+h}$  is the expected market value of equity between the period  $t+1$  and  $t+h$  conditional on the multi-period market return.

However, equity owners will have to absorb losses in case of crisis. The sensitivity of a bank's equity conditional upon a (future) crisis of the financial system is captured by the long-run marginal expected shortfall,  $LRMES_{it}$ , such that  $LRMES_{it} = E_t(R_{it+1:t+h}|R_{mt+1:t+h} < C)$ .<sup>5</sup>  $LRMES_{it}$  can be interpreted as the bank expected loss per € conditional on a particular market index falling by more than the threshold loss,  $C = -40\%$ , at a time horizon of six-months. Hence,  $(1 - LRMES_{it})$  represents the devaluation of the market value of equity after a shock has hit the system. Equation (3) can be written as:

$$\begin{aligned} SRISK_{it} &= kD_{it} - (1-k)(1 - LRMES_{it})E_{it} \\ &= E_{it} [kL_{it} + (1-k)LRMES_{it} - 1], \end{aligned} \quad (4)$$

where  $L_{it}$  is the leverage ratio  $D_{it} + E_{it} / E_{it}$ . Hence, the systemic risk of a financial institution is higher the higher its leverage, the higher its expected equity loss given a market downturn (higher tail dependence), and the larger the bank. Note that SRISK may become negative if a bank has a low degree of leverage and/or a low marginal expected shortfall.

SRISK delivers a clearly interpretable unit of measurement: the amount of funds needed to compensate the capital shortfall. The higher a bank's capital shortfall, the higher is the probability that bank will be distressed. If the entire sector is in distress and exhibits an aggregate capital shortage, banks find it hard to collectively improve their balance sheets. This generates negative externalities to the rest of the economy. Note also that a higher prudential capital ratio expressed by  $k$  implies that banks would need a larger amount of capital to maintain operations during crisis times which in turn causes an increase in the capital shortfall.

Acharya et al. (2012) propose proxying the  $LRMES$  using the daily available  $MES$ , where  $LRMES_{it} \cong 1 - \exp(18 * MES_{it})$ . The marginal expected shortfall (MES) is defined as the one-day expected equity loss per dollar invested in a bank if the overall market declines by less than 2 percent (Acharya et al. 2012).

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<sup>5</sup> See Appendix A for a detailed description of how to estimate LRMES.

*LRMES* reflects the statistical interconnectedness of a bank with the rest of the system. It indicates a financial institution's expected fall in equity conditional upon the market falling by more than a given threshold within the next six months. The higher the connectedness or correlation of the financial institution with the market, the higher is the *SRISK* measure for this institution. Hence, a highly interconnected bank would have a high marginal contribution to systemic risk.

In sum, *SRISK* is the difference between the required capital and the available capital, conditional on a substantial decline in the overall market. Banks with the largest shortfall are assumed to be the greatest contributor to the shortfall of capital in the system. Banks falling short of capital are vulnerable to runs, forcing them to liquidate long-term assets. This might fuel downward spirals in asset prices and destabilize the stability of the financial system. There is thus an important distinction between an institution's failure in normal times, without an aggregate capital shortage, and an institution's failure when the whole system is undercapitalized. Only the latter displays a key feature of systemic risk, which *SRISK* captures. In this sense, Acharya et al. (2010) provide a theoretical model in which negative externalities arise due to a capital shortfall of one firm conditional on situations in which the whole financial system is undercapitalized.

### 3.2 National versus European Perspectives

A priori, one might expect *SRISK* to be higher for the national than for the European market. In the extreme case of a monopolistic domestic bank without foreign operations, the capital of this bank would move one-to-one with the capital of the domestic banking system. The smaller the domestic market share of the bank becomes and the more the bank diversifies its activities away from the domestic market, the weaker will be the link between bank  $i$  and the national banking market. This suggests that it is not clear a priori that *SRISK* is necessarily higher when taking the national than the European market as a benchmark. Generally, a bank's contribution to systemic risk depends on its market share, the degree of diversification, and the exposure to market risk at home and abroad (Acharya et al. 2010).

As we are interested in comparing the contribution to systemic risk of a bank at the national ( $N$ ) and at the European level ( $E$ ), we follow Benoit (2014) and distinguish two measures of systemic risk:

$$SRISK_{it}^E = kD_{it} - (1 - k)(1 - LRMES_{it}^E)E_{it} \quad (5)$$

$$SRISK_{it}^N = kD_{it} - (1 - k)(1 - LRMES_{it}^N)E_{it} \quad (6)$$

Because there is nothing that a priori prevents *LRMES* with respect to the home market to be smaller or larger than with respect to the European market, the difference between the two measures of systemic risk may be positive or negative:

$$\begin{aligned}\Delta SRISK_{it} &= SRISK_{it}^E - SRISK_{it}^N \\ &= (1 - k)(LRMES_{it}^E - LRMES_{it}^N)E_{it}\end{aligned}\tag{7}$$

This difference reveals in which market a downturn induces a higher capital shortfall, and it proxies at which level the bank is contributing more to systemic risk. If  $\Delta SRISK_{it} < 0$  the bank exhibits a *national effect*, i.e., the bank has a smaller ability to absorb losses in case of a decline in the domestic market compared to a decline of the European market. If national SRISK is smaller than Euro Area SRISK ( $\Delta SRISK_{it} > 0$ ), a *Euro Area effect* prevails: a bank contributes more to a decline in the capitalization of the European banking sector than to a decline in the capitalization of the national banking sector given a systemic shock occurs. In this case, the national supervisor may have insufficient incentives to internalize the contribution of banks' to systemic risk at the Euro Area level. This could be one reason for an inaction bias at the national level when it comes to the activation of macroprudential policies aimed at strengthening the resilience of banks.

### 3.3 Data Sources

SRISK is calculated based on high-frequency stock market data which are publicly available. This facilitates comparability across studies but restricts our analysis to banks listed on the stock market. For many European banking systems, the number of banks for which we can calculate SRISK covers only a relatively small share of the market. The German banking market, for instance, is dominated by relatively small savings and cooperative banks as well as their central institutions. In our sample, publicly listed banks for which we can calculate the SRISK have a market share of only about 5% in 2012.

To calculate SRISK, we resort to data provided by *Datastream*. The SRISK of bank *i* consists of three data components: the book value of total liabilities, the market value of equity, and the long-run marginal expected shortfall (LRMES). For 97 banks in 17 Euro Area countries, we obtain yearly data on the book value of total liabilities and the daily market value of equity measured as shares outstanding times share price. A list of banks for which we could match the SRISK to balance sheet data from *Bankscope* for the year 2008 can be found in the Appendix. Out of the 97 banks, we can match 67 banks by using the ISIN number as identifier. For the remaining banks, we cannot find a counterpart in *Bankscope*. For the 128 banks, which are supervised by the SSM, we can identify 124 in our *Bankscope* sample. Due to the fact that not all of these banks are listed, we can only compute the SRISK for a reduced sample and the regression analysis is based on 39 SSM banks.

LRMES gives the sensitivity of a bank's equity return to a shock to the market. It is based on the bank's stock price and the Euro Area or the national market index. To compute SRISK at the Euro Area level, we make use of the EURO STOXX Total Market Index (TMI) that represents a broad coverage of Euro Area companies. For the national level, we make use of

STOXX Country Total Market Indices (TMI). These indices have two advantages. First, they are available for all 17 Euro Area countries. Second, they allow taking into consideration financial and real sector developments. Our approach is also similar to Acharya et al. (2012) and Laeven et al. (2014b) who use the S&P 500 index and no bank specific index for the market return. For robustness, we repeat our analysis with bank indices. The disadvantage of the latter might be that they can be driven by particular banks and capture only the performance of the financial sector.

Summary statistics of the daily stock market data used for the calculation of SRISK can be found in Table 1, which covers the national returns, the return of the EURO STOXX Total Market Index, and the average across the returns of all banks in the sample. It can be observed that mean values are on average close to zero. The standard deviation is smaller in relative terms for the Euro Area stock return compared to the national stock returns, suggesting possibilities for diversification.

### ***3.4 Descriptive Statistics***

Table 2 shows summary statistics for SRISK at the national and the European level. Panel (a) uses daily data, Panel (b) uses annual data. On average, SRISK at the European level is close to SRISK at the national level. In order to check whether the averages cloud relevant patterns of heterogeneity across countries or banks, Table 3 shows the number of banks for which the difference between SRISK at the Euro Area level and SRISK at the national level is positive. Based on daily data, we first calculate the difference between the two levels for each bank. We then average this difference for each bank over two periods: a pre-crisis period (2002-2006) and a crisis period (2007-2013). Based on these average differences, we count the number of banks per country for which the difference is greater than zero, i.e. the average contribution to systemic risk measured by SRISK is higher at the Euro Area level.

Table 3 reveals a considerable degree of cross-country heterogeneity. On the one hand, there are countries like Germany, for which the majority of banks have a positive difference, i.e. a higher level of SRISK at the Euro Area level. On the other hand, the number of banks with a positive difference is small in countries like Greece (zero banks out of seven) or Italy (around one third). Differences emerge also across time: Overall and for some countries such as Austria, the number of banks for which the difference is positive has decreased during the crisis period. But there are also countries in which the number of banks with a higher contribution to systemic risk at the Euro Area level has increased during the crisis period, e.g. France or Belgium.

Graph 1 plots SRISK, averaged across 97 listed banks within 17 Euro Area countries. It shows that, both, national SRISK and European SRISK substantially increased in 2007. Before the crisis, the average capital shortfall of European banks was around 5 billion Euros.

This number increased to about 10-15 billion Euros in the years 2008-2014. On average, the contribution of listed banks to systemic risks during times of systemic distress has thus increased. These patterns are very similar when considering SRISK at the national and at the European level. If anything, average  $\Delta SRISK_{it}$  has been slightly negative throughout.

According to this measure, the contribution of banks to systemic risk has thus been higher at the national than at the European level. Thus, on average, this would reduce the risk of an inaction bias of national regulators.

## 4 Measuring Drivers of Systemic Risk

The systemic importance of banks increases in their size, their risk, their degree of connectedness, and their exposure to macroeconomic risks. In addition, structural characteristics of banking systems may affect the systemic importance of banks across countries. Next, we describe how we measure potential bank- and country-level drivers of systemic risk.

### 4.1 Bank-Level Determinants of Systemic Risk

Banks' balance sheet and income statement data are taken from *Bankscope*. Given that the market data from *Datastream* are based on consolidated balance sheets, we resort to consolidated statements from *Bankscope* if available. The data appendix provides more detailed information on the variables used, and summary statistics are provided in Table 4.

To correct the data for implausible values, we exclude observations for which total assets are missing. We drop observations if assets, equity, or loans are negative. We do the same if the variables expressed as percentages such as the liquidity ratio are negative or exceed 100%. A bank remains in the sample only if it belongs to one of the following types: bank holding company, commercial banks, cooperative banks, and savings banks. However, we ensure that all 130 banks which fall under the SSM as well as those banks for which we have computed the SRISK are part of the sample. We keep only banks with at least three observations. Finally, in order to correct for outliers, we winsorize the variables at the top and bottom percentile.

One key driver of systemic risk is *bank size*, which we measure through (log) total assets. Shocks to large banks can affect aggregate outcomes simply because of granularity effects (Bremus et al. 2013). But large banks can also benefit from a "too-big-to-fail" subsidy which might affect their risk-taking behavior (IMF 2014). Furthermore, the business models of larger banks differ from those of smaller banks (Laeven et al. 2014). They tend to be more complex in their organizational structure and to be more involved in market-based activities. All these features imply that large banks are systemically more important, hence we expect a positive effect of bank size.

To capture characteristics of banks' *business models*, we include the ratio of loans to total assets (in %) as well as the share of non-interest income in total income (in %). Previous studies show that banks which are more involved in non-traditional activities show a higher exposure to (systemic) risk (Brunnermeier et al. 2012, Demirgüç-Kunt and Huizinga 2010). From a theoretical point of view, the impact of banks' business models on systemic risk is not clear-cut. On the one hand, a more diversified portfolio which combines loans and other, securitized assets can reduce banks' idiosyncratic risk of failure. On the other hand, market-based activities are often more volatile and thus more risky. For example, De Jonghe (2010) shows that non-interest generating activities increase banks' systemic risk exposure. DeYoung and Torna (2013) find for a sample of US banks that fee-based non-traditional activities lowered the risk of failure during the recent crisis whereas asset-based nontraditional activities increased it.

The choice of the business model also determines the *profitability* of a bank, which we capture through return on assets (RoA) (in %). The effect of RoA on systemic risk is not clear cut a priori. Return on assets can be considered to be a crude proxy for the market power of banks. The link between market power and bank risk-taking, in turn, is ambiguous. Many cross-country studies report a negative relationship between banks' market power and risk (Ariss 2010, Beck 2008, Schaeck et al. 2009). This negative relationship is in line with the theories of Allen and Gale (2004) and Martinez-Miera and Repullo (2010), who argue that less intense competition increases banks' margins and buffers against loan losses. But banks with a high degree of market power may also inflict excessively high funding costs on corporate customers, ultimately leading to higher credit risk and bank instability (Boyd and De Nicoló 2005).

As a proxy for the idiosyncratic risk of banks and the ability to liquidate assets in times of distress, we include the *non-performing loans* (NPL) ratio (in %). When the whole financial system is in distress and liquidity is scarce, banks with a high share of non-performing assets are likely to come under distressed. If banks are forced to write down non-performing loans held at market prices, these fire sales can cause a further decline in prices. This can affect other banks with common exposures in case they also have to write down their respective assets (Allen et al. 2012).

We include two measure of *liquidity risk*. Liquidity risk related to the structure of banks' assets is measured as the ratio of liquid assets to total assets (in %). A high share of illiquid assets on banks' balance sheets reduces flexibility and results into losses if banks are forced to liquidate assets prematurely to meet unexpected demand for liquidity by depositors (Allen and Gale 2000). To capture liquidity risk stemming from the liability side of banks' balance sheets, we include the ratio of short-term deposits to total deposits (in %). A high share can fuel unsound expansions of banks' balance sheets and the build up of systemic risks (Perotti

and Suarez 2009, Shin 2010). In the run-up to the recent crisis, for instance, banks' reliance on short-term debt led to an increase in leverage. This mechanism broke down as soon as banks faced difficulties in rolling over short-term debt to finance long-term assets due to freezes of the interbank market (Gale and Yorulmazer 2013).

We also include information about the *complexity* of banks' (international) activities. The more complex the international organization of a bank, the more difficult it is to restructure and possibly resolve its operations in times of distress. This, in turn, may create bail out expectation. In fact, the classification of banks as globally, systemically important financial institutions (G-SIFIs) by the FSB has increased the implicit state subsidies enjoyed by these banks (SVR 2014). Implicit subsidies may be particularly relevant for large banks, given that an effective regime for the resolution of large, internationally active banks has been missing during the time period of our study. Even though the international reform agenda has moved into the right direction, bank resolution is still largely uncharted territory.

We thus control for the assignment of the G-SIFI status by the FSB by creating a dummy which equals one for the years in which a bank was declared as a G-SIFI and zero otherwise. Also, we capture the complexity of an international banking organization by drawing on data provided in the *Bankscope Ownership Module*. This allows calculating measures for business complexity as has been done in Cetorelli and Goldberg (2014). Business complexity is measured as a normalized Herfindahl index across the different types of specializations of a bank's domestic and foreign subsidiaries. It is defined such that higher values indicate a higher degree of business complexity, i.e. the bank has subsidiaries with differing specializations including financial and non-financial activities. We consider only those subsidiaries for which the headquarter is the direct (level one) and ultimate (at least 50% of ownership) owner. Graph 2 shows first results and relates the SRISK to business complexity for the year 2013.

Following the criteria chosen by the ECB to determine whether a bank should be supervised by the SSM, we also control for *financial assistance*. To do so, we exploit the State Aid Register of the *European Commission* (European Commission 2015). We create a dummy which equals one if the bank has received state aid and zero otherwise. More specifically, whenever a bank in our sample appears as a case in the State Aid Register, we assign a value of one to the state aid dummy at the time when the decision about the state aid request was made. We do not discriminate between the type of state aid, i.e. guarantees, recapitalizations, or direct grants.

In Table 5, we compute the average SRISK for subsamples of banks. We differentiate between banks that have received state aid, have been assigned the G-SIFI status, or show a high degree of business complexity. On average, SRISK is higher for banks classified as G-SIFI compared to those banks which have not been assigned the G-SIFI status. Furthermore,

the difference between SRISK measured at the Euro Area level and SRISK measured at the national level tends to be positive if a bank has received state aid or if it has been classified as a G-SIFI.

To obtain a more systemic impression of how bank characteristics derived from balance sheet data affect systemic risk, Table 6 shows pairwise correlations for the whole sample of banks over the period 2002-2013. There is a strong positive correlation among SRISK and the different measures for bank size as well as the liquidity ratio, and a negative correlation among SRISK and the share of loans in total assets. For all other variables, the correlations are rather small.

#### 4.2 Country-Level Determinants of Systemic Risk

In line with the ECB's criteria to determine whether a bank falls under the SSM, we also measure the role of banks' international activities. Unfortunately, bank-level data on banks' cross-border activities is not available. We thus resort to aggregate data on banks' cross-border activities from the Consolidated Banking Statistics of the *Bank for International Settlements (BIS)* to measure the importance of cross-border activities.

Graph 3 plots cross-border exposures of a country's banking system against the average SRISK across all banks in the respective country. In countries in which banks maintain larger cross-border activities, average SRISK is higher than in financially less open countries.

## 5 Regression Results

### 5.1 The Empirical Model

With measures of systemic risk and data on potential drivers of such risk at hand, we can now turn to answering our second research question: What are the determinants of banks' contribution to systemic risk at the national compared to the European level? And do the drivers of systemic risk differ at the national and at the European level?

We essentially estimate an empirical model similar to Laeven et al. (2014a, b), explaining SRISK derived from equations (5)-(7) by bank- and country-level variables:

$$SRISK_{ijt}^R = \alpha_i + \gamma_t + \beta_1 X_{ijt-1} + \beta_2 G - SIFI_{ijt} + \beta_3 StateAid_{ijt} + \varepsilon_{ijt} \quad (8)$$

Our panel consists of  $i = 1, \dots, 67$  banks across  $j = 1, \dots, 17$  countries and  $t = 2002, \dots, 2013$  years. where  $R$  denotes the level at which systemic risk is measured Euro Area ( $E$ ), national ( $N$ ), or the difference between the two ( $\Delta$ ). We account for bank-invariant characteristics by including bank-fixed effects  $\alpha_i$ . Common macroeconomic developments are captured through year fixed effects ( $\gamma_t$ ).



Bank-specific factors are captured by  $X_{ijt-1}$ . These include proxies for bank size (log of total assets), the business model (loan share, share of non-interest income), profitability (RoA), the quality of loans (share of non-performing loans), liquidity risk (share of liquid assets, share of short-term deb). In addition, we include a G-SIFI dummy ( $G - SIFI_{ijt}$ ), which is equal to one if a bank has been assigned the G-SIFI status at time  $t$  and zero otherwise, and a dummy for  $StateAid_{ijt}$ , which equals one if a bank has received state aid in a particular year and zero otherwise.

## 5.2 *Baseline Regression Results*

In Table 7, we regress SRISK measured at different regional levels on bank-level variables capturing possible sources of risk. Columns 1-3 show results for the full sample of banks. Columns 4-6 focus on banks supervised under the SSM ("SSM banks").

For the full sample, we find a positive and significant impact of bank size on systemic risk. This finding is not very surprising, given that large banks are typically considered to be more systemically important than smaller banks. It also confirms previous research (Laeven et al. 2014 a, b). Our proxy for bank size – the log of total assets – does not answer the question through which channel large banks become systemically important. Large banks, for instance, are more active internationally than smaller banks, and they operate with more complex business models. Below, we will include interactions between size and other bank-level explanatory variables to learn more about the specific links between size and systemic risk.

Two additional variables confirm the impact of bank size and show, at the same time, the role of regulatory policy. The correlation between the dummy indicating whether a bank has received state aid and systemic risk is positive and highly significant. Again, this is not very surprising since rescue measures have been targeted at the larger banks. Also, since the G-SIFI status aims at capturing the systemic importance of a bank, it enters with a positive sign, albeit only at the 10%-level of significance. When restricting the dataset to the SSM banks, only the state aid dummy retains its positive and significant sign. The other two proxies for banks size become insignificant, presumably because there is insufficient variation across the SSM banks in terms of size.

Turning next to the impact of banks' business models, we find a rather strong and robust impact of the loan share. Banks with a high share of loans in total assets have a lower degree of systemic risk, and this effect is robust across the two sub-samples. The point estimate is higher for SRISK relative to the national market, and the difference in the point estimates is also statistically significant as shown by the significant coefficient in columns 3 and 6. Overall, these results show that a high share of loans and thus of more traditional banking activities makes banks less systemically important, and that this effect is stronger at the national level.

The loan share measures the type of business model by looking at the structure of assets. An alternative measure uses the income shares derived from different types of business. More specifically, we include the share of non-interest in total income. Here, the data tell a somewhat different story: banks with a higher share of non-interest income contribute less to systemic risk. However, this effect is less strong, and it also disappears in the SSM sample. Overall, these findings show caution against drawing quick conclusions regarding the superiority of specific business models when it comes to the measurement of systemic risk.

Another variable which has a quite robust and significant impact on systemic risk is bank profitability. More profitable banks have a higher level of systemic risk, and this effect is stronger at the national than at the European level. One explanation for this positive correlation could be that banks' returns are used to calculate both, RoA and SRISK. However, we derive our explanatory variable for profitability from annual balance sheet data whereas the SRISK is calculated from daily stock market data. This should weaken concerns that the correlation between SRISK and profitability is spurious. In robustness tests, we exclude profitability (Table 10) from the set of explanatory variables, and the main results are unchanged.

In line with expectations, banks with a higher share of bad loans in their balance sheet contribute more to systemic risk. The sign on this variable is positive and significant for both sub-samples, although the significant is weaker for the SSM sample. There are no significant differences between systemic risk viewed from a national and a European viewpoint.

Interestingly, both of our proxies for banks' exposure to liquidity risk are insignificant in both samples. Recall that one channel through which an aggregate shortage of capital in the banking system could affect individual banks is their ability to liquidate assets prematurely. Therefore, one would expect liquidity risk to matter. Our results instead suggest that measures affecting profitability, riskiness of assets, and the structure of assets have a stronger impact on systemic risk.

### **5.3 *Interactions with Bank Size***

Size is an important factor affecting banks' contribution to systemic risk (Laeven et al. 2014b). Some reform proposals thus go as far as to impose outright restrictions on bank size (Johnson and Kwak 2010). However, bank size might be a proxy for other factors that affect banks' contribution to systemic risk such as the degree of internationalization or the degree of interconnectedness.

In order to analyze how bank size affects systemic risk, we include interactions between size and other bank-level explanatory variables. Large banks may, for instance, rely more on short-term financing, which exposes them to rollover risk if liquidity shocks occur. Large banks might also find it easier to diversify and invest in non-traditional activities like trading.

These, in turn, could affect banks' contribution to systemic risk (Gennaioli et al. 2013). To further explore the role of bank size in combination with other key characteristics for banks' contribution to systemic risk, we interact the balance sheet variables with the log of total assets (Table 8).

The first result is that, when including interaction terms, log assets itself turns insignificant. This suggests that the effects of bank size indeed run through bank-specific factors. The remaining variables by and large retain their signs, but the statistical significance weakens. The one variable which loses its significance is the share of non-performing loans. Turning to the significance of the interaction terms, we find that the negative effects of the loan share and of non-interest income described above are stronger for the larger banks in the sample.

In Graphs 4 and 5, we plot average marginal effects of the different explanatory variables conditional on bank size. These plots show how the economic importance of each of the variables for systemic risk varies with bank size. The plots confirm the results of the point estimates: the negative effect of non-interest income is stronger the larger a bank is. The marginal effects of return on assets and of the non-performing loans ratio are positive, and they increase in bank size (Graphs 4 and 5, lower panel).

The difference between SRISK at the Euro Area and at the national level increases for banks with a higher loan share or with a lower profitability (Columns 3 and 6). This suggests that a more traditional business model generates a buffer against systemic shocks. Yet, its impact differs across the two regional levels. The reason therefore might be that banks that operate more at the Euro Area level are more engaged in wholesale activities. Also, a higher profitability at larger banks aligns the systemic relevance at both levels which should make the shifting of negative externalities to a different regional level less attractive. Average marginal effects are depicted in Graph 6. The average marginal effect of the loan share (return on assets) is significantly positive (negative) and its absolute value increases with bank size.

#### **5.4 Robustness Tests**

To test the robustness of our results, we have restricted the sample to the crisis period (2007-2013). Results are shown in Table 9 and remain mostly robust whereas the size variable gains in magnitude. This might suggest that especially the large banks showed high values of SRISK during the crisis period.

In Table 10, we exclude the variable return on assets (Columns 1-3) and include the Tier I capital ratio (Columns 4-6). Excluding the measure for profitability renders the non-interest income ratio and the non-performing loans ratio insignificant pointing towards multicollinearity. However, we can confirm the effects of bank size, the loan share and the G-SIFI respectively state aid dummy. Including the Tier I capital ratio affects the significance of

bank size and the non-interest income ratio. Again the other variables remain significant while the capital ratio itself is not significant.

## 6 Concluding Remarks

With the establishment of the European Banking Union, the regulation and supervision of systemically important banks has been moved to the Euro Area level. Centralized supervision through the Single Supervisory Mechanism (SSM) at the ECB aims at applying uniform microprudential rules across countries. But the SSM also has macroprudential powers as it can tighten certain national macroprudential policies. Whether it would be in the interest of the European supervisor to overrule national macroprudential authorities depends, inter alia, on the assessment of systemic risk. In this paper, we ask whether the assessment of systemic risk differs for regulators adopting a national or a European perspective.

We use a measure of systemic risk, SRISK, that has been proposed by Brownlees and Engle (2012). SRISK measures the marginal contribution of a bank to an aggregate shortfall of capital in the banking system. We calculate this measure for about 100 European banks that are listed on the stock market. Our sample spans the years 2002-2013. We distinguish the contribution of banks to a shortfall of capital at the national and at the European level. The two measures of systemic risk can differ because banks have different market shares at home and abroad or because they have different degrees of diversification and thus different return correlations. We then analyze the determinants of systemic risk at the national and at the Euro Area level. Our research has three main findings.

First, on average, banks' contribution to systemic risk at the national level is slightly higher than that at the Euro Area level. However, this does not hold for all banks and countries in the sample. Especially large banks with presumably a higher exposure towards other Euro Area countries are likely to contribute more to systemic risk at the Euro Area level. As regards time trends, we find that systemic risk has increased during the financial crisis.

Second, we analyze the determinants of banks' contribution to systemic risk. To do so, we match the sample of banks for which we have calculated the SRISK based on market data to balance sheet characteristics obtained from *Bankscope*. As expected, large banks are more systemically important than smaller banks. Interestingly, there is no direct link between the reliance of banks on more traditional activities and the degree of systemic importance. Banks with a high share of loans are less systemically important, but the same holds for banks with a high share of non-interest income in total revenues. These effects are stronger for the larger banks in the sample. More profitable banks and banks with a high share of non-performing loans tend to be more systemic as well. We do not find a significant impact of liquidity risk on our measure of systemic risk.

Third, the main results hold irrespective of the regional level considered. This suggests that there is no trade-off in assigning macroprudential oversight to the national versus the European level as concerns the micro-level determinants of bank risk. While the determinants do not change with the regional level, banks' contribution to systemic risk can still differ in magnitude. Our results show that there can be specific features which explain why banks contribute differently to systemic risk at the national compared to the European level. The mitigating impact of the loan share on systemic risk, for instance, is stronger at the national than at the European level.

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## Data Appendix

For the measurement of a bank's contribution to systemic risk, we calculate the SRISK which is mostly derived from market data obtained from *Datastream*. For the analysis of the determinants behind banks' contribution to systemic risk, we rely on various data sources. Balance sheet data are taken from *Bankscope*. Data on cross-border activities are obtained from the *Bank for International Settlements (BIS)* and information on public support measures directed towards the financial system comes from the *European Commission*.

### List of banks

All banks that were listed on the stock market in 2008, i.e. we could calculate the SRISK for these banks.

| Country | Name of bank   |
|---------|--|
| Austria | Bank für Tirol und Vorarlberg AG-BTV (3 Banken Gruppe)   |
| Austria | BKS Bank AG  |
| Austria | Erste Group Bank AG  |
| Austria | Oberbank AG  |
| Austria | Oesterreichische Volksbanken AG  |
| Austria | Raiffeisen Bank International AG   |
| Austria | Volksbank Vorarlberg e.Gen.  |
| Belgium | Dexia SA   |
| Belgium | KBC Ancora Actions   |
| Belgium | KBC Groep NV/ KBC Groupe SA-KBC Group  |
| Cyprus  | Bank of Cyprus Public Company Limited-Bank of Cyprus Group   |
| Cyprus  | Hellenic Bank Public Company Limited   |
| Cyprus  | USB Bank Plc   |
| Finland | Aktia Bank Plc   |
| Finland | Alandsbanken Abp (A)   |
| France  | Banque de la Réunion   |
| France  | BNP Paribas  |
| France  | Caisse Régionale de crédit agricole mutuel Atlantique Vendée-Crédit Agricole Atlantique Vendée                     |
| France  | Caisse Régionale de Crédit Agricole Mutuel Brie Picardie-Crédit Agricole Brie Picardie                             |
| France  | Caisse régionale de crédit agricole mutuel d'Alpes-Provence-Credit Agricole Alpes Provence                         |
| France  | Caisse régionale de credit agricole mutuel de la Touraine et du Poitou-Credit Agricole de la Touraine et du Poitou |
| France  | Caisse régionale de crédit agricole mutuel de l'Ille-et-Vilaine-Crédit Agricole de l'Ille-et-Vilaine               |
| France  | Caisse régionale de crédit agricole mutuel de Normandie-Seine  |
| France  | Caisse régionale de crédit agricole mutuel de Paris et d'Ile-de-France-Crédit Agricole d'Ile-de-France             |
| France  | Caisse Régionale de Crédit Agricole Mutuel du Languedoc  |
| France  | Caisse régionale de Crédit Agricole mutuel du Morbihan-Crédit Agricole du Morbihan                                 |
| France  | Caisse régionale de crédit agricole mutuel Loire Haute-Loire-Crédit Agricole Loire Haute-Loire                     |
| France  | Caisse régionale de crédit agricole mutuel Nord de France-Crédit Agricole Nord de France                           |
| France  | Caisse régionale de credit agricole mutuel Sud Rhône -Alpes-Credit Agricole Sud Rhône Alpes                        |
| France  | Caisse Régionale de Crédit Agricole Mutuel Toulouse 31-Crédit Agricole Mutuel Toulouse 31 CCI                      |
| France  | Crédit Agricole S.A.   |
| France  | Crédit Foncier de Monaco-CFM Monaco  |
| France  | Crédit Industriel et Commercial - CIC  |
| France  | Natixis  |
| France  | Société Générale   |
| Germany | Commerzbank AG   |
| Germany | Deutsche Bank AG   |
| Germany | Deutsche Postbank AG   |
| Germany | IKB Deutsche Industriebank AG  |
| Germany | Lb.Hessen-Thüringen GZ   |
| Germany | Merkur-Bank KGaA   |

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|             |   |
|-------------|---|
| Germany     | Net-M Privatbank 1891 AG  |
| Germany     | Oldenburgische Landesbank - OLB   |
| Germany     | quirin bank AG  |
| Germany     | Stadtwerke Hannover AG  |
| Germany     | UmweltBank AG   |
| Greece      | Alpha Bank AE   |
| Greece      | Attica Bank SA-Bank of Attica SA  |
| Greece      | Eurobank Ergasias SA  |
| Greece      | General Bank of Greece SA   |
| Greece      | National Bank of Greece SA  |
| Greece      | Piraeus Bank SA   |
| Greece      | Proton Bank S.A.  |
| Ireland     | Allied Irish Banks plc  |
| Ireland     | Bank of Ireland-Governor and Company of the Bank of Ireland                 |
| Italy       | Banca Carige SpA  |
| Italy       | Banca Finnat Euramerica SpA   |
| Italy       | Banca Monte Dei Paschi  |
| Italy       | Banca Piccolo Credito Valtellinese-Credito Valtellinese Soc Coop            |
| Italy       | Banca popolare dell'Emilia Romagna  |
| Italy       | Banca popolare dell'Etruria e del Lazio Soc. coop.                          |
| Italy       | Banca Popolare di Milano SCaRL  |
| Italy       | Banca Popolare di Sondrio Societa Cooperativa per Azioni                    |
| Italy       | Banca Profilo SpA   |
| Italy       | Banco di Desio e della Brianza SpA-Banco Desio                              |
| Italy       | Banco di Sardegna SpA   |
| Italy       | Banco Popolare - Società Cooperativa-Banco Popolare                         |
| Italy       | Credito Emiliano SpA-CREDEM   |
| Italy       | Intesa Sanpaolo   |
| Italy       | Mediobanca SpA-MEDIOBANCA - Banca di Credito Finanziario Società per Azioni |
| Italy       | UniCredit SpA   |
| Italy       | Unione di Banche Italiane Scpa-UBI Banca                                    |
| Lithuania   | Siauliu Bankas  |
| Luxembourg  | Espirito Santo Financial Group S.A.   |
| Malta       | Bank of Valletta Plc  |
| Malta       | FIMBank Plc   |
| Malta       | HSBC Bank Malta Plc   |
| Malta       | Lombard Bank (Malta) Plc  |
| Netherlands | ING Groep NV  |
| Netherlands | Van Lanschot NV   |
| Portugal    | Banco BPI SA  |
| Portugal    | Banco Comercial Português, SA-Millennium bcp                                |
| Portugal    | BANIF - Banco Internacional do Funchal, SA                                  |
| Slovakia    | OTP Banka Slovensko, as   |
| Slovakia    | Prima banka Slovensko a.s.  |
| Slovakia    | Tatra Banka a.s.  |
| Slovakia    | Vseobecna Uverova Banka a.s.  |
| Slovenia    | Abanka Vipava dd  |
| Slovenia    | Nova Kreditna Banka Maribor d.d.  |
| Spain       | Banco Bilbao Vizcaya Argentaria SA  |
| Spain       | Banco de Sabadell SA  |
| Spain       | Banco Popular Espanol SA  |
| Spain       | Banco Santander SA  |
| Spain       | Bankia, SA  |
| Spain       | Bankinter SA  |
| Spain       | Caixabank, S.A.   |
| Spain       | Ficha de LIBERBANK  |

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## Bank-level data

The following bank-level data are taken from *Bankscope*:

Bank size to GDP: This is measured by the percentage share of a bank's assets to GDP of the country in which the bank is located.

Liquid assets: The liquidity ratio (in %) is defined as the ratio of banks' liquid assets relative to total assets.

Loan share: The variable loan share is defined as the ratio of total loans to total assets (in %).

Market share: This is approximated by the percentage share of a bank's assets to total assets in the banking system.

Non-interest income: We use non-interest income relative to total income (gross interest income and non-interest income) (in %).

Non-performing loans (NPL): The NPL ratio is defined as the fraction of impaired loans relative to gross loans (in %).

Return on assets (RoA): RoA is the percentage ratio of operating profits to total assets.

Short-term debt: To measure the reliance of banks on short-term funding, we use the sum of deposits from banks, repos and cash collateral, plus other deposits and short-term borrowing relative to total liabilities (in %).

Total assets: We use the logarithm of banks' total assets (in millions of USD).

Tier 1 capital ratio: We use the Tier 1 regulatory capital ratio (in %).

Furthermore, we use data from the *Bankscope Ownership Module*, the *Financial Stability Board* and the *European Commission*:

Complexity: We use the *Bankscope Ownership Module* to obtain information on a bank's subsidiaries, their business model and specialization. Data is available for the year 2013 and we derive a normalized Herfindahl index (HHI) capturing complexity in the business model following Cetorelli and Goldberg (2014). The HHI is defined as follows:

$$HHI_i = \frac{T}{T-1} \left( 1 - \sum_{i=1}^T \left( \frac{count^i}{totalcount^i} \right)^2 \right) \text{ where } T \text{ is the number of affiliate types of a bank's}$$

subsidiaries (banks, insurance companies, mutual and pension funds, other financial subsidiaries, nonfinancial subsidiaries). The HHI is defined between zero, lowest complexity, and one, highest complexity. Based on this HHI, we create a dummy which equals one if the bank is highly complex ( $HHI > 0.9$ ) and zero otherwise.

G-SIFI: We create a dummy, which equals one if a bank was assigned the status as globally, systemically important financial institution (G-SIFI) by the *Financial Stability Board* for a given year, and zero otherwise.

State aid: We make use of the State Aid Register provided by the *European Commission*, which gives information on support measures like recapitalization or the provision of guarantees for individual banks. If a bank is listed as a case and received any kind of state aid, we assign a value of one at the decision date of the support measure and zero otherwise.

## **Data used to calculate systemic risk (SRISK)**

Book value of total liabilities: Total liabilities represent all short and long term obligations expected to be satisfied by the company (*Datastream/ Worldscope*). The book value of liabilities includes, but is not restricted to: Current Liabilities, Long Term Debt, Provision for Risk and Charges (non-U.S. corporations), Deferred taxes, Deferred income, Other liabilities, Deferred tax liability in untaxed reserves (non-U.S. corporations), Unrealized gain/loss on marketable securities (insurance companies), Pension/Post retirement benefits, Securities purchased under resale agreements (banks). The book value of liabilities excludes: Minority Interest, Preferred stock equity, Common stock equity, Non-equity reserves.

Market index: We use the EURO STOXX Total Market Index (TMI). This index is a regional subset of the STOXX Europe TMI Index which covers approximately 95 percent of the free float market capitalization of Europe = 552 Constituents. With a variable number of components, the EURO STOXX TMI Index represents a broad coverage of Euro Area companies. The index includes Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal and Spain. The EURO STOXX TMI comprises large, mid and small capitalization indices: the EURO STOXX TMI Large Index, the EURO STOXX TMI Mid Index and the EURO STOXX TMI Small Index (*www.STOXX.com*).

Market value of equity: Market value is the share price multiplied by the number of ordinary shares in issue. The amount in issue is updated whenever new tranches of stock are issued or after a capital change. For companies with more than one class of equity capital, the market value is expressed according to the individual issue (*Datastream/ Worldscope*).

National market indices: For the national stock index, we use the STOXX Country Total Market Indices (TMI) representing the relevant country as a whole. It covers approximately 95 percent of the free float market capitalization of companies in the represented country, with a variable number of components (*www.STOXX.com*).

Stock prices: Stock prices of market listed banks (*Datastream/ Worldscope*).

## **Country-level variables**

Cross-border exposures: To capture banks' foreign activities, we use cross-border assets of banking systems (in % of GDP) from the Consolidated Banking Statistics of the *Bank for International Settlements* (BIS). These data are available at the country level.

**Table 1: Summary Statistics for Stock Market Data**

This table shows summary statistics for the daily stock market data (excluding weekend days). The national STOXX indices, the EURO STOXX index and banks' stock returns cover the period 28.12.2001-01.01.2014. The stock returns of the 97 banks are taken from consolidated accounts. Both the returns of the market indices and banks' stock returns are calculated as first log differences. For more details on data sources, see the description in the Data Appendix.

|               | Obs.    | Mean       | Std. dev. | Skewness | Kurtosis | Min    | Max   |
|---------------|---------|------------|-----------|----------|----------|--------|-------|
| Austria       | 3 065   | 0.0002141  | 0.0155    | -0.197   | 25.28    | -0.171 | 0.172 |
| Belgium       | 3 065   | -0.0000102 | 0.0139    | -0.679   | 14.51    | -0.159 | 0.101 |
| Cyprus        | 3 063   | -0.0005762 | 0.0227    | -0.268   | 10.96    | -0.243 | 0.162 |
| Finland       | 3 065   | -0.0001403 | 0.0193    | -0.085   | 15.92    | -0.192 | 0.187 |
| France        | 3 065   | 0.0000252  | 0.0152    | -0.006   | 13.68    | -0.146 | 0.133 |
| Germany       | 3 065   | 0.0001031  | 0.0166    | 0.042    | 28.68    | -0.202 | 0.194 |
| Greece        | 3 065   | -0.0003444 | 0.0190    | 0.109    | 7.99     | -0.105 | 0.149 |
| Ireland       | 3 065   | 0.0000756  | 0.0164    | -0.253   | 21.40    | -0.198 | 0.202 |
| Italy         | 3 065   | -0.0001221 | 0.0151    | -0.065   | 10.67    | -0.121 | 0.109 |
| Lithuania     | 3 063   | 0.0001356  | 0.0191    | -7.072   | 248.53   | -0.546 | 0.261 |
| Luxembourg    | 3 065   | 0.0002132  | 0.0227    | -0.417   | 12.65    | -0.184 | 0.165 |
| Malta         | 2 878   | 0.0002387  | 0.0170    | 0.670    | 117.93   | -0.278 | 0.275 |
| Netherlands   | 3 065   | -0.0000284 | 0.0148    | -0.040   | 16.80    | -0.141 | 0.140 |
| Portugal      | 3 065   | -0.0001547 | 0.0120    | -0.107   | 10.65    | -0.103 | 0.102 |
| Slovakia      | 2 499   | 0.000195   | 0.0246    | -0.612   | 17.20    | -0.288 | 0.148 |
| Slovenia      | 3 063   | 0.0001632  | 0.0117    | -0.526   | 10.92    | -0.096 | 0.087 |
| Spain         | 3 065   | 0.0000188  | 0.0154    | 0.168    | 8.57     | -0.095 | 0.137 |
| Euro Area     | 3 654   | -0.000069  | 0.0138    | -0.066   | 7.45     | -0.082 | 0.099 |
| Stock returns | 532 784 | -0.0001801 | 0.0270    | -1.681   | 211.72   | -1.760 | 1.250 |

**Table 2: Summary Statistics for SRISK**

This table shows summary statistics for the systemic risk measure SRISK. The sample comprises 97 banks listed on the stock market in the Euro Area and the period 28.12.2011-01.01.2014. SRISK is calculated from stock market data and measured in billion Euros. We proceed like Brownless and Engle (2012, 2015) to calculate a bank's marginal contribution to systemic risk when there is an aggregate capital shortfall in the national (Euro Area) market (Section 3). Panel (a) is based on daily data; Panel (b) provides summary statistics for the SRISK aggregated to the yearly frequency.

a) Daily

|                    | Obs.    | Mean  | Std. dev. | Skewness | Kurtosis | Min    | Max    |
|--------------------|---------|-------|-----------|----------|----------|--------|--------|
| SRISK (National)   | 275,130 | 8.18  | 21.49     | 3.91     | 20.20    | -56.70 | 171.95 |
| SRISK (Euro area)  | 275,130 | 8.13  | 21.57     | 3.93     | 20.39    | -37.74 | 171.91 |
| SRISK (Difference) | 275,130 | -0.05 | 1.71      | 2.17     | 61.46    | -48.61 | 32.30  |

b) Annual

|                    | Obs.  | Mean | Std. dev. | Skewness | Kurtosis | Min    | Max    |
|--------------------|-------|------|-----------|----------|----------|--------|--------|
| SRISK (National)   | 1,142 | 7.76 | 20.94     | 4.00     | 21.01    | -19.90 | 156.66 |
| SRISK (Euro area)  | 1,142 | 7.85 | 21.03     | 4.01     | 21.05    | -17.76 | 158.58 |
| SRISK (Difference) | 1,142 | 0.09 | 1.49      | 9.95     | 132.88   | -3.24  | 25.12  |

**Table 3: Summary Statistics for the Difference Between SRISK (European – national)**

This table shows the number of banks where the average difference between  $SRISK_{it}^E$  and  $SRISK_{it}^N$  is greater than zero. The sample comprises all 97 market listed banks in the Euro Area over the period 2002-2013. In a first step, we calculate the difference between SRISK (E), measured at the Euro Area level, and SRISK (N), measured at the national level, based on daily data for each bank. In a second step, we average this difference for each bank over two periods: a pre-crisis period, from 2002 to 2006, and a crisis period, from 2007 to 2013. Based on these average differences, we count the number of banks per country for which the difference is greater than zero, i.e. the average contribution to systemic risk measured by SRISK is higher at the Euro Area level.

|              | Pre-crisis period (2002-2006)                   |                          | Crisis period (2007-2013)                       |                          |
|--------------|---|--------------------------|---|--------------------------|
|              | Number of banks<br>with $\Delta SRISK_{it} > 0$ | Total number of<br>banks | Number of banks<br>with $\Delta SRISK_{it} > 0$ | Total number of<br>banks |
| Austria      | 4   | 7                        | 1   | 7                        |
| Belgium      | 0   | 3                        | 3   | 3                        |
| Cyprus       | 1   | 3                        | 1   | 3                        |
| Finland      | 1   | 2                        | 0   | 2                        |
| France       | 7   | 20                       | 12  | 20                       |
| Germany      | 9   | 11                       | 10  | 11                       |
| Greece       | 0   | 7                        | 0   | 7                        |
| Ireland      | 2   | 2                        | 1   | 2                        |
| Italy        | 5   | 17                       | 4   | 17                       |
| Lithuania    | 0   | 1                        | 0   | 1                        |
| Luxembourg   | 1   | 1                        | 1   | 1                        |
| Malta        | 1   | 4                        | 1   | 4                        |
| Netherlands  | 1   | 2                        | 1   | 2                        |
| Portugal     | 1   | 3                        | 0   | 3                        |
| Slovakia     | 3   | 4                        | 2   | 4                        |
| Slovenia     | 2   | 2                        | 0   | 2                        |
| Spain        | 5   | 8                        | 0   | 8                        |
| <b>Total</b> | <b>43</b>                                       | <b>97</b>                | <b>37</b>                                       | <b>97</b>                |

**Table 4: Summary Statistics for the Bank-Level Variables**

This table shows summary statistics for the explanatory variables. The sample is based on all Euro Area banks listed on the stock market in our sample and covers the period 2002-2013. *Total assets* denote the logarithm of bank assets in millions of USD. *Loan share* gives the ratio of total loans to total assets (in %). *Non-interest income* is measured relative to total income (in %). *RoA* is the ratio of operating profits to total assets (in %). *NPL* is defined as the fraction of impaired loans relative to gross loans (in %). *Liquid assets* measures the fraction of the liquidity held by a bank relative to total assets (in %). *Short-term debt* indicates the share of short-term debt in total liabilities (in %). *Tier 1 capital ratio* is the Tier 1 regulatory capital ratio (in %). Market share gives the ratio of a bank's assets to the sum of all banks' assets in a banking system (in %). Bank size to GDP is the percentage share of a bank's assets to its country's GDP. For more details, see the description in the Data Appendix.

|                                | Obs. | Mean  | Std. dev. | Skewness | Kurtosis | Min   | Max    |
|--------------------------------|------|-------|-----------|----------|----------|-------|--------|
| Bank size to GDP (%)           | 853  | 27.55 | 44.57     | 2.44     | 9.43     | 0.00  | 248.05 |
| Liquid assets (%)              | 853  | 18.24 | 14.22     | 1.79     | 6.35     | 3.12  | 70.50  |
| Loan share (%)                 | 850  | 61.72 | 19.96     | -1.07    | 3.59     | 5.08  | 89.18  |
| Market share (N, %)            | 853  | 6.31  | 10.25     | 2.93     | 17.07    | 0.00  | 94.39  |
| Non-interest income (%)        | 819  | 22.24 | 11.55     | 2.08     | 10.01    | 3.37  | 74.02  |
| Non-performing loans (NPL) (%) | 595  | 7.05  | 7.08      | 2.25     | 8.72     | 0.26  | 41.85  |
| RoA (%)                        | 852  | 0.46  | 1.32      | -2.00    | 10.26    | -5.66 | 4.33   |
| Short-term debt (%)            | 820  | 24.85 | 19.34     | 1.03     | 3.13     | 0.22  | 72.57  |
| Tier 1 capital ratio (%)       | 591  | 10.33 | 4.35      | 2.72     | 12.19    | 5.70  | 31.20  |
| Total assets (log, mn USD)     | 853  | 10.29 | 2.29      | -0.17    | 2.77     | 4.00  | 14.75  |

**Table 5: Systemic Risk, State Aid, and Complexity**

This table shows mean values for the SRISK (yearly, bn Euros) at the Euro Area and national level as well as the difference between the two for the period 2002-2013. The first two columns show results for the subsample of banks for which the state aid dummy equaled one at a specific date and for the observations for which the state aid dummy was zero. Column (3) compares the average SRISK of those banks which had been assigned the status of a G-SIFI at any point in time to those banks for which the G-SIFI dummy has never been one (Column (4)). Columns (5) and (6) compare banks which are more complex to those which showed a lower degree of business complexity. For more details, see the description in the Data Appendix.

|                    | State aid |       | G-SIFI |       | Complexity |       |
|--------------------|-----------|-------|--------|-------|------------|-------|
|                    | Yes       | No    | Yes    | No    | Yes        | No    |
| SRISK (Euro area)  | 28.69     | 8.77  | 75.25  | 3.74  | 24.22      | 6.84  |
| SRISK (National)   | 28.65     | 8.85  | 75.23  | 3.79  | 24.38      | 6.93  |
| SRISK (Difference) | 0.04      | -0.08 | 0.02   | -0.05 | -0.16      | -0.09 |



**Table 6: Correlations Between SRISK and Bank-Level Variables**

This table shows pairwise correlations between the SRISK at the Euro Area (national) level which is derived from stock market data and bank characteristics obtained from *Bankscope* across the whole sample for the period 2002-2013. The bank characteristics comprise: *Total assets* given by the logarithm of bank assets in millions of USD. *Loan share* gives the ratio of total loans to total assets (in %). *Non-interest income* is measured relative to total income (in %). *RoA* is the ratio of operating profits to total assets (in %). *NPL* is defined as the fraction of impaired loans relative to gross loans (in %). *Liquid assets* measures the fraction of the liquidity held by a bank relative to total assets (in %). *Short-term debt* indicates the share of short-term debt in total liabilities (in %). *Tier 1 capital ratio* is the Tier 1 regulatory capital ratio (in %). *Market share (N)* gives the ratio of a bank's assets to the sum of all banks' assets in a banking system (in %). *Bank size to GDP* is the percentage share of a bank's assets to its country's GDP. For more details, see the description in the Data Appendix.

|                      | SRISK<br>(EA) | SRISK<br>(N) | Total<br>assets | Loan<br>share | Non-int.<br>income | RoA   | NPL   | Liquid<br>assets | Short-term<br>debt | Tier 1<br>ratio | Market<br>share (N) | Bank size<br>to GDP |
|----------------------|---------------|--------------|-----------------|---------------|--------------------|-------|-------|------------------|--------------------|-----------------|---------------------|---------------------|
| SRISK (Euro area)    | 1.00          |              |                 |               |                    |       |       |                  |                    |                 |                     |                     |
| SRISK (National)     | 1.00          | 1.00         |                 |               |                    |       |       |                  |                    |                 |                     |                     |
| Total assets         | 0.61          | 0.61         | 1.00            |               |                    |       |       |                  |                    |                 |                     |                     |
| Loan share           | -0.45         | -0.45        | -0.17           | 1.00          |                    |       |       |                  |                    |                 |                     |                     |
| Non-interest income  | -0.03         | -0.03        | -0.30           | -0.29         | 1.00               |       |       |                  |                    |                 |                     |                     |
| RoA                  | -0.07         | -0.07        | 0.05            | 0.05          | 0.10               | 1.00  |       |                  |                    |                 |                     |                     |
| NPL                  | -0.12         | -0.12        | -0.26           | 0.12          | -0.07              | -0.47 | 1.00  |                  |                    |                 |                     |                     |
| Liquid assets        | 0.28          | 0.28         | -0.08           | -0.80         | 0.36               | -0.02 | 0.03  | 1.00             |                    |                 |                     |                     |
| Short-term debt      | -0.12         | -0.13        | -0.03           | 0.20          | 0.06               | 0.11  | -0.04 | -0.15            | 1.00               |                 |                     |                     |
| Tier 1 capital ratio | 0.02          | 0.02         | -0.32           | -0.39         | 0.51               | 0.12  | 0.18  | 0.39             | 0.14               | 1.00            |                     |                     |
| Market share (N)     | 0.21          | 0.21         | 0.30            | -0.24         | -0.14              | 0.08  | -0.04 | 0.11             | -0.29              | 0.04            | 1.00                |                     |
| Bank size to GDP     | 0.43          | 0.43         | 0.47            | -0.24         | -0.17              | 0.00  | -0.10 | 0.09             | -0.23              | -0.05           | 0.52                | 1.00                |

**Table 7: Determinants of Systemic Risk: Bank-Level Variables**

This table reports fixed effects regressions for the full sample and the sample of banks which will be supervised by the SSM. The dependent variable is the SRISK (bn Euros). In columns (1) and (4), the reference level is the Euro Area and in columns (2) and (5), the national level. In columns (3) and (6), the dependent variable denotes the difference between SRISK (EA) and SRISK (national). The explanatory variables include bank-level variables: log of total assets, loans to total assets (in %), non-interest income to total income (in %), return on assets (in %), non-performing loans to total loans (in %), liquid assets to total assets (in %), and short-term debt to total liabilities (in %). All variables are lagged by one period and centered around their means. G-SIFI denotes a dummy which equals one if the bank was classified as a globally systemically important bank by the Financial Stability Board and zero otherwise. State aid denotes a dummy which equals one if the bank received state aid following the State Aid Register of the European Commission and zero otherwise. The sample comprises yearly data of stock listed banks in Euro Area countries over the time period 2002-2013. The regressions take into account bank and year fixed effects. Standard errors are clustered by individual bank and depicted in parentheses. The p-values are as follows: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

|   | (1)                 | (2)                             | (3)                   | (4)                  | (5)                            | (6)                   |
|---|---------------------|---------------------------------|-----------------------|----------------------|--------------------------------|-----------------------|
|   | <i>SRISK EA</i>     | Full sample<br><i>SRISK NAT</i> | $\Delta$ <i>SRISK</i> | <i>SRISK EA</i>      | SSM sample<br><i>SRISK NAT</i> | $\Delta$ <i>SRISK</i> |
| Log assets <sub><i>t-1</i></sub>          | 7.799**<br>(3.748)  | 7.764**<br>(3.807)              | 0.035<br>(0.286)      | 7.287<br>(7.305)     | 7.020<br>(7.359)               | 0.268<br>(0.570)      |
| Loan share <sub><i>t-1</i></sub>          | -3.070**<br>(1.323) | -3.297**<br>(1.380)             | 0.227**<br>(0.096)    | -6.970***<br>(2.268) | -7.399***<br>(2.362)           | 0.429**<br>(0.159)    |
| Non-interest income <sub><i>t-1</i></sub> | -1.419*<br>(0.733)  | -1.466*<br>(0.747)              | 0.047<br>(0.040)      | -2.403<br>(1.567)    | -2.460<br>(1.574)              | 0.057<br>(0.067)      |
| RoA <sub><i>t-1</i></sub>                 | 1.079**<br>(0.520)  | 1.159**<br>(0.544)              | -0.080**<br>(0.032)   | 2.414*<br>(1.355)    | 2.558*<br>(1.397)              | -0.144**<br>(0.060)   |
| NPL <sub><i>t-1</i></sub>                 | 1.544***<br>(0.562) | 1.537***<br>(0.575)             | 0.007<br>(0.035)      | 2.625*<br>(1.429)    | 2.590*<br>(1.461)              | 0.035<br>(0.079)      |
| Liquid assets ratio <sub><i>t-1</i></sub> | -0.041<br>(0.672)   | -0.115<br>(0.673)               | 0.075<br>(0.050)      | -0.931<br>(1.015)    | -1.079<br>(1.014)              | 0.148*<br>(0.087)     |
| Short-term debt <sub><i>t-1</i></sub>     | -1.043<br>(0.914)   | -1.122<br>(0.945)               | 0.079<br>(0.065)      | -1.029<br>(1.671)    | -1.121<br>(1.727)              | 0.091<br>(0.131)      |
| G-SIFI <sub><i>t</i></sub>                | 7.830*<br>(4.283)   | 7.825*<br>(4.357)               | 0.005<br>(0.187)      | 7.141<br>(4.489)     | 7.090<br>(4.575)               | 0.051<br>(0.216)      |
| State aid <sub><i>t</i></sub>             | 6.599***<br>(2.129) | 6.748***<br>(2.205)             | -0.149<br>(0.147)     | 4.795**<br>(1.825)   | 4.761**<br>(1.808)             | 0.034<br>(0.117)      |
| Observations                              | 472                 | 472                             | 472                   | 284                  | 284                            | 284                   |
| R <sup>2</sup>                            | 0.341               | 0.339                           | 0.143                 | 0.399                | 0.396                          | 0.200                 |
| Number of banks                           | 76                  | 76                              | 76                    | 39                   | 39                             | 39                    |

**Table 8: Determinants of Systemic Risk: Interaction with Bank Size**

|   | (1)                  | (2)                             | (3)                   | (4)                  | (5)                            | (6)                   |
|---|----------------------|---------------------------------|-----------------------|----------------------|--------------------------------|-----------------------|
|   | <i>SRISK EA</i>      | Full sample<br><i>SRISK NAT</i> | $\Delta$ <i>SRISK</i> | <i>SRISK EA</i>      | SSM sample<br><i>SRISK NAT</i> | $\Delta$ <i>SRISK</i> |
| Log assets <sub><i>t-1</i></sub>  | 5.190<br>(3.388)     | 4.903<br>(3.428)                | 0.287<br>(0.328)      | 6.126<br>(5.450)     | 5.853<br>(5.493)               | 0.273<br>(0.615)      |
| Loan share <sub><i>t-1</i></sub>  | -3.106***<br>(1.013) | -3.342***<br>(1.033)            | 0.236***<br>(0.083)   | -3.951*<br>(1.954)   | -4.068**<br>(1.989)            | 0.117<br>(0.101)      |
| Non-interest income <sub><i>t-1</i></sub>                                   | -1.528<br>(0.930)    | -1.570<br>(0.950)               | 0.042<br>(0.049)      | 2.552<br>(1.696)     | 2.673<br>(1.741)               | -0.121<br>(0.084)     |
| RoA <sub><i>t-1</i></sub>   | 1.598*<br>(0.868)    | 1.684*<br>(0.890)               | -0.086*<br>(0.045)    | 0.997<br>(1.433)     | 1.206<br>(1.469)               | -0.209**<br>(0.082)   |
| NPL <sub><i>t-1</i></sub>   | 1.671<br>(1.073)     | 1.640<br>(1.094)                | 0.032<br>(0.059)      | 2.621<br>(1.586)     | 2.599<br>(1.599)               | 0.022<br>(0.083)      |
| Liquid assets ratio <sub><i>t-1</i></sub>                                   | 0.036<br>(0.846)     | -0.042<br>(0.842)               | 0.078<br>(0.057)      | 0.594<br>(1.242)     | 0.552<br>(1.259)               | 0.042<br>(0.071)      |
| Short-term debt <sub><i>t-1</i></sub>                                       | 0.717<br>(1.018)     | 0.731<br>(1.031)                | -0.014<br>(0.060)     | 1.167<br>(1.260)     | 1.333<br>(1.271)               | -0.167<br>(0.149)     |
| G-SIFI <sub><i>t</i></sub>  | 7.411**<br>(3.661)   | 7.385*<br>(3.718)               | 0.026<br>(0.206)      | 9.546**<br>(3.561)   | 9.512**<br>(3.626)             | 0.034<br>(0.242)      |
| State aid <sub><i>t</i></sub>   | 6.361***<br>(1.956)  | 6.519***<br>(2.002)             | -0.157<br>(0.141)     | 4.689**<br>(1.812)   | 4.671**<br>(1.757)             | 0.018<br>(0.126)      |
| <i>Interaction terms between the explanatory variables and log assets</i>   |                      |                                 |                       |                      |                                |                       |
| Log assets <sub><i>t-1</i></sub> *Loan share <sub><i>t-1</i></sub>          | -2.432*<br>(1.413)   | -2.694*<br>(1.407)              | 0.262*<br>(0.134)     | -3.266<br>(2.243)    | -3.678<br>(2.193)              | 0.412<br>(0.246)      |
| Log assets <sub><i>t-1</i></sub> *Non-interest income <sub><i>t-1</i></sub> | -3.273***<br>(0.915) | -3.398***<br>(0.932)            | 0.124**<br>(0.058)    | -8.979***<br>(1.990) | -9.235***<br>(1.974)           | 0.255<br>(0.160)      |
| Log assets <sub><i>t-1</i></sub> *RoA <sub><i>t-1</i></sub>                 | 1.269<br>(0.765)     | 1.306*<br>(0.784)               | -0.037<br>(0.044)     | 3.554<br>(2.504)     | 3.437<br>(2.556)               | 0.116<br>(0.197)      |
| Log assets <sub><i>t-1</i></sub> *NPL <sub><i>t-1</i></sub>                 | 1.166<br>(0.770)     | 1.184<br>(0.789)                | -0.018<br>(0.043)     | 1.448<br>(2.209)     | 1.427<br>(2.243)               | 0.022<br>(0.136)      |
| Log assets <sub><i>t-1</i></sub> *Liquid assets ratio <sub><i>t-1</i></sub> | -1.482<br>(1.066)    | -1.645<br>(1.037)               | 0.163**<br>(0.081)    | -1.205<br>(2.606)    | -1.475<br>(2.528)              | 0.270*<br>(0.156)     |
| Log assets <sub><i>t-1</i></sub> *Short-term debt <sub><i>t-1</i></sub>     | -1.030<br>(1.337)    | -1.145<br>(1.390)               | 0.115<br>(0.091)      | -1.104<br>(2.674)    | -1.396<br>(2.739)              | 0.292<br>(0.205)      |
| Observations  | 472                  | 472                             | 472                   | 284                  | 284                            | 284                   |
| R <sup>2</sup>  | 0.405                | 0.407                           | 0.184                 | 0.499                | 0.501                          | 0.254                 |
| Number of banks   | 76                   | 76                              | 76                    | 39                   | 39                             | 39                    |

Notes to Table 8: This table reports fixed effects regressions for the full sample and the sample of banks which will be supervised by the SSM. The dependent variable is the SRISK (bn Euros). In columns (1) and (4), the reference level is the Euro Area and in columns (2) and (5), the national level. In columns (3) and (6), the dependent variable denotes the difference between SRISK (EA) and SRISK (national). The explanatory variables include bank-level variables: log of total assets, loans to total assets (in %), non-interest income to total income (in %), return on assets (in %), non-performing loans to total loans (in %), liquid assets to total assets (in %), and short-term debt to total liabilities (in %), and their interactions with bank size. All variables are lagged by one period and centered around their means. G-SIFI denotes a dummy which equals one if the bank was classified as a globally systemically important bank by the Financial Stability Board and zero otherwise. State aid denotes a dummy which equals one if the bank received state aid following the State Aid Register of the European Commission and zero otherwise. The sample comprises yearly data of stock listed banks in Euro Area countries over the time period 2002-2013. The regressions take into account bank and year fixed effects. Standard errors are clustered by individual bank and depicted in parentheses. The p-values are as follows: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

**Table 9: Robustness: Crisis Sample**

This table reports fixed effects regressions for the full sample and the sample of banks which will be supervised by the SSM. The dependent variable is the SRISK (bn Euros). In columns (1) and (4), the reference level is the Euro Area and in columns (2) and (5), the national level. In columns (3) and (6), the dependent variable denotes the difference between SRISK (EA) and SRISK (national). The explanatory variables include bank-level variables: log of total assets, loans to total assets (in %), non-interest income to total income (in %), return on assets (in %), non-performing loans to total loans (in %), liquid assets to total assets (in %), and short-term debt to total liabilities (in %). All variables are lagged by one period and centered around their means. G-SIFI denotes a dummy which equals one if the bank was classified as a globally systemically important bank by the Financial Stability Board and zero otherwise. State aid denotes a dummy which equals one if the bank received state aid following the State Aid Register of the European Commission and zero otherwise. The sample comprises yearly data of stock listed banks in Euro Area countries over the time period 2007-2013. The regressions take into account bank and year fixed effects. Standard errors are clustered by individual bank and depicted in parentheses. The p-values are as follows: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

|   | (1)                  | (2)                  | (3)                   | (4)                  | (5)                  | (6)                   |
|---|----------------------|----------------------|-----------------------|----------------------|----------------------|-----------------------|
|   | Full sample          |                      |                       | SSM sample           |                      |                       |
|   | <i>SRISK EA</i>      | <i>SRISK NAT</i>     | $\Delta$ <i>SRISK</i> | <i>SRISK EA</i>      | <i>SRISK NAT</i>     | $\Delta$ <i>SRISK</i> |
| Log assets <sub><i>t-1</i></sub>          | 13.893***<br>(3.931) | 13.894***<br>(4.024) | -0.000<br>(0.299)     | 20.788**<br>(7.753)  | 20.739**<br>(7.796)  | 0.049<br>(0.607)      |
| Loan share <sub><i>t-1</i></sub>          | -4.084***<br>(1.472) | -4.352***<br>(1.552) | 0.267**<br>(0.119)    | -7.713***<br>(2.659) | -8.154***<br>(2.771) | 0.442**<br>(0.193)    |
| Non-interest income <sub><i>t-1</i></sub> | -1.473**<br>(0.616)  | -1.533**<br>(0.626)  | 0.060<br>(0.042)      | -2.390*<br>(1.298)   | -2.481*<br>(1.296)   | 0.091<br>(0.083)      |
| RoA <sub><i>t-1</i></sub>                 | 0.808<br>(0.490)     | 0.902*<br>(0.518)    | -0.094***<br>(0.033)  | 1.961<br>(1.237)     | 2.138<br>(1.278)     | -0.178***<br>(0.056)  |
| NPL <sub><i>t-1</i></sub>                 | 0.757<br>(0.607)     | 0.750<br>(0.630)     | 0.007<br>(0.038)      | 1.728<br>(1.369)     | 1.744<br>(1.392)     | -0.016<br>(0.082)     |
| Liquid assets ratio <sub><i>t-1</i></sub> | -0.749<br>(1.033)    | -0.900<br>(1.032)    | 0.150*<br>(0.084)     | -1.611<br>(1.749)    | -1.888<br>(1.738)    | 0.277*<br>(0.142)     |
| Short-term debt <sub><i>t-1</i></sub>     | -1.027<br>(0.724)    | -1.128<br>(0.770)    | 0.102<br>(0.070)      | -0.972<br>(1.148)    | -1.042<br>(1.230)    | 0.070<br>(0.130)      |
| G-SIFI <sub><i>t</i></sub>                | 3.839<br>(3.617)     | 3.730<br>(3.663)     | 0.109<br>(0.153)      | 3.265<br>(3.770)     | 3.133<br>(3.829)     | 0.132<br>(0.187)      |
| State aid <sub><i>t</i></sub>             | 4.838***<br>(1.387)  | 4.981***<br>(1.408)  | -0.143<br>(0.103)     | 4.228***<br>(1.448)  | 4.255***<br>(1.416)  | -0.027<br>(0.113)     |
| Observations                              | 399                  | 399                  | 399                   | 236                  | 236                  | 236                   |
| R <sup>2</sup>                            | 0.283                | 0.285                | 0.162                 | 0.351                | 0.353                | 0.217                 |
| Number of banks                           | 76                   | 76                   | 76                    | 39                   | 39                   | 39                    |

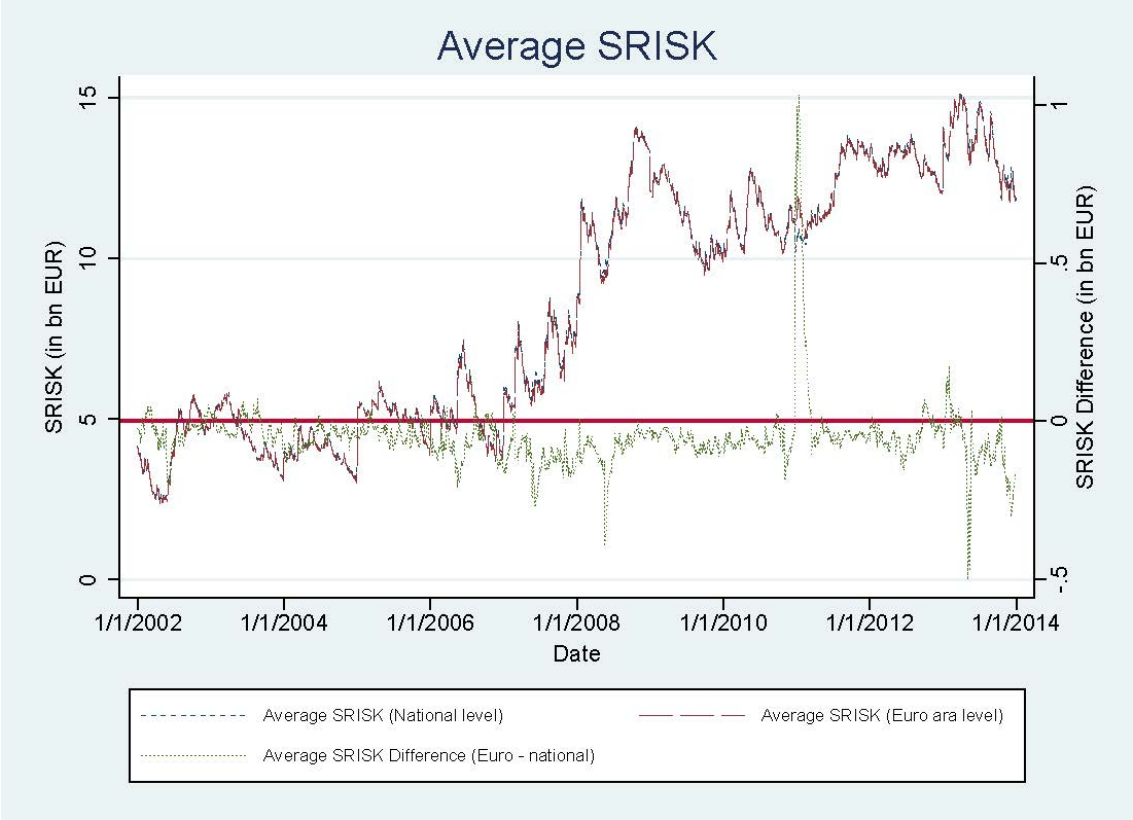
**Table 10: Robustness: Alternative Variables**

This table reports fixed effects regressions. The dependent variable is the SRISK (bn Euros). In columns (1) and (4), the reference level is the Euro Area and in columns (2) and (5), the national level. In columns (3) and (6), the dependent variable denotes the difference between SRISK (EA) and SRISK (national). The explanatory variables include bank-level variables: log of total assets, loans to total assets (in %), non-interest income to total income (in %), return on assets (in %), non-performing loans to total loans (in %), liquid assets to total assets (in %), short-term debt to total liabilities (in %), and the Tier 1 capital ratio (in %). All variables are lagged by one period and centered around their means. G-SIFI denotes a dummy which equals one if the bank was classified as a globally systemically important bank by the Financial Stability Board and zero otherwise. State aid denotes a dummy which equals one if the bank received state aid following the State Aid Register of the European Commission and zero otherwise. The sample comprises yearly data of stock listed banks in Euro Area countries over the time period 2002-2013. The regressions take into account bank and year fixed effects. Standard errors are clustered by individual bank and depicted in parentheses. The p-values are as follows: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1.

|  | (1)                 | (2)                 | (3)                   | (4)                        | (5)                  | (6)                   |
|--|---------------------|---------------------|-----------------------|----------------------------|----------------------|-----------------------|
|  |                     | Excl. RoA           |                       | Incl. Tier 1 capital ratio |                      |                       |
|  | <i>SRISK EA</i>     | <i>SRISK NAT</i>    | $\Delta$ <i>SRISK</i> | <i>SRISK EA</i>            | <i>SRISK NAT</i>     | $\Delta$ <i>SRISK</i> |
| Log assets <sub><i>t-1</i></sub>           | 8.179**<br>(4.071)  | 8.171*<br>(4.166)   | 0.007<br>(0.304)      | 6.241<br>(4.895)           | 6.155<br>(4.935)     | 0.086<br>(0.264)      |
| Loan share <sub><i>t-1</i></sub>           | -3.039**<br>(1.324) | -3.264**<br>(1.383) | 0.225**<br>(0.098)    | -4.085**<br>(1.571)        | -4.380***<br>(1.637) | 0.295**<br>(0.115)    |
| Non-interest income <sub><i>t-1</i></sub>  | -0.962<br>(0.737)   | -0.975<br>(0.754)   | 0.013<br>(0.041)      | -1.328<br>(0.893)          | -1.343<br>(0.901)    | 0.015<br>(0.043)      |
| RoA <sub><i>t-1</i></sub>                  |                     |                     |                       | 1.228*<br>(0.693)          | 1.315*<br>(0.724)    | -0.087**<br>(0.037)   |
| NPL <sub><i>t-1</i></sub>                  | 1.060<br>(0.667)    | 1.018<br>(0.693)    | 0.043<br>(0.040)      | 2.210***<br>(0.709)        | 2.182***<br>(0.715)  | 0.028<br>(0.037)      |
| Liquid assets ratio <sub><i>t-1</i></sub>  | -0.060<br>(0.693)   | -0.136<br>(0.696)   | 0.076<br>(0.050)      | 0.268<br>(0.723)           | 0.148<br>(0.721)     | 0.120**<br>(0.059)    |
| Short-term debt <sub><i>t-1</i></sub>      | -1.227<br>(0.933)   | -1.319<br>(0.963)   | 0.092<br>(0.065)      | -1.067<br>(0.960)          | -1.204<br>(1.003)    | 0.136*<br>(0.076)     |
| Tier 1 capital ratio <sub><i>t-1</i></sub> |                     |                     |                       | -1.048<br>(0.877)          | -1.030<br>(0.879)    | -0.018<br>(0.027)     |
| G-SIFI <sub><i>t</i></sub>                 | 8.110*<br>(4.330)   | 8.126*<br>(4.407)   | -0.016<br>(0.186)     | 8.107*<br>(4.565)          | 8.070*<br>(4.646)    | 0.037<br>(0.209)      |
| State aid <sub><i>t</i></sub>              | 6.595***<br>(2.172) | 6.743***<br>(2.251) | -0.148<br>(0.147)     | 5.392**<br>(2.217)         | 5.398**<br>(2.212)   | -0.006<br>(0.097)     |
| Observations                               | 472                 | 472                 | 472                   | 406                        | 406                  | 406                   |
| R <sup>2</sup>                             | 0.334               | 0.331               | 0.133                 | 0.347                      | 0.344                | 0.158                 |
| Number of banks                            | 76                  | 76                  | 76                    | 63                         | 63                   | 63                    |

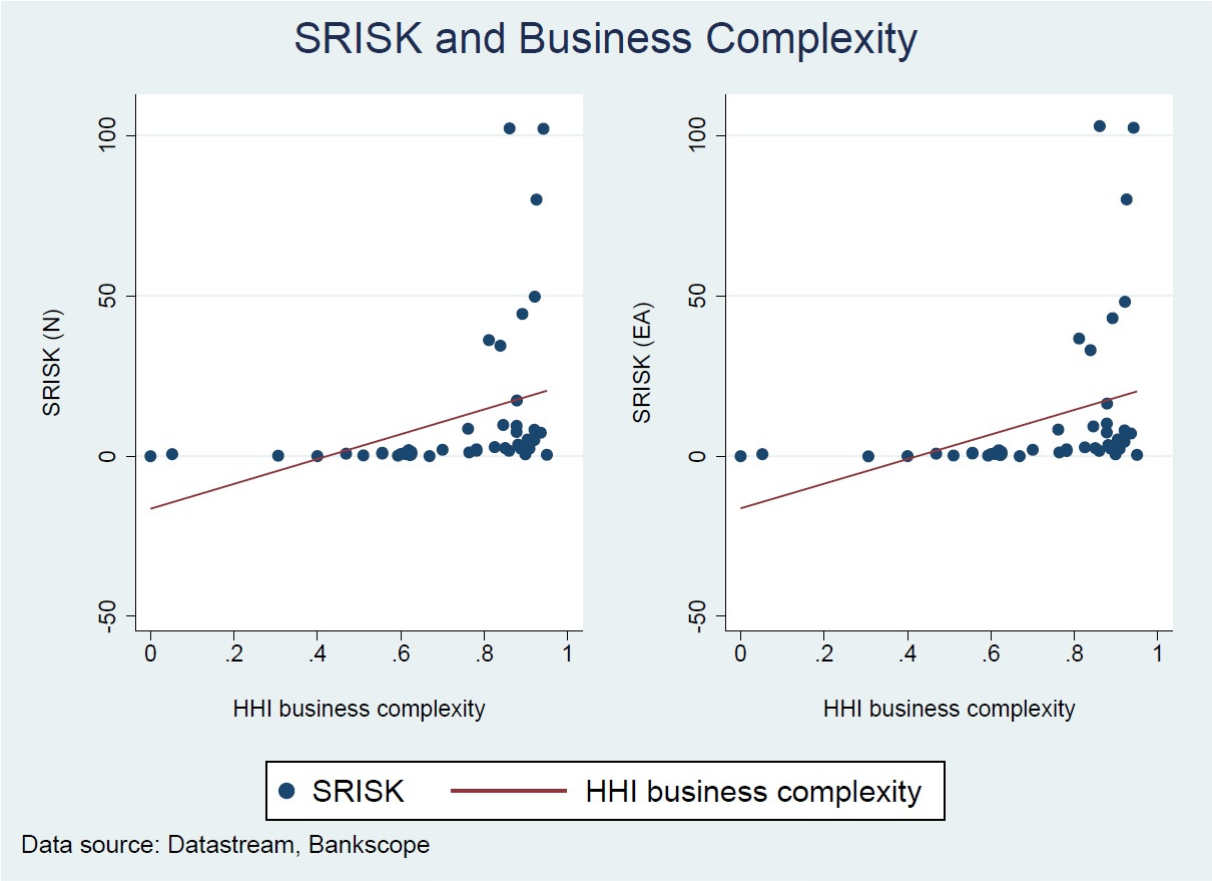
### Graph 1: Systemic Risk over Time

This graph shows the evolution of the systemic risk measure SRISK at the national and Euro Area level over time. The sample comprises 97 banks listed on the stock market in the Euro Area in the period 2002-2013. SRISK is derived from banks' stock market data and is averaged across all banks and across all 17 Euro Area countries. We depict the Euro Area SRISK (red, long-dashed line; left axis), the national SRISK (blue, dashed line; left axis) and the difference between the two (green, dotted line; right axis).



**Graph 2: SRISK and Business Complexity**

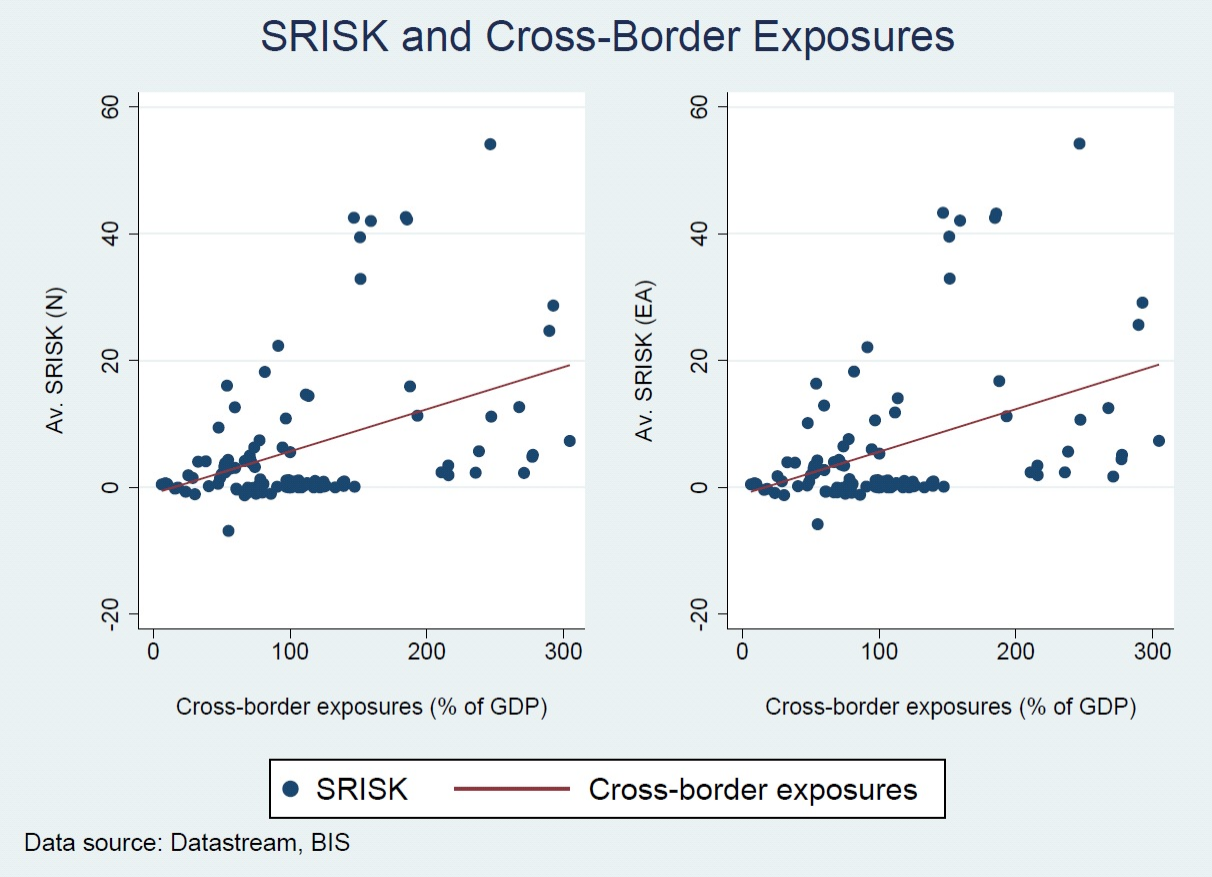
The following graph shows the SRISK (bn Euros) measured at the national (left) and Euro Area (right) level and compares it to the measure for business complexity. Business complexity is derived from a Herfindahl index based on the range of specializations of a bank’s domestic and foreign subsidiaries. The graph is based on all banks in the sample for which these data are available and the year 2013.





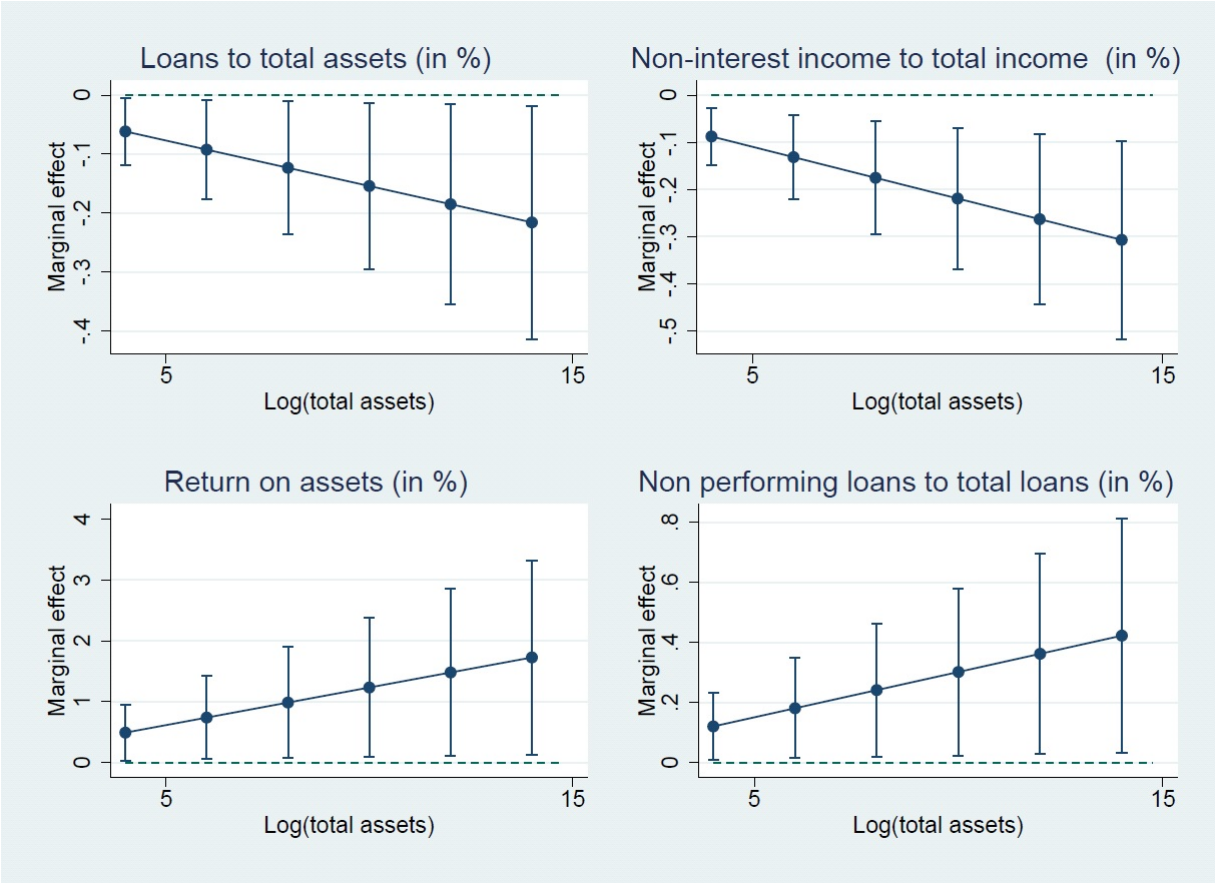
**Graph 3: SRISK and Cross-Border Exposures**

The following graph shows the average SRISK (bn Euros) across all banks in one country and the period 2002-2013. SRISK is measured at the national (left) and Euro Area (right) level and it is compared to a country's banking systems' cross-border activities (% of GDP) as obtained from the *Bank for International Settlements*.



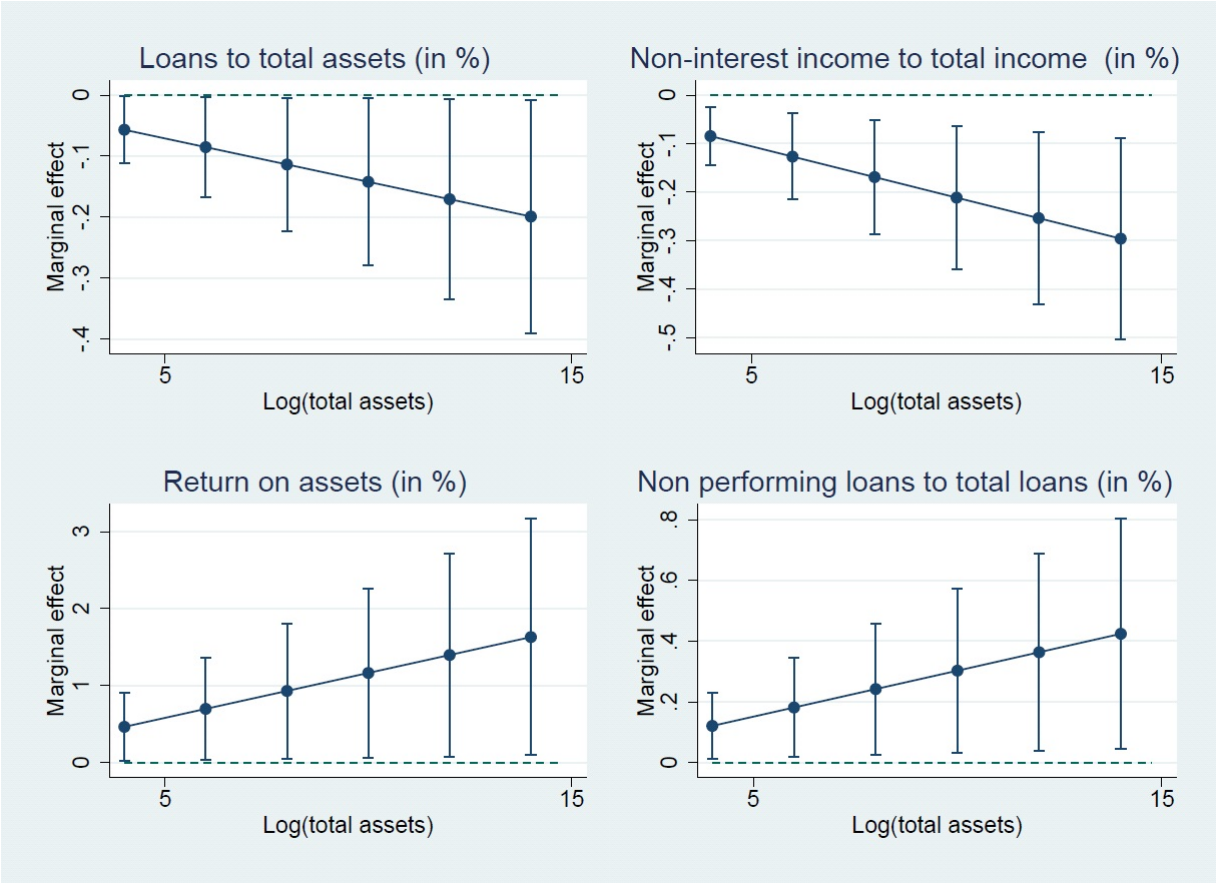
**Graph 4: Average Marginal Effects Conditional on Bank Size- SRISK (national)**

The following graphs show the average marginal effects of loans to total assets (in %), non-interest income to total income (in %), return on assets (in %), non-performing loans to total loans (in %), on SRISK (national) and conditional on bank size measured by the log of total assets. The estimated marginal effects are denoted by dots, which are surrounded by 95% confidence bands.



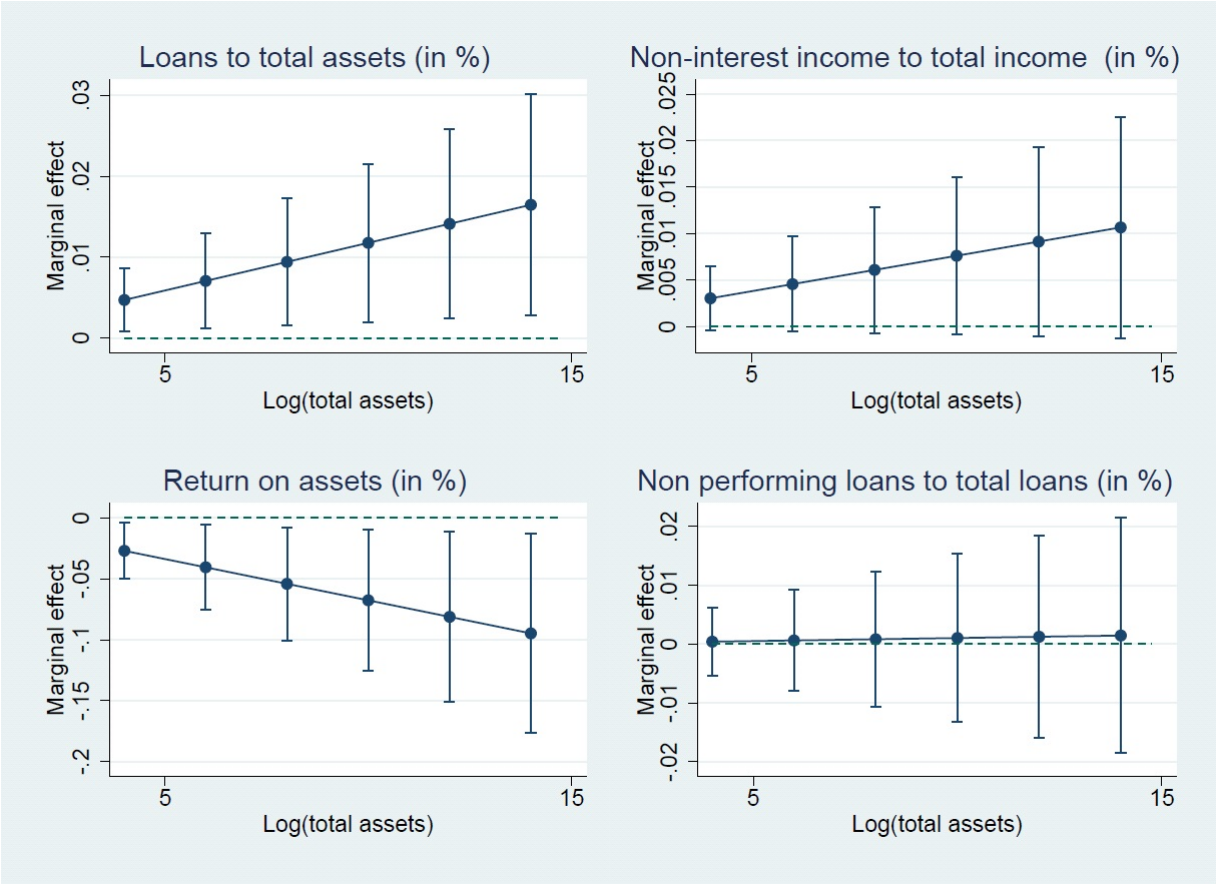
**Graph 5: Average Marginal Effects Conditional on Bank Size- SRISK (Euro)**

The following graphs show the average marginal effects of loans to total assets (in %), non-interest income to total income (in %), return on assets (in %), non-performing loans to total loans (in %), on SRISK (Euro Area) and conditional on bank size measured by the log of total assets. The estimated marginal effects are denoted by dots, which are surrounded by 95% confidence bands.



**Graph 6: Average Marginal Effects Conditional on Bank Size- SRISK (Euro-national)**

The following graphs show the average marginal effects of loans to total assets (in %), non-interest income to total income (in %), return on assets (in %), non-performing loans to total loans (in %), on SRISK (Euro Area-national) and conditional on the log of total assets. The estimated marginal effects are denoted by dots, which are surrounded by 95% confidence bands.



## Appendix A: LRMES - Estimation Procedure

This appendix describes how we have estimated the long-run marginal expected shortfall (LRMES). There are three steps involved: decomposition of stock and index returns, MES calculation and finally deriving LRMES.

### A.1 Return Decomposition

As a first step towards calculating marginal expected shortfall, market returns need to be decomposed based on a time series model that allows for time-varying volatilities and correlations. Consider the demeaned market return at time  $t$ ,  $R_{mt}$ , and the demeaned return stock return of a given bank  $i$  at time  $t$ ,  $R_{it}$ :

$$R_{mt} = \sigma_{mt} \varepsilon_{mt}, \quad (\text{A1})$$

$$R_{it} = \sigma_{it} \varepsilon_{it}, \quad (\text{A2})$$

where  $\sigma_{mt}$  and  $\sigma_{it}$  are conditional standard deviations, and  $\varepsilon_{mt}$  and  $\varepsilon_{it}$  are conditional standardized residuals. According to the CAPM model, rearranging the regression of  $R_{it}$  on  $R_{mt}$  will yield:

$$R_{it} = \beta_{it} R_{mt} + \eta_{it} [\dots] \quad (\text{A3})$$

$$R_{it} = \rho_{it} \sigma_{it} \varepsilon_{mt} + \sigma_{\eta_{it}} \xi_{it} \quad (\text{A4})$$

According to Benoit (2014), the variance of the returns of bank  $i$  can be computed by:

$$V(R_{it}) = \sigma_{it}^2 = \sigma_{it}^2 \rho_{it}^2 + \sigma_{\eta_{it}}^2 \quad (\text{A5})$$

The first part of equation A(5) refers to systematic risk and the last part is the idiosyncratic risk component. Extracting the idiosyncratic risk component gives:

$$\begin{aligned} \sigma_{\eta_{it}}^2 &= \sigma_{it}^2 (1 - \rho_{it}^2) \\ \sigma_{\eta_{it}} &= \sigma_{it} (1 - \rho_{it}^2)^{1/2} \end{aligned} \quad (\text{A6})$$

Substituting A(6) into A(4):

$$\begin{aligned}
R_{it} &= \rho_{it}\sigma_{it}\varepsilon_{mt} + \sigma_{it}(1-\rho_{it}^2)^{1/2}\xi_{it} \\
R_{it} &= \sigma_{it}(\rho_{it}\varepsilon_{mt} + (1-\rho_{it}^2)^{1/2}\xi_{it})
\end{aligned}
\tag{A(7)}$$

Decomposing returns thus yields the following expression:

$$R_{mt} = \sigma_{mt}\varepsilon_{mt}, \tag{A(8)}$$

$$R_{it} = \sigma_{it}(\rho_{it}\varepsilon_{mt} + (1-\rho_{it}^2)^{1/2}\xi_{it}), \tag{A(9)}$$

$$(\varepsilon_{mt}, \xi_{it}) \sim F \tag{A(10)}$$

Equations A(8) to A(10) consist of two volatility processes and one correlation process. We estimate the volatility processes as a GJR-GARCH model. This method was chosen because it allows for asymmetric volatility clustering, indicating that large negative changes are more likely to be clustered than positive changes. For the correlation process, we opted for a Dynamic Conditional Correlation (DCC) model because that allows correlations to rise faster when both asset prices are declining than when they are both increasing. This set up is needed for the next step: the MES calculation.

## A.2 Short-Run Estimation of the Marginal Expected Shortfall (MES)

With reference to the decomposed market and stock returns above, the Marginal Expected Shortfall (MES) is defined as:

$$MES_{it} = E_{t-1}(-R_{it} | R_{mt} < C) \tag{A(11)}$$

$$MES_{it} = \sigma_{it}\rho_{it}E_{t-1}(\varepsilon_{mt} | \varepsilon_{mt} < C/\sigma_{mt}) + \sigma_{it}(1-\rho_{it}^2)^{1/2}E_{t-1}(\xi_{it} | \varepsilon_{mt} < C/\sigma_{mt}) \tag{A(12)}$$

Equation A(11) demonstrates the Marginal Expected Shortfall that occurs to bank  $i$  after a market decline of at least  $C$ . Equation A(12) incorporates A(8) and A(9) and divides the MES in two components that can both be interpreted economically. The first part delivers an essential ingredient to understand systemic risk, namely the product of the firm volatility and its correlation with the broad market. The second component measures the importance of tail dependence. It is zero if the residuals in A(10) independent.

To simulate MES, shocks are drawn from the empirical distribution of  $F$  and the process follows A(8) to A(9). If some of these simulations suffice the threshold loss  $C$  and exceed the one day loss of -2%, the mean loss of each bank's equity is computed.

### **A.3 Long-Run Estimation of the Marginal Expected Shortfall (LRMES)**

To estimate LRMES, the system above is simulated six months into the future many times. The most pessimistic scenarios are defined as a crisis whenever the broad index falls by 40 percent over the next six months. For these scenarios, the expected loss of equity value of bank  $i$  is called the Long Run Marginal Expected Shortfall or LRMES. Put differently, this is the average of the fractional returns of the firm's equity conditional on the crisis scenario. Acharya et al. (2012) propose to approximate  $LRMES_{it}$  as  $1 - \exp(18 * MES_{it})$ .