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SYSTEMIC RISK AND SYSTEMIC IMPORTANCE MEASURES DURING THE CRISIS

by Sergio Masciantonio[†] and Andrea Zaghini[‡]

Abstract

Systemic risk and systemic importance are two different concepts that emerged from the crisis and are now widely employed to assess the potential impact of shocks that hit one specific bank on the banking system as a whole. However, these two measures are often improperly used and misunderstandings arise. This paper sheds light on their meaning, methodology and information content. Empirically, the two measures provide different information; it is therefore worth investigating both to thoroughly understand single name and aggregate systemic risk exposure. In addition, by relying on the standard risk management perspective, we suggest how to integrate systemic importance and systemic risk concepts. We provide two new measures of systemic risk exposure and compare them with the standard one (SRISK).

Contents

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1. Introduction[1]

The global financial crisis started in 2007 has been a watershed for various fields of economics. With its widespread disruption of financial markets and the rapid transmission among financial institutions that almost brought the entire financial system to its knees, the crisis highlighted the lack of understanding of many macro-financial linkages and the existence of several crucial flaws in the global financial framework. The new issues under investigation can be grouped in two main fields: systemic risk (Brunnermeier and Oehmke, 2013) and systemic importance (FSB, 2011). The two notions can be thought of as the two sides of the same coin. However, they have mainly been studied separately and some sources of misunderstanding still exist. The main purpose of the paper is to shed light on their characteristics and distinctions, both conceptually and empirically, and to provide a unique framework through which assess and combine their information content.

Concerning systemic risk, it can be fairly said that, before the eruption of the crisis, financial risk was poorly understood, measured, managed and regulated (Bernanke, 2012). The poor understanding of financial risk lays its foundations in the popular concept that risk can be mitigated through its redistribution among market agents. This concept is entirely rational at the firm's level. However, it hides the fact that risk redistribution and diversification does not eliminate risk itself. Aggregate risk was generally out of the radar before the crisis and its relationship with the risk borne by each market agent was only rarely taken into consideration. No wonder that before the global financial crisis the problem of systemic risk had a much lesser relevance in the economic debate.

Academic contributions trying to fill this gap flourished after the crisis. Before the crisis, a proper way to measure systemic risk did not exist. Analogously there were no measures about the contribution of each financial institution to systemic risk. Nowadays, the number of proposed measures is proliferating, and some of them – given their robustness – are starting to be considered as benchmarks (SRISK, CoVaR, etc.).[2]

[2] This effort was flanked by a considerable determination by financial regulators and policy makers to improve the way market agents manage their risks and to update financial regulations in order to take account of the systemic risk. To improve the management of individual risks, for instance, financial institutions were forced to increase their capital levels, to improve the quality of the capital held, to reduce their reliance on short-term funding, to increase the risk-weighting of several assets categories.

Systemic importance is a different concept and it is related to, but not limited to, the "too-big-to-fail" issue. The latter, although not new (Mishkin, 2006), gained further consideration after Lehman Brothers' disorderly bankruptcy in 2008. It was then clear that the collapse of a single, possibly not very big, but deeply interconnected financial institution could have a systemic impact on the global financial system. Therefore, financial regulators around the world decided to effectively tackle the problem of financial institutions of a systemic dimension. Their failure had to be made less likely and, should any occur, less severe and disruptive, in order to reduce the likelihood of a public bailout (FSB, 2011). In addition, also contagion effects should be made less likely and largely mitigated.

First of all, to effectively address the problem of systemic dimension, large and potentially threatening institutions need to be identified. While size is certainly important, a bank's systemic impact is also likely to be positively associated to its interconnectedness, which can capture its potential for contagion to other financial institutions; to the lack of readily available substitutes and to its overall complexity, which can jeopardize the resolution of existing contractual obligations (IMF/BIS/FSB, 2009). Therefore, in 2011 the Financial Stability Board (FSB 2011) published an integrated set of policy measures to address the systemic and moral hazard risks associated with global systemically important financial institutions (SIFIs). In the same publication the FSB identified an initial group of global systemically important banks (G-SIBs) using a methodology developed by the Basel Committee on Banking Supervision (BCBS) which assesses five bank characteristics: size; interconnectedness; substitutability; complexity; and cross-jurisdictional activity (BCBS 2011a, BCBS 2013). By 2019, G-SIBs will be required to hold additional capital and a proper total loss absorbency capacity to be bailed-in in case of resolution (FSB, 2014). Given the significant consequences of being labelled a G-SIB, the assessment methodology and the final score/ranking should be fully understood by the banks under scrutiny and the financial market in general.

A straightforward issue, related to both systemic risk and systemic importance, is their contribution to the systemic fragility of the global financial market. This issue lies in the micro-prudential view of systemic risk (Acharya and Öncü, 2013), where systemic risk contribution (SRC) arises from the spillover of financial distress of a single financial institution to the rest of the financial sector. Besides the measurement of the actual level of systemic risk in the financial system, this micro-prudential view is faced with two slightly different and complementary issues. The time-varying contribution of each financial institution to the aggregate systemic fragility depends crucially on the measurement of the risk borne by each institution and the systemic impact that the failure of a financial institution might have on the rest of the financial system. Therefore, in this perspective, the contribution to the overall systemic fragility could arise from an institution's state-contingent riskiness, from an institution's structural systemic dimension, and potentially from the interaction of the two. In the paper we will follow this line of reasoning

when looking at and integrating the two kinds of measures. Indeed, while in recent years several measures of systemic risk have been suggested and many papers proposed comparisons among different measures, most of the contributions focused on the theoretical properties of models dealing with systemic risk alone. The relationship between systemic risk and systemic importance has attracted much scarcer interest in the literature. This paper tries to fill this gap, and put both systemic risk measures and systemic importance measures in a broader perspective.

In order to investigate the relation between the two concepts, we rely on selected measures of systemic importance and systemic risk. As far as systemic importance is concerned, given that the scores stemming from the BCBS methodology are not available before 2010, we rely on the systemic importance indicator (SI) by Alessandri et al. (2015), which employ a methodology that is consistent with the BCBS approach and it is based on publicly available data for a large set of banks (Masciantonio, 2015). Concerning systemic risk, we rely instead on two commonly used measures: the marginal expected shortfall (MES) by Acharya et al. (2017) and the delta conditional Value-at-Risk (ΔCoVaR) by Adrian and Brunnermeier (2016). Using those indicators, we are able to provide an assessment and a comparison of the information content of the different measures throughout the financial crisis. Moreover, given the growing relevance of the role of the domestic systemically important banks (D-SIBs), we replicate the analysis at the European Union (EU) level (BCBS, 2012 and EBA, 2014).

As a further contribution, we suggest that the traditional risk management framework can be used as the common background through which interpret the systemic importance and systemic risk concepts. We start from the fact that more elaborate risk measures (as for instance the SRISK by Acharya et al. 2012 and Brownlees and Engle 2017) try to merge the bank's SRC with the monetary loss in case of default, thus they are different from standard systemic risk measures and provide an assessment of what can be called "systemic risk exposure" (SRE). Measures of the SRE type are commonly based on the standard risk management framework; we show that they can be decomposed into two part: a SRC component multiplied by a measure of the systemic exposure of the bank. We argue that the systemic importance indicator discussed in the paper can be used as the baseline systemic exposure measure. Thus a possibly new measure emerges from the product of the two components and we label it the "systemic expected exposure" (SEE). The integration of systemic risk and systemic importance measure can be usefully implemented by regulators and supervisors in order to more carefully assess the risks faced by the banking system and the consequences for the overall financial stability.

The rest of the paper is organized as follows. Section 2 briefly explores the current state of the debate in the literature. Section 3 describes the selected systemic risk and systemic importance measures and provides the rationale for the adoption of the risk management framework. Section 4 presents an assessment of the information content of the selected

measures. Section 5 analyses and compares the dynamics of the different integrated measures of systemic exposure over the crisis period. Section 6 investigates the role of G-SIBs, D-SIBs and international subsidiaries. Section 7concludes.

2. The literature

Recently, several broad and detailed definitions of systemic risk have been proposed, such as "externalities which, if unheeded, could jeopardize financial stability" (Angelini et al. 2012), or "the threat that developments in the financial system can cause a break-down of the financial system and massive damages to the real economy" (Trichet, 2009). Following a formal request from the G20 group, IMF, BIS and FSB published in 2009 a joint Report (IMF/BIS/FSB, 2009) that offers two clear intuitions about systemic importance and systemic risk. Systemic risk is "the risk of disruption to financial services that is caused by an impairment of all or parts of the financial system and has the potential to have serious negative consequences for the real economy". Conversely, "a financial institution is considered 'systemically important' if its failure or malfunction causes widespread distress either as a direct impact or as a trigger for broader contagion". The two definitions highlight the different nature of the phenomena: systemic risk is related to the time-varying probability that a dangerous event for the financial stability may happen, whereas the concept of systemic importance hinges on the magnitude of the disruptive effects that a default of an institution may cause.

Also at the micro level, several measures of the contribution of each institution to the overall systemic risk have been proposed in the most recent years. However they are often aimed at conceptualizing, defining and measuring different aspects of systemic risk. Among the most followed one, Acharya et al. (2017) define the systemic risk (contribution) of a financial institution as the propensity to be undercapitalized when the system as a whole is undercapitalized and propose their systemic expected shortfall index (SES) as a general measure. Partly building on that, Acharya et al. (2012) and Brownlees and Engle (2017) introduce the SRISK index. The SRISK of a financial institution is defined as the expected capital shortage the corporation would suffer in case of a systemic event. Both the SES and the SRISK are based on the concept of marginal expected shortfall (MES), which is the expected loss that an investor in the shares of a financial firm would suffer were the market experiencing a substantial decline, a proxy of a systemic event.

Adrian and Brunnermeier (2016) suggest a measure, the ΔCoVaR, which has a specular perspective with respect to MES. It is based on the Value-at-Risk (VaR) of the overall financial system conditional on an individual institution being under distress. Although the two measures, MES and ΔCoVaR, differ in perspective, they share the same approach aimed at examining the

co-dependence of single institutions with the overall financial system's health (Bisias et al., 2012).[3]

Given the very large heterogeneity and size of the literature on the systemic risk contribution (SRC), also the number of papers comparing the different measures has flourished. For instance, Bisias et al. (2012) provide a superb survey of the growing number of systemic risk measures, with clear descriptions and evaluations of their analytical properties. However, most of the contributions are focused on the analytical properties of the indicators, rather than on the empirical results arising from their application to real-world data (Löffler and Raupach 2013, Benoit et al. 2016).

A common feature of SRC measures is that they are market-based: relying on several different market-data sources, they are likely to encompass the overall degree of risk aversion and the market's idiosyncratic risk perceptions towards an institution. This in turn points to a possible drawback of the market-based models: their limited universality. Being based on financial markets data they can be applied only to a subset of existing financial institutions – those publicly listed and traded – neglecting non-listed banks and foreign subsidiaries. This issue can involve a relevant number of banks, and it is particularly important when subsamples of the global economy are considered to detect D-SIBs. All in all, the different nature of the SRC measures, the historic variability and their possible applicability limit, often accompanied by significant modelling complexity, make SRC measures not always suitable for supervisory and regulatory purposes.

On the other end of the spectrum, systemic importance measures have mainly been in the spotlight of financial regulators. It should be not surprising that regulators tend to prefer measures of risk that rest on general and specific firm characteristics, business models, and levels of transactions in specific markets or instruments (thus mainly balance sheet data), rather than relying on market-sensitive data (BCBS 2011a, 2013). Indeed, the features usually taken into account can be considered as "structural" as they change only very slowly and tend to present a limited variability over the cycle.

Even though other methodologies have been proposed to measure systemic importance, the one proposed by BCBS (2011a, 2013) represents the state of the art in the process of

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[3] In addition to the quoted measures and papers there are many other contributions, the literature on the topic is huge. For instance, and without the aim of being exhaustive: Huang et al. (2012) measures the systemic risk of the banking sector as a hypothetical distress insurance premium (DIP): the insurance cost to protect against losses in a distressed banking system. Tarashev et al. (2009) present a methodology that takes as inputs measures of system-wide risk and allocates them to individual institutions relying on the Shapley value. Based again on Shapley values, Drehmann and Tarashev (2011) propose a measure to evaluate the contribution of interconnected banks to systemic risk which depends materially on the bank's role in the interbank network. Dungey et al. (2013) propose a network-based methodology to rank systemic risk contributions.

identifying and quantifying the systemic importance of financial institutions. It involved the joint work of supranational institutions, national supervisory authorities and market participants.[4] The BCBS approach relies on a simple indicator-based procedure grounded on five sources of systemic importance to be calculated for each bank: size, interconnectedness, substitutability, complexity, and cross-jurisdictional activity. Thus it encompasses several dimensions of systemic importance, which are captured by both quantitative and qualitative indicators. In 2011, the FSB adopted the BCBS approach to compute the systemic score of 75 large banks and provided first "official" list of G-SIBs.[5]

For the analysis intended in the paper, there are two main drawbacks stemming from the BCBS/FSB evaluation process: 1) the systemic importance scores have not been made public yet for all the bank under scrutiny; 2) the ranking of G-SIBs starts from 2010 only, well after the burst of the global financial crisis. In addition, the fact that the process deals exclusively with the global economy, and the possibility to override the scores by supervisory judgment – although limited in scope – somewhat blur the transparency of the process. In an attempt to amend these shortcomings, Masciantonio (2015) implemented the BCBS (2011a) procedure relying exclusively on publicly available data. The author provides the first complete ranking of banks according to systemic importance for 2010 and 2011, and he shows a very good matching with respect to the FSB (2011) selection. Refining the methodology, Alessandri et al. (2015) provide for the period 2007-2012 not only the rankings but also the values of the systemic importance index (SI) for three different samples of top 100 banks: the global economy, the EU and the euro area. Examining separately the subsets of banks for the EU and the euro area is important at the "local" level, since several banks might have a significant impact on the domestic financial system even if they are not systemic from a global point of view (BCBS, 2012; EBA, 2014).

The literature has not yet adequately dealt with the integration between systemic risk and systemic importance measures, neither from an analytical nor an empirical point of view. In addition, the recent empirical contributions are employing very heterogeneous definitions of systemic importance (often based on the relative or absolute size of banks but even on measures of systemic risk) when analyzing it in relation with standalone risk measures (as CDS spreads or market returns) and systemic risk measures (usually ΔCoVaR and SRISK).

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[4] Among the other methodologies, ECB (2006) proposes an identification of large and complex banking groups for the assessment of the stability of the euro-area financial system; the 2010 US federal law known as Dodd Frank Act sets a threshold of $50 billion in the book value of assets for a bank holding company to be designated as systemically important. In addition, FSOC (2011) looks at non-bank financial institutions and IAIS (2013) focuses on Global Systemically Important Insurers (G-SIIs).

[5] Every year, the FSB provides a rank of global systemically important banks (G-SIBs), however never disclosing the score values. The selected SIBs are allocated to four buckets of increasing capital surcharges (up to 2.5% of risk-weighted assets). An additional empty bucket of 3.5% of risk-weighted assets is proposed to discourage further systemic increases.

For instance, Völz and Wedow (2011) use, in their analysis of banks' CDS spreads, both a linear and a quadratic term of the ratio of the market capitalization over home country's GDP to proxy the systemic importance of a bank. From the one hand, they find that larger banks generally show lower CDS spreads, supporting the existence of the traditional too-big-to-fail (TBTF) effect; from the other hand, they report that the relationship between bank size and CDS spreads reverts at some point, hinting that very big banks have already reached a systemic dimension that makes them too big (or too systemic) to bail out. Bertay et al. (2013) make a distinction between a bank's absolute size (measured by the log of total assets) and its systemic size (computed as the liabilities-to-GDP ratio). They find that bank asset returns and the return on equity increase with absolute size but decline with systemic size. Barth and Schnabel (2013) use instead a systemic risk measure (ΔCoVaR) to take into account the systemic dimension of banks, while they refer to the ratio of total assets over GDP as the measure of their absolute size. They report that a higher systemic contribution is associated with lower CDS spread, suggesting that instead of the traditional TBTF effect we are already facing a too-systemic-to-fail effect. Zaghini (2014) analyses the evolution of the market monitoring of large banks (according to total assets) and G-SIBs (according to the FSB ranking in 2012 and 2013). He finds that while before the financial crisis G-SIBs enjoyed a lower spread on the primary bond market, as all other big banks, after the crisis they had to face an increased market monitoring, namely higher bond spreads. Finally, Laeven et al. (2016) rely on the banks' size as the proxy of systemic importance and both ΔCoVaR and SRISK as measures of systemic risk. They study the variation in the cross-section of standalone risk (equity market returns) and systemic risk of large banks during the financial crisis (2007-2008). They find, in particular, that systemic risk grows with bank size and it is inversely related to bank capital, and this effect exists above and beyond the effect of bank size and capital on standalone bank risk.

In the remainder of the paper, we first describe the main characteristics of selected systemic importance and systemic risk measures, then work toward their integration into a unique framework and a full exploitation of their different information contents.

3. The systemic expected exposure: concepts and data

The rationale for interpreting systemic importance within the same framework as systemic risk lays in the type of information they provide. The interdependency of the two concepts can be easily understood resorting to the perspective embedded in standard risk management indicators. Disentangling this relation is the aim of this Section.

The design and operation of risk-management systems has been at the core of the efforts of the banking industry in the two decades before the global financial crisis. The management of market risk, with its ubiquitous VaR, has been the cornerstone of the discipline,

which soon extended the same methodologies to the management of credit and operational risk (Crouhy et al., 2001). Although risk management models had been harshly criticized for their failure to detect actual risk during the global financial crisis, the main models of valuation and risk assessment are still at the core of risk management of financial institutions, also thank to the role they play in the computation of capital adequacy requirements in the Basel framework. It is thus not surprising that the risk management perspective has commonly been used in the literature to develop measures of systemic risk (see, for instance, Lehar, 2005, and Yamai and Yoshiba, 2005). Indeed, standard risk management measures used at the bank's portfolio level, like the value-at-risk (VaR) and the expected shortfall (ES), can be easily adapted to the financial system to gauge the systemic risk exposure of the whole banking sector.

In particular, systemic risk crucially depends on the measurement of the ex-ante, ex-post and contemporaneous probability distribution of a systemic event. The most direct measures of systemic risk are given by the joint conditional distributions of negative outcomes of financial institutions. Indeed, a high comovement in negative territory of single-name and market-wide asset returns accounts for a higher systemic risk contribution. Systemic risk measures gauge the increase in tail comovement that might arise due to the spreading of financial distress across institutions (Adrian and Brunnermeier, 2016).

In this group of measures we find the already mentioned ΔCoVaR by Adrian and Brunnermeier (2016) and the MES by Acharya et al. (2017), which we will use throughout analysis. Both ΔCoVaR and MES are derived by extending to the whole financial system two standard risk measures commonly used in commercial banks to measure firm-level risk: the value-at-risk (VaR) and the expected shortfall (ES), respectively.

More in detail, the VaR is the most that a bank loses with confidence $1 - \alpha$, that is: $\Pr(R_j < -VaR_\alpha) = \alpha$, where R_j is the bank's return (Acharya et al., 2017). The CoVaR of an institution is the VaR of its asset value (for a given α) conditional on another event (market distress). Finally, the ΔCoVaR measures the contribution of each institution to the systemic risk as the difference between the CoVaR of the financial system conditional on that institution being in distress (i.e., the individual j stock's return being equal to its $\alpha\%$ VaR value), and the CoVaR of the financial system in the median state of the institution ($\alpha=50$):

$$\Delta CoVaR(R_{M|j}, \alpha) = CoVaR(R_{M|j}, \alpha) - CoVaR(R_{M|j}, 50) \tag{1}$$

where R_M is the market portfolio return.

While several observers find the ΔCoVaR one of the most accurate systemic risk indicators (IMF, 2011; Arsov et al., 2013), Adrian and Brunnermeier (2016) show that there might be a loose link between an institution's VaR and its contribution to the systemic risk measured by the ΔCoVaR. Thus, relying on the ΔCoVaR alone might not be sufficient for a

thorough assessment of the financial sector systemic risk (Bisias et al., 2012). Moreover, Acharya et al. (2012) show that CoVaR measures are not explicitly sensitive to size and leverage.

As concerns our second systemic risk measure, it is derived from a bank's ES, which is its expected loss conditional on the loss being greater than the VaR. Acharya et al. (2017) define the MES as the marginal contribution of firm j to the expected shortfall of the financial system. More formally, the MES of firm j is the expected value of the stock return R_M conditional on the market portfolio taking a loss greater than its Value-at-Risk at α%:

$$MES(R_j, \alpha) = E\big(R_j | R_M < VaR(R_M, \alpha)\big) \tag{2}$$

Higher levels of the MES imply that firm j is more likely to be undercapitalized in the bad states of the economy and thus contribute more to the aggregate risk of the financial system.[6]

ΔCoVaR and MES can be seen as complements, rather than substitutes, given their specular perspective. While the ΔCoVaR aims at measuring the risk on the system posed by individual institutions, the MES points at measuring the risk on an individual institution posed by a systemic distress. However, the two measures have a similar nature, as they are both based on the joint distributions of asset returns. They are a-theoretical and just provide an estimate of correlated losses, rather than a causality link. In this light, it is particularly useful to compare the information that these two measures can provide.

An important difference exists between idiosyncratic VaR and ES and their systemic counterparts, ΔCoVaR and MES. While the former are calculated on the basis of actual profit and loss distributions, the latter are calculated on the basis of conditional stock returns distributions, which provide a standardized measure of a bank's market performance. Therefore, the distress used in these measures is based on stock prices declines of an institution and of the financial system (proxied by the stock index). Various negative stock returns thresholds are used to proxy crisis or distress scenarios.

While ΔCoVaR and MES can actually assess quite carefully the degree of systemic risk contribution of each institution, they lack the ability to properly take into account the impact dimension. Other measures, such as the SRISK by Acharya et al. (2012) and Brownlees and Engle (2017) or the SES by Acharya et al. (2017), try to combine the information implied in the joint probability distributions with the loss (or capital shortfall, CS) incurred in a systemic event.

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[6] Brownlees and Engle (2017), in order to include the MES in their SRISK framework, rely on an advanced econometric technique for the estimation. They propose a bivariate conditionally heteroskedastic model to determine the dynamics of the log stock return of a firm and the log market return at a given date. The specification requires estimating time-varying volatility and correlation, as well as non-linear tail dependence. A multi-step GARCH approach and a Dynamic Conditional Correlation approach are proposed for the first two, while a non-parametric kernel estimator is used to estimate the tail dependence.

Therefore the SRISK and the SES measure the bank systemic risk exposure (SRE), rather than the systemic risk alone.

Both measures can be decomposed in a "risk" part and in an "exposure" part. For instance, starting from the SRISK definition (Acharya et al. 2012):

$$SRISK_{i,t} = E_{t-1}(\text{Capital Shortfall}_i|\text{Crisis}),\tag{3}$$

it can be shown that the measure can be written as: [7]

$$SRISK_{i,t} = f(MES) * (k * lev - 1) * Equity_{i,t}\tag{4}$$

Equation (4) shows that SRISK can be thought of as the product of (the elaboration of) a bank's MES and a measure of the bank's market exposure (as captured here by its market-based leverage and equity). In other words, the systemic risk exposure measured by the SRIK can be approximated by a systemic risk contribution measure times a systemic exposure measure.[8]

By generalizing this perspective, we suggest that SI (the systemic importance measure) can be regarded as a synthetic and more accurate measure of a bank's systemic exposure. Indeed, systemic importance measures offer a normalized non-cyclical assessment of the potential impact on the whole financial system brought about by the failure of a financial institution.

It is important to stress that systemic exposure should not be described in terms of a financial firm's failure *per se*, but in the broader context of a firm's overall contribution to system-wide failure. In this regard, systemic importance appears better suited than leverage, as used in SRISK and SES. Moreover, although leverage can provide a rough measure of the claims that the rest of the system has towards a given financial institution, systemic importance may more accurately rank the importance of the claims according to their complexity and the type of claimant. It can also capture other significant aspects when measuring a bank's distress impact on the rest of the financial system, like its (non-)substitutability and its global clout.

Therefore, equation (4) not only allows to interpret systemic risk and systemic importance under the same framework, but it also suggests a broader approach. Indeed, for

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[7] See the Annex for the basic algebra.

[8] As regards the SES, Acharya et al. (2017) show that the systemic risk of a firm is equal to the product of three components: the real social costs of a crisis per dollar of capital shortage; the probability of a crisis and the expected capital shortfall of the firm in a crisis. Their SES measure is then calculated relying on these components: the "size" of a firm's exposure to systemic risk, that is its systemic importance (as proxied by its leverage), the MES (proxying the expectation of a firm's contribution to realized systemic risk) and two interaction components (accounting for excess returns due to increased credit risk and excess cost of financial distress). The two most relevant variables to calculate the SES are the MES and the leverage of the firm. A similar reasoning to that performed above on SRISK, only more complicated, can be performed for the SES.

each bank and for the system as a whole, we can obtain a systemic risk exposure measure (SRE) as the product of a systemic risk contribution measure and systemic exposure measure:

$$SRE = SRC * SE. \tag{5}$$

In order to actually compute our SRE measures, we use the ΔCoVaR and the MES as SRC measures, whereas the chosen SE measure is the SI by Alessandri et al. (2015). We call them systemic expected exposure (SEE) measures: SSE(COV) and SEE(MES), respectively.

As already mentioned, the computation of both ΔCoVaR and MES is based on market data, while the SI relies on firm characteristics, mainly from balance sheet data. Being based on different sources of information and showing a different behavior over the business cycle, their joint analysis allows a more thorough measurement and understanding of the systemic risk exposure of an institution in absolute terms and over the cycle. Moreover, by construction, systemic importance measures do not take into account the proper risk – either systemic or idiosyncratic – incurred by a financial institution. In this light, there is a considerable scope for assessing their information content together with systemic risk measures. Moreover, while the separate analysis of the two kinds of measures has been the basic approach of supervisors, their integration may bring relevant additional information which is otherwise lost.

An important backing for aligning systemic risk concepts with the risk management framework is given by the crucial role played by VaR and ES in present day banking risk management, regulation and supervision. While these measures strictly focus on bank's idiosyncratic riskiness (and solvability), the global financial crisis showed that each bank's contribution to systemic risk can be far more important, even when a bank is perfectly solvent (Flannery, 2014). It is evident that limiting the supervision to the idiosyncratic risk can be sub-optimal both from a micro- and a macro-prudential perspective (Acharya et al. 2017). Thus, our broader approach could fit well in the supervisory toolbox.

As a further step, the role played by VaR and ES measures allows a comparison between the risk management framework and the typical credit risk framework – as originally set in Basel II (BCBS, 2006) and later updated in Basel III (BCBS, 2011b). Gordy (2003) presents a flexible model generalization showing how this approach to risk management and systemic risk could be easily reconciled with the most used credit-risk models. The latter models are based on the familiar concepts of probability of default (PD) and loss given default (LGD). The combination of the two leads, in the Basel framework, to the well-known Expected Loss concept (*EL=PD*LGD*). Basel credit risk framework is typically applied to the exposures of a bank's loan portfolio. But, once we shift from the loan portfolio to the financial system perspective, the portfolio composed of several loans is equivalent to the financial system composed by several banks. Concepts similar to PD, LGD and EL could then be applied to banks in relation to the financial system.

For instance, it is easy to see that systemic importance can parallel, for the whole system, the LGD of a single bank distress (BCBS 2011a). However, the definition of a bank's PD might not fit well in a systemic risk context for two reasons.[9] On the one hand, the PD is a too restrictive measure of risk. Indeed, banks very rarely default, but can more often find themselves in distress leading to contagion and increased systemic risk. During the global financial crisis, it has been common to see banks being taken over by rivals, bailed-out by governments or meddling through prolonged periods of distress. All these cases sparked considerable market turmoil and increased systemic risk, despite defaults rarely took place. On the other hand, a bank's PD measures the idiosyncratic risk, while in the systemic context we are interested in a bank's contribution to systemic risk. Therefore, the measurement of a bank's contribution to systemic risk is a way to improve the Basel framework, which is designed to take into account each institution's risk seen in isolation (Acharya et al., 2017).

4. The Data

As introduced in the previous section, to compute SEE(COV) and SEE(MES), our SRE measures, we rely on ΔCoVaR and MES data. As regards the former, we calculate the daily realization of the ΔCoVaR, for the period 2007-2015 and then we compute their monthly averages. ΔCoVaR calculations (at the 99th percentile) are based on Bisias et al. (2012) and their Matlab code. The financial system variation has been measured as the daily returns over the S&P500 for the global sample and as the daily returns over the DJ EUSTOXX for the EU sample. We compute the variation of each institution's market-valued total assets as the daily returns of its market capitalization. The conditional distribution of the financial system and each bank is estimated as a function of a set of state variables. To remain in line with Adrian and Brunnermeier (2016) and Bisias et al. (2012), we include the following conditioning state variables: VIX index, change in the UST yield spread (10Y – 3M), change of 3M T-bill rate, change in credit spread (10Y BAA bonds – 10Y UST). Considering the high relevance of European banks within the global sample, we also include the euro-denominated yield spread (10Y – 3M) on German government securities.[10] When the EU sample alone is considered, we include as conditioning state variables: the VSTOXX index, the change in the German and

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[9] The same would apply to other credit risk concepts, like the expected default frequency, as in the Moody's KMV Credit Risk framework (Crouhy et al., 2000), that are often used interchangeably with the PD.

[10] Note that the calculation of ΔCoVaR for a global sample may be less robust for banks headquartered in areas different from the US or Europe (e.g. Asia) and with a strong domestic orientation. In some instances the relation between the daily return of such banks with the SP500 or with the conditioning state variables can be relatively weak.

Italian yield spread (10Y – 3M), the change of 3M Euribor rate and the change in the EU credit spread (10Y BAA bonds – 10Y German Bund). All the above-mentioned series are sourced from Datastream. Monthly data for the MES are instead provided by the NY Stern Volatility Lab.[11]

Table 1. Categories of systemic importance(1)
1. **Size:**   a)   Total exposures as defined for use in the Basel III leverage ratio (20%);   2. **Interconnectedness:**   a)   Intra-financial system assets (6.67%);   b)   Intra-financial system liabilities (6.67%);   c)   Total marketable securities (6.67%);   3. **Substitutability:**   a)   Assets under custody (6.67%);   b)   Payments cleared and settled through payments systems (6.67%);   c)   Values of underwritten transactions in debt and equity markets (6.67%);   4. **Complexity:**   a)   OTC derivatives notional value (6.67%);   b)   Level 3 assets (6.67%);   c)   Held for trading and available for sale value (6.67%);   5. **Cross-jurisdictional activity:**   a)   Cross-jurisdictional claims (10%);   b)   Cross-jurisdictional liabilities (10%).
Source: BCBS (2011a)   (1) relative weights in parentheses

As for the systemic importance measure, the SI by Alessandri et al. (2015) is based on the methodology developed by the BCBS (2011a, 2013) applied to publicly available data. In particular, the construction of the SI stems from 12 indicators grouped in five main categories of systemic importance: size, interconnectedness, substitutability, complexity, and cross-jurisdictional activity (Table 1). The scores of these 5 categories are collected from the sample of the largest 100 banks in the reference samples (global economy and EU), according to their size.[12] While size, interconnectedness and complexity are mainly calculated through balance sheet data, substitutability is calculated relying on industry league tables and cross-jurisdictional activity by decomposing BIS cross-jurisdictional banking statistics. All in all, the SI represents

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[11] We thank Rob Capellini, V-Lab Director, for providing the data.

[12] As concerns the EU sample, following the BCBS (2012) document on D-SIBs, the top 100 banks are drawn not only from banks headquartered in the EU but also from subsidiaries of foreign banks. The inclusion of foreign subsidiaries in the sample accounts for the fact that the failure of a foreign banking group may impose costs to the economy hosting the subsidiary, especially when the foreign subsidiary plays an important role in the host financial system.

banks' actual systemic importance as defined by regulators, but measured through published data (Masciantonio, 2015).[13]

Alessandri et al. (2015) apply this methodology to compute the SI over the period 2007-2012 – well before the start of the FSB exercise – thus allowing the assessment of the role of G-SIBs and EU-SIBs throughout the crisis. In particular, they obtain the subset of "systemically important" banks from the overall sample by selecting the banks which show an SI score higher than the average (100 basis points).

In our analysis, we consider all the banks in the global and EU samples of Alessandri et al. (2015) – the top-100 banks in each year, according to their total assets, both systemically important or not – whose shares are publicly listed on a stock market.[14] We expand the time horizon to cover the period 2007-2015. Since balance sheet data are publicly released to the market only with some delay (each institution releases data about financial year $t-1$ some months after its end, thus during year t), there is a closer connection with the market data of the following year. Therefore, as usually done in the literature when dealing with market data and balance sheet data, we associate systemic risk measures for year t with the SI score for year $t-1$.

As a comparison for our results we use the SRSIK as the benchmark SRE measure. Also the estimates the SRISK are published by the New York Stern Volatility Laboratory at the daily and monthly frequency.

Finally, our approach leads to another interesting issue: while it can be reasonably expected to find a positive correlation between SEE and SE (proxied by SI) or SEE and SRC (proxied by ΔCoVaR and MES), are SE and SRC measures correlated in any way? In particular, do systemically important banks have a higher systemic expected distress contribution? After all G-SIBs, as other TBTF institutions, enjoy an implicit guarantee to be bailed out by governments that could lead to higher risk-taking (Li and Zinna, 2014). Such an outcome would be no surprise, if one refers to the credit risk literature, where PD and LGD can well be correlated (Schuermann, 2004; Bohn and Stein, 2011). However, while the SRC could well show a cyclical

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[13] Analogously to Alessandri et al. (2015) and to the BCBS (2013) updated rules text, for each bank, we calculate the score of each indicator by dividing the individual bank amount by the aggregate amount summed across all banks in the sample. The score obtained for each indicator is multiplied by 10,000 to express it in basis points. Once all the indicators have been computed, it is possible to calculate the overall score of every bank simply by adding up scores in each category and scaling the score up by 10,000 to express it in basis points. It is then possible to rank all the selected banks according to their overall systemic importance and to identify the G-SIBs subset.

[14] Most of the G- and EU-SIBs are actually publicly listed. However, several banks of the EU-SIB set had to be dropped from the exercise, either because they are not included in the V-Lab set or because they are not publicly listed. They are: Fortis Bank, LBBW, DZ Bank, Credit Mutuel, Rabobank, Bayerische Landesbank, Dresdner Bank, BPCE Group (Caisse d'Epargne, Banques Populaires). When instead a bank is listed on multiple stock exchanges, we consider the stock price of the market where the bank is headquartered (e.g. NYSE for US banks, 'A' shares for Chinese banks, etc.).

behavior, the same is not true for the SE. So, conceptually, we would not expect a significant positive correlation between the two measures. In addition, the correlation between systemic risk contribution and systemic importance measures could lead to possibly non-linear outcomes in the SRE measurement, making the rationale for aggregating the individual components less strong. However, we show in the next section that in our framework the positive correlation does not happen to be in place and that both systemic importance and systemic risk contribution measures have to be taken into consideration as determinants of the SRE.

5. Systemic importance vs systemic risk measures

In order to have a first glimpse of the relationship between SE and SRC measures, Figure 1 and Figure 2 show some scatter plots of the variables of interest over the period 2007-2015. The top graphs in Figure 1 plot the SI against the yearly MES averages in the global sample (left panel) and the EU sample (right panel). Both plots suggest at most a weak relationship between the two variables: for the global sample there is mild positive correlation which seems instead to almost disappear for the European sample.

The bottom graphs substitutes the MES with the ΔCoVaR, as the SRC measure. Again, even though a higher variability is reported, there is no evidence of a significant relationship between the two variables in both samples. The significant dispersion of the ΔCoVaR distribution can be explained through the higher volatility of stock prices in some domestic stock markets, in particular those with a relatively limited liquidity.[15]

Figure 1: scatter plots of MES and ΔCoVaR vs SI(1)

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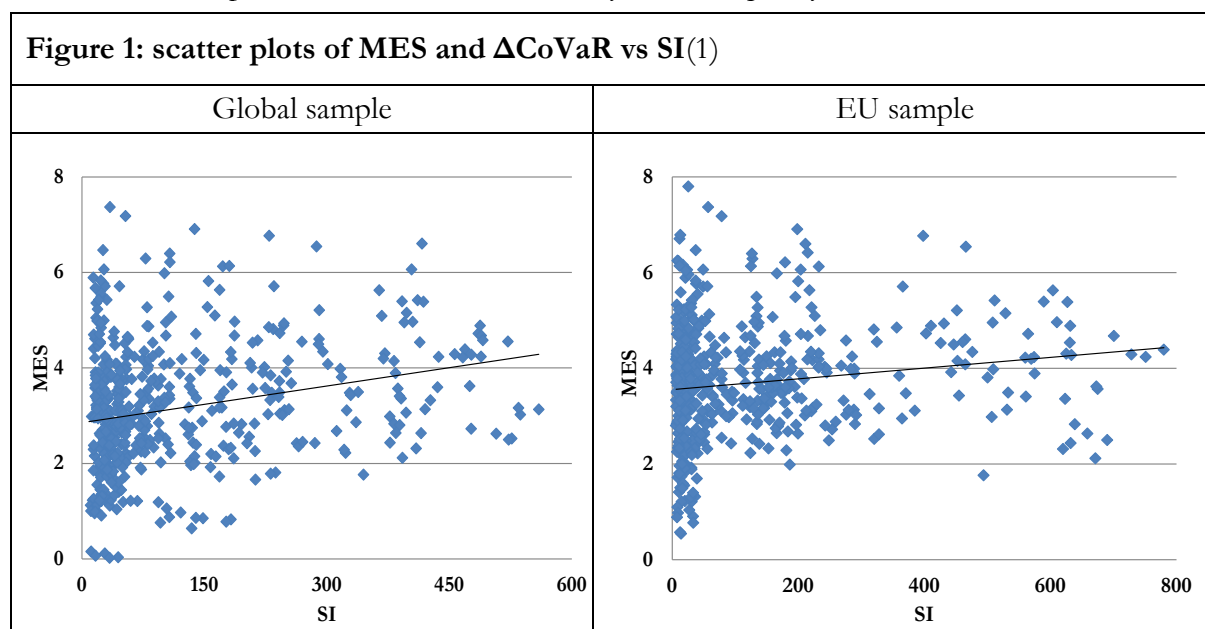
[15] For the global sample, in particular, this might also be due to a relatively weak reach of the conditioning state variables (mainly from the US and the EU) on some markets (e.g. China and Japan).

(1) Yearly averages over the period 2007-2014. The global sample consists of 639 bank/year observations, the EU sample consists of 498 bank/year observations.
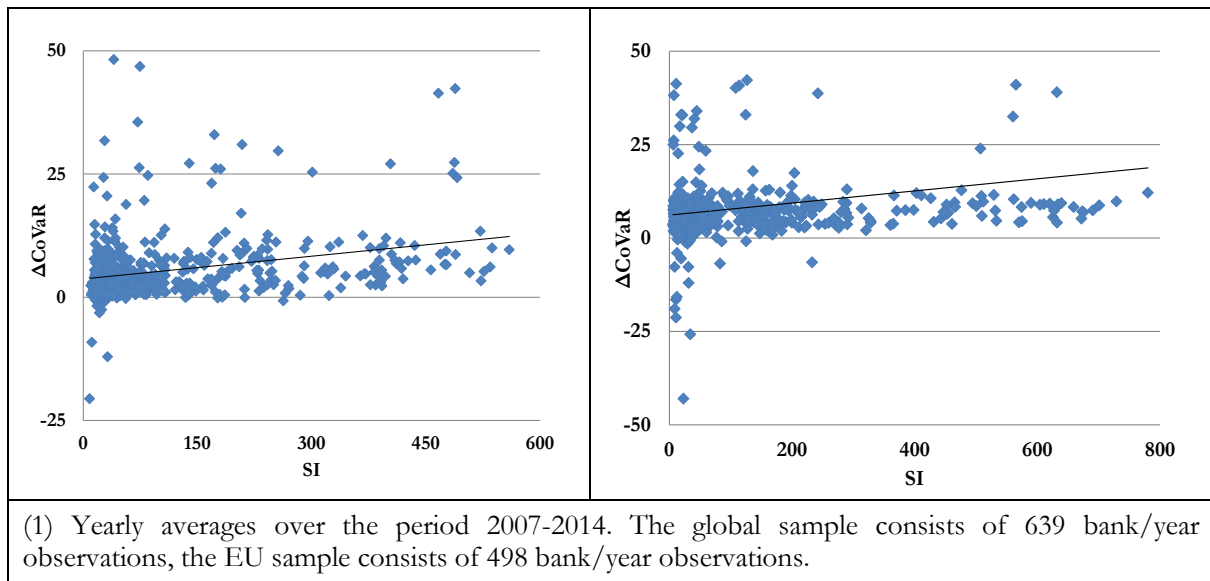
Figure 2 captures instead a relevant aspect of the relationship between the systemic risk exposure (measured by the SRISK) and SRC and SE. Differently from Figure 1, the top graphs show an evident positive relationship between the SRISK and the MES and the bottom graphs depict an even stronger positive relationship between the SRISK and the SI, for both the global sample and the EU sample. This evidence is broadly confirmed by looking at the correlation coefficients (Table 2): while there is just a mild correlation between our chosen SRC and SE measures in both samples, the correlation between the SRISK and the SRC measures is usually larger (but somewhat less clear when the ΔCoVaR is considered), and the correlation between the SRISK and the SE measure is a strong 80%. Therefore, this preliminary evidence supports the idea that the systemic risk exposure can be decomposed into a SRC and a SE component, and that both components independently contribute to the overall systemic risk exposure.[16]

A more thorough analysis can be performed through panel regressions. We run two sets of regressions, with the same model specifications for both the global sample (Table 3) and the EU sample (Table 4). Equations are run with fixed-effects and robust standard errors clustered by bank. We employ Z-scores to allow an easier interpretation of the results and we rely on average annual data for the MES, the ΔCoVaR and the SRISK and lagged annual SI over the period 2007-2015.[17]

[16] Results about pairwise correlations hold also when SI is used in logs.

[17] As a robustness check we run all the regressions displayed in Table 3 and Table 4 relying on the contemporaneous values of the SI. In addition, we also introduced the log of total assets among the regressors to take into account a possible correlation with size (Leaven et al. 2016). No relevant differences emerged.

Figure 2: scatter plots of SI and MES vs SRISK(1)
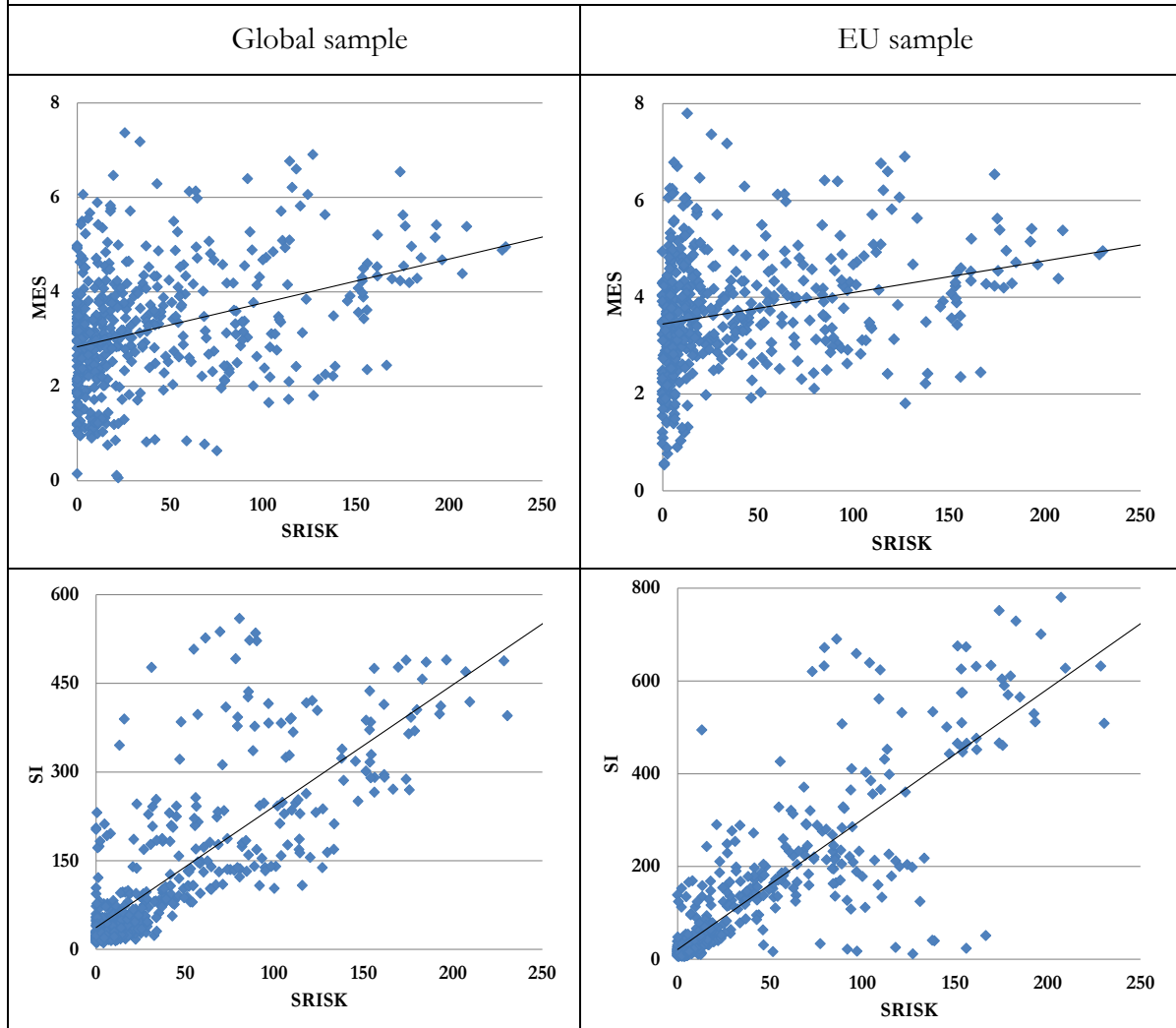
(1) Yearly averages over the period 2007-2014. The global sample consists of 639 bank/year observations, the EU sample consists of 498 bank/year observations.

Table 2. Correlation coefficients

	Global Sample					**EU Sample**			
	MES	ΔCoVaR	SI	SRISK		MES	ΔCoVaR	SI	SRISK
MES	1	-	-	-	MES	1	-	-	-
ΔCoVaR	0.326	1	-	-	ΔCoVaR	0.104	1	-	-
SI	0.227	0.241	1	-	SI	0.159	0.187	1	-
SRISK	0.363	0.185	0.796	1	SRISK	0.275	0.223	0.837	1

Pairwise Pearson correlation coefficients based on annual data for 102 global banks and 80 EU banks over the period 2007-2014. Total observations: 648 (global sample), 508 (EU sample.).

In regression (1), the MES is the endogenous variable, while the SI is the regressor. The coefficient is not statistically significant neither in the global nor in the EU sample. The same applies in regression (2) where the ΔCoVaR is the endogenous variable: the absence of a relationship with lagged SI is still evident. The first hint is that the information stemming from the SI (the systemic exposure measure) and MES and ΔCoVaR (the systemic risk contribution measures) is more or less orthogonal. On the contrary, when the ΔCoVaR is regressed against the MES (regression 3) – there is a statistically significant positive relationship in both samples (even if the adjusted R^2 is very low, particularly in the EU case). This is so because the MES and the ΔCoVaR are both meant to measure the systemic risk contribution of a financial institution – although with different methodologies. Similar set of regressions were run by Acharya et al. (2017) and by Adrian and Brunnermeier (2016), to show that a clear relation exists between MES and ΔCoVaR and other indicators of systemic stress (e.g. CDS, equity returns, capital shortfalls).

We have the most interesting results when a measure of systemic risk exposure (SRISK) is used as the endogenous variable (regressions 4-7). When the SRISK is regressed against the MES in regression (4), the coefficient of the latter variable is positive and significant. However, the adjusted R^2 is still small in both samples (0.10 in the global sample and 0.07the EU sample). Instead, when the SI is used as regressor (regression 5), not only is the coefficient positive and statistically significant in both samples, but also the adjusted R^2 is substantially higher (0.66 and 0.73 in the global sample and the EU sample, respectively). This goodness of fit is particularly relevant as it suggests that the systemic exposure is the main driver of the systemic risk exposure, while the contribution of the systemic risk contribution is of a minor dimension.

Regression (6) further strengthens this result. When both MES and lagged SI are included as regressors, their coefficients are positive and statistically significant. However, with respect to the regression including the SI only, the adjusted R^2 records just a marginal increase, confirming a dominant role for the SI. The latter regression has been run for the EU sample also restricting the sample to the sole institutions headquartered in the EU, therefore excluding all the subsidiaries of non-EU banks (regression 7). The magnitude of the lagged SI coefficient increases significantly and the adjusted R^2 raises to almost 90%. This in turn suggests that the European systemically important banks have a distinctive higher systemic risk exposure, thus their identification and monitoring is of the utmost relevance from a financial stability perspective.

All in all, the reported evidence suggests that the chosen SE index (SI) yields substantially independent information with respect to the traditional systemic risk measures (MES and ΔCoVaR). In addition, the SI looks particularly relevant in contributing to the systemic risk exposure: when a bank has a high SI, it can be expected to have also a high SRISK, regardless of the systemic risk contribution.

Table 3. Regression results: Global sample						
Regressors	**MES** (1)	**ΔCoVaR** (2)	**ΔCoVaR** (3)	**SRISK** (4)	**SRISK** (5)	**SRISK** (6)
SI (-1)	-0.0469 (-0.49)	0.0977 (0.22)			1.0518 (12.28)***	1.001 (10.62)***
MES			0.3622 (2.76)***	0.2288 (2.53)**		0.2558 (11.39)***
Constant	0.1405 (19.2)***	0.1901 (14.5)***	0.0362 (40.1)***	-0.0087 (-2.53)**	0.1841 (27.6)***	0.1251 (19.91)***
Bank Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R²	0.048	0.062	0.108	0.097	0.662	0.716
N. of obs.	639	644	967	916	639	639

Notes: FE regressions. *T*-statistics in parentheses. Symbols *, **, *** represent significance at the 10%, 5%, 1% level.

Table 4. Regression results: EU sample							
Regressors	**MES** (1)	**ΔCoVaR** (2)	**ΔCoVaR** (3)	**SRISK** (4)	**SRISK** (5)	**SRISK** (6)	**SRISK** (7)
SI (-1)	0.0716 (0.51)	-0.2986 (-0.75)			0.6999 (5.14)***	0.6852 (5.06)***	0.8144 (12.36)***
MES			0.1548 (3.93)***	0.1822 (2.96)***		0.2062 (4.36)***	0.2278 (10.84)***
Constant	0.2278 (15.5)***	0.1039 (21.5)***	0.0145 (9.5)***	-0.0029 (-20.1)***	0.1721 (12.4)***	0.1251 (11.19)***	0.0709 (5.78)***
Bank Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R²	0.021	0.031	0.012	0.068	0.727	0.738	0.894
N. of obs.	498	498	748	755	498	498	365

Notes: FE regressions. *T*-statistics in parentheses. Symbols *, **, *** represent significance at the 10%, 5%, 1% level. Regressions (1)-(6) refer to the whole EU sample, regression (7) refers to the EU sample when subsidiaries of non-EU banks are not taken into account

A direct policy implication is that high-SI banks should be closely monitored since they are inherently a potential threat to the financial stability, regardless of their size. Moreover, it is worth stressing that the SI can also be calculated for non-listed financial institutions (being listed is instead a necessary requirement for asset-price based systemic risk measures), thus considerably enlarging the pool of scrutinized institutions. This circumstance is particularly relevant in the EU, where the share of SIBs which are not publicly listed cannot be neglected.

Thus, relying on systemic risk measures alone (or even together with systemic importance measures for the same set of listed banks) would exclude several banks which are instead relevant from the financial stability perspective. The overall assessment would fall short of the actual level of systemic fragility/resilience of the overall banking sector. Instead, given the high explanatory power of the systemic exposure in assessing the systemic relevance of banks, high-SI non-listed banks can still be actively considered in systemic risk analysis by looking at their SI scores only.

6. Systemic measures during the crisis

In this Section we study, over the crisis years, the behavior of the systemic risk exposure measures introduced in equation (5): the SEE(MES), which is the product of the (lagged) SI as systemic exposure and the MES as SRC, and the SEE(COV), which is the product of the (lagged) SI as SE and the ΔCoVaR as SRC.[18] Even though both the MES and the ΔCoVaR are suitable SRC measures, their different perspective on systemic risk – as explained in Section 3 – suggests to look at the SEE(MES) and SEE(COV) as potential complements rather than strict substitutes.

We analyze the development at the monthly frequency of the two measures together with the SRISK, which is a fully comparable measure of systemic risk exposure, for the global sample (Figure 3) and the EU sample (Figure 4). For the sake of exposition, the series presented in Figures 3 and 4 have been aggregated through a non-weighted average of single-bank values and the three risk indicators have been normalized (January 2008=100).[19]

The three indicators seem to reflect the common wisdom about the difficulties faced by banks during the global financial crisis (2008Q3-2009Q2) and the sovereign debt crisis (2011Q3-2012Q3). Indeed, the level of systemic risk exposure suggested by the three measures peaks at the bankruptcy of Lehman Brothers and remains high for several quarters. A return to the 2008 levels is recorded only in the second half of 2009. However, strains to the global

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[18] In other words, the computed SEE(MES) and SEE(COV) measures can be interpreted as the MES and the ΔCoVaR weighted for the systemic importance of each bank. This in turn implies that, while the level of SEE measures is due to the joint contribution of both indicators, the variability within a single year is entirely due to the chosen SRC measure.

[19] We think that also for the SRISK, which is a money value, the average is the most appropriate aggregation (the alternative being the simple sum). We base our assessment on the fact that the sample of banks is not fixed. Indeed, several banks entered or exited the top-100 bank sample during the period under review. Moreover, some of them were not publicly listed for all the period or were de-listed at a certain stage. Then, the evolution of the sum of SRISK over time might have reflected the change in the sample composition, rather than the time-varying risk. However, the actual difference between the series aggregated through the average and the sum appears to be small.

financial system resumes from 2010, when Greece disclosed significant fiscal unbalances which hampered the smooth access to financial markets of both the Greek sovereign and the private sector. Soon the crisis extended to other peripheral countries (Portugal and Ireland) and in the second half of 2011 became a truly euro area-wide systemic crisis when also Italy and Spain were involved. The sovereign debt crisis started to abate in 2011Q4, with the extraordinary measures undertaken by the ECB (Durré et al., 2013). In mid-2012 the EU Banking Union was first envisaged and, soon afterwards, Mario Draghi's stance to do "whatever it takes" to preserve the euro, virtually put an end to the sovereign debt crisis in the euro area.

**Figure 3: SEE(COV), SEE(MES) and SRISK index over the crisis (global sample)**
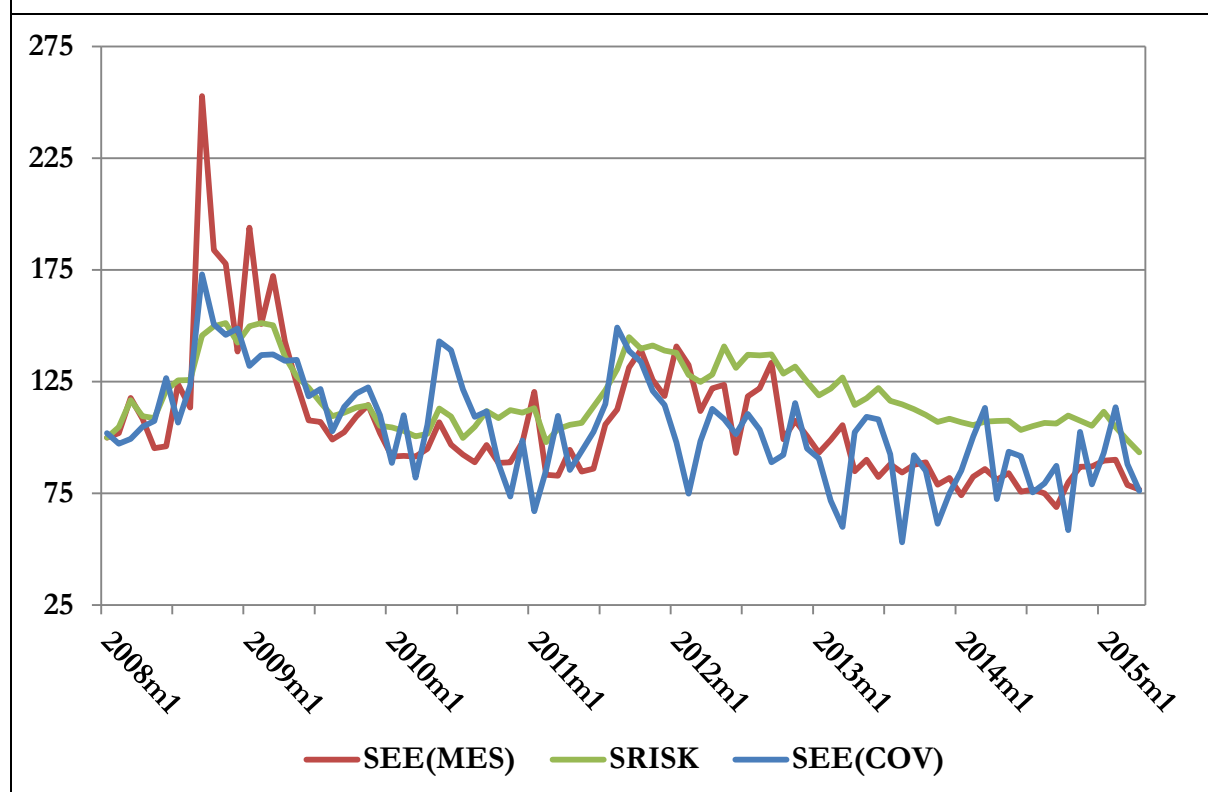
Over the whole period the correlation coefficient is rather high, ranging from 55.3% between the SRISK and the SEE(COV) to 81.0% between the SRISK and the SEE(MES) in the global sample, and ranging from 41.5% between the SEE(COV) and the SEE(MES) to 79.1% between the SRISK and the SEE(COV) in the EU sample.

Thus, at a first glance, Figures 3 and 4 seem to show a relatively similar pattern for the three measures of systemic exposure and point to a milder level of stress experienced during the sovereign debt crisis than that experienced during the global financial crisis for both samples. This should not be surprising, since the sovereign debt crisis affected mainly the euro area (and only some countries in particular) and was centered on sovereigns, rather than on banks like the previous crisis episode. However, a closer analysis of the three indicators shows significant

differences. Both samples show that the SRISK presents a smoother pattern, without significant peaks, even in the most stressful periods. On the contrary, the SEE(COV) presents the most erratic behavior and captures several short-term peaks (like the 2010Q2 liquidity draught in the euro area, which followed the Greece request for international aid), but its high variability makes it somewhat difficult to interpret the underlying trends.[20] Finally, the SEE(MES) appears to strike a balance between the two features. Indeed, it is able to capture peaks in the distribution of the systemic expected loss, but, at the same time, it is not too volatile and it allows trends' identification quite easily.

Figure 4: SEE(COV), SEE(MES) and SRISK over the crisis (European sample)
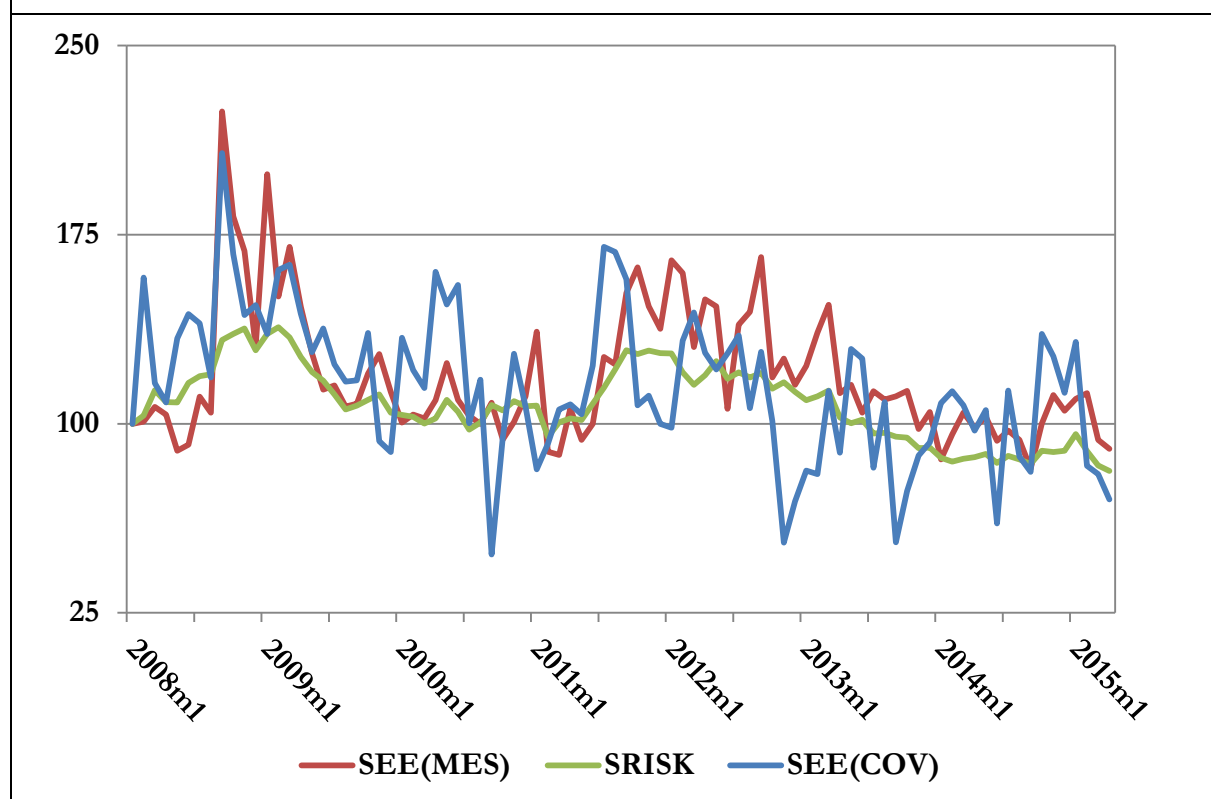
In addition, there are significant differences regarding the extent of the stress they signal in the two crisis phases, in both samples. For the global sample (Figure 3), the SEE(MES) and the SEE(COV) point to a much higher market turmoil during the global financial crisis than the euro-area sovereign debt crisis, while the SRISK shows a similar aggregate level of systemic exposure during the two episodes. This is surprising since the euro-area sovereign debt crisis is usually referred to as an idiosyncratic shock affecting mainly European banks. Even though European banks represent an important share of the overall global sample (on average 35%),

[20] Note that since the ΔCoVaR showed a very large volatility (with several observations far away from the average), for the easy of comparison it has been transformed in logs.

the crisis remains a local episode: at the global level it cannot be compared to the turmoil triggered by the Lehman Brothers collapse. However, the SRISK suggest that the systemic expected loss recorded at the global financial crisis peak and that recorded in the most acute phase of the sovereign debt crisis differ by a mere 5%. Instead, according to the SEE(MES) and the SEE(COV) the difference is at more reasonable levels (44% and 29%, respectively). As a mean of comparison, the S&P500 Index decreased by more than 50% at peak of the global financial crisis (from 2008Q3 to 2009Q1), while it decreased by about 10% at the peak euro-area sovereign debt crisis (from 2011Q2 to 2011Q4).

Restricting the analysis to European banks only (Figure 4) makes the euro-area sovereign debt crisis a more important episode, thus one would expect that the same risk measure would signal a more limited distance between the two crisis peaks than in the global sample. This is so for the SEE(MES), which shows a value of the sovereign debt peak which is 17% lower than the global financial crisis peak (from 44% in the global sample), and the SEE(COV), for which the difference reduces to 10% from 29%. The SRISK instead suggests for the European sample exactly the same distance recorded for the global sample (5%). Thus, the latter measure seems not able to highlight any significant difference between the global crisis and the sovereign debt crisis in neither the global nor the EU sample. Looking again at the stock market development for a benchmark, the DJ EUROSTOXX index decreased by 45% at the peak of the global financial crisis and by 21% during the most acute phase the euro-area sovereign debt crisis.

Summing up, while the three measures provide useful insights into the crisis dynamics, the differences among them suggest it would be advisable to rely on a flexible approach based on several of them, rather than only on a single measure, even if it were computationally burdensome. However, our proposed SRE measures are relatively simple to add to the authorities' tool kit once both MES and ΔCoVaR are already included.[21]


7. Subsidiaries and SIBs

In this section we expand the analysis to two further issues to deepen the understanding and the comparison of the measures of systemic exposure: the role of international subsidiaries and the relative weight of SIBs. We focus on the SEE(MES) and the SRISK since both are based on the same systemic risk measure (MES).[22]

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[21] See Billio et al. (2012) and Giglio et al. (2016) for studies showing that relying on a combination of systemic risk measures has a more predictive power than any single measure in explaining and predicting banks' performance during a crisis.

[22] For the SEE(COV) results are similar to those stemming from SEE(MES).

At least part of the similarity in the development of the SEE(MES) and the SRISK in the global and EU samples reported in Figure 3 and Figure 4 is due to the presence of subsidiaries of foreign banks in the EU, which makes the European sample somewhat more global and less local. Figure 5 depicts the development of the SEE(MES) and the SRISK for the sample of EU banks with and without subsidiaries. Indeed, when the subsidiaries (many of them systemically important at the EU level) are dropped from the sample, the results provided by the two measures are markedly different.[23]

Figure 5. SRISK and SEE(MES) with and without extra-EU subsidiaries
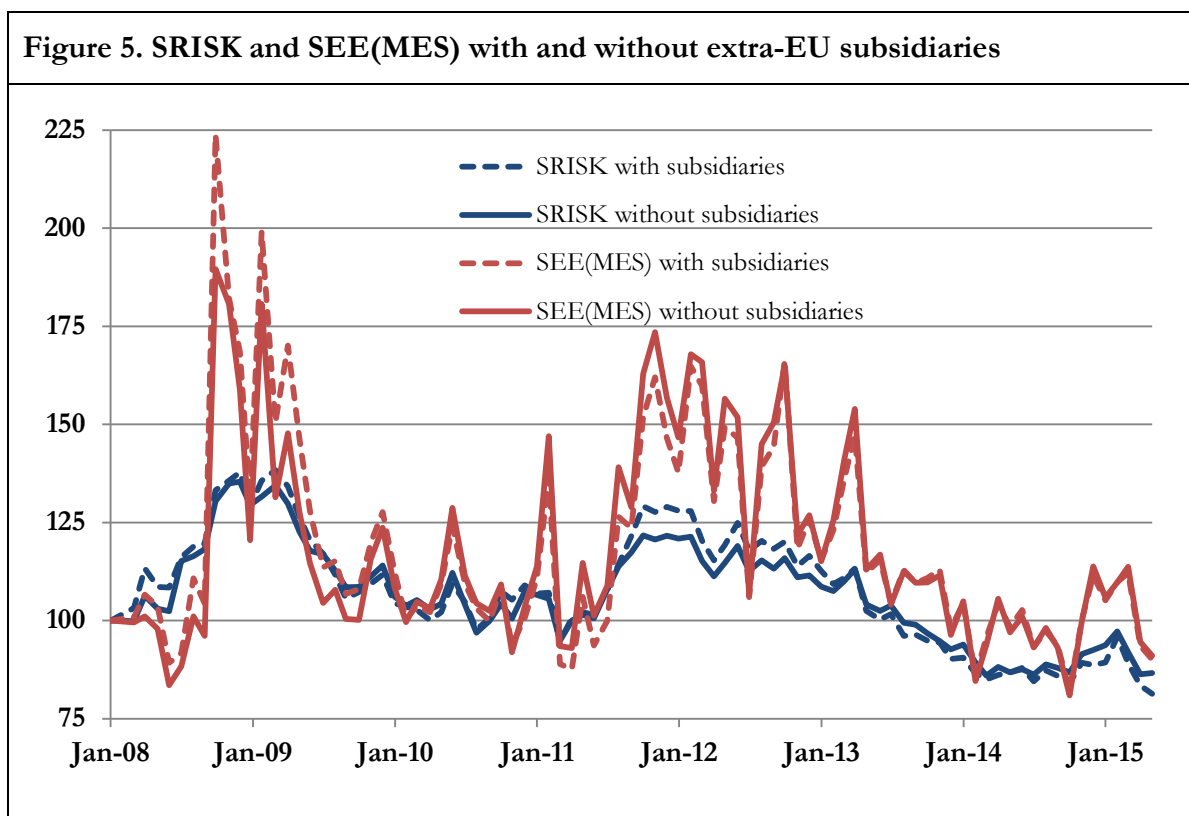
As expected, the SEE(MES) without subsidiaries (the continuous red line) signals both a reduction of the systemic exposure during the global financial crisis and an increase during the sovereign debt crisis. Somewhat puzzling instead, the SRISK suggests that the systemic exposure in the EU sample measured after the collapse of Lehman Brothers is almost unaffected by the exclusion of the extra-EU subsidiaries and it is even reduced over the sovereign debt crisis. Thus, while for the SEE(MES) the two peaks recorded during the two waves of the crisis are much closer when excluding the foreign subsidiaries, for the SRISK the two peaks are further away. Not only is the difference between the peaks in the two crises smaller when measured by the SEE(MES) than by the SRISK (9% and 11% respectively), but

[23] In terms of the SI, the share of systemic importance explained by the EU subsidiaries (mainly from US) is sizable. It increased from 17% in 2007 to 21% in 2011 and then levelled off.

we have again the baffling evidence that the closer we come to the banks which should be more involved in the sovereign debt crisis the less is the overall systemic exposure suggested by the SRISK.

Table 5. SIBs' contribution to systemic exposure measures						
	Global sample			European sample		
	SRISK	SEE(MES)	SEE(COV)	SRISK	SEE(MES)	SEE(COV)
2007	86.8	81.5	79.9	78.7	87.8	85.6
2008	81.9	83.5	87.3	84.9	89.3	86.3
2009	81.3	81.7	82.1	83.0	87.5	87.2
2010	82.1	80.8	84.5	81.8	90.5	90.2
2011	80.9	82.0	85.1	83.0	91.1	90.3
2012	78.3	78.6	82.6	82.9	89.1	91.1
2013	75.7	75.2	82.9	80.4	85.3	89.1
2014	76.1	74.8	80.3	78.9	85.8	89.0
Data refer to all banks with a valid SI value in each sample.						

A second aspect which is worth investigating is the relative contribution to the systemic exposure measures of the systemically important banks within the samples (Table 5). Actually, G-SIBs and EU-SIBs account for most of the systemic risk exposure values (ranging from 75% to 90% in 2014). In the global sample, the three shares are of similar magnitude as they signal a downward trend started during the sovereign debt crisis. In addition, for the SEE(MES) and the SRISK the share in 2014 is significantly smaller than that in 2007 (between 7 and 11 percentage points), whereas it is almost unchanged for the SEE(COV).

For the EU sample instead, the picture is more heterogeneous. Usually, the shares are higher than those of the global sample, suggesting a higher degree of concentration in the EU banking sector. In addition, there is not a common trend and in 2014 the share is higher than in 2007 for the SEE(MES), smaller for the SEE(COV) and almost unchanged for the SRISK. Finally the SRSIK always lays well below the other two measures.

This basic evidence lead to a straightforward implication about SIBs: given their overwhelming contribution to the systemic exposure (being it assessed with the SRISK or the SEE measures), it is of paramount importance for them to be subject to enhanced supervision. Even focusing on just the around 30 banks labelled as G-SIBs by the FSB accounts for a good proxy of systemic relevance of the global banking sector. Even more so for the EU sample, in which the share explained by the domestic SIBs is even larger.

A final comparison for the SIBs is performed at the micro level. In Table 6 we show the list of the top 10 banks according to the three systemic risk exposure measures in 2007. A significant heterogeneity is evident for the global sample (upper panel): there appear 17 different

banks and only four are listed in each rank (Barclays, Deutsche Bank, Morgan Stanley, RBS). However, things largely improve when the top 30 banks are considered (a selection large enough to include all the banks deemed as SIBs by the FSB): only 38 banks are selected, many of them (23) appearing in each rank. This evidence suggests that while the three measures select fairly well the most systemically relevant banks, they weight differently banks' basic characteristics.[24]

Table 6. Top 10 banks according to systemic risk exposure		
SRISK	**SEE(MES)**	**SEE(COV)**
Global sample		
Deutsche Bank	Deutsche Bank	Citigroup
Barclays	Barclays	Deutsche Bank
BNP Paribas	BNP Paribas	JP Morgan
Crédit Agricole	Royal Bank of Scotland	Goldman Sachs
UBS	Citigroup	Lehman Brothers
Royal Bank of Scotland	JP Morgan	Merrill Lynch
ING Bank	UBS	Bank of America
Société Générale	Morgan Stanley	Royal Bank of Scotland
Morgan Stanley	Credit Suisse	Morgan Stanley
HBOS	Goldman Sachs	Barclays
EU sample		
Deutsche Bank	Deutsche Bank	BNP Paribas
Barclays	BNP Paribas	Royal Bank of Scotland
BNP Paribas	Royal Bank of Scotland	Deutsche Bank
Crédit Agricole	Barclays	HSBC
UBS	Société Générale	Barclays
Royal Bank of Scotland	Crédit Agricole	Crédit Agricole
ING Bank	HSBC	Société Générale
Société Générale	Banco Santander	Unicredit
Morgan Stanley	Citigroup	Banco Santander
HBOS	Morgan Stanley	ING Bank
Data refer to all banks with a valid SI value in each sample.		

[24] The Spearman's rank correlation coefficient among the three measures for the whole set of banks in 2007 is relatively high. It goes from 68% between SRISK and SEE(COV) to 76.5% between SRISK and SEE(MES) and it is even larger for the two SEE measures (86.7%). Similar values are found in the following years, however a downward trend is detected for the correlation between SRISK and SEE(COV).

When the EU sample is taken into consideration (lower panel), the top 10 banks selected by the three measures are taken from a smaller pool of 14 banks, six of which appear in each rank (Barclays, BNP Paribas, Crédit Agricole, Deutsche Bank, RBS, Société Générale). Enlarging the analysis to the top 25 banks (a number consistent with the FSB selection mechanism), we find that just 29 banks may be labelled as domestic SIBs for the EU in 2007, 20 of which showing in each rank.[25] In addition, there are six subsidiaries from foreign banks always selected as EU-SIBs and other four selected as EU-SIBs by one measure at least.

Also from the evidence gathered in this Section, we can claim that the low computational burden of the SEE measures makes them a useful alternative to the SRISK, at least at the aggregate level. The SEE(MES) in particular, looks to capture in a timely and efficient way the systemic exposures of the considered samples and adjust to changes in the sample in the expected way. The usefulness of this measure is also true at the micro level. Within the samples of banks, several institutions show a very close tracking between the SEE(MES) and the SRISK (e.g. BNP Paribas, UBS). Yet, some banks show a systematically higher SRISK value (e.g. JP Morgan, Santander, Unicredit), while others show a systematically higher SEE(MES) value (Goldman Sachs, Lehman Brothers). These structural differences are most likely due to the richness of the data included in the SI. In fact, while the main variable behind the capital shortfall of the SRISK is the leverage, the SI instead takes into account a wider set of variables from both the asset side and liability side of each institution balance sheet.

8. Conclusions

In the paper we propose the traditional risk management framework as the base for the assessment and integration of selected measures of systemic importance and systemic risk contribution. While the former have primarily drawn the attention of regulatory and supervisory authorities, the latter have attracted the interest of the academia. The measurement of the systemic importance deals with the assessment of the consequences on the global financial system of the failure of a bank, whereas systemic risk contributions try to capture the joint probability of distress of financial institutions in presence of a systemic event. The opportunity of a cross-fertilization among the two branches has been so far missed. We rely on the standard risk management framework to suggest ways to usefully combine the two measures.

In a first step of the analysis we compare the information content of two well-known measures of systemic risk contribution (MES and ΔCoVaR) with that of the systemic

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[25] The Spearman's coefficient among the three measures is more stable and larger for the EU sample than the global one. Over the period 2007-2014 it averages 86.2% between SRISK and SEE(MES), 78.4% between SRISK and SEE(COV) and 91.6% between SEE(MES) and SEE(COV).

importance measure (SI) proposed by the FSB and computed according to Alessandri et al. (2015), for both a global and a EU sample. Interestingly, the information they provide is almost orthogonal and does not present significant overlaps, suggesting that it is inherently different. This should not be surprising since the measurement of systemic importance is almost entirely based on balance sheet data while the measurement of systemic risk contribution mainly relies on market data.

Since the SI can be calculated for almost every bank, while systemic risk measures need the bank to be publicly listed, supervisors and researchers are able to broaden the scope of the systemic fragility/resilience analysis far beyond the set of publicly-listed banks. In addition, given that SI scores change slowly over time, it gives time to supervisors to thoroughly assess the degree of systemic risk exposures and to timely tackle specific sources of instability. Policies aimed at shoring up the capital base and the loss absorbency ability of G-SIBs – like the capital add-on and the total-loss absorbency capacity (TLAC) requirements (BCBS, 2011; FSB, 2015) – are an example.

The lack of a strong correlation between the two measures not only suggests that both must be taken into account by regulators but also supports the idea that they can be successfully integrated. In analogy with the traditional risk management framework, we introduce two systemic expected exposure measures (SEE(MES) and SEE(COV)) based on the product of a systemic risk value and a systemic importance value.

Relying on a direct comparison, we then show that the SEE measures can be successfully used as indicators of the systemic expected exposure – similarly to other measures proposed in the literature (e.g. SRISK). Over the period 2007-2015, they provide a neutral assessment of the stress faced by the banking sector at the global and EU level. Furthermore, both SEE measures are somewhat more accurate in capturing peaks and short-term developments in systemic exposure than the SRISK, whose relatively smooth dynamics are sometimes at odds with the abrupt changes experienced during the global financial crisis and the euro-area sovereign debt crisis. Similarly, the SEE measures appear to better catch the differences between the global and EU samples, especially when the impact of subsidiaries from non-EU banks is deducted. The latter result is due to the flexible framework of the SI, which allows assessing also the systemic importance of subsidiaries.

All in all, given the limited computational burden to calculate the SEE measures, their flexibility and accuracy, they might well be a useful instrument to be added to financial regulators and supervisors' toolbox. Indeed, they can improve the readability of some indicators and also easing the comparability of different measures enhancing the overall assessment of financial stability.

Annex

As explained in Section 3, the SRISK and the SES measure the bank systemic risk exposure, rather than the systemic risk alone. Both measures can be decomposed in a "risk" part and in an "exposure" part. This annex proposes the algebra for the SRISK.

$SRISK_{i,t}$ can be described as the expected capital shortfall that a firm would face in a crisis (Acharya et al. 2012):

$$SRISK_{i,t} = E_{t-1}(\text{Capital Shortfall}_i|\text{Crisis}). \tag{A.1}$$

Since the capital-shortfall depends on its market-based leverage, we get :

$$SRISK_{i,t} = E_{t-1}((k(Debt + Equity)\text{-}Equity)|\text{Crisis}) = kDebt_{i,t} - (1\text{-}k)(1\text{-}LRMES_{i,t}) * Equity_{i,t} \tag{A.2}$$

where k is an exogenous parameter accounting for a prudential capital ratio (which is akin to a leverage ratio). In Acharya et al. (2012) and in V-Lab SRISK calculations, k is set equal to 5.5% for European banks and equal to 8% for all the other banks (the difference is based on the different prevailing accounting rules). *Equity* is the market value of equity in t. In a crisis, the capital shortfall can be calculated considering that the book value of debt can be expected to remain relatively unchanged, while equity values would fall.

The *LRMES* determines the expected market performance of the firm in a crisis. LRMES stands for Long Run Marginal Expected Shortfall and is a monotonic transformation of the MES. In particular LRMES has been approximated by: LRMES $= 1 - \exp(-18*MES)$.[26]

The market value of equity is expected to go down with LRMES and MES. Expanding (A.2), we have:

$$SRISK_{i,t} = kDebt_{i,t} + k(1\text{-}LRMES_{i,t}) * Equity_{i,t} - (1\text{-}LRMES_{i,t}) * Equity_{i,t}$$

By using the notation $f(MES) = (1\text{-}LRMES_{i,t}) = \exp(-18*MES_{i,t})$, we can rewrite as follows:

$$SRISK_{i,t} = kDebt_{i,t} + k \, f(MES) * Equity_{i,t} - f(MES) * Equity_{i,t} \tag{A.3}$$

From (A.2) and the general theoretical framework of Acharya et al. (2012), it is possible to derive the market-based function of leverage in this framework:

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[26] In later versions of the SRISK calculation a different approximation has been used. The *LRMES* is calculated directly according to this formula: *LRMES* $= 1\text{-}(\exp(\log(1\text{-}d)*beta)$, where d is the six-month crisis threshold for the market index decline and its default value is 40%; and beta is the firm's Dynamic Conditional Beta. Besides the fact that *LRMES* is anyway a type of MES, for the sake of presentation we keep the link between LRMES as MES, as presented above.

$$\text{Leverage} = lev = \frac{TotalAssets}{market-based\ Equity} = \frac{D+f(MES)E}{f(MES)E}. \tag{A.4}$$

At the same time from (A.3), we get that:

$$f(MES) *lev = \frac{D+f(MES)E}{E}. \tag{A.5}$$

Since SRISK is a dollar amount, to have a normalized measure we divide it by the Equity of each bank, thus having:

$$\frac{SRISK}{E} = \frac{kD+kf(MES)E}{E} - \frac{f(MES)E}{E} = k\frac{(D+f(MES)E)}{E} - f(MES)$$

$$= k\ f(MES)\ lev - f(MES) = f(MES)\ (k*lev\ -1)$$

from which we finally obtain:

$$SRISK_{i,t} = f(MES) * (k * lev - 1) * Equity_{i,t} =$$

$$= exp(-18*MES_{i,t}) * (k * lev - 1) * Equity_{i,t} \tag{A.6}$$

Equation (A.6) shows that SRISK can be thought of as the product of (the elaboration of) a bank's MES times a measure of the bank's market exposure (as captured here by its market-based leverage and equity). In other words, the systemic risk exposure measured by the SRIK can be approximated by a systemic risk contribution measure times a systemic exposure measure.[27]

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[27]As regards the SES, Acharya et al. (2017) show that the systemic risk of a firm is equal to the product of three components: the real social costs of a crisis per dollar of capital shortage; the probability of a crisis and the expected capital shortfall of the firm in a crisis. Their SES measure is then calculated relying on these components: the "size" of a firm's exposure to systemic risk, that is its systemic importance (as proxied by its leverage), the MES (proxying the expectation of a firm's contribution to realized systemic risk) and two interaction components (accounting for excess returns due to increased credit risk and excess cost of financial distress). The two most relevant variables to calculate the SES are the MES and the leverage of the firm. A similar reasoning to that performed above on SRISK, only more complicated, can be performed for the SES.

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