SYSTEMIC RISK, 
AN EMPIRICAL APPROACH

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ABSTRACT

We have developed a quantitative analysis to verify the extent to which the sources of systemic risk identified in the academic and regulatory literature actually contribute to it. This analysis shows that all institutions contribute to systemic risk albeit to a different degree depending on various risk factors such as size, inter-connection, un-substitutability, balance sheet and risk quality. From the analysis we conclude that using a single variable or a limited series of variables as a proxy for systemic risk generates considerable errors when identifying and measuring the systemic risk of each institution. When designing systemic risk mitigation measures, all contributing factors should be taken into account. Likewise, classifying institutions as systemic/non-systemic would mean giving similar treatment to institutions that may bear very different degrees of systemic risk, while treating differently institutions that may have very similar charge of systemic risk inside. Therefore, we advocate that some continuous approach to systemic risk -in which all institutions are deemed systemic but to varying degrees- would be preferable. We acknowledge that this analysis may prove somehow limited in the way that it is not founded on a predefined conceptual approach, does not fully consider other very relevant qualitative factors\textsuperscript{1} and accounts only for some of the relevant sources of systemic risk in the banking system\textsuperscript{2}. These limits are currently set due to data availability and state of the art in empirical research, but we believe that these should not hinder our work identifying the true sources of systemic risk and our aim to help avoiding any partial and thus limited prudential policy approach

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\textsuperscript{1}Such as the quality of supervision, the regulatory framework and the crisis management framework of each jurisdiction

\textsuperscript{2}That is the case of interconnectedness, where only theoretical work has been put in place and scarce variables to approximate it are available.
1. Motivation and main objectives

Academic and regulatory literature defines systemic risk as the risk of a major dysfunction or instability of the financial system caused by one or more parties, and whose direct and indirect effects have potential extremely severe externalities for both the financial system and the real sector (Acharya (2009) and FSB/IMF/BIS (2009)). International regulatory bodies have identified the need to control such risk as a priority in order to guarantee the financial stability of the system and avoid distortions that could prevent the efficient assignment of savings, investment, consumption and the correct payment process of the the economy (Jukka Vessala, FFS Sept. 2009). All those functions are nowadays carried out by the financial system.

The negative externalities associated with the potential risk stemming from financial activity justified the introduction of a specific prudential supervisory framework. However, it proved to be insufficient to effectively reduce risk when it gets to systemic dimensions. Basel III strives to fill in the gaps and weaknesses identified in the previous framework such as what relates to capital quality and quantity, liquidity management, risk inherent to trading activities, etc. Within this new framework, the Financial Stability Board (FSB) and the Basel Committee on Banking Supervision (BCBS) are analyzing the ways of modulating regulatory pressure on to the systemic risk nature at both the system and the institution -level. For example, those most systemic institutions would be charged with extra capital per each unit of risk that builds up their systemic nature. This would bring that some entities (seemingly the most systemic) would be always penalized more than those considered less systemic ones.

The report by the FSB/IMF/BIS shows the enormous variety of approaches to systemic risk that are currently used by the different domestic supervisors, which ranges from sophisticated models to simple synthetic indicators. The report concludes about the nature of systemic risk to be time varying and multi-factor led. This renders its analysis more challenging even. In this context, considering qualitative aspects of banks that could work as mitigating or incremental factors of risk stands out very as appealing among regulatory and academic work. The novelty and complexity of the topic added to the non observable nature of the subject of study suggest the idea of considering adding some type of ex ante expert’s view in the identification process of our analysis.

The disparity of approaches, together with the complexity of the problem, and the data availability shortages, may encourage regulators to take excessively simplistic solutions to tackle the analysis such as limiting the number of variables to define Systemic Risk or to define closed lists of institutions characterized as systemic. Giving too much weight to a limited number of variables (like using solely "size" as proxy for risk) simply because they are easier to fetch and measure and ignoring other equally important sources of risk could not only result in a very partial view of the problem, but also have very severe consequences on the financial

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3Acharya (2009) offers an overview of the regulatory and positive aspects of systemic risk, under which he identifies it with the risk of the failure of the system as a whole arising from the correlation of the elements (assets) on the balance sheets of institutions.

4Guidance to assess the systemic importance of financial institutions, de BIS-FMI-FSB 2009
system itself. Doing this, could disregard the benefits of diversification and impede the financial sector reaping in full the benefits of scale and scope economies. The unintended consequence could be a loss of strength and stability of the financial system and the atomization and increased cost of the banking business with questionable benefits for the stability of the financial system.

This document aims to contribute to the debate by building a "proxy" for systemic risk for each institution and for the system itself and discussing its potential uses and shortcomings. It will be based on criteria gathered from academic and regulatory literature (FSB, BIS, IMF and ECB) that relates to the following factors: size, inter-connectedness, unsustitutability and other equally important sources of systemicity such as the strength of institutions (measured in terms of balance sheet quality and composition), the liquidity and financing position and risk management quality. Our goal is to extract the information about systemic risk contained in variables identified by regulators and academics as those most contributing to systemic risk. We will address this creating a synthesis indicator capable of proxying the latent systemic risk nature of each financial institution within the sample. This will enable us to assess the contribution of each risk variable to global systemic risk, evaluate the contribution of each institution to risk, assess the degree of systemicity of each institution thought the time and to give a wide measure of systemic risk for the entire the system through the cycle.

The aim of this analysis is two-fold: on the one hand it is to explain how a simplistic approach to systemic risk may fail to provide a correct classification of banks according to their systemic nature, and on the other is to give an insight of the alternative lines that prudential policy could take care of when addressing systemic risk (leverage, interconnectedness, etc). Following this line, we find that though far from perfect, the conclusions that yield from our analysis are robust to any possible methodological flaws standing since we exert the value of the approach on the policy side, not on the method.

We deem very important to contribute to a theoretical base for the approach to this matter but believe also that it will take years if not decades to consolidate a proved and unified theoretical approach. We are aware that our vein of analysis may fail not to rely explicitly on a defined conceptual framework, however we have tried to fetch any possible approach found in the literature by means of including the variables that the academic and regulatory work have used to set their conceptually sustained view on systemic risk matter. Given that our indictor is (after the math) equivalent to a weighted average variables accounting as source of risk we believe implicitly embedding the conceptual frameworks held in the literature where such risk sources come from.

We have have decided no to take a unique and explicit conceptual approach because we think that every framework is conditioned by its by its specific non-closed and non observable representation of systemic risk and will remain thus subject to constant change and revision over the years.
2. OVERVIEW OF EXISTING RESEARCH INTO THE IDENTIFICATION AND MEASUREMENT OF SYSTEMIC RISK

The analysis of risk as a problem caused by an institution capable of causing damage to the general system has led to a widespread academic and regulatory debate since the damage that the Lehman’s fall caused was perceived. The macro-prudential identification, assigning, measurement and management of the systemic nature of institutions has adopted different focuses (too big to fail, too interconnected to fail, too important to fail, etc), measurement methodologies CoVar, Systemic Risk Shortfall, Exposure analysis, etc. and variety in the use of data (market versus balance sheet). Therefore resulting in different ways of identifying risk, its causes and the policies needed to address it. It should be bear in mind that a "systemic event" is by nature a non observable event and as such, it requires the use of proxies to identify it. As stated in the MoU of the Cross Border Financial Stability Group\(^5\)(CBFSG, 2008), the identification of a systemic event is changeable over time and cannot just be based on quantitative criteria. There is no straightforward way to assess a factor as systemic, but this condition is always conditional to a specific economic, regulatory or financial endowment that jointly with such factor may result in the externality produced leading to a general system failure. Moreover, systemic risks are not immutable, but - as they depend on time and context - may appear or disappear in one and the same institution. This makes it very difficult to identify a systemic crisis and its connection to specific characteristics of the banking system at a given moment. That is the reason why our analysis has not taken the way of seeking causal relations between regressors and an independent variable seemingly accounting for risk.

Although an ad hoc quantitative criterion linking characteristics to systemic events cannot be established, the expert’s view in the literature may help to confine what we understand as systemic risk in its different sources (collected in different variables). That such risk has systemic consequences will not only be difficult to measure for the reasons mentioned above, but will always be conditional on the definition we have given of a "systemic event" and the proxy we have chosen to identify it.

Seminally, the Bank of England’s Financial Stability Review (2001) published some criteria for selecting a large and complex institution as a candidate for being systemic\(^6\), although it offered no definition of systemic risk as such. Jointly, the BIS/IMF/FSB in its paper Guidance to assess the systemic importance of financial institutions (2009) and the European Central Bank (ECB)’s Financial Stability Review (2006) provided a more general definition of a systemic event as that generated by one or more financial institutions and that has severe consequences on the financial and real sectors. These documents presented a wide range of approaches for the analysis too that still coexists today with different shores of the literature: network analysis, risk based-portfolio models and stress testing and scenario analysis.

\(^5\)Group made up of supervisors, central banks and ministers of finance of the European Union.

\(^6\)An Large and Complex Financial Institution (LCFI) is systemic if it is at least within the top ten in its position versus the following characteristics: Equity Book Runners, Bond Bookrunners, Syndicated Loan Bookrunners, Interest Rate Derivatives Outstanding, Holders of Custody Assets.
A vast amount of literature attributes systemic risk to one of the sources mentioned above (size, inter-connectedness and unsuitutability and balance sheet quality\(^7\)), and uses one of the alternative focuses detailed below.

Bartman and Brown (2009) use three methods to quantify the probability of the systemic failure of the world banking system: correlations between returns on assets, the Merton Structural Method (1974) and the inference of PDs from options prices. Their findings state that the probability of a bank’s crisis leading to a systemic crisis is small. Tarashev, Borio and Ionadis (2009) use the Shapley Value to attempt to identify the impact of different determining factors (balance sheet characteristics of an institution) in the probability of the latter causing a crisis of similar characteristics. Brunnemeier (2009) uses market data and proposes a measurement (CoVar) to calculate the incremental risk produced by an institution, measured as the difference between the VaR of the system conditional on the fact that an institution (i) is in stress, less the VaR of the system in normal conditions. Hang, Zhe and Zhe (2009) measure the systemic risk of leading financial institutions by using an approximation of such risk called "distress insurance premium" which is equivalent to the premium that the banking sector would pay to cover itself against a potential loss exceeding a specific share of the liabilities of the system (as an insurance franchise). The premium is calculated with PDs and using the correlation data among balance sheet assets. Acharya and others (2010) use market data to identify systemic risk with the expected contribution from each ith-institution to a systemic event (Systemic Expected Shortfall, SES). And they measure it as the cost of the banking sector when it becomes infra-capitalized, weighted by the contribution made by the institution to such event. The marginal contribution of each bank is linked to a rate requiring it to internalize the negative externality of its participation in the system. Their document has a prudential focus. Leaven and Valencia (2008) find common patterns in the crisis that they identify as systemic (significant signs of financial stress - bank runs, bank liquidations, close of wholesale market financing, etc. - accompanied by large-scale public sector intervention in the system), but the number of cases considered systemic are scarce. Even in the latter cases, their frequency, intensity and duration changes over the time, is heterogenous and difficult to link with the characteristics of the institutions making up the banking system of that period.

This paper presents a pragmatic approach for proxying systemic risk through quantitative analysis. Owing to the aforementioned difficulty in finding factors which explicitly information on systemic risk, we have chosen a methodology which includes all the variables identified as containing significant information on it, with the intention of obtaining the most robust, efficient and least-biased approach possible. To that end, the variables commonly identified as sources for systemic risk have been used. Owing to the difficulty in specifying variables, sample and method, the most general approach possible has been undertaken in the selection of variables and the sample of banks used. Same was the methodology chosen, as for allowing processing the information as objectively as possible. The methodological criterion followed to obtain the indicator is the maximization of the information contained in the sample and that such information remains structurally invariant overtime.

\(^7\)The Squam Lake Working Group on Financial Regulation (2009) also makes reference to variables such as solvency, balance sheet composition and liquidity of institutions.
Notwithstanding our efforts to obtain the most robust and a priori unbiased indicator of systemic risk we acknowledge that the main weakness of our approach is that the identification of such indicator among the set of factors implies some degree of apriorism. However, we think that as far as the apriori we have introduced is not our personal view but commonly accepted by the academy and policy makers we are more on the safe side. Besides, other methodologies such as CoVar rely on market information that proves to be procyclical and fail to discriminate among institutions in good times plus implicitly incorporates the probability of banks being bailed out. Other approaches such as network analysis are data intensive, computational costly and usually imply the introduction of strong assumptions about system structure.

3. Variables accounting for systemically important sources of risk

There are different dimensions throughout the systemic nature of risks assumed by an institution may be analyzed. Attached there is a list of variables classified by the dimension they belong to, that have been used in creating our indicator. These variables depict the the generally accepted sources of systemic risk (Figure 2 - Appendix). We have selected on according to data availability.

Size is the main criterion found in the literature. It is considered that size is a direct channel for systemic risk to pass on to the real sector and the rest of the financial system. The size argument is backed by the relatively bigger impact for the system derived from the crisis of a large institution. This proportionally bigger impact comes from the greater difficulty in replacing the vital functions provided by these institutions and to find a solution for orderly wind down (eg: more difficult to find a buyer) as well as from its usual higher interconnection with the rest of the financial system. Size is also associated with riskier balance sheet structures as they face lower funding cost just because creditors consider them as systemic and therefore able to be bail out. Typically, size variables focus on the size of the balance sheet either as a whole or each of its parts (assets and liabilities). Frequently, size indicators are based on assets, deposits and/or credit. In this analysis we will use variables of the three making them relative to world GDP. We do this to render each measure comparable with each other. Since we identify size with a source of systemic risk, these indicators are expected to have a positive weighting on the total risk indicator.

The quality of the balance sheet -as was made clear by the Squam Lake Working Group (2009)- plays a very important role too when defining systemic risk. A weak and unstable balance sheet makes an institution vulnerable to market, credit and liquidity -risks. Barrel and others (2005) found evidence of an increased probability of a systemic banking crisis whenever solvency, leverage and liquidity are below the desired levels. In this sense, it sounds sensible to direct policy to guarantee enough loss absorption capacity, sufficient liquidity, a correct risk administration and a sound ability to organically generate capital.

The literature divides balance sheet information into variable groups that have gained/lost prominence over the years in line with the nature of the various emerging distresses along the crisis times. The crisis arose as a liquidity issue that turned into a problem of adverse selection when nobody knew the true quality of the assets in the balance sheets. In the latest stance of the crisis the financial distress
evolved into a solvency issue as such, for which it was not only necessary to rely on existing capital buffers (static solvency) but also on the ability to generate capital organically\(^8\) (dynamic solvency).

**Solvency indicators**

An increase in these indicators is related to an additional contribution to balance sheet stability and therefore they should be seen as risk mitigating elements. In a synthesis indicator for risk, we would expect them to be weightining with negative loads diminishing risk with any marginal improvement of each of the included gauged variables. The literature identifies the following ratios as especially significant:

- **Core Tier1**: resembles the amount of pure capital held by an institution and therefore, it gives information about its maximum reaction capacity in a going concern situation, which is generally dealt with equity and retained income.
- **Tier1**: takes into consideration the additional capital with which an institution may deal with its solvency before going into liquidation. The additional capital consists of preferred shares which, owing to their nature, incentives and consequences, are less able to absorb losses.
- **Leverage Ratio** (and corrected leverage ratio in respect of off-balance sheet assets): both ratios refer to level of leverage an institution has to deal with.
- **Off-balance sheet assets**: the aforementioned variables do not give sufficient consideration to the contribution made to solvency by off-balance sheet assets to the institution’s financial situation. It is therefore necessary to include this variable that reflects the greater level of flexibility for an institution when it has these assets. Off balance sheet items are guarantees, committed credit lines and other contingent liabilities. Other types or off balance sheet items (the normally referred as riskier off balance sheet items, such as structured products, etc are never available under balance sheet data)

**Liquidity indicators**

The outbreak of the crisis was identified on several occasions with a temporary moment of market illiquidity, either due to the interbank failure (in general for the entire banking sector at the beginning of 2009) or to the absence of a wholesale market in which to liquidate structured assets (e.g. Lehman), and because of bank runs in the retail sector (e.g. Northern Rock). The following are found among the indicators most frequently used in available literature:

- **Deposits to assets**: In principle, deposits are a relatively stable source of financing in normal times, although such stability may vary in terms of the type of deposit and the depositor, as well as the level of coverage. However, in times of crisis, deposits may become more volatile.

\(^8\)In this sense, the strength of its results (what we refer to here as performance indicators) gains true significance
• **Money Market & Short-Term Funding to Assets.** Financing in wholesale markets should in principle pose a greater systemic risk, inasmuch as they are a source of inter-connection in the financial system. On the other hand, the ability to finance itself in these markets gives a bank greater diversification in its sources of financing and therefore contributes to its financial strength. Since the effect of greater inter-connection is taken up by the variable of financing in the interbank market, it cannot be ruled out that the contribution of this variable to systemic risk will be negative, as it picks up the additional (risk reducing) effect mentioned\(^9\).

**Asset mix indicators**

As a sub-species of balance sheet quality, available literature locates credit risk and market risk in two indicators:

- **Total gross lending to assets:** this indicator reflects the weight of traditional business on a bank’s balance sheet. We would expect a negative contribution of this variable to systemic risk.

- **Share of on-balance sheet securities.** This reflects the weight that market activities can have on the bank’s balance sheet. These activities, as well as being more volatile, present a greater degree of inter-connection with the rest of the financial system. We would therefore expect a positive contribution to systemic risk.

**Risk management quality indicators**

These work as proxies of the business concern for a correct risk administration.

- **Short-term debt to total debt.** This variable accounts for the risk of refinancing that could be acute in a general funding crisis as experienced recently. On the other hand at the same time the pressure to refinancing implies a greater discipline, risk monitoring and active management. The (negative) sign of this variable could be conditioned by the fact that during the sample period it becomes more difficult to get access to long term market funding. This means that as long as issuance of debt is subdued short term debt that cannot be refinanced decreases quicker than medium and long term debt and automatically the ratio of short term vs total debt also decreases. This effect should be more apparent for those institutions with greater refinancing problems and therefore a lower ratio could be positively correlated with systemic risk in crisis times when market discipline is exaggerated as opposite of what we can expect in normal times when maturity mismatches could entail the build up of huge liquidity risks.

- **Net Interest Margin.** The culture that focuses on maximizing the higher part of the earnings statement - banking business, purely speaking - is interpreted as a risk mitigation factor. The elasticity of the system to this factor is interpreted as negative. Net Interest Margin is not net of loan loss provisions (LLP). We acknowledge that this could pose problems for comparability, but believe that the effect of LLP is already considered in the ROE item of the model. On the other hand, detracting LLPs from the

\(^9\)we have tested this by estimating the indicator in absence of the interbank financing variable and the result was as expected
Margin could bring some degree of distortion to our analysis because LLPs are not homogenously accounted in every bank.

The unsustitutability of certain strategic services may increase the negative externality produced by its disappearance. Unsubstitutability depends on an institution’s monopoly position in a certain market and the complexity of the service it offers. A service that is difficult to replace is that of clearing and custody. This paper documents unsustitutability as the degree to which an institution contributes infrastructure to the financial system. In this case, the clearing and settlement infrastructure. We approximate this variable with the proportion of assets safeguarded by custodian banks over the total volume of assets under custody. We understand that this indicator should contribute to the total risk of the system and therefore have a positive weighting. We advise caution with data of this type, as the source from which they are extracted is not the balance sheet but voluntary contributions to the Global Custody Net. This source of data does not take into consideration nested positions of accounts under the custody of one unit within another; therefore the data contributed by some institutions will contain a certain level of bias.

The variables relating to the system of payments also offer information on the degree of unsustitutability of a specific institution. The ECB classifies both systemic and non systemic relevance of a bank as payment instrument in the system in two groups: SIRP (systemically important) and PIRP (non-systemic), but does not provide any metrical variable that can be used within the scope of this analysis.

As stated before some indicators of the degree of concentration of market services may also have a reading for the degree of substitutability that these have. In this vein, although we have grouped some indicators under the Size category, the information that they carry also refers to the degree of substitutability though only in a very rough and approximate way since only size and not concentration factors have been taken.

Inter-connectedness, the available literature also distinguishes the factors that attribute risk indirectly\(^\text{10}\), that is to say, factors that are transmitters of the externality produced when the risk becomes systemic. These variables are gathered together as indicators of the inter-connectedness among the items making up the financial system. In practice, market indicators are used, such as those shown on the attached table, or alternatively, balance sheet data. We could only approximate this variable by means of the level of interbank exposure of each institution and acknowledge thus that this approximation may be relatively partial. The importance of inter-connectedness may be infra-estimated in our analysis for this reason but it is the furthest we can get using this type of data and approach. Most of the exercises in this vein are inevitably theoretical or simulation based due to the absence of

\(^{10}\)Nicolò and Kwast (2002) identify the degree of inter-connection as a source of systemic risk.
IMF GFSR introduces the "too interconnected to fail" concept; the 2009 Mou also identifies the degree of interconnection as one of the sources of risk; Chan Lau (2009) uses network analysis on balance sheet data to evaluate interconnection risk when one or more institutions suffer a credit or financing shock, and draws up an interconnection risk measurement that is equal to the average capital loss suffered by the banking system due to one or more types of shocks to the such system.
data and require large computational workload, falling thus beyond possible scope of this analysis.

We have chosen to introduce an inter-connectedness variable based on the degree of exposure of each bank to the interbank market. We understand that this variable gives information on the amplifying effect of its own risk to the rest of the market, and we therefore believe that it should have a positive weighting in our risk indicator. Furthermore, this variable can be read from the liquidity point of view (as mentioned beforehand) since it may be a source of instability given the dependence of the institution on the interbank market and not the real sector of the business as such. The form of the crisis at the beginning of 2009 (when financing was impossible for any term in the interbank market) is a good example of this risk. Once again, the elasticity of systemic risk to the banking inter-connection indicator of an institution should therefore be positive. The shortage of variables (available as balance sheet data) that could provide information on inter-connection risk could pose a specification problem for the estimation of the indicator. However, although we recommend caution in this regard, we also consider that other variables also indirectly contribute additional information on inter-connection and therefore filter the possible distortion introduced by the infra-specification of the model. A variable which implicitly contributes information on inter-connectedness is the degree of custody of each bank.

**Performance indicators**

Take into consideration the contribution of an institution to the capacity of the system to organically generate liquidity and resources to remain solvent. Indicators of returns and efficiency which give insight of the rise of flows that may could be retained to create capital and contribute to the expectations channel (Tobin’s Q) by which the banking system recapitalizes itself in the financial market.

- **Return on Average Equity and Return on Average Assets**: both indicators should necessarily reduce the systemicity of a banking institution represented in the market, as they are indicators of strength. We expect the elasticity of risk to these components to be negative.
- **Cost-to-income/efficiency**: it is understood that the greater the efficiency of an institution, the more its capacity to retain profit and generate capital organically. Efficiency weighs negatively on total risk. Hence its opposite (cost-to-income) should contribute positively.

In the available literature we find other variables identified as a source of risk. In considering size, the ECB finds it important to use the number of affiliates, whilst the BIS/IMI/FSB takes into consideration the market share of each institution (in loans and deposits). These variables have not been used in this analysis as they are only found at aggregate level. The ECB finds sources of risk on the side of liquidity in contingent liabilities and additional factors arising from the asset mix related to cross-border and interbank assets. With respect to risk management quality, several approaches in academic literature find risk mitigation factors in the degree of diversification, and incremental effects in the degree of intermediation with financial derivatives (trade income) and the forex market (fx income). These variables have not been used in the analysis because they are not available in the
data base used (Bankscope or any other publicly available database with data for the sample used).

Figure 2 of the Appendix attached, also shows a list of other variables (market) which tend to be used as inter-connectedness proxies. These variables have not been used because of the problems mentioned and due to their availability.

4. DATA BASE

The analysis has been made with balance sheet data. The available literature documents the distortion produced on market data when the financial markets are distressed. The volatility of returns and CDSs, for example, was strongly altered by public aid programmes implemented across the board during the crisis times, programmes that actually prevented policy makers to gauge the true picture of each bank’s real risk state. On the other hand, there is a consensus that in times of instability that financial markets tend to become short-sighted and irrational. An example of this is the fact that for a long time, the market attributed the same risk (CDS spread) to the bond of a Spanish multinational company (with 83% of its market revenues coming from outside the country) as to a Spanish Treasury bond. In view of these problems we consider the second alternative the most reliable way of approximating sources of risk.

We recall that the variables considered are all those available indicators stated in academic and regulatory literature. With the same spirit of generality, we have chosen a sample of banks with total assets worth exceeding EUR. 100 Bn. Institutions for which Bankscope and Bloomberg did not have the balance sheet and earnings statement data needed have been excluded from this analysis, Doing this, we have come to a list of the 100 biggest banks in the system. The estimation was carried out in a panel data fashion for the 2006 - 2009 sampling period. We have focused on the results of a panel data to avoid inconsistencies arising from the size of the sample and the variability of the sources of risk from year to year. With the panel data analysis, we obtain robust estimations of factors over time, not determined by the nature of the emerging risk during a given year.

5. A CAUTIOUS APPROACH

We recognize that certain information related to risk mitigating factors has not been considered in the selection of variables: That was due to availability reasons and due to the diversity of data. The corporate structure of the different institutions also makes it impossible to compare many diversification data among the different banks. Other risk mitigation sources are the degree of diversification and the type of legal structure of each bank, elements which have proved to be fundamental pillars of the institutions that have best survived the crisis. This means that our analysis over-estimates the systemic risk of well diversified and organized banks.

Variables of size have been taken in terms relative to world GDP. We understand that this decision may limit to a certain degree the ability of the indicator to perceive the systemic risk of an institution -local level, but this decision is justified

\textsuperscript{11}Many of these banks (24) make up the list of banks requiring cross-border supervision, according to the FSB
for reasons of comparability and consistency in creating a global indicator. This means that our analysis under-estimates the systemic risk of local banks.

A recognized problem of any approach dealing with bank data is that it fails to gauge other financial but not banking based sources of risk such as those stemming from the insurance sector and other financial intermediaries. We would like to extend the scope of this analysis in the near future.

Certain variables that are important for defining the indicator (ROA, interest margin, etc.) depend on local conditions which make comparison among banks located in different geographical areas difficult (e.g., interest rates or margins resulting from the tightness of the market in which each institution is located), but this does not prevent such factors from being a significant risk factor - or otherwise - for each institution, and should therefore be considered as part of their vulnerability (or strength).

Further, we acknowledge that our data set could also be partially influenced by public aid programmes put in place and with ultimate effect on banks balance sheets but that said, we also believe that this data are the best one can get and are by far less distorted than market data. We choose therefore to use them.

An additional issue arising from the use of data is that balance sheet data are unable to fetch latent imbalances within the banking system that ultimately yield to crisis. But this issue is generally recognized, as for instance market (CDS etc) data used under the ECB indicator for systemic risk did not anticipate the looming crisis either. Nevertheless that distortion is considered in our conclusions.

6. Methodology

Our approach adheres to the position taken by the Bank of Spain (2010) and strives to come close to the approach found at the ECB (2006) and the IMF (2010). These define a series of balance sheet variables to establish a systemic order score to individual banks. To this end, and in the aim of allowing the systemic relevance of each variable to the total aggregate indicator to be assigned objectively, we have used a Principal Component Analysis approach (PCA). We have decided for this methodology an not for CoVar or Network -like approach because although we deem the latter very useful approaches for theoretical and monitoring purposes, they could fail to provide the timely insight on systemic risk sources that match our prudential intentions. Besides, in the aim of anticipating the affordable alternatives that the regulators will consider in their assessment of the systemic nature of banks. The latter will very likely be a compound measure of the various systemic risk sources identified. Performing conditional PCAs was an appealing alternative but it would have implied identifying a priori some closed form of Systemic Risk. This could yield in some bias in our analysis. As stated before we are trying to implement the general and overarching view found in the literature. This method allows reducing the information gathered in our sample of indicators to a much lower number of synthetic indicators which provide segments of independent information. The obtaining of such indicators involves estimating the factor loads on which the original variables will be rely so that they to form the final indicator. Once the information has been reduced and segmented into such indicators,
we resort to an expert opinion to decide which of them could be interpreted as an indicator of systemic risk. By construction, once it has been decided that a specific component contributes specific information, such as that of systemic risk, the possibility that such information could be found in another of the discarded indicators is excluded. Once the indicator is obtained, its loads are used to weigh up the characteristics gathered from each bank and obtain its systemic score. The estimation process is detailed in the methodological appendix.

7. Results

7.1. Characterizing the sources of risk. By means of the PCA, we extract the first p-factors that explain about two thirds of the information contained in the set of data. These factors are weighted sums of the systemic risk variables. From these factors, we select our systemic risk indicator candidate on the basis of the proportion of information from the original data that it summarizes and on the basis of its consistency with the preconceived idea of the characteristics that such indicator should have, both internally and externally (i.e., that its weighings on risk factors have the appropriate signs and the results concerning performance of systemic risk over time).

We are focusing the analysis on the results extracted under a panel data approach estimated through (part of) the cycle that goes along the crisis years 2006 to 2009. Examining the loads from the aforementioned indicators (Table 2), we again identify a distinctive pattern in the first indicator. We observe that unlike the other collected possible candidates, this indicator is a linear combination (a weighted sum) of variables whose value increases when:

- The ability to organically generate resources deteriorates
- The activity devoted to retail business is reduced
- Leverage is increased
- Size is increased
- The volume of financial assets (securities) on the balance sheet is increased
- Access to market funding falls
- The ability to retain resources deteriorates due to efficiency costs
- Interbank market funding dependency high
- Exposure to the interbank market increases
- The number of assets under custody increases
- Solvency is reduced

And therefore, all the characteristics included in available literature on the typification of a synthetic systemic risk indicator are met. Also, the indicator preserves the desirable characteristics mentioned above concerning information explained and stability (see underneath table 1). We will call this indicator the Santander Systemic Risk Indicator (SSRI).

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12Size variables are expressed relative to world GDP. Leverage Ratios are expressed in times. Liquidity and Asset Mix Ratios are expressed as share of Assets. Short Term Debt is expressed relative to Total Debt. custody assets are rendered to total custody assets in the system. RMQ stands for Risk Management Quality
Table 1. Sources of Risk Extracted Principal Components and Candidates for Systemic Risk Indicator ($\lambda^{SR}$)

<table>
<thead>
<tr>
<th>Variables / Factors</th>
<th>$\gamma_{SR}^1$</th>
<th>Weight of $\gamma_{SR}^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assets</td>
<td>0.42</td>
<td>8.0%</td>
</tr>
<tr>
<td>Credit</td>
<td>0.21</td>
<td>5.3%</td>
</tr>
<tr>
<td>Deposits</td>
<td>0.24</td>
<td>6.0%</td>
</tr>
<tr>
<td>Core Tier1</td>
<td>-0.15</td>
<td>3.9%</td>
</tr>
<tr>
<td>Tier1</td>
<td>-0.05</td>
<td>1.3%</td>
</tr>
<tr>
<td>Off Bal.</td>
<td>-0.13</td>
<td>3.3%</td>
</tr>
<tr>
<td>Leverage</td>
<td>0.34</td>
<td>8.5%</td>
</tr>
<tr>
<td>Real LR</td>
<td>0.13</td>
<td>3.3%</td>
</tr>
<tr>
<td>Depos/Assets</td>
<td>0.02</td>
<td>0.5%</td>
</tr>
<tr>
<td>ST. Funding</td>
<td>-0.19</td>
<td>4.8%</td>
</tr>
<tr>
<td>Gross Loans</td>
<td>-0.20</td>
<td>5.0%</td>
</tr>
<tr>
<td>Securities</td>
<td>0.28</td>
<td>7.1%</td>
</tr>
<tr>
<td>Short T. Debt</td>
<td>-0.24</td>
<td>6.1%</td>
</tr>
<tr>
<td>NHM</td>
<td>-0.34</td>
<td>8.6%</td>
</tr>
<tr>
<td>Custody</td>
<td>0.08</td>
<td>2.1%</td>
</tr>
<tr>
<td>Interbank Exp.</td>
<td>0.22</td>
<td>5.5%</td>
</tr>
<tr>
<td>ROAA</td>
<td>-0.36</td>
<td>8.9%</td>
</tr>
<tr>
<td>ROAE</td>
<td>-0.24</td>
<td>6.1%</td>
</tr>
<tr>
<td>Cost-to-Inc.</td>
<td>0.23</td>
<td>7.7%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Est. Quality</th>
<th>$\lambda$</th>
<th>4.26</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of variance</td>
<td>42.2%</td>
<td>22.4%</td>
</tr>
<tr>
<td>Determinant</td>
<td>4.26</td>
<td>4.26</td>
</tr>
</tbody>
</table>

7.2. The direct and total impact of risk sources on to the SSRI. On examination of the indicator loads, it is possible assess the direct effects of the various sources of risk on to the SSRI. We derive these direct effects from the elasticities (weighings) of SSRI to each of the risk variables. By doing this one would find that the risk arising from size weights approximately 19% in the indicator, while solvency and liquidity strike by 26%. The capacity to organically generate capital in a recurrent manner contributes by 21%, while the sound risk management policy matters by 14% of the indicator. Asset mix weights 12% and the risk arising from inter-connectedness and unsustitutability of services would seemingly add 8% to the weighting. It is important to bear in mind however, that risk sources are never standing alone as they interact throughout innumerable channels with each other. This is easy to see having a look to the correlations among the risk variables selected for this analysis (figure 2 - Appendix) where we find that size, solvency, balance sheet quality and performance are significatively correlated. This brings the idea that risk factors operate not only in a direct manner -as described above- but also throughout other indirect channels that reduce or amplify their direct effect accordingly to correlation shared with other risk variables. We use this correlations to asses the direct and indirect impact of each of the risk variables and determine that the total impact of each variable group taking in consideration such cross-effects would yield: 31% for size, 18% for solvency and liquidity, 17% for risk management quality, 15% to the capacity to organically generate capital in a recurrent manner, 12% for balance sheet composition, and 7% for inter-connectedness and unsustitutability as a whole.

13 We take the effect by normalizing the elasticities of the SSRI to each of the identified sources of risk
14 Asset volume, for instance, represents a risk itself and throughout other size and balance sheet factors too that add to the weighting. However since the same variable is negatively correlated to performance and solvency variables, these detract from the final effect too
From a policy point of view, the latter brings us to consider the cross effects among risk factors, as these may amplify or mitigate the originally envisaged major sources of risk. A policy rule that considers risk factors should strive to be as diversified as possible to remain neutral on the innumerable cross effects among variables, taking a wide set of variables in our measure would be advisable. Likewise, we consider that from the prudential viewpoint, the systemic risk mitigation measures imposed on an institution should depend on the factors that cause such risk. Thus, certain solutions may be presented:

(1) Through an increase of the levels of solvency (Core Tier1, Leverage Ratio, etc.) and liquidity, an option already addressed by Basel III,
(2) Treatment of the rest of the sources of systemic risk that have also proved to be significant.

As stated before, any policy rule should bear in mind not only the benefits but also the costs involved in such measures. These measures are not substitute but complementary measures. Enhancing balance sheet composition, risk management quality and the ability to generate capital organically in a recurrent manner are measures as effective as others and do not involve direct costs that could restrict credit in quantity and prices. On the other hand, additional capital charges could have a nil marginal effect on the level of total risk and their cost could exceed the additional stability they provide.

7.3. Systemic Risk through the cycle 2006 - 2009. Owing to the fact that the objective of the indicator is a prudential framework, we should bear in mind that creating an indicator based on these factors in a specific year to apply systemic measures in future periods is not forward-looking and could result in the penalizing of institutions for characteristics they no longer have, or (or vice-versa) reducing their systemic load, although the risk information deduced from the ratios in a specific year had worsened. Table 2 shows average band errors committed one and/or two periods forward if the load estimated in the year (t) to add to the score of each institution according to the characteristics found in year $t+k^{15}$ was used. We observe that the risk scores are systematically infra-estimated. However, the error made if we use the average of the loads would be much less, and that is the reason for choosing to use a central risk measurement. A panel estimate offers that central risk measure, consistent with the scores obtained year by year, which preserves the ability to correctly delimit the systemic institutions.

<table>
<thead>
<tr>
<th>Table 2. Average Forward Scoring Error - one and two steps ahead</th>
</tr>
</thead>
<tbody>
<tr>
<td>one step</td>
</tr>
<tr>
<td>Upper Quartile</td>
</tr>
<tr>
<td>Median</td>
</tr>
<tr>
<td>Lower Quartile</td>
</tr>
</tbody>
</table>

$^{15}$The error is the difference between the score obtained in the current year, obtained with loads estimated on the basis of balance sheet information for that year, less the same score obtained with the characteristics of the current year but with loads estimated on the basis of information existing 1 or 2 years previously.
Table 3 shows the different weighings of the risk indicators selected every year between 2006 and 2009. As can be seen, the interpretation of the loads remains consistent throughout time, only varying in the intensity of the factors, but not in their sign. In the same way, we can also see that the indicator estimated over the years collects similar proportions of information, as reflected by trace criterion of the indicators (see below of Table 1). We see that although the significance of certain factors has changed over time, this change has been consistent with the changing nature of the crisis. For example, we observe that the weight of exposure to the interbank market in the indicator was twice as much in 2007/2008 than in 2009, when this market began to reactivate itself. And we also see that certain factors have lost importance as a result of the absence of problems arising from them, such as size, custody and the existence of off-balance sheet assets. The changes in the composition of the indicator have only involved intensity (weight of the factors) and not sign, showing the stability of the estimation. However, the variability of such composition should be borne in mind on designing the indicator for macro-prudential purposes. The risk factors collected in 2007 (adverse selection versus balance sheet composition) were different from the 2008 risk factors (solvency crisis) or 2009 (liquidity crisis), and will therefore have a different weighting in the risk score obtained each year.

### Table 3. Risk Weightings Evolution along 2006 2009 for \( \lambda^{SR} \)

<table>
<thead>
<tr>
<th>Variables/Factors</th>
<th>2009</th>
<th>2008</th>
<th>2007</th>
<th>2006</th>
<th>Average</th>
<th>Consistent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assets</td>
<td>0.32</td>
<td>0.29</td>
<td>0.31</td>
<td>0.36</td>
<td>0.31</td>
<td>yes</td>
</tr>
<tr>
<td>Credit</td>
<td>0.21</td>
<td>0.19</td>
<td>0.20</td>
<td>0.26</td>
<td>0.21</td>
<td>yes</td>
</tr>
<tr>
<td>Deposits</td>
<td>0.24</td>
<td>0.21</td>
<td>0.21</td>
<td>0.29</td>
<td>0.23</td>
<td>yes</td>
</tr>
<tr>
<td>Core Tier1</td>
<td>-0.15</td>
<td>-0.25</td>
<td>-0.17</td>
<td>-0.02</td>
<td>-0.14</td>
<td>yes</td>
</tr>
<tr>
<td>Off Bal.</td>
<td>-0.13</td>
<td>-0.12</td>
<td>-0.15</td>
<td>-0.19</td>
<td>-0.11</td>
<td>yes</td>
</tr>
<tr>
<td>Leverage</td>
<td>0.14</td>
<td>0.33</td>
<td>0.35</td>
<td>0.33</td>
<td>0.32</td>
<td>yes</td>
</tr>
<tr>
<td>Solvency</td>
<td>0.13</td>
<td>0.23</td>
<td>0.00</td>
<td>0.13</td>
<td>0.12</td>
<td>yes</td>
</tr>
<tr>
<td>Deposit/Assets</td>
<td>0.02</td>
<td>-0.03</td>
<td>-0.01</td>
<td>0.08</td>
<td>0.01</td>
<td>yes</td>
</tr>
<tr>
<td>Liquidity</td>
<td>-0.19</td>
<td>-0.14</td>
<td>-0.20</td>
<td>-0.18</td>
<td>-0.19</td>
<td>yes</td>
</tr>
<tr>
<td>Gross Loans</td>
<td>-0.20</td>
<td>-0.19</td>
<td>-0.20</td>
<td>-0.01</td>
<td>-0.01</td>
<td>yes</td>
</tr>
<tr>
<td>Securities</td>
<td>0.28</td>
<td>0.30</td>
<td>0.23</td>
<td>0.27</td>
<td>0.28</td>
<td>yes</td>
</tr>
<tr>
<td>Short &amp; Debt</td>
<td>-0.24</td>
<td>-0.25</td>
<td>-0.25</td>
<td>-0.16</td>
<td>-0.24</td>
<td>yes</td>
</tr>
<tr>
<td>RMQ</td>
<td>-0.34</td>
<td>-0.31</td>
<td>-0.35</td>
<td>-0.34</td>
<td>-0.33</td>
<td>yes</td>
</tr>
<tr>
<td>Interbank Exp.</td>
<td>0.08</td>
<td>0.07</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>yes</td>
</tr>
<tr>
<td>Un aust. &amp; Inter.</td>
<td>0.22</td>
<td>0.20</td>
<td>0.25</td>
<td>0.24</td>
<td>0.20</td>
<td>yes</td>
</tr>
<tr>
<td>ROAA</td>
<td>-0.36</td>
<td>-0.33</td>
<td>-0.38</td>
<td>-0.37</td>
<td>-0.35</td>
<td>yes</td>
</tr>
<tr>
<td>ROAE</td>
<td>-0.24</td>
<td>-0.31</td>
<td>-0.22</td>
<td>-0.15</td>
<td>-0.24</td>
<td>yes</td>
</tr>
<tr>
<td>Cost to Inc.</td>
<td>0.23</td>
<td>0.20</td>
<td>0.25</td>
<td>0.17</td>
<td>0.22</td>
<td>yes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Cum. Variance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \lambda_1 )</td>
<td>22.4</td>
<td>24.8</td>
<td>21.9</td>
<td>21.9</td>
<td></td>
</tr>
<tr>
<td>( \lambda_2 )</td>
<td>35.2</td>
<td>37.6</td>
<td>37.1</td>
<td>37.1</td>
<td></td>
</tr>
<tr>
<td>( \lambda_3 )</td>
<td>47.4</td>
<td>50.2</td>
<td>48.8</td>
<td>48.8</td>
<td></td>
</tr>
<tr>
<td>( \lambda_4 )</td>
<td>55</td>
<td>57.2</td>
<td>57.2</td>
<td>57.2</td>
<td></td>
</tr>
<tr>
<td>( \lambda_5 )</td>
<td>63</td>
<td>64.9</td>
<td>64.9</td>
<td>64.9</td>
<td></td>
</tr>
<tr>
<td>Cum. Determinat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \lambda_1 )</td>
<td>4.6</td>
<td>4.7</td>
<td>4.2</td>
<td>4.4</td>
<td></td>
</tr>
<tr>
<td>( \lambda_2 )</td>
<td>10.4</td>
<td>12.7</td>
<td>11.5</td>
<td>11.8</td>
<td></td>
</tr>
<tr>
<td>( \lambda_3 )</td>
<td>24</td>
<td>27.2</td>
<td>26.8</td>
<td>27.5</td>
<td></td>
</tr>
<tr>
<td>( \lambda_4 )</td>
<td>34.5</td>
<td>43.5</td>
<td>42.5</td>
<td>44.0</td>
<td></td>
</tr>
<tr>
<td>( \lambda_5 )</td>
<td>45.5</td>
<td>62.2</td>
<td>62.6</td>
<td>63.8</td>
<td></td>
</tr>
</tbody>
</table>

7.4. A measure of System Wide-Systemic Risk. On having an estimated indicator by means of panel data, we can consistently apply the loads of the SSRI indicator to the variables of the banks each year. This does not just make it possible
to establish intra-group bank comparisons each year, but also to check institution’s degree of systemicity over the time. Additionally, given that institutions would be comparable with themselves and with the rest of institutions along the time, we are capable to obtain a measure of systemicity of the entire system over the period analyzed. On figure 1 a measure of System Wide Systemic Risk has been plotted. This measure is obtained by showing the median risk score found in the system along the sample period. One may distinguish how (according to our measure) banking systemic distress was rather contained 2006 but after that systemic risk increased to take its full blown levels during 2008. It was only in 2009 when after massive international policy action (monetary and fiscal stimulus, bail out, new regulatory regimes, accounting changes) the risk was leveled down somehow although the looming threat to the system is by far that of the normal times (2006). This indicator offers the same reading as the systemic risk indicator plotted by the ECB in its Financial Stability Report since 2009.

7.5. Distribution and classification of banks according to systemic scoring. The attached figure 4 in the Appendix shows how the 100 banking institutions are distributed according to the chosen indicators for systemic risk (the chart at the bottom right corner pictures the distribution of banks according to the SSRI). We can see that the distribution of the institutions is very asymmetrical in all the variables used. The asymmetry in the separate distributions of each variable may lead to a biased selection of banks candidates to be systemic. This is even more likely when fewer criteria are used to delimit the systemic risk perimeter. A clear example of an error that could arise based on size can be seen on figure 5 in the Appendix. Here, we observe that following the criterion of size, on classifying the 100 institutions as systemic when they breach median threshold, would yield unduly penalize 16% of banks classified as systemic when they are not (type I error), whilst at the same time one would be ignoring 14% of the sample institutions that (according to SSRI) are systemic (type II error). The expected stability cost of such a misclassification justifies the selection of a synthetic indicator that uses a richer set of risk variables to gauge all possible systemic risk sources embedded in each bank. An indicator combining all the variables, such as the SSRI, renders the distribution of banks the closest to normality (according to Jacqe Bera) bis a bis the rest of systemic variables taken independently. This allows a scaling of the
resulting banking systemic scores closer to a continuum, making thus the setting of thresholds for qualifying systemic less discrete and thereof less partial.

These results have several policy implications. A prudential policy based on a single variable would give rise to a partial and possibly wrong classification, of both systemic and not systemic banks (type 1 and 2 errors), introducing a high expected cost in the event of crisis. An example of these types of classification errors is given Figure 5 - Appendix . Similarly, focusing on a single dimension of one variable would bias the choice towards a single source of risk, when the criterion followed indicates that the sources of such risk are multiple (e.g. in the case of size: assets, liabilities, credit risk, market risk, etc.).

8. Conclusions

The main conclusions of this analysis are:

• All financial institutions contribute to systemic risk, albeit to a different degree. Their contribution is driven by various risk factors embedded in multiple groups of variables such as size, inter-connection, unsubstitutability balance sheet quality and the quality of risk management.

• Using a single variable or a limited series of variables, as a proxy for systemic risk fails to provide a full explanation and results in numerous errors when attempting to identify and measure the systemic risk of each institution.

Based on this analysis, we advocate the following from the policy point of view:

• When designing systemic risk mitigation measures, all contributing factors need to be taken into account in the policy cost function. A prudential policy based on a single variable and on a single dimension of a variable would give rise to an incorrect classification both of systemic institutions (type 1 error) and institutions not considered systemic (type 2 error), introducing a high expected cost in the event of crisis.

• Likewise, classifying institutions as systemic/non-systemic would mean giving similar treatment to institutions that may actually have very different degrees of systemic risk whilst treating very differently institutions that may present similar levels of systemic risk.

• A continuous measure of risk is preferable to a simple systemic/non-systemic classification; under this approach all institutions would be systemic but to varying degrees.

• Systemic risk may be addressed through different measures:
  – Reinforcing solvency and liquidity standards as already envisaged by Basel III (increasing capital levels and adjusting capital charges to riskier activities like those held in the trading book).
  – Addressing the other relevant sources of systemic risk linked to each institution’s risk profile, that is: improving risk management, corporate governance and adopting a business model capable to organically generate recurrent capital.
  – Addressing institution’s complexity, market services unsubstitutability and inter-connectedness within the system.
We consider that a purely quantitative approach has serious limitations as it does not take into account some relevant unquantifiable factors that could mitigate or exacerbate systemic risk. This analysis attempts to be as broad and objective as possible and also considers the qualitative dimension by using other quantitative indicators as a proxy for it\(^{17}\). However, due to the unavailability and diversity of relevant data\(^{18}\), the analysis fails to consider risk mitigation sources such as the quality of supervision, the regulatory framework and the crisis management framework of each jurisdiction, or the degree of diversification and the legal structure of a bank. All of which are elements that have proved to be fundamental pillars of the financial systems that have best survived the crisis. That said, we believe this reinforces the conservative approach of our analysis, and hence its conclusions for those systems where these variables are of a high quality.

Any macro-prudential tool should not focus solely on quantitative indicators but consider qualitative factors as well. These factors prove crucial in defining the risk profile of an entity. The complexity, volatility of bank operations, transparency, its cross-border legal structure, and degree of exposure to financial markets and the existence of living wills are all good examples of the aforementioned qualitative dimension that could help to mitigate or exacerbate the degree of systemic risk in the system. Particularly relevant to assess systemic risk is the information provided by the recovery and resolution plans as they provided information on a crisis assumption that complements the business as usual information provided by accounting statements.

Although we recognize the relevance of having sound capital and liquidity standards, we also deem very important having good internal risk management and corporate governance practices. All the latter framed within a set of close micro-prudential supervision policy scheme. In order to avoid excessive complexity at the bank level and to facilitate substitutability of vital services, we find crucial the development of recovery and resolution plans (living wills). The latter, jointly with a strengthening of international co-ordination for crisis management, will reduce the risk of contagion. Equally important is that macro-supervision to be reinforced to take into full consideration the risks derived from inter-connectedness.

On the other hand, a prudential solution should consider not only the benefits but also the costs involved in such measures. The above mentioned additional factors are equally effective as other measures, but crucially they do not involve direct costs that could restrict the viability of institutions or the availability of credit, in quality and price. On the other hand, additional capital charges could have a nil marginal effect on the level of total risk and their cost could exceed the additional stability they provide.

\(^{17}\)That would be the case for example of risk management quality variables used here

\(^{18}\)The corporate structure of the different institutions also makes it impossible to include diversification as a specific variable for the analysis
9. METHODOLOGICAL APPENDIX

9.1. Creating the data base. In the first stage we construct a panel entailing the different variables / ratios mentioned before as sources of risk for each of the 100 banks in the sample along the 2006 - 2009 years. The data are standardised to facilitate their comparison among variables and for their flexibility when creating the indicator.

We use the Bankscope data base, which provides balance sheet data for the sample of Banks selected. All the necessary data that could not be extracted from Bankscope were obtained from Bloomberg, in order to complete the desired data base. Those banks whose information systematically is missing\footnote{BPCE, created in 2009, and its predecessors Groupe Banques Populaires and Groupe Caisse des Depots, or Lehman Brothers and Bear Stearns, which failed in 2008} are excluded from the sample coining up to 100 banks. Thus, for each year, we have a sample of Q variables X N banks = (19x100). In certain cases (barely 32 yearly observations from 1900) where some data were needed to complete one of the ratios, the information for previous years has been updated using the hypothesis that the dynamics of the omitted variable was similar to that of those variables available, helping thus completing the sample. All in all we have used a sample comprising 7,600 observations (N x Q x T = 100 x 19 x 4 = 7,600) collected along the years 2006 to 2009.

9.2. The Method of Principal Component Analysis. Principal Component Analysis considers the existence of a non observable structure of $p$ factors, that sumarizes the original information held in a data set of higher dimensions $k > p$.

$$[\hat{Y}'(t)_{k\times1} - \mu] = \hat{Y}'(t)_{k} = \Gamma \hat{Z}'(t)_{p} + \hat{E}'(t)_{k}$$

Where

$$\hat{Y}'(t)_{k} \sim [\hat{o}_k, \hat{\Sigma}_{k\times k}] \hat{Z}'(t)_{p} \sim [\hat{o}_p, \hat{\Lambda}_{p\times p}] \hat{E}'(t)_{k} \sim [\hat{o}_k, \Phi_{k\times k}]$$

Estimating the latent factors is equivalent to solving an eigenvector $\Gamma^* /$ eigenvalue $\Lambda^*$ problem upon a data set made of the covariance matrix of the data. Alternatively it may be seen as obtaining the Jordan decomposition of a non singular matrix. Where $\Gamma^*$ is the targeted new base that sets orthogonality condition of the transformation. $\Gamma_k^* = arg \left[ \Gamma_k^* \Sigma_k = \hat{\Lambda}_k^* \Gamma_k \right]$

Thus

$$\hat{Y}'(t)_{k\times1} = \hat{\Gamma}_{k\times p} \hat{Z}'(t)_{p\times1} \Leftrightarrow \hat{Z}'(t)_{p\times1} = \hat{\Gamma}_{p\times k} \hat{y}'(t)_{k\times1}$$
Estimating PCA carries the following properties that are found suitable for our analysis, since the guarantee (in theory) unbias, efficiency, non overlapping information and parsimony.

\[ \text{plim}(T)^{-1} \left[ \mathbf{Z}'(t)_p \right] \longrightarrow E \left[ \mathbf{Z}'(t)_p \right] = 0 \]

\[ \text{plim}(T)^{-1} \left[ \mathbf{Z}'(t)_p \mathbf{Z}(t)_p \right] = \widehat{\Lambda}_p \longrightarrow \Gamma \Sigma Y \cdot \Gamma = \widehat{\Lambda}_p \]

\[ \text{Var} \left[ \mathbf{Z}'(t)_p \right] \quad \text{trace}(\widehat{\Lambda}_p) = \sum_{j=1}^{p} \lambda_j \approx 1 \]

\[ \text{Var} \left[ \mathbf{Z}'(t)_k \right] \quad \text{trace}(\Lambda_k) = \sum_{j=1}^{k} \lambda_j \neq 0 \]

\[ \text{det}(\widehat{\Sigma}_k) \leq \text{det}(\widehat{\Lambda}_k) < \text{det}(\widehat{\Lambda}_p) = \prod_{j=1}^{p} \lambda_j \neq 0 \]

\[ \text{plim}(T)^{-1} \left[ \mathbf{Z}'(t)_k \mathbf{Y}'(t)_k \right] \longrightarrow E \left[ \mathbf{Z}(t)_k \mathbf{Y}(t)_k \right] = \widehat{\Lambda}_{p \times p} \Gamma_{p \times k} = \Gamma_{p \times k} \Sigma Y \cdot \Gamma_{p \times k}^* \]

\[ \Gamma_{p \times k}^* \Gamma_{p}^* = I_{k \times k} \]

**9.3. Extracting the Principal Components.** To obtain our indicator from the extracted set of latent factors (principal components \( \mathbf{Z}'(t)_p \)), we need to seize the latent risk factor by means of obtaining an indicator capable of summarizing a large share of all the relevant information related to the risk that underlies our panel data. As stated before, the method used for extracting the latent variables is the principal components approach (PCA). We have chosen this method instead of factor analysis due to technical reasons. We have selected the P-factors necessary to cover at least +60% of the sample information, here measured as the trace of the diagonalised variance. That is generally our case when we take \( P > 4 \) principal components in our summary. Additionally, since the product of the first p-factors extracted (the determinant of the diagonalised covariance matrix) is far from zero we ensure not to have singularity problems and to gain certain precision in the estimation of the components of each eigen-vector extracted that will be used as weighings for our systemic risk indicator. The estimation requires some cautious approach to the results. The latent non linearities in the relationships among risk variables could -in a context of linearly estimated factors- yield confusing values and parameter sings.

By construction, each of the \((p < Q)\) factors extracted (principal components) are synthesis of the independent pieces of the information matrix (the covariance matrix of the standardized risk variables, Figure 3 - Appendix). These factors will be orthogonal to each other, allowing us to be guarantee that there are no duplications among the components extracted and helping out to isolate the systemic risk component.

The analysis has been made by rotating and not rotating the results of the decomposition. For the sake of clarity of interpretation, only the results without rotation are presented in this document. Five main components were extracted, made up of linear combinations using the charges of the matrix eigen-vectors. The
eigen-vectors extracted represent the vector of factor loads use to obtain each of the p- main factors, which are, in short, each of the possible linear (orthogonal) combinations that can be formed with the chosen variables. Each eigen-vector tallies with the aforementioned eigen-values, by which we can attribute the first eigen-value to the first factor (to the first main combination of variables), the second eigen-value to the second factor, etc. Thus, we observe that the first linear combination of variables explains approximately 22% of the total variance of the sample, the second, 12.8%, the third, 12.1% and so on. The first factor is always that which summarizes most information of the entire data matrix.

9.4. **Identifying the systemic risk component.** Each main component provides information independently from the rest of the components. Through the expert eye, we identify which of the different linear combinations (components) preserve the properties we are seeking as a risk indicator, i.e., which of the factors is composed of a sum of variables with whose variation what we conceive as systemic risk increases or decreases. The indicator selection (described above) clearly pointed to the first indicator as the most suitable for approximating such risk.

9.5. **Grouping banks by risk score and ceteris paribus analysis.** Once such factor (if it exists among the indicators) has been identified, its weighings can be used to obtain the risk load of each bank that arises from its balance sheet information. Thus, we obtain a score on the degree of risk of each bank which we can arrange as a “bank risk ranking”. Since the analysis has been done in a panel data fashion (2006 -2009) the estimated factor loads are taking all common and fix effects of the data sheet intertemporally. Using this through the cycle estimated loads we may fix the systemic score for each bank in comparative terms (within and between samples) along the sampling years. This offers an intertemporal measure of systemic risk at both the individual and the system wide levels.

9.6. **Validating the results.** In order to check the degree of inductivist bias that could have been introduced in this analysis, a confirmatory analysis exercise has been performed on the results. Two classifications made on a reduced number of banks\(^{20}\) have been compared: an ex ante classification made by a dendrogram of similarities and another, ex post, by our PCA analysis (under 1 and 5 factors). As can be seen on Figure 6 - Appendix, the results show that as assumed the grouping made by the PCA analysis is consistent with that which would arise if we simply had focused on the similarities among their characteristics.

\(^{20}\)For the sake of clarity, the 26 largest banks have been selected from the sample, which coincide with those that require cross-border supervision according to the FSB
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10. Tables and Graphs
### Figure 2. Candidate Variables for Systemic Risk - All held in literature

<table>
<thead>
<tr>
<th>Possible Risk Indicators</th>
<th>Indicator Information</th>
<th>Selected</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td>Assets to World GDP (AGDP)</td>
<td>Total assets as a percentage of domestic GDP</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Deposit to World GDP (DGDIP)</td>
<td>Market share in banking deposits and lending</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Share of Credit to World Credit (SCGDP)</td>
<td>Market share in payment transactions</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Degree of concentration of various markets (CONC)</td>
<td>Vol. Transactions engaged</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Assets under custody / Total Assets in custody (AuC)</td>
<td>Vol. Assets warehoused or managed</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Num. Of Subsidiaries (NS)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Balance Structure</strong></td>
<td>Leverage Ratio (equity/total assets)</td>
<td>Leverage position</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Leverage Ratio (capitale off balance)</td>
<td>Leverage position Real</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Core Tier1 (CT1)</td>
<td>Risk Based Indicators</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Off Balance Assets / Total Assets (OBATA)</td>
<td>Shadow Risk Proxy</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Liquidity</strong></td>
<td>Maturity Missmatch</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Short Term Liquidity Indicators</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Long Term Liquidity Indicators</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dep/Assets (DA)</td>
<td>Capturing the funding decision of the Bank</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>M/Market &amp; Short Term Funding / Assets (MM&amp;STFtA)</td>
<td>Capturing the vulnerability to rate volatility, specially relevant during liquidity dry up periods</td>
<td>✓</td>
</tr>
<tr>
<td><strong>Asset Mix</strong></td>
<td>Gross Loans/Assets (LA)</td>
<td>Exposure to real cycle</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Sec/Assets (SA)</td>
<td>Exposure to financial cycle</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Mortgages</td>
<td></td>
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<tr>
<td></td>
<td>Cross Border Assets (CBA)</td>
<td>Exposure to foreign cycle</td>
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<tr>
<td></td>
<td>Interbank Assets (IA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other Assets (OA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Risk Management Culture</strong></td>
<td>Short Term Debt / Total Debt (STDT/TD)</td>
<td>Incentive alignment and risk franchising</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Non Interest Income to Total Income (NIR)</td>
<td>Measure of income diversification</td>
<td></td>
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<tr>
<td></td>
<td>Net Interest Margin (%)</td>
<td>Measure of Relational</td>
<td></td>
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<tr>
<td></td>
<td>Trade Income (TI)</td>
<td>Measure of Investment-like business</td>
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<tr>
<td></td>
<td>FX-Revenues (FXR)</td>
<td>Measure of</td>
<td></td>
</tr>
<tr>
<td><strong>Performance</strong></td>
<td>Return on Average Assets (ROAA) (%)</td>
<td>Capability to generate organically resources</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Return on Average Equity (ROAE) (%)</td>
<td>Capability to generate organically resources</td>
<td>✓</td>
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<tr>
<td></td>
<td>Cost to Income Ratio (%)</td>
<td></td>
<td></td>
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<tr>
<td><strong>Interconnectivity</strong></td>
<td>Eonia Overnight Lending Contribution (EOLC)</td>
<td>Interbank Market Weight</td>
<td></td>
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<tr>
<td></td>
<td>Market Capitalisation (MC)</td>
<td>Exposure of others to bank</td>
<td></td>
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<tr>
<td></td>
<td>Subordinated Debt Issuance (SDI)</td>
<td>Exposure of others to bank</td>
<td></td>
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<tr>
<td></td>
<td>Interbank Exposure/ Tier1 Capital()</td>
<td>Exposure of others to bank</td>
<td></td>
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<tr>
<td></td>
<td>Intra-group exposures</td>
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<tr>
<td></td>
<td>Ranking in markets in which the institution is a significant player</td>
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<td></td>
<td>Share in transactions volume in markets in which the institution participates</td>
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<tr>
<td></td>
<td>Credit spreads, bond spreads and price to book value (level and correlation)</td>
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</tr>
<tr>
<td><strong>Substitutability</strong></td>
<td>World wide custody (and clearing and compensation) (AuC)</td>
<td>Infrastructure Provider</td>
<td>✓</td>
</tr>
<tr>
<td></td>
<td>Sectoral breakdown of deposits and lending</td>
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<td></td>
<td>Volume Interbank activity</td>
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<td></td>
<td>Volume of corresponding banking</td>
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</tr>
<tr>
<td></td>
<td>Pinchman Herfindahl Index</td>
<td>Concentration Levels in services</td>
<td></td>
</tr>
</tbody>
</table>

21 Variables not selected (✓) were due to availability reasons.
Figure 3. Correlation Matrix of Systemic Risk Variables.

Red marked fields mean significant correlation between variables.

Black - white figures mean correlation degrees - significance levels
Figure 4. Kernel-distributions of banks by variables vs Santander Systemic Risk Indicator
Figure 5. Classification of Banks According to Size and SSRI

Figure 6. Confirmatory Analysis - Ex ante/Ex post comparison of Bank groupings (banks are dendograms endlines)
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