Universidad de Navarra

Facultad de Ciencias Económicas y Empresariales

Working Paper nº 21/12

Derivatives Holdings and Systemic Risk in the U.S. Banking Sector

María Rodríguez-Moreno
European Central Bank

Sergio Mayordomo
University of Navarra

Juan Ignacio-Peña
Universidad Carlos III de Madrid

Derivatives Holdings and Systemic Risk in the U.S. Banking Sector

María Rodríguez-Moreno, Sergio Mayordomo, Juan Ignacio Peña

Working Paper No.21/12
December 2012

ABSTRACT

This paper studies the impact of the banks' portfolio holdings of financial derivatives on the banks' individual contribution to systemic risk over and above the effect of variables related to size, interconnectedness, substitutability, and other balance sheet information. Using a sample of 91 U.S. bank holding companies from 2002 to 2011, we compare five measures of the banks' contribution to systemic risk and find that the new measure proposed in this study, Net Shapley Value, outperforms the others. Using this measure we find that the banks' holdings of foreign exchange and credit derivatives increase the banks contributions to systemic risk whereas holdings of interest rate derivatives decrease it. Nevertheless, the proportion of non-performing loans over total loans and the leverage ratio have much stronger impact on systemic risk than derivatives holdings. We find that before the subprime crisis credit derivatives decreased systemic risk whereas during the crisis increased it. So, credit derivatives seemed to change their role from shock absorbers to shock issuers. This effect is not observed in the other types of derivatives.

María Rodríguez-Moreno
European Central Bank
maria.rodriguez_moreno@ecb.int

Sergio Mayordomo
School of Economics and Business Administration
University of Navarra
smayordomo@unav.es

Juan Ignacio Peña
Department of Business Administration
Universidad Carlos III de Madrid
ypenya@eco.uc3m.es

Derivatives Holdings and Systemic Risk in the U.S. Banking Sector

This version 17-09-2012
First version: 16-12-2011

María Rodríguez-Moreno[1]
European Central Bank
Neue Mainzer Strasse 66,
60311 Frankfurt am Main (Germany)
maria.rodriguez_moreno@ecb.int

Sergio Mayordomo
University of Navarra
School of Economics and Business Administration
Edificio Amigos
31009 Pamplona (Spain)
Email: smayordomo@unav.es

Juan Ignacio Peña
Universidad Carlos III de Madrid
Department of Business Administration
C/ Madrid, 126
28903 Getafe (Madrid, Spain)
ypenya@eco.uc3m.es

[1] Corresponding author: María Rodríguez-Moreno. The authors acknowledge Germán López-Espinosa, Óscar Arce, Chen Zhou, Simone Manganelli, Stefano Corradin, David Marques-Ibáñez and seminar participants at European Central Bank, FDIC, 29th GdRE Annual International Symposium on Money, Banking and Finance, CNMV and Universidad Autónoma de Madrid for their useful comments and suggestions. The opinions in this article are the sole responsibility of the authors and they do not necessarily coincide with those of the European Central Bank. Peña acknowledges financial support from Ministerio de Economia y Competitividad grant ECO2012-35023.

Derivatives Holdings and Systemic Risk in the U.S. Banking Sector

Abstract

This paper studies the impact of the banks' portfolio holdings of financial derivatives on the banks' individual contribution to systemic risk over and above the effect of variables related to size, interconnectedness, substitutability, and other balance sheet information. Using a sample of 91 U.S. bank holding companies from 2002 to 2011, we compare five measures of the banks' contribution to systemic risk and find that the new measure proposed in this study, Net Shapley Value, outperforms the others. Using this measure we find that the banks' holdings of foreign exchange and credit derivatives increase the banks contributions to systemic risk whereas holdings of interest rate derivatives decrease it. Nevertheless, the proportion of non-performing loans over total loans and the leverage ratio have much stronger impact on systemic risk than derivatives holdings. We find that before the subprime crisis credit derivatives decreased systemic risk whereas during the crisis increased it. So, credit derivatives seemed to change their role from shock absorbers to shock issuers. This effect is not observed in the other types of derivatives.

Keywords: Systemic risk; derivatives; Shapley value

JEL Codes: C32; G01; G21

1. Introduction

Since the beginning of the current financial and economic crisis, the concern about systemic risk has increased, becoming a priority for regulatory authorities. These authorities realized that systemic risk is not a transitory problem and consequently, new institutional arrangements have been approved to address this challenging issue. The Financial Stability Oversight Council (FSOC) in the U.S. and the European Systemic Risk Board (ESRB) in the E.U. have been set to identify systemic risk, prevent regulatory loopholes, and make recommendations together with existing regulatory authorities. The concerns about systemic risk have also extended to securities markets regulators. Thus, the International Organization of Securities Commissions' (IOSCO) has also established a Standing Committee on Risk and Research to coordinate members' monitoring of potential systemic risks within securities markets.

In this setting it is crucial for the banking regulatory institutions to be able to analyze and understand the determinants of a banks' contribution to systemic risk. This information would help them not only to improve currently available systemic risk measures and warning flags but also to develop a taxation system on the basis of the externalities generated by a banks' impact on systemic risk. Additionally, securities market regulators are interested in understanding the contribution of traded financial instruments, for instance financial derivatives, to systemic risk in order to consider new regulatory initiatives. Finally, investors should be concerned with the extent to which derivatives holdings affect the systemic impact of a given bank in order to assess the appropriate reward required to bear this kind of risk. Stulz (2009) pointed out the lack of rigorous empirical studies on the social benefits and costs of derivatives and in particular their role in the financial crisis 2007-09. This paper aims to improve our understanding of these social costs and benefits examining whether the use of financial derivatives was a relevant factor in the destabilization of the banking system during the recent financial crisis.

The spectacular growth in banks' balance sheet over recent decades reflected increasing claims within the financial system rather than with non-financial agents. One key driver of this explosive intra-system activity came from the growth in derivatives markets and consequently in the growth of derivatives holdings in the banks' balance-sheets. A proportion of this growth may have been motivated by their use for hedging purposes justified by theory supporting the rationality of hedging decisions at individual bank level (e.g., Koppenhaver, 1985). This stance also finds support in empirical evidence suggesting the advantages of different hedging strategies for financial firms, again at individual level, see among others Jaffe (2003). However, another substantial proportion of this growth is due to proprietary trading activities by banks. Both activities, hedging and trading, are regarded as potentially useful and profitable by banks. However, it is well known that financial decisions that are rational at individual level can have negative consequences at system level. Is this also the case with respect to the banks' holdings of financial derivatives? The, admittedly very scarce, literature on this subject suggests that this might be the case, Calmès and Théoret (2010) find that off-balance-sheet activities reduce banks' mean returns, simultaneously increasing the volatility of their operating revenue and therefore increasing banks' systemic risk. Nijskens and Wagner (2011) report that the first use of credit derivatives is associated with an increase in a bank's risk, largely due to an increase in banks' correlations and therefore in their systemic risk. However, as far as we know, no evidence is available on the direct impact of derivatives holdings on the banks' individual contributions to systemic risk. Ours is a first attempt to fill this gap. For such aim, we combine two analyses; we first measure the banks' individual contributions to systemic risk and then, we estimate the effects of their holdings of financial derivatives on the banks' contributions to systemic risk.

To assess the banks' contributions to systemic risk we use the following five measures: ΔCoVaR, ΔCoES, Asymmetric ΔCoVaR, Gross Shapley Value (GSV) and Net Shapley Value (NSV). The ΔCoVaR is the difference between the Value at Risk (VaR) of the banking system conditional on bank i being in distress minus the VaR of the banking system conditional on bank i being in its median state. The ΔCoES applies the same idea but using the Expected Shortfall instead of the VaR (see Adrian and Brunnermeier, 2011). The Asymmetric ΔCoVaR represents a variation of the standard ΔCoVaR specification that allows for asymmetries in this specification (see López, Moreno, Rubia and Valderama, 2011). The GSV measures the average contribution to systemic risk of bank i in all possible groups in which the whole financial system can be divided (see Tarashev, Borio, and Tsatsaronis, 2010). Finally we propose an alternative measure to the GSV called NPV in which we get rid of the idiosyncratic component present in the former measure by subtracting from the GSV the VaR of the bank i.

We estimate these five measures for a subset of the 91 biggest U.S. bank holding companies for the period that spans from 2002 to 2011. We then compute the correlation of the systemic risk measures with an index of systemic events and run a Granger causality test between pairs of measures; and find that the NSV presents the closest association with the index and Granger causes more frequently the other measures.

Then, using this measure of systemic risk as the dependent variable, we examine six issues: (1) is there a relationship between the banks' holdings of financial derivatives and their contributions to systemic risk?; (2) is this relationship uniform across derivatives classes?; (3) is the impact on systemic risk the same irrespective of whether the derivative is held for trading or for other purposes?; (4) is the relationship between derivatives holdings and systemic risk sensitive to the emergence of the subprime crisis?; (5) in the case of credit derivatives, is their impact dependent on whether the bank is net protection seller or net protection buyer?; (6) besides derivatives, are there other balance sheet asset items which are significant contributors to systemic risk?.

We find the following results:

1. Yes. There is a significant relationship between the fair value of derivatives holdings of bank j in quarter t and the contribution to systemic risk of bank j in quarter $t+1$. Therefore derivatives holdings act as leading indicators of systemic risk contributions.
2. No. Banks' holdings of credit and foreign exchange derivatives have an increasing effect on systemic risk whereas holdings of interest rate and commodity derivatives have a decreasing effect.
3. No. Usually derivatives held for trading have a significant effect, either positive (foreign exchange) or negative (interest rate, commodity) whereas derivatives held for other purposes do not significantly affect systemic risk.
4. Yes and No. We find that before the subprime crisis credit derivatives decreased systemic risk whereas after the crisis increased it. But the way foreign exchange, interest rate, equity and commodity derivatives influence systemic risk remains unchanged.
5. Yes. If the bank is net protection buyer its credit derivatives holdings increase its systemic risk.

6. Yes. Some variables (measured as ratios over total assets) are also leading indicators of systemic risk contributions. Increases in the following variables increase systemic risk contributions: total loans, net balance to banks belonging to the same banking group, leverage ratio and the proportion of non-performing loans (measured in this case, relative to total loans). On the other hand, increases in total deposits decrease systemic risk. The variables with the highest economic impact on systemic risk are the proportion of non-performing loans to total loans and the leverage ratio. In fact, their economic impact is higher than the one corresponding to derivatives holdings.

The rest of the paper is organized as follows. Section 2 describes the methodology. In section 3 we describe the data. Section 4 reports the main empirical findings. In section 5 we present some robustness tests, and we conclude in section 6.

2. Methodology

2.1. Systemic Risk: Measures and Comparison

We consider the following five measures of the individual contribution of banks to systemic risk: (i) ΔCoVaR, (ii) ΔCoES, (iii) Asymmetric ΔCoVaR, (iv) Gross Shapley Value (GSV) and (v) Net Shapley Value (NSV). The details of the characteristics and the estimation of the systemic risk measures can be found in Appendix B.[2]

As in Rodriguez-Moreno and Peña (2012) we use two criteria to rank the five measures: (a) the correlation with an index of systemic events and policy actions, and (b) the Granger causality test. The first criterion compares the correlation of each measure with the main systemic events and policy actions and the second criterion points out the measures acting as leading indicators of systemic risk. Both criteria focus on different

[2] Acharya, Pedersen, Philippon and Richardson, (2011a, b) propose an alternative measure of the individual contribution to systemic risk called realized SES that measures the propensity of bank *i* to be undercapitalized when the whole system is undercapitalized. We exclude this measure from the discussion in the main text because, by construction, it is quarterly estimated and we cannot carry out the comparison with the considered five measures. Nevertheless, we estimate this measure, conduct the baseline regression to analyze the determinants of banks contributions to systemic risk and find that the results are fully in agreement with the main findings of this paper.

aspects of systemic risk and complement to each other to provide a robust diagnostic of the most reliable individual contribution to systemic risk measures.[3]

In the first criterion we use an influential event variable (IEV), which is a categorical variable that captures the main events observed and policy actions taken during the financial crisis based on the Federal Reserve Bank of St. Louis' crisis timeline.[4] The IEV takes value 1 whenever there is an event, under the hypothesis that those events should increase systemic risk, and is equal to -1 whenever there is a policy action, under the hypothesis that policy action's aim is to decrease systemic risk (and the action is usually successful). Otherwise it equals zero. The ranking method is based on the McFadden R-squared, a measure of goodness of fit. For each bank i in the sample we run a multinomial regression in which the dependent variable is the IEV and the explanatory variable is the systemic risk measure j for bank i (where $j = 1, \dots, 5$ and $i = 1, \dots, 91$) and then estimate the McFadden R-squared. The comparison of the different pairs of systemic risk measures, referred to the same bank, is done by assigning a score of +1 to the measure with the highest R-squared and -1 to the one with the lowest. Finally, we add up the scores obtained for each measure across the 91 banks.[5] By doing this, we avoid penalizing those measures that provide leading information and penalizing those events or political actions which have been discounted by the market before the event.

The second criterion is based on the Granger causality test (Granger, 1969). To rank the measures we give a score of +1 to a given measure X if X Granger causes another measure Y at 5% confidence level and -1 if X is caused in the Granger sense by Y. As a consequence, the best measure gets the highest positive score and the worst measure the highest negative score. Next, we add up the scores obtained by each measure across the 91 banks. Technical details on the procedure to compare the systemic risk measures can be found in Appendix C.

[3] In Rodriguez-Moreno and Peña (2012) the authors use an additional criterion based on the Gonzalo and Granger's (1995) methodology. To carry out this analysis, the pairs of systemic risk measures have to be cointegrated. However, this requirement is not satisfied in several of the pairs of measures and so, we do not consider it.

[4] Timeline crisis can be accessed via http://timeline.stlouisfed.org/.

[5] This ranking procedure is related to the well-known Condorcet voting method. However to avoid some of the problems of the Condorcet approach we also allow for negative as well as positive scores.

2.2. Determinants of systemic risk

We implement a panel regression analysis in which the individual bank *i*'s contribution to systemic risk in quarter *t* is regressed on the following variables (all in quarter *t-1*): bank's holdings of derivatives, proxies for the standard drivers of systemic risk (size, interconnectedness, and substitutability), other balance sheet information and the aggregate level of systemic risk. We employ a Prais-Winsten regression with correlated panels, corrected standard errors (PCSEs) and robust to heteroskedasticity and contemporaneous correlation across panels. Our panel regression model is described by the following equation:

$$SR_{i,t} = \alpha + \sum_{n=1}^{N} \gamma_n Y_{n,i,t-1} + \sum_{m=1}^{M} \omega_m Z_{m,i,t-1} + \sum_{s=1}^{S} \beta_s X_{s,i,t-1} + Time\ Effects + \varepsilon_{i,t} \quad (1)$$

where the dependent variable is the bank's *i* contribution to systemic risk as measured by the Net Shapley Value. The vector of variables $Y_{n,i,t}$ contains the proxies for the bank *i* size and its degree of interconnectedness and substitutability. The vector $Z_{m,i,t}$ contains variables related to other banks characteristics: balance-sheet quality and the aggregate level of systemic risk one and two quarters ago. The aggregate variables are obtained after aggregating the levels of systemic risk of the U.S. commercial banks (without considering the bank *i*), dealer-broker and insurance companies. The vector of variables $X_{s,i,t}$ refers to the banks' holdings of financial derivatives.

2.3. Research questions

We examine six issues that have not been addressed previously in literature regarding the role of derivatives holdings and their possible connections with systemic risk:

1. The first question to ask is whether the banks' holdings of financial derivatives contribute in any significant way to systemic risk. If this is indeed the case, then many other important questions come into play.
2. The next obvious question is whether this relationship is uniform across derivatives classes or are there differences in the impact between foreign exchange and interest rate derivatives, for example.
3. Given that our databases allow us to distinguish between derivatives held for trading or for other purposes, the next question is whether the impact on systemic risk is the same irrespective of the reason they are being held.

4. Given the abrupt change in market conditions since July 2007 a pressing question is to study whether the relationship between derivative holdings and systemic risk is sensitive to the emergence of the subprime crisis. The answer to this question could be very illuminating in the sense that some derivatives that were thought to play the role of shock absorbers before the crisis (this was the predominant view on the derivatives industry in general)[6] may have changed their nature once the subprime crisis starts.
5. In the specific case of credit derivatives, one may think that a bank that is a net protection buyer and therefore is hedging its credit risk to some extent, should contribute to a lesser extent to the overall systemic risk. Testing whether this is indeed the case helps to understand the actual role of these controversial instruments.
6. Additionally, it seems natural to ask what other balance sheet asset items are significant contributors to systemic risk and in particular which ones have the biggest economic impact on systemic risk.

3. Data and Explanatory Variables

3.1 Data

The Bank Holding Company Data (BHCD) from the Federal Reserve Bank of Chicago is our primary database.[7] Additional information (VIX, 3-monthTbill rate, 3-month repo rate, 10-year Treasury rate, BAA-rate bond, and MSCI index returns) is collected from DataStream and the Federal Reserve Bank of New York.

Our data set is composed of U.S. bank holding companies with total assets above $5billion in either the first quarter of 2006 or the first quarter of 2009. Therefore our focus is on relatively big banks in either the pre-crisis or the ongoing crisis period. Additional filters are banks for which we have information on their stock prices, banks that held at least one type of derivatives analyzed in this paper, and, we exclude banks

[6] "As is generally acknowledged, the development of credit derivatives has contributed to the stability of the banking system by allowing banks, especially the largest, systemically important banks, to measure and manage their credit risks more effectively" Greenspan (2005).

[7] http://www.chicagofed.org/webpages/banking/financial_institution_reports/bhc_data.cfm

that defaulted or were acquired before 2007.[8] Our final sample consists of quarterly information for 91 bank holding companies from March 2002 to June 2011.[9]

Table 1 contains the 91 banks and information about their size (market capitalization in millions of dollars). In terms of size we observe a huge variance across banks under the analysis being by far Bank of America, Citigroup and JP Morgan the largest banks in the sample.

3.2. Explanatory Variables

Next we summarize the five groups of potential determinants of the banks' contribution to systemic risk (a detailed description can be found in Appendix A):

3.2.1. Banks Holdings of Derivatives

We consider five types of derivatives: credit, interest rate, foreign exchange, equity, and commodity. The holdings of derivatives are considered in terms of the fair value that is defined in the instructions of preparation of the BHCD as "the price that would be received to sell an asset or paid to transfer a liability in an orderly transaction between market participants in the asset's or liability's principal (or most advantageous) market at the measurement date". The holdings of derivatives are reported in the balance sheet with positive (asset side) or negative (liabilities side) fair values which refer to the amount of revaluation gains or losses from the ''marking to market'' of the five different types of derivative contracts.[10, 11] We focus on the total fair value (i.e., positive plus negative fair values) because it allows us to take into account the total exposures to the derivatives' counterparties and, at the same time, the counterparty risk. Alternatively to the fair value, we could use the notional amount outstanding; however according to the Office of the Comptroller of the Currency (OCC) Quarterly Reports on Bank

---

[8] We deal with bank mergers as in Hirtle (2008) who adjusts for the impact of significant mergers by treating the post-merger bank as a different entity from the pre-merger bank. This is the case of the case of the Bank of New York Company and Mellon Financial Corp.

[9] The BHCD provides information about approximately 7.800 banks holdings that were alive before 2002.

[10] Unlike other securities, derivative contracts involve two possible positions and positive fair values mean negative fair values on the counterparty. According to the Dodd-Frank Act, the required information to private funds advised by investment advisers to guarantee an appropriate monitoring of systemic risk in securities markets includes: amount of assets under management and use of leverage, trading and investment positions, types of assets held, or trading practices, among others contracts.

[11] The statement of Financial Accounting Standard No. 133 "Accounting for Derivative Instruments and Hedging Activities" requires all derivatives, without exception and regardless of the accounting treatment of the underlying asset, to be recognized in the balance sheet as either negative fair values (liabilities) or positive fair values (assets).

Trading and Derivatives Activities notional values can provide insight into potential revenue and operational issues but do not provide useful measure of the risk taken and so, could be meaningless from the systemic risk perspective.[12]

Figure 1 depicts the average fair values of the banks holdings of interest rate, foreign exchange, credit, equity and commodity derivatives over total assets. Interest rate derivatives represent the most widely used derivative during the whole sample period. Between 2003 and September 2007 they performed a downward trend that finished with the eruption of the subprime crisis in summer 2007. At the time of the Lehman Brothers collapse, the weight of interest rate derivatives more than doubled moving from 2% to 6% in one quarter. Since then, the holdings of interest rate derivatives have remained high and evolved within the 4-6% interval. Between 2002 and the Lehman Brothers episode, foreign exchange derivatives were the second most used derivatives and remained below 1% during almost the entire sample period. Credit derivatives performed a remarkable increase after summer 2007 and reached their maximum level in March 2009. In that period credit derivatives became the second most frequently used derivatives. Equity and commodity derivatives have lower weight in the sample. Equity derivatives did not experience large variations while commodity derivatives increased after the Bearn Stearns collapse probably coinciding with the increase in the commodity prices.

For the interest rate, foreign exchange, equity, and commodity derivatives we distinguish the effect of the holdings of derivatives held for trading from the ones held for purposes other than trading. Contracts held for trading purposes include those used in dealing and other trading activities accounted for at fair value with gains and losses recognized in earnings. Derivative instruments used to hedge trading activities are also reported in this category. For the credit derivatives we distinguish the effects of the holdings of derivatives in which the bank is the guarantor (protection seller) or the beneficiary (protection buyer).

Although previous literature about the effect of financial derivatives on systemic risk is scarce, some papers suggest the possible role of credit derivatives as determinant of systemic risk (see Stulz, 2004 and Acharya, 2011). Moreover, the hedging offered by

[12] The use of the derivatives fair value is a standard procedure in the literature (e.g. Venkatachalam, 1996; or Livne, Markarian and Milne, 2011).

derivatives could also lead banks to take more risk on the underlying asset. This fact could destabilize the banking sector if markets are not perfectly competitive (Instefjord, 2005).

3.2.2. Size

The impact of size on systemic risk is increasing and possibly non-linear as documented in Pais and Stork (2011). Tarashev, Borio and Tsatsaronis (2010) convincingly argue that larger size implies greater systemic importance, that the contribution to system-wide risk increases more than proportionately with relative size, and that a positive relationship between size and systemic importance is a robust result. The logarithm of the market capitalization (share price multiplied by the number of ordinary shares in issue) is used as the proxy for its size. This is a common practice in finance (e.g. Ferreira and Laux, 2007) and accounting (e.g. Bhen, Choi, and Kang, 2008) literature. We use market value instead of total assets to avoid any collinearity problem because banks' total assets have been employed to define and standardize most of the variables. We add the square of the size variable to our regression to control any potential non-lineal relation between size and systemic risk.

3.2.3. Interconnectedness and substitutability

Interconnectedness measures the extent to which a bank is connected with other institutions in such a way that its stress could easily be transmitted to other institutions. Substitutability can be defined as the extent to which other institutions or segments of the financial system can provide the same services that were provided by failed institutions. These two concepts are not easy to measure and there is therefore scarce evidence quantifying their effects on systemic risk.

As pointed out by Acharya, Pedersen, Philippon, and Richardson (2011a), the dimensions of systemic risk can be also translated into the following groups: size, leverage, risk, and correlation with the rest of the financial sector and economy. Due to the difficulty of measuring substitutability and interconnectedness, they are grouped in a more general group: correlation of the bank with the financial sector and economy.

To control for these dimensions we first employ some variables that could be more related to the interconnectedness dimension and then other variables related to the substitutability dimension. In the first group we consider the net balances to subsidiary banks and non-banks as a way to study the net position of a bank within the group.

Additionally, this first dimension is captured by means of the correlation between the average daily individual bank's stock returns and the S&P500 index returns during the corresponding calendar quarter *t* (hereafter correlation with S&P500 index) in line with Allen, Bali, and Tang (2011).

In the second group we include variables related with the substitutability as reflected into the services that are provided by the banks, and we also distinguish between variables referred to the core and non-core banking activities. Brunnermeier, Dong and Palia (2011) find that non-interest to interest income variable (proxy for the non-core or non-traditional activities such as trading and securitization, investment banking, brokerage or advisory activities) has a significant contribution to systemic risk; we include this variable in our regressions. On the other hand, the amount of loans to banks and depository institutions relative to total assets and the total loans (excluding loans to banks and depository institutions) relating to total assets represent the bank's core or traditional activities. We distinguish between loans to the financial system and other loans enabling us to study whether they have different effects on systemic risk. Finally, we use the ratio of the bank's commercial paper holding relative to total assets as a proxy for the interbank activities given that we do not have direct information on the interbank lending. As Cummins and Weiss (2010) state, the inter-bank lending and commercial paper markets were critical in the subprime crisis. These variables could also indicate to some extent the degree of interconnectedness of a given bank given that the larger the total amount of the loans the larger is the expositions of a given bank to their borrowers. The difficulty of defining proxies related to the bank degree of substitutability could be one of the reasons that explain the scarcity of studies quantifying the effect of this dimension of systemic risk.[13] We define the variables referred to interconnectedness relative to the bank total assets.

[13] We are aware of only one study analyzing the effect of the substitutability dimension on systemic risk: Cummings and Weiss (2010). The authors study whether the U.S. insurers' activities create systemic risk and show that the lack of substitutability of insurers is not a serious problem. According to their results even a default of large insurers would not create a substitutability problem because other insurers could fill this gap. However, we consider that banking sector differs from the previous one and for this reason a positive effect of the substitutability dimension on the bank contribution to systemic risk cannot be ruled out.

3.2.4. Balance Sheet Information

We use several variables that refer to the balance sheet quality: (i) leverage, (ii) total deposits relative to total assets, (iii) maturity mismatch, and (iv) non-performing loans to total loans.

One of the dimensions proposed by Acharya, Pedersen, Philippon, and Richardson (2011b) is leverage, however true leverage is not straightforward to measure due to the limited market data breaking down off- and on-balance-sheet financing. According to them we define leverage as follows:

$$Leverage = \frac{book\ assets - book\ equity + market\ equity}{market\ value\ of\ equity} \quad (2)$$

As pointed out by Acharya and Thakor (2011) higher bank leverage creates stronger creditor discipline at individual bank level but it also increases systemic risk. However, some empirical analyses do not find significant effect of leverage on systemic risk (see Brunnermeier et al., 2011; or López, et al., 2011). Mizrach (2011) shows conventionally measured leverage as an unreliable indicator of systemic risk and suggests a more detailed examination of bank balance-sheets and asset holdings.

Other two potential explanatory variables are maturity mismatch and deposits to total assets. Thus, the higher the mismatch the more likely the bank is exposed to funding stress. Deposits to total assets have two different interpretations. On the one hand during financial distress periods banks could rely more on deposits (see Boyson, Helwege, and Jindra, 2011). On the other hand, activities that are not traditionally associated with banks (outside the realm of traditional deposit taking and lending) are associated with a larger contribution to systemic risk and activities related to deposits taking are associated with a lower contribution to systemic risk. Total deposits could contribute to decrease systemic risk because they provide a shock-absorbing buffer.

Regarding the ratio of non-performing loans to total loans, the growth of credit and the easy access to financing observed before the subprime crisis could have increased substantially the role of this variable as a significant determinant of the bank's contribution to systemic risk.

3.2.5. Aggregate systemic risk measure

The aggregate systemic risk for each bank *i* is estimated as the sum of the individual contribution to systemic risk of all the banks with the exception of bank *i*, the 8 major broker-dealers, and the 23 major insurance companies. This variable captures the deterioration of the financial system's health. We use two lags of the aggregate measure of systemic risk to control by speed of adjustment to the aggregate level of risk and to absorb any lagged aggregated information transmitted into the current observation.

Table 2 reports the main descriptive statistics of the explanatory variables in the baseline analysis. We observe that the holdings of financial derivatives represent, on average, a small proportion of the total assets. They range from the interest rate derivatives, averaging 3.1% of total assets to commodity derivatives averaging only 0.1%. Net balances due to bank represent, on average, a lower proportion than net balances due to non-banks. The average correlation of the individual banks with S&P500 index is quite large (0.6) which suggests a substantial interconnectedness of the banking system with the overall market. Average total loan and loan to banks represent around 61% and 0.2% of the total assets, respectively. The average ratio non-interest to interest income is close to 0.5 and average maturity mismatch is close to 10%. Finally, the balance sheet category, total deposits represent, on average, almost 70% of total assets.

4. Empirical Results

4.1. Individual Systemic Risk Measures and Their Comparison

Panel A of Table 3 reports the main descriptive statistics of the individual quarterly measures. The signs for all the measures are set such that the higher the measure, the higher the bank's contribution to systemic risk. The measures are defined in basis points. We observe a common pattern in all of them with a huge difference between the mean and the maximum due to the big jump during Lehman Brothers episode.

We then rank the systemic risk measures according to the two criteria stated in Section 2.1 and Appendix C: (a) the correlation with an index of systemic events and policy actions and (b) Granger causality test. Panel B of Table 3 contains the final scores. Comparing the five weekly measures, we observe that under both criteria, the NSV obtains the highest score followed by the GSV. Therefore, for the baseline analysis we use the NSV as the proxy for the bank contribution to systemic risk. Some robustness checks using alternative measures of systemic risk are conducted in Section 5.

Other additional aspects of the different measures are worth mentioning. The co-risk measures strongly rely on the performance of the state variables and employ little firm specific information (i.e., information contained on stock prices, total assets and book equity). So, these measures provide very similar output for different banks independent of the bank's risk profile. To give an example, the estimation of CoVaR for every bank *i* (equations B.1.1-B.1.3) is done using the growth rate of the market value of total financial assets (at system level) as the dependent variable; and a set of state variables and the growth rate of the market value of total financial assets of bank *i* as explanatory variables. The results of the quantile regression shows that the coefficient measuring the impact of the market value of the total financial assets of bank *i* on this measure of systemic risk is significant only for 11 of the 91 banks at 10% of significance level when quantile level is 1% ($q = 0.01$) and in zero cases when quantile level is 50% ($q = 0.5$). Therefore individual bank's CoVaR is largely determined by the same set of common variables. For this reason, we expect strong similarities across banks in terms of this systemic risk measure.[14]

Regarding the computation of the GSV for bank *i*, this measure includes the VaR of bank *i* as an additional element in estimating the individual contribution to systemic risk. But in non-stress periods (where the individual contribution of bank *i* to system risk is negligible) this measure is largely determined by the evolution of the VaR of bank *i* which is a measure of the bank's individual risk.[15] To solve this shortcoming, we consider an alternative measure which is net of the impact of a proportion of the individual VaR, the Net Shapley Value. That is, we get rid of the bank's idiosyncratic risk and focus on the bank's contribution to systemic risk by subtracting the VaR from the GSV. Some robustness checks are carried out in Section 5.

4.2. Determinants of Systemic Risk: the Effect of Banks' Holdings of Derivatives

In addition to the banks' average contribution to systemic risk, Figure 2 depicts the average fair value of derivatives ratio held across banks for trading and for other purposes than trading relative to total assets. In the case of credit derivatives, we report

[14] To quantify these similarities, we estimate pairwise correlations between the individual VaR and the systemic risk measure for each bank. The average correlations are 0.98, 0.94 and 0.95 for the ΔCoVaR, ΔCoES and asymmetric CoVaR, respectively.

[15] We estimate the average correlation between the GSV and the VaR for each of the 91 banks. The average correlation for the period 2002-20011 is equal to 0.98 while this correlation drops to 0.75 using the NSV.

the average holdings relative to total assets and the average difference between the fair value of credit derivatives in which the banks act as beneficiary (buy protection) and those in which they act as guarantor (sell protection). The series corresponding to the average bank holdings of derivatives are lagged one period (*t-1*) and the systemic risk measure is depicted at period *t* such as they appear in regression (1). In general terms, we observe that trading positions are the most relevant for all the types of derivatives. The extensive use of derivatives for trading purposes could be due to banks moving towards innovative fee-producing activities as pointed out by Allen and Santomero (2001). These trading activities have generated substantial revenues for large banks as can be observed in the OCC's Quarterly Reports on Bank Trading and Derivatives Activities but they have also led to large losses. Regarding credit derivatives, we observe that the beneficiary positions are on average larger than guarantor positions[16]. In interest rate and commodity derivatives panels, we observe that one quarter before the date corresponding to the most pronounced increase in systemic risk, holdings held for trading depict a downward trend, equity holdings for trading purposes remained stable during this systemic episode. The correlation between the holdings of interest rate and equity derivatives for trading purposes lagged one quarter on the one hand, and the systemic risk measure from the end of 2007 to the beginning of 2009 on the other hand; are negative and it is almost zero for case of the commodity derivatives. Finally, we find a closer relation between systemic risk and the positions in both credit and foreign exchange derivatives. We observe a slight increase in the holdings of the former and a significant increase in the latter one quarter before the main systemic event in the sample. Thus, the correlations of the holdings of these derivatives lagged by a quarter and the systemic risk measure during the period in which we observe the highest banks contributions to systemic risk were significantly positive.

We address the first, second and sixth research questions stated in Section 2 by means of Table 4, which shows the results of the estimation of equation 1 (the baseline specification). Column 1 reports the estimated coefficients and their standard errors. Column 2 reports the standardized coefficient (i.e., the product of the coefficient and the standard deviation of the explanatory variable) and column 3 the economic impact of

[16] The implication is that net guarantors are other non-bank financial institutions (insurance companies, hedge funds)

the statistically significant variables (i.e., the ratio of the standardized coefficient over the average value of the dependent variable).

There is a significant relation between the credit, interest rate, foreign exchange and commodity derivatives holdings of bank *i* in quarter *t* and the contribution to systemic risk of bank *i* in period *t+1*. Equity derivatives holdings do not affect systemic risk. Holdings of credit and foreign exchange derivatives have an increasing effect on systemic risk whereas holdings of interest rate and commodities derivatives have a decreasing effect. Foreign exchange derivatives have the highest economic impact on systemic risk.

The positive and significant effect of credit derivatives may be due to the fact that banks positions in credit derivatives are held for trading activities rather than for hedging loans (Minton, Stulz, and Williamson, 2009). These authors estimate that the net notional amount of these derivatives that is used for hedging loans is below 2% of the total notional amount of this type of derivatives and is less than 2% of their loans. In this line, Kiff, Elliot, Kazarian, Scarlata, and Spackman (2009) state that a large portion of CDS buyers do not hold the underlying bond but are either speculating on the default of the underlying reference or protecting other interests.

The positive and significant effect of the variable referring to the use of foreign exchange derivatives casts some doubts on the argument against increased regulation of the foreign exchange derivatives based on the assumption of the high level of transparency of the foreign exchange market and that they performed smoothly during the financial crisis. An extreme situation, such as the devaluation of the currency of a large country, could lead to high losses for important players in this market and could make the global shock that this devaluation would cause even worse. According to the BIS (2008) report on the progress in reducing foreign exchange settlement risk, the establishment and growth of the CLS Bank has achieved significant success however, a notable share of foreign exchange transactions are settled in ways that still generate significant potential risks across the global financial system and so, further action is required. However, the clearing process is concentrated in one clearing house (the CLS Bank) and this fact could have negative systemic implications (see Duffie and Zhu, 2011).

In regards to the negative and significant effect of the holdings of interest rate derivatives; previous literature such as Brewer, Minton, and Moser (2000) and Carter and Sinkey (1998) suggest the use of these derivatives being more frequent in banks more exposed to interest rate risk. Thus, the Carter and Sinkley (1998) and Downing (2012) results support the hypothesis that banks use interest-rate derivatives to hedge interest rate risk. In fact, we find that the correlation between the 10-year U.S. Government bond yield and the holdings of interest rate derivatives is 0.91 indicating that the use of these derivatives is determined by decreases in the interest rate. This finding is in line with the one presented by Christoffersen, Nain, and Oberoi (2009) who show a negative relation between the use of interest rate derivatives and the interest rate movements. These authors argue that even if companies are able to anticipate the interest rate policy, it is possible that they cannot adjust the debt exposure; however they can adjust the swap exposures to reduce the cost of debt. This negative correlation could also be consistent with a higher cost of interest rate volatility during economic downturns.

The effects of the use of equity and commodity derivatives on banks' risk or performance have been scarcely addressed in previous literature. One reason explaining the lack of empirical studies on this topic could be the lower relative importance of the positions on equity and commodity derivatives as can be observed in Figure 1. However, while the effect of the equity derivatives is not significant, commodity derivatives have a negative and significant effect on the dependent variable.

The holdings of commodity derivatives, as occurs with the other derivatives, could be justified by the search for higher yields in a low interest rate environment. Moreover, the increase in the use of commodity derivatives could be propitiated, as stated in Basu and Gavin (2010), by the movement from real estate derivatives to commodity derivatives coinciding with the appearance of the problems in the subprime market. Other theories suggest that banks could use commodity derivatives to hedge inflation risk, to take advantage of the increase in the commodity prices around the systemic event, or because they are negatively correlated with equity and bond returns (Gorton and Rouwenhorst, 2006). Basu and Gavin (2010) show that when commodity prices peak in June 2008, the correlation with the equity index was, on average, negative. In fact, we observe the highest holdings of commodity derivatives by banks in this period.

After summer 2008 the correlation becomes extremely positive and holdings of commodity derivatives diminished substantially from their highest levels.

Regarding the effect of the size, substitutability, interconnectedness and balance-sheet related variables, we find that increases in the following variables increase systemic risk contributions: total loans, net balance to banks belonging to the same banking group, leverage ratio and the proportion of non-performing loans over total loans. On the other hand, increases in total deposits decreases systemic risk. The effect of the size related variables is not significant given that size is our primary criterion for sample selection. The variables with the highest economic impact on systemic risk are the proportion of non-performing loans to total loans and the leverage ratio. For instance, one standard deviation increase in the proportion of non-performing loans to total loans in quarter *t*, increases the bank's contribution to systemic risk in quarter *t+1* to 17% above its average level.

No other variable presents significant effects. In particular and in contrast to Brunnermeier et al. (2011) non-interest to interest income is not significant when derivatives holding are included in the equation. This discrepancy could be also due to the different sample, time periods, systemic risk measures, or explanatory variables employed in the two papers. Size effect is not significant, as expected, given the sample selection bias.[17] Finally, the aggregate systemic risk level in the previous quarter contributes positively and significantly to increase the individual contribution to systemic risk but the effect of aggregate systemic risk does not go beyond one quarter before the current one.[18]

Summing up, although the two variables with the highest economic impact on the bank's contribution to systemic risk are the non-performing loans relative to total loans

---

[17] We have repeated the analysis using the logarithm of total assets and its square as alternative variables to proxy the bank size and find similar results.
[18] The use of these lagged measures enables us to mitigate the potential autocorrelation in the residuals. Nevertheless, we check whether there is significant first order autocorrelation in the residuals by means of individual tests for each bank. The coefficient for the first order autocorrelation is only significant in 25 out of the 91 banks being its average magnitude around 0.3 for these 25 banks. We conduct an additional test to discard the existence of first order correlation in the residuals. Thus, we calculate the average residual for each date across the 91 banks and regress this series on its lagged value. The estimated coefficient is not significantly different from zero and so, we do not find evidence in favor of the presence of autocorrelation.

and the leverage variables; the bank's holdings of financial derivatives also have significant effects but of a much lower magnitude.

Some literature has considered that the use of derivatives should not pose significant levels of risk to the economy or to individual corporations. For instance, Stulz (2004) concludes that we should not fear derivatives but have a healthy respect for them. He considers that losses from derivatives are localized but the whole economy gains from the existence of derivatives markets. Hentschel and Kothari (2001) question whether corporations are reducing or taking risks with derivatives, their answer is "typically not very much of either". The authors find an absence of higher risks due to the effect of derivatives (even among firms with large derivatives positions) which in their view shows that the concern over widespread derivative speculation is unfounded. Along this line, Cyree, Huang, and Lindley (2012) find that the effects of derivatives (interest rate, foreign exchange, and credit derivatives) on market valuation are not statistically distinguishable from zero in either good times or bad times.

Our results do not imply that the use of derivatives by banks is inconsequential as far as systemic risk is concerned. They do imply that their impact, albeit statistically significant, plays a second fiddle in comparison with traditional variables such as leverage or the proportion of non-performing loans over total loans. Furthermore, the use of derivatives could indirectly affect the systemic contribution of banks given that derivatives require limited up-front payments and enable banks to take more leveraged positions. Additionally, the use of derivatives could lead to diminished monitoring of loans when the banks are considered to have used the right hedging strategies.

To address research questions three and five we look at Table 5 in which we distinguish holdings of derivatives (interest rate, foreign exchange, equity and commodity, respectively) used for trading and for other purposes using two different variables. In the case of credit derivatives we use the difference between the fair values of the holdings in which the bank is the beneficiary (buys protection) and guarantor (sells protection).

Derivatives held for purposes other than trading do not significantly contribute to systemic risk. However, foreign exchange and interest rate derivatives for trading purposes and to lesser extent equity derivatives affect systemic risk.

We find a positive and significant effect of the variable representing the holdings of foreign exchange derivatives for trading purposes. Fan, Mamun, and Tannous (2009) suggest that the reduction in risk gained from using foreign exchange derivatives for hedging purposes is offset by the increase in trading activities. Banks could use this type of derivatives to hedge foreign exchange risk and be engaged in trading activities which would expose them to additional risk at the same time.

Contrary to the effect of foreign exchange derivatives, interest rate derivatives held for trading have a negative and significant effect on systemic risk. Hirtle (1997) shows that the increase in the use of interest rate derivatives by U.S. bank holdings, which served as derivatives dealers, correspond to a greater interest rate risk exposure during the period 1991-1994. This result could be reflecting that derivatives enhance interest rate risk exposure for bank holding companies. Additionally, banks mainly lend to firms using floating rates and for this reason, they could aim to increase their trading in interest rate derivatives when the interest rates begin to diminish. According to Stulz (2004), derivatives can create risk at a firm level if they are used episodically and with no experience in their use. However, interest rate derivatives are broadly used by banks. The most common interest rate derivative is based on swaps, which account for around 70%, and in particular the “plain vanilla” interest rate swap. Banks participating more heavily in interest-rate swaps have a higher loans to asset ratio (Brewer, Minton, and Moser, 2000) and stronger capital positions (Carter and Sinkey, 1998).

The fact that the equity derivatives held for trading purposes have a negative and significant effect could be due to the use banks made of these derivatives during the crisis. Thus, the maximum value of the fair value ratio of equity derivatives for trading relative to total assets is reached by September 2007 and since then; this ratio has remained stable and decreased at the end of the sample.

We observe that as banks act as a net beneficiary when participating in the credit derivatives markets, its contribution to systemic risk increases. Given that the protection seller could default, a buyer of a CDS contract assumes counterparty risk, so the concern of heightened counterparty risk around the Lehman Brothers collapse could explain this effect. Moreover, as pointed out by Giglio (2011), the buyer of protection could suffer even larger loses if the default of the reference entity triggers the default of the counterparty (double default), given that the buyer would have a large amount owed by the bankrupt counterparty. Even the presence of collateral may not be enough to solve this counterparty risk related to double default problem. According to Giglio (2011), the buyers of CDS were aware of this residual counterparty risk and considered that the best way to reduce it was to buy additional CDS protection against their counterparty, which increased the cost of buying CDS protection. Banks being net buyers of protection have lower capital ratios, higher ratios of risk-based assets to total assets, and are users of other types of derivatives (Minton, Stulz, and Williamson, 2009). On the other hand, the banks that are more profitable, more liquid, or have a higher ratio of deposits over total assets are less likely to be net protection buyers.

Finally we address the fourth research question by means of Table 6. As stated in section 2.3, we aim to test whether the relationship between derivatives' holdings and systemic risk is sensitive to the emergence of the subprime crisis. To do that, we split the fair value of the holdings of every derivative (credit, interest rate, foreign exchange, equity and commodity derivatives) in two variables: the first variable represents the holdings of derivatives multiplied by a dummy variable which is equal to one before the first quarter of 2007 (no crisis dummy) while the second variable is obtained by multiplying the holdings of derivatives and a dummy variable which equals one after the first quarter of 2007 (crisis dummy). Then, we estimate equation 1 focusing on the role of every derivative before and during the crisis in separate ways. We observe a negative effect of the credit derivatives holdings on systemic risk before the subprime crisis but a positive and significant effect during the crisis which evidences a change of role of the credit derivatives. Credit derivatives behaved as shock absorbers before the subprime crisis but as credit issuers during the crisis. This change of role is not observed in other derivatives. The effect of interest rate derivatives holdings is negative and significant before and during the crisis. The effect of foreign exchange derivatives is always positive although non-significant before the crisis, but significant during the crisis. The holdings of commodity derivatives hedge systemic risk in both periods but significantly only before the crisis.

5. Robustness Test

So far we have studied the factors that explain the individual contribution to systemic risk. At this point our main aim is to ensure the reliability of our previous analysis proposing alternative dependent and explanatory variables.

5.1. Alternative Indicators of Systemic Risk

We first consider an alternative specification of the NSV in which we include a synthetic bank constructed as the weighted average of the remaining banks that do not belong to the system and are not used to estimate the measure (column 2). The second measure represents a variation of the NSV in which we aggregate the information within a given quarter by summing up all the weekly estimated measures instead of using the end of quarter information (column 3). The third measure corresponds to the GSV (column 4).

Comparing columns 1 and 2, we find similar results for both definitions of the NSV. Therefore, our results are robust to the use of either the largest banks (column 1) or all banks in the form of a synthetic bank (column 2) to define the core banks that form the system. The only difference when we sum up the weekly NSV within a given quarter (column 3) with respect to results in column 1 is that the size (correlation with S&P500) are now non-significant (significant).

Regarding the GSV (column 4), which has been found to be the second most reliable measure, we find similar results to those obtained for the baseline specification. Nevertheless, some differences should be mentioned: the explanatory power of the regressors decreases (from 0.49 to 0.43), size now exhibits a significant convex shape, loans to banks and depositary institutions, and maturity mismatch are now positive and significant.

Additionally, we estimate the five systemic risk measures for a portfolio that consists of only the 16 largest banks and compare them on the basis of their relation to the IEV and Granger causality test, obtaining once again that the NSV is the most reliable measure. In fact, the pairwise correlation between the NSV estimated in the baseline analysis and the NSV using a portfolio of the largest 16 banks is, on average, 0.99.

5.2. Alternative Explanatory Variables

As in Brunnermeier et al. (2011) we also use as an explanatory variable the lagged level of bank risk according to its VaR (defined in positive terms) instead of the aggregate lagged level of systemic risk. In this case, the R-squared increases from 0.49 to 0.53 and the effect of the VaR variable is positive and significant at any level of significance. The effect of the remaining explanatory variables is similar to those in the baseline regression. In view of this, our results are robust to the use of the bank's VaR to control for the level of risk in the previous quarter.

To take into account the effect of the degree of concentration in the banking sector, we include the Herfindahl-Hirschman index referred to the banks' total assets as an additional explanatory variable. This variable does not have a significant effect at any level of significance and both the coefficients and levels of significance of the explanatory variables are unchanged with respect to the results obtained in the baseline regression. [19]

6. Conclusions

The recent financial crisis has exposed the dangers lurking in oversized banking sector balance sheets. One major concern for regulators has been the astonishing growth in derivatives markets and consequently in the swelling of derivatives holdings in banks' balance-sheets. The aim of this paper is to address the extent to which this situation has increased systemic risk.

First, we propose an alternative measure of the individual contribution to systemic risk that is based on the Gross Shapley Vale and that we call Net Shapley Value. This measure allows us to get rid of the idiosyncratic component present in the last measure. Then, we compare alternative systemic risk measures and find that the Net Shapley Value outperforms the others. Using the Net Shapley Value as our proxy for systemic risk we find strong evidence of derivative holdings acting as leading indicators of banks' systemic risk contributions. However, their effects are not alike because credit and foreign exchange derivatives have a positive effect on systemic risk whereas holdings of interest rate and commodity derivatives have a negative effect. The derivatives impact on systemic risk is only found when the derivative is held for trading. Furthermore, we find that before the subprime crisis credit derivatives decreased systemic risk whereas after the crisis increased it. But foreign exchange, interest rate, equity and commodity derivatives influence systemic risk in the same way in both time periods.

[19] Detailed results of the alternative specifications are available upon request.

Surprisingly, the data suggest that if a bank is net protection buyer its credit derivatives holdings increase its individual contribution to systemic risk. This fact casts doubt on the real role of these controversial instruments with respect to banks' contributions to systemic risk. The concern about heightened counterparty risk around the Lehman Brothers collapse could explain this effect.

Finally, other balance sheet variables are also leading indicators of systemic risk contributions. Increases in the following variables increase systemic risk contributions: total loans, net balance to banks belonging to the same banking group, leverage ratio and the proportion of non-performing loans (measured in this case relative to total loans), on the other hand, increases in total deposits decreases systemic risk. The variables with the highest economic impact on systemic risk are the proportion of non-performing loans to total loans and the leverage ratio. In fact, in terms of economic impact on systemic risk, the balance sheet items related to traditional banking activities (leverage, non-performing loans) have the stronger effect.

Our results provide some implications for regulators and bankers alike. The move toward increasing derivatives holdings might be endogenous to the banking industry, in the sense that it was first originated by banks themselves. In the last years banks shifted their activities from the traditional lending activities toward, a priori, more profitable ones, like trading derivatives. But the reasons for doing that are related to low profitability of traditional activities. Based on the endogeneity of this move toward activities that increased profitability at the price of higher exposure to market risks, our paper suggest that some of these activities, in particular trading in interest rate derivatives had actually reduced the contribution of individual banks to systemic risk. On the other hand, trading in foreign exchange and credit derivatives (during the crisis) had increased their contributions to systemic risk. So the claims that all derivatives have pernicious effects on the overall financial system are not borne out by the data. Therefore, the process of re-regulation that is under way in many countries should be carefully designed to avoid hindering activities that are actually diminishing systemic risk. Financial stability is a public good that can inform corporate investment and financing decisions and thus any new regulatory initiative should be very carefully designed to give the different instruments within an asset class, in this case, derivatives, the appropriate regulatory oversight.

On the other hand, given the empirical evidence reported in this paper, the economic impact of non-performing loans and leverage on systemic risk is much stronger than the derivatives' impact. Therefore the traditional banking activities related to these two items should be closely watched by regulators worried about systemic risk episodes.

References

Acharya, V. V., 2011. A Transparency Standard for Derivatives. NBER Working Paper No. 17558.

Acharya, V. V., Pedersen, L. H., Philippon, T., Richardson, M., 2011a. Quantifying Systemic Risk: How to Calculate Systemic Risk Surcharges. Chapter in NBER Book Quantifying Systemic Risk, Joseph G. Haubrich and Andrew W. Lo, editors.

Acharya, V. V., Pedersen, L. H., Philippon, T., Richardson, M., 2011b. Measuring Systemic Risk. Working paper, New York University.

Acharya, V. V., Thakor, A., 2011. The Dark Side of Liquidity Creation: Leverage and Systemic Risk. Working Paper, Federal Reserve Bank of New York.

Adrian, T., Brunnermeier, M. K., 2011. CoVar. Federal Reserve Bank of New York Staff Report 348.

Allen, L., Bali, T. G., Tang, Y., 2011. Does Systemic Risk in the Financial Sector Predict Future Economic Downturns?. Working Paper.

Allen, F., Santomero, A. M., 2001. What do financial intermediaries do? Journal of Banking and Finance 25, 271-294.

Bank for International Settlements, 2008. Progress in Reducing Foreign Exchange Settlement Risk.

Basu, P., Gavin, W.T., 2010. What explains the growth in commodity derivatives?" Federal Bank of St. Louis review 93, 37-48.

Behn, B., Choi, J. H., Kang, T., 2008. Audit Quality and Properties of Analysts' Earnings Forecasts. The Accounting Review 83, 327-349.

Boyson, N., Helwege, J., Jindra, J., 2011. Crisis, Liquidity Shocks, and Fire Sales at Financial Institutions. Working Paper. Available at SSRN: http://ssrn.com/abstract=1633042

Brewer, E., Minton, B., Moser, J., 2000. Interest-Rate Derivatives and Bank Lending. Journal of Banking and Finance 24, 353-379.

Brunnermeier, M. K., Gang D., Palia, D., 2011. Banks' Non-Interest Income and Systemic Risk. Working Paper. Available at SSRN: http://ssrn.com/abstract=1786738

Calmès, C., Théoret, R., 2010. The impact of off-balance-sheet activities on banks returns: an application of the ARCH-M to Canadian data. Journal of Banking and Finance 34, 1719–1728.

Carter, D. A., Sinkey, J. F., 1998. The Use of Interest Rate Derivatives by End-Users: The Case of Large Community Banks. Journal of Financial Services Research 14, 17-34.

Christoffersen, P., Nain, A., and Oberoi, J., 2009. Interest Rate Shocks and Corporate Risk Management. Working Paper, McGill University

Cummins, J. D., Weiss, M. A., 2010. Systemic Risk and the U.S. Insurance Sector. Temple University Working Paper.

Cyree, K., Huang, P., Lindley, J., 2012. The Economic Consequences of Banks' Derivatives Use in Good Times and Bad Times. Journal of Financial Services Research 41, 121-144.

Dodd-Frank Wall Street Reform and Consumer Protection Act.

Downing, J., 2012. Banks, Price Risk, and Derivatives: Evidence and Implications for the Volcker Rule and Fair-Value Accounting. Working Paper.

Duffie, D., Zhu, H., 2011. Does a central clearing counterparty reduce counterparty risk?. The Review of Asset Pricing Studies 1, 74-95.

Fan, H. Mamun, A. Tannous, G., 2009. What determines Bank Holding Companies Foreign Exchange Derivatives For Trading and for Other-Than-Trading. Working Paper.

Ferreira, M. A., Laux, P. A., 2007. Corporate Governance, Idiosyncratic Risk, and Information Flow. Journal of Finance 62, 951-989.

Giglio, S., 2011. Credit Default Swap Spreads and Systemic Financial Risk. Working Paper.

Gorton, G., Rouwenhorst, K. G., 2006. Facts and Fantasies about Commodity Futures. Financial Analysts Journal 62, 47-68.

Gonzalo, J., Granger, C., 1995. Estimation of common long-memory components in cointegrated systems. Journal of Business and Economic Statistics 13, 27-35.

Granger, C.W.J., 1969. Investigating causal relations by econometric models and cross-spectral methods, Econometrica 37, 424-438.

Greenspan, A., 2005. Risk transfer and financial stability. Remarks by Chairman to the Federal Reserve Bank of Chicago's Forty-first Annual Conference on Bank Structure, Chicago, Illinois, on May 5, 2005.

Hentschel, L., Kothari, S. P., 2001. Are Corporations Reducing or Taking Risks with Derivatives? Journal of Financial and Quantitative Analysis 36, 93-118.

Hirtle, B. J., 1997. Derivatives, Portfolio Composition, and Bank Holding Company Interest Rate Risk Exposure. Journal of Financial Services Research 12, 243-266.

Hirtle, B., 2008. Credit Derivatives and Bank Credit Supply. FRB of New York Staff

Instefjord, N., 2005. Risk and Hedging: Do Credit Derivatives Increase Bank Risk? Journal of Banking and Finance 29, 333-345.

Jaffe, D., 2003. The Interest Rate Risk of Fannie Mae and Freddy Mac. Journal of Financial Services Research 24, 5-29.

Kiff, J., Elliot, J., Kazarian, E., Scarlata, J., Spackman, C., 2009. Credit Derivatives: Systemic Risks and Policy Options. IMF Working Paper 09/254.

Koenker, R., Bassett, G., 1978. Regression Quantiles. Econometrica 46, 33-50.

Koppenhaver, G. D., 1985. Bank Funding Risk, Risk Aversion, and the Choice of Futures Hedging Instrument. Journal of Finance 40, 241-255.

Livne, G., Markarian, G., Milne, A., 2011. Bankers' Compensation and Fair Value Accounting. Journal of Corporate Finance 17, 1096-1115.

López, G., Moreno, A., Rubia, A., Valderrama, L., 2011. Asymmetric Covar: An Application to International Banking. Systemic Risk, Basel III, Financial Stability and Regulation 2011.

Minton, B., Stulz, R., Williamson, R., 2009. How Much Do Banks Use Credit Derivatives to Hedge Loans? Journal of Financial Services Research 35, 1-31.

Mizrach, B., 2011. Leverage and VaR as Measures of Bank Distress: Comment on Endogenous and Systemic Risk. Rutgers University Working Paper.

Nijskens, R., Wagner, W., 2011. Credit risk transfer activities and systemic risk: How banks became less risky individually but posed greater risks to the financial system at the same time. Journal of Banking and Finance 35, 1391-1398.

Rodriguez-Moreno, M., Peña J.I., 2012. Systemic Risk Measures: the Simpler the Better? Journal of Banking and Finance, in press.

Stulz, R. M., 2004. Should We Fear Derivatives? Journal of Economic Perspectives 18, 173-192.

Stulz, R., 2009. Credit Default Swaps and the Credit Crisis. NBER Working Paper No. 15384.

Tarashev, N., Borio, C., Tsatsaronis, K., 2010. Attributing systemic risk to individual institutions. BIS Working Papers No 308, May.

Venkatachalam, M., 1996. Value-Relevance of Banks' Derivatives Disclosures. Journal of Accounting and Economics 22, 327-355.

Appendix A

In this appendix we provide a detailed description of the explanatory variables obtained from the database Bank Holding Company Data (Federal Reserve Bank of Chicago) that are employed in this paper:

Fair value of credit derivatives: this variable is defined as the sum of the total fair value (positive and negative) of the total gross notional amount in which the reporting bank is beneficiary or guarantor.[20]

Fair value of interest rate, foreign exchange, equity and commodity derivatives: this variable is defined as the sum of the total fair value of the total gross notional amount for each of the four previous types of derivative contracts held for trading and for purposes other than trading by the banks. The total fair value is obtained as the sum of the positive and negative fair values.[21]

Commercial paper: The total amount outstanding of commercial paper issued by the reporting bank holding company to unrelated parties. Commercial paper matures in 270 days or less and is not collateralized.

Loan to banks: this variable includes all loans and all other instruments evidencing loans (except those secured by real estate) to depository institutions chartered and headquartered in the U.S. and the U.S. and foreign branches of banks chartered and headquartered in a foreign country.

Maturity mismatch: this variable is defined as the ratio of short term debt relative to total assets.

Net balance to bank: difference between all balances and cash due to related banks[22] and all balances and cash due from related banks. Due to accounts are liabilities accounts that represent the amount of funds currently payable to another account. Due from accounts are assets accounts that represent the amount of deposits currently held at another company.

Net balance to non-bank: this variable is the difference between all balances and cash due to related non-banks and all balances and cash due from related non-banks.[23]

Non-interest to interest Income: this variable is the ratio between the total non-interest income and total interest income. The former includes the sum of income from fiduciary activities, service charges on deposit accounts in domestic offices, and trading gains (losses) and fees from foreign exchange transactions, among others. The later includes interest and fee income on loans secured by real estate in domestic offices, interest and fee income on loans to depository institutions in domestic offices, credit cards and related plans, interest income from assets held in trading accounts, among others.

Non-performing loans: this variable is the sum of total loans, leasing financing receivables, debt securities and other assets past due 90 days or more.

---

[20] Credit derivatives are off balance sheet arrangements that allow one party (beneficiary or protection buyer) to transfer the credit risk of the reference asset to another party (guarantor or protection seller).

[21] The total fair values are reported as an absolute value.

[22] Banks directly or indirectly owned by the top-tier parent bank holding company, excluding those directly or indirectly owned by the reporting lower-tier parent bank holding company.

[23] Nonbank companies directly or indirectly owned by the top-tier parent bank holding company, excluding those directly or indirectly owned by the reporting lower-tier parent bank holding company.

Total deposits: this variable includes the amount of all noninterest-bearing deposits plus the time certificates of deposits of $100,000 or more held in foreign offices of the reporting bank.

Total loans: this variable includes all loans except to the commercial paper and the loans reported in the *loan to banks* variable.

Appendix B

This appendix contains the details on the estimation of the five systemic measures that we consider in this paper. The systemic risk measures are estimated on a weekly basis. In order to conduct quarterly regression analysis we consider the last observation of the quarter. However, for the baseline measure we also consider the sum of the observations during the corresponding quarter as a robustness test.

B.1. Co-Risk Measures

Adrian and Brunnermeier (2011) based their analysis on the growth rate of the market value of total financial assets, X_t^i, which is defined as the growth rate of the product between the market value of institution *i* and its ratio of total assets to book equity.[24] *VaR* and *CoVaR* are estimated by means of quantile regression (Koenker and Bassett, 1978). The time-variant measures are based on the following equations in weekly data:

$$X_t^i = \alpha^i + \gamma^i M_{t-1} + \varepsilon_t^i$$
$$X_t^{system} = \alpha^{system|i} + \beta^{system|i} X_t^i + \gamma^{system|i} M_{t-1} + \varepsilon_t^{system|i} \quad (B.1.1)$$

where M_t^i is a set of state variables.[25] In order to perform the quantile regression, we assume a confidence level of 1% what implies to estimate a *VaR* at 1%. Once the coefficients of equation B.1.1 have been estimated through quantile regression, we replace them into equation B.1.2 to obtain the *VaR* and *CoVaR*.

$$VaR_t^i(q) = \hat{\alpha}_q^i + \hat{\gamma}_q^i M_{t-1}$$
$$CoVaR_t^i(q) = \hat{\alpha}_q^{system|i} + \hat{\beta}_q^{system|i} VaR_t^i(q) + \gamma_q^{system|i} M_{t-1} \quad (B.1.2)$$

Finally, the marginal contribution of institution *i* to the overall systemic risk, which is called delta co-value-at-risk ($\Delta CoVaR_i$), is calculated as the difference between $CoVaR_i$ conditional on the distress of the institution (i.e., $q = 0.01$) and the $CoVaR_i$ conditional of the "normal" state of the institution (i.e., $q = 0.5$)

$$\Delta CoVaR_t^i(1\%) = CoVaR_t^i(1\%) - CoVaR_t^i(50\%) \quad (B.1.3)$$

On the basis of equation B.1.3 we obtain the weekly $\Delta CoVaR_t^i$. We also apply this methodology to estimate co-expected shortfall ($CoES_i$) which is defined as the expected shortfall of the financial system conditional on $X^i \leq VaR_q^i$. See Adrian and Brunnermeier (2011) for the details.

---

[24] At portfolio level, the growth rate of the market value of total financial assets is computed as a weighted average of the growth rates of the constituents of the portfolio lagged one period.

[25] This set is composed by VIX, *liquidity spread* (i.e., 3-month repo minus 3-month bill rate), change in 3-month Treasury bill rate, *slope of the yield curve* (i.e., 10-year Treasury rate minus 3-month bill rate), *credit spread* (i.e., 10 Year BAA rated bonds minus 10-year Treasury rate) and return of the MSCI index.

B.2. Asymmetric CoVaR

López, et al. (2011) propose to extend the $\Delta CoVaR_t^i$ methodology in order to capture asymmetries in the estimation of the co-value-at risk. They propose the following specification:

$$X_t^i = \alpha^i + \gamma^i M_{t-1} + \varepsilon_t^i$$
$$X_t^{system} = \alpha^{system|i} + \beta^{+system|i} X_t^i I_{(X_t^i \geq 0)} + \beta^{-system|i} X_t^i I_{(X_t^i < 0)} + \gamma^{system|i} M_{t-1} + \varepsilon_t^{system|i} \quad (B.2.1)$$

where $I_{(\cdot)}$is an indicator function that takes 1 if the condition of the subscript is true and zero otherwise. Under this specification, Adrian and Brunnermeier (2011) approach can be seen as an special case in which $\beta^{+system|i} = \beta^{-system|i} = \beta^{system|i}$. As in Adrian and Brunnermeier (2011), equation B.2.1 is estimated using quantile regression at 1%. Then, $CoVaR_t^i$ is estimated according to equation B.2.2:

$$VaR_t^i(q) = \hat{\alpha}_q^i + \hat{\gamma}_q^i M_{t-1}$$
$$CoVaR_t^i(q) = \hat{\alpha}_q^{system|i} + \hat{\beta}_q^{-system|i} VaR_t^i(q) + \gamma_q^{system|i} M_{t-1} \quad (B.2.2)$$

B.3. Gross Shapley Value of Value-at-Risk

In order to apply this methodology it is *sufficient* to define a "characteristic function" (ϑ) which should define the system-wide VaR when it is applied to the entire system. Once the characteristic function have been defined, the contribution of bank i to the subsystem S equals the difference between the risk of subsystem S and the risk of the subsystem when bank i is excluded from it ($S - \{i\}$). So, the Gross Shapley Value (GSV_i) equals to the expected value of such contribution when the *N!* possible orderings may occur with the same probability. Mathematically GSV_i is defined as,

$$GSV_i = \frac{1}{N} \sum_{n_s=1}^{N} \left[\frac{1}{c(n_s)} \sum_{\substack{S \supset i \\ |S| = n_s}} (\vartheta(S) - \vartheta(S - \{i\})) \right] \quad (B.3.1)$$

where $\sum$ denotes the entire financial system, $S \supset i$ are all the possible subsystems in $\sum$ containing i, |S| represents the number of institutions in the subsystem and $c(n_s)$ comprises the number of all possible subsystem with n_s institutions which is defined as $c(n_s) = \frac{(N-1)!}{(N-n_s)!(n_s-1)!}$.

In order to carry out the practical implementation of this methodology, we estimate the characteristic function as in Adrian and Brunnermeier (2011) (i.e., through quantile regression). The number of considered banks in the system implies the main challenge of this methodology. In this article we analyze 91 bank holding companies and hence, we would have to estimate 2.48E27 different subsystems. Given the unfeasibility of storing such amount of information we define a subset of the 15 largest banks in such a way that for studying every institution we consider 16 banks (i.e., the largest 15 banks plus the bank under study).[26] This modification

[26] The selected banks are: Bank of America, Bank of New York Company, Bank of New York Mellon, BB&T, Charles Schwab, Citigroup, Fifth Third Bancorp, JP Morgan Chase and Company, Metlife, PNC Financial Services Group, State Street, Suntrust Banks, United States Bancorp, Wachovia Corporation and Wells Fargo and Company.

enables us to reduce the size of our problem without biasing the results because those banks represent more than the 80% of the average total assets of the whole system.

Additionally we estimate this measure in an alternative way in which the system (16 banks) is composed of the largest 14 banks, the bank under study and a “synthetic” bank created from the remaining 76 banks which are weighed by the market value of total financial assets. By creating this representative bank, we take all the available information of the system (including the information contained in the small banks). This approach will be considered as a robustness test.

B.4. Net Shapley Value of Value-at-Risk

We now extend the expression for the GSV for a given bank *i* as presented in equation B.3.1 to show that during non-stress periods the individual contribution of this bank to the aggregate systemic risk should be close to zero and consequently this measure will be governed by the individual VaR of bank *i*. To show this, we consider an economy that is composed by 4 banks ($n = 1, \ldots, 4$). The possible subsystems and the GSV when we study the contribution of bank 1 to the risk of the economy would be:

Subsystems (S): $\{1\}, \{1,2\}, \{1,3\}, \{1,4\}, \{1,2,3\}, \{1,2,4\}, \{1,3,4\}, \{1,2,3,4\}$

$$GSV_1 = \frac{1}{4}\Big[VaR(\{1\}) + \frac{1}{3} * \Big(\big(VaR(\{1,2\}) - VaR(\{2\})\big) + \big(VaR(\{1,3\}) - VaR(\{3\})\big) + \big(VaR(\{1,4\}) - VaR(\{4\})\big)\Big) + \frac{1}{3} * \Big(\big(VaR(\{1,2,3\}) - VaR(\{2,3\})\big) + \big(VaR(\{1,2,4\}) - VaR(\{2,4\})\big) + \big(VaR(\{1,3,4\}) - VaR(\{3,4\})\big)\Big) + \big(VaR(\{1,2,3,4\}) - VaR(\{2,3,4\})\big)\Big] \quad (B.4.1)$$

In non-stress periods (no systemic risk) bank *i* does not contribute to the overall level of risk and the only term which would differ from zero would be VaR($\{1\}$). To check the extent of this problem we estimate the average correlation between the GSV and the VaR for each of the 91 banks. The average correlation for the period 2002-20011 is 0.98. This suggests that GSV is not an appropriate measure in our sample due to their strong correlation with the bank’s VaR.

In order to palliate this GSV’s drawback we introduce an alternative measure which is free from the impact of the individual value-at-risk. The main reason justifying this adjustment being the VaR_i measures bank *i* specific market risk. But VaR_i does not measure how much risk bank *i* is adding to the whole system. This new measure is named as the Net Shapley Value (NSV_i). Mathematically, it is defined as:

$$NSV_i = GSV_i - \frac{1}{N} VaR_i \qquad (B.4.2)$$

Additionally, we estimate the NSV measure for a portfolio that consists of only the 16 largest banks. Note that considering 16 banks we can define the system on the basis of a whole portfolio of banks instead of focusing on a core subset of banks and adding individually the remaining smaller banks and obtain that the pairwise correlation between the NSV estimated in the baseline analysis and the NSV using a portfolio of the largest 16 banks is, on average, 0.99.

Appendix C

In this appendix we describe the methodology employed to compare the systemic risk measures described in Appendix B. As in Rodriguez-Moreno and Peña (2012) we use two criteria to compare the five individual contribution of bank to systemic risk measures: (i) the correlation with an index of systemic events and policy actions, and (ii) the Granger causality test.

To implement the first criterion we carry out a multinomial regression for each bank j in sample, where the dependent variable is the influential event variable (IEV, a categorical variable that takes value 1 whenever there is an event; -1 whenever there is a political action; 0 otherwise) and the explanatory variable is the systemic risk measure.

$$IEV_t = \alpha + \beta SystemicRiskMeasure_{i,j,t-k} + \varepsilon_t \qquad (C.1)$$

The subindex i refers to a given systemic risk measure (i.e., NSV, GSV, $\Delta CoVaR$, $\Delta CoES$ or asymmetric $\Delta CoVaR$), j refers to bank under analysis ($j = 1, \dots, 91$) and k refers to the number of lags in the regression ($k = 0,1,2$).[27] Next, the McFadden R-squared for each regression is obtained as follows:

$$R^2 = 1 - \frac{ln\hat{L}(M_{Full})}{ln\hat{L}(M_{Intercept})} \qquad (C.2)$$

where M_{Full} refers to the full model and $M_{Intercept}$ to the model without predictors, and $\hat{L}$ is the estimated likelihood.[28]

The second criterion is based on the Granger causality test (Granger, 1969). This test examines whether past changes in one variable, X_t, help to explain contemporary changes in another variable, Y_t. If not, we conclude that X_t does not Granger cause Y_t. Formally, the Granger causality test is based on the following regression:

$$\Delta Y_t = \alpha + \sum_{i=1}^{p} \beta_{yi} \Delta Y_{t-i} + \sum_{i=1}^{p} \beta_{xi} \Delta X_{t-i} + \varepsilon_t \qquad (C.3)$$

where Δ is the first-difference operator and ΔX and ΔY are stationary variables. We reject the null hypothesis that X_t does not Granger cause Y_t if the coefficients β_{xi} are jointly significant based on the standard F-test.

[27] Results do not change when other lags are considered.

[28] To evaluate the goodness-of-fit for a multinomial regression, several pseudo R-squared has been developed. We employ McFadden R-squared due to its appropriate statistical properties.

Table 1: Descriptive Statistics of Bank Holding Companies

This table reports the name of the 91 banks which form the sample and related information about their size (average market value in millions of U.S. dollars).

id	Bank Holding	Market Value	id	Bank Holding	Market Value
1	Alabama National Bancorp	1,063	47	M&T Bank	9,396
2	Amcore Financial	467	48	Marshall & Ilsley	6,824
3	Associated Banc-Corporation	2,939	49	MB Financial	804
4	Bancorpsouth	1,636	50	Mellon Financial	16,300
5	Bank of America	140,000	51	Metlife	31,400
6	Bank of Hawaii	2,201	52	National Penn Bancshares	758
7	Bank of New York Co	27,000	53	NBT Bancorp	661
8	Bank of New York Mellon	38,100	54	New York Community Bancorp	4,612
9	BB&T	18,200	55	Newalliance Bancshares	1,492
10	Bok Financial	2,589	56	Northern Trust	12,300
11	Boston Private Financial	569	57	Old National Bancorp	1,318
12	Capital One Financial	16,900	58	Pacific Capital Bancorp	941
13	Cathay General Bancorp	1,095	59	Park National	1,230
14	Central Pacific Financial	510	60	PNC Financial Services	19,600
15	Charles Schwab	21,500	61	Privatebancorp	588
16	Chittenden Corp	1,119	62	Provident Bankshares	644
17	Citigroup	188,000	63	Regions Financial New	9,923
18	Citizens Republic Bancorp	970	64	Sky Financial Group	2,583
19	City National	2,681	65	South Financial Group	1,012
20	Colonial Bancgroup	1,758	66	State Street	19,000
21	Comerica	7,893	67	Sterling Bancshares	621
22	Commerce Bancshares	2,989	68	Sterling Financial	572
23	Community Bank System	571	69	Suntrust Banks	18,700
24	Cullen Frost Bankers	2,537	70	Susquehanna Bancshares	1,004
25	CVB Financial	878	71	SVB Financial Group	1,503
26	East West Bancorp	1,418	72	Synovus Financial	6,150
27	FNB	978	73	TCF Financial	2,986
28	Fifth Third Bancorp	21,300	74	Texas Capital Bancshares	547
29	First Citizens Bancorporation	411	75	Trustmark	1,488
30	First Commonwealth Financial	761	76	United States Bancorp	46,700
31	First Horizon National	3,939	77	Ucbh Holdings	921
32	First Midwest Bancorp	1,280	78	UMB Financial	1,310
33	First National of Nebraska	1,222	79	Umpqua Holdings	817
34	Firstmerit	1,935	80	United Bankshares	1,219
35	Fulton Financial	2,066	81	United Community Banks	721
36	Glacier Bancorp	765	82	Valley National Bancorp	2,390
37	Greater Bay Bancorp	1,315	83	Wachovia Corp	48,200
38	Hancock Holding	1,040	84	Webster Financial	1,762
39	Harleysville National Corp	450	85	Wells Fargo and Company	104,000
40	Huntington Bancshares	4,518	86	Wesbanco	530
41	Iberiabank	583	87	Western Alliance Bancorp	580
42	International Bancshares	1,405	88	Whitney Holding Corp	1,411
43	Investors Bancorp	1,480	89	Wilmington Trust	1,924
44	Investors Financial Services	3,005	90	Wintrust Financial	776
45	JP Morgan Chase and Co	117,000	91	Zions Bancorporation	5,051
46	Keycorp	10,200			

Table 2: Descriptive Statistics

This table reports the descriptive statistics (mean, median, standard deviation, maximum, minimum, and number of observations) of the five groups of determinants of systemic risk under analysis: *size* (log market value); *interconnectedness and substitutability* (commercial paper, loan to banks, total loans, non-interest to interest income, correlation with S&P500, net balances due to banks, net balances due to non-banks); *balance sheet* (leverage, maturity mismatch, total deposits and non-performing loans); *aggregate systemic risk; banks holdings of derivatives* (fair value of credit, interest rate, foreign exchange, equity and commodity derivatives).

	Mean	*Median*	*Stard. Dev.*	*Max.*	*Min.*	*N. Obs.*
Log market value	14.778	14.872	0.391	19.428	9.258	3154
Comercial paper/TA	0.002	0.002	0.002	0.095	0.000	3154
Loan to banks/TA	0.002	0.002	0.002	0.071	0.000	3154
Total loans/TA	0.611	0.615	0.043	0.937	0.012	3154
Non-interest to interest income/TA	0.500	0.493	0.125	5.305	-0.648	3154
Correlation with S&P500	0.592	0.615	0.148	0.956	-0.555	3154
Net balance to bank/TA	0.000	0.000	0.000	0.019	-0.023	3154
Net balance to non-bank/TA	0.012	0.012	0.004	0.060	0.000	3154
Leverage	9.893	6.690	7.739	17.890	0.260	3154
Maturity mismatch	0.095	0.095	0.036	0.640	0.000	3151
Total deposits/TA	0.685	0.686	0.040	0.905	0.001	3154
Non-performing loans/Total loans	0.015	0.009	0.014	0.162	0.000	3154
Aggregate systemic risk measure	0.098	0.046	0.106	38.578	7.363	3154
Credit derivatives/TA	0.003	0.001	0.003	0.486	0.000	3154
Interest rate derivatives/TA	0.031	0.027	0.015	1.653	0.000	3154
Foreign exchange derivatives/TA	0.006	0.006	0.002	0.257	0.000	3154
Equity derivatives/TA	0.002	0.002	0.001	0.087	0.000	3154
Commodity derivatives/TA	0.001	0.001	0.001	0.206	0.000	3154

Table 3: Systemic Risk Measures: Descriptive Statistics and Ranking

This table reports the main descriptive statistics of the systemic risk measures and their ranking based on the average McFadden R-squared and Granger causality test. Panel A reports the descriptive statistics of five systemic risk measures in basis points: Net Shapley value (NSV), Gross Shapley Value (GSV), Co-risk measures (ΔCoVaR and ΔCoES), and asymmetric ΔCoVaR. They are reported on quarterly basis calculated at the last week of the corresponding quarter. Panel B reports the ranking scores for the systemic risk measures. The comparison of different pairs of systemic risk measures, referred to the same bank, based on the McFadden R-squared criterion is done by assigning a score of +1 to the measure with the highest R-squared and -1 to the lowest. The comparison based on the Granger causality test is done by applying the test to pairs of systemic risk measures, referred to the same bank, and giving a score of +1 to measure X if X Granger causes another measure Y at 5% confidence level and -1 if X is caused in the Granger sense by Y. Finally we add up the scores obtained by each measure across the 91 banks to obtain the one with highest score.

Panel A

	Mean	*Median*	*Stard. Dev.*	*Max.*	*Min.*	*N. Obs.*
Net Shapley Value	11.07	6.21	11.44	176.39	-76.03	3154
Gross Shapley Value	93.22	82.33	49.34	546.15	6.08	3154
Delta co-value-at-risk	745.63	641.86	486.21	3205.45	22.69	3154
Delta co expected shortfall	454.96	396.00	306.43	2216.00	-303.65	3154
Asymmetric Delta co-value-at-risk	765.25	660.07	488.35	4327.27	-151.70	3154

Panel B

	Net Shapley Value	*Gross Shapley Value*	*Delta co-value-at-risk*	*Delta co-expected-shortfall*	*Asymmetric Delta co-value-at-risk*
McFadden R-squared	266	84	-44	-280	-26
Granger causality test	13	10	-20	-1	-2
Total	279	94	-64	-281	-28

Table 4: Baseline Regression

This table reports the results of the baseline unbalanced panel regressions. The dependent variable is the individual contribution to systemic risk measured as the Net Shapley Value which is measured in basis points. Our database is formed of 91 banks and spans from 1Q2002 to 2Q2011. We estimate the coefficients by means of a Prais-Winsten robust to heteroskedasticity, contemporaneous correlation across panels. Column 1 reports the results where bank holdings of derivatives are measured by means of the total fair value (sum of positive and negatives). Column 2 reports the standardized coefficient (i.e., the regression coefficient as in column 1 times standard deviation of the corresponding explanatory variable). Column 3 contains the standardized coefficient (as in column 2) over the mean of the dependent variable (in percentage) for the variables which are different from zero at 1 or 5% significance levels. The symbol *** (**) denotes the significance level at 1% (5%). The results correspond to the estimated coefficient and the robust standard errors.

	(1) *Coefficient [SE]*	(2) *Standardized coefficient*	(3) *Economic Impact (%)*
Log market value $_{t-1}$	-4.16 [2.51]	-1.627	
Log of squared market value $_{t-1}$	0.09 [0.08]	1.006	
Commercial paper $_{t-1}$ */TA*	30.62 [31.56]	0.051	
Loan to banks $_{t-1}$ */TA*	19.71 [44.78]	0.032	
Total loans $_{t-1}$ */TA*	9.67*** [2.84]	0.416	3.755
Non-interest to interest income $_{t-1}$	0.79 [0.83]	0.099	
Correlation with S&P500 $_{t-1}$	2.36 [2.89]	0.349	
Net balance to bank $_{t-1}$ */TA*	477.97*** [95.60]	0.200	1.803
Net balance to non-bank $_{t-1}$ */TA*	-23.38 [17.40]	-0.098	
Leverage $_{t-1}$	0.15*** [0.04]	1.161	10.486
Maturity mismatch $_{t-1}$	0.21 [2.62]	0.007	
Total deposits $_{t-1}$ */TA*	-18.16*** [3.47]	-0.719	-6.493
Non-performing loans $_{t-1}$ */Total loans*	136.40*** [44.56]	1.955	17.655
Aggregate systemic risk measue $_{t-1}$	67.13*** [16.82]	7.147	64.550
Aggregate systemic risk measue $_{t-2}$	-27.54 [16.51]	-2.932	
Credit derivatives $_{t-1}$ */TA*	34.33*** [8.22]	0.110	0.989
Interest rate derivatives $_{t-1}$ */TA*	-11.51*** [2.78]	-0.168	-1.517
Foreign exchange derivatives $_{t-1}$ */TA*	93.58*** [24.68]	0.225	2.036
Equity derivatives $_{t-1}$ */TA*	-39.55 [43.21]	-0.028	-0.256
Commodity derivatives $_{t-1}$ */TA*	-26.29** [12.36]	-0.031	-0.276
Constant	46.06** [19.82]		
Time Effects	Yes		
Number of Observations	2947		
Number of Groups	91		
Min. Observations per Group	13		
Avg. Observations per Group	33.2		
Max. Observations per Group	36		
R-squared	0.4904		

Table 5: Analysis of the held position

This table reports the results of a variation in the baseline unbalanced panel regressions in which we focus on the held position on derivatives. For credit derivatives we study the difference between fair value of holdings in which the bank is the beneficiary and the holdings in which the bank is the guarantor. For interest rate, foreign exchange, equity and commodity derivatives we distinguish holdings used for trading and for purposes other than trading using two different variables. The dependent variable is the individual contribution to systemic risk measured as the Net Shapley Value which is measured in basis points. Our database is formed of 91 banks and spans from 1Q2002 to 2Q2011. We estimate the coefficients by means of a Prais-Winsten robust to heteroskedasticity, contemporaneous correlation across panels. Column 1 reports the coefficients relative to holdings of derivatives. Column 2 reports the economic impact in percentage. It is assessed as the standardized coefficient over the mean of the dependent variable and is reported for the variables which are different from zero at 1 or 5% significance levels. The symbol *** (**) denotes that the variable is significant at 1% (5%). The results correspond to the estimated coefficient and the robust standard errors.

	(1)	(2)
	Coefficient [SE]	*Economic Impact (%)*
Beneficiary minus Guarantor $_{t-1}$ / TA	932.01*** [357.42]	1.242
Interest rate derivatives held for purposes other than trading $_{t-1}$ /TA	224.71 [117.51]	
Interest rate derivatives held for trading $_{t-1}$ /TA	-8.44*** [2.79]	-1.021
Foreign exchange derivatives held for purposes other than trading $_{t-1}$ /TA	60.3 [242.19]	
Foreign exchange derivatives held for trading $_{t-1}$ /TA	102.63*** [26.09]	2.098
Equity derivatives held for purposes other than trading $_{t-1}$ /TA	105.07 [62.01]	
Equity derivatives held for trading $_{t-1}$ /TA	-145.03** [58.43]	-0.737
Commodity derivatives held for purposes other than trading $_{t-1}$ /TA	-2498.5 [2,927]	
Commodity derivatives held for trading $_{t-1}$ /TA	-18.65 [12.74]	
Constant	57.15*** [19.22]	
Control variables	Yes	
Time Effects	Yes	
Number of Observations	2947	
Number of Groups	91	
R-squared	0.4934	

Table 6: Sensitivity to the subprime crisis

This table reports the results of a variation in the baseline unbalanced panel regressions in which we distinguish the role before and during the crisis of every derivative in a separate way. The dependent variable is the individual contribution to systemic risk measured as the Net Shapley Value which is measured in basis points. Our database is formed of 91 banks and spans from 1Q2002 to 2Q2011. We estimate the coefficients by means of a Prais-Winsten robust to heteroskedasticity, contemporaneous correlation across panels. We split the holdings of derivatives in two variables: the first variable represents the holdings of derivatives up to the first quarter of 2007 and the second variable represents the holdings of credit derivatives after the first quarter of 2007. We consider the total fair value of credit (column 1), interest rate (column 2), foreign exchange (column 3), equity (column 4) and commodity (column 5) derivatives. The results presented correspond to the estimated coefficient relative to holdings of derivatives. The symbol *** (**) denotes the significance level at 1% (5%).

	(1)		(2)		(3)		(4)		(5)	
	Coefficient	*Economic Impact*	*Coefficient*	*Economic Impact*	*Coefficient*	*Economic Impact*	*Coefficient*	*Economic Impact*	*Coefficient*	*Economic Impact*
*Credit derivatives $_{t-1}$ /TA * no crisis dummy*	-115.82									
*Credit derivatives $_{t-1}$ /TA * crisis dummy*	24.16**	0.74								
Credit derivatives $_{t-1}$ /TA			42.13**	1.22	1.13	0.03	23.12		31.56***	0.91
*Interest rate derivatives $_{t-1}$ /TA * no crisis dummy*			-10.69***	-1.30						
*Interest rate derivativest-1 /TA * crisis dummy*			-12.78***	-2.32						
Interest rate derivatives $_{t-1}$ /TA	-10.65***	-1.40			-8.67***	-1.14	-10.67***	-1.41	-11.37***	-1.50
*Foreign exchange derivatives $_{t-1}$ /TA * no crisis dummy*					57.71					
*Foreign exchange derivativest-1 /TA * crisis dummy*					123.03***	4.03				
Foreign exchange derivatives $_{t-1}$ /TA	94.58***	2.07	91.75***	2.01			94.73***	2.08	93.69***	2.05
*Equity derivatives $_{t-1}$ /TA * no crisis dummy*							-65.31			
*Equity derivativest-1 /TA * crisis dummy*							-6.75			
Equity derivatives $_{t-1}$ /TA	-11.59		-45.79		-18.63				-39.84	
*Commodity derivatives $_{t-1}$ /TA * no crisis dummy*									-37.54**	-0.28
*Commodity derivatives $_{t-1}$ /TA * crisis dummy*									-13.48	
Commodity derivatives $_{t-1}$ /TA	-22.72		-26.71**	-0.28	-24.98**	-0.26	-26.17**	-0.28		
Constant	46.72**		46.79**		45.46**		44.75**		46.41**	
Control variables	Yes		Yes		Yes		Yes		Yes	
Time Effects	Yes		Yes		Yes		Yes		Yes	
Number of Observations	2947		2947		2947		2947		2947	
Number of Groups	91		91		91		91		91	
R-squared	0.4908		0.4905		0.4922		0.4906		0.4905	

Table 7: Alternative Dependent Variables

This table reports the results of a variation in the baseline unbalanced panel regression in which different specifications of the dependent variable (contributions to systemic risk) are considered while the explanatory variables employed do not change. Our database is formed of 91 banks and spans from 1Q2002 to 2Q2011. We estimate the coefficients by means of a Prais-Winsten robust to heteroskedasticity, contemporaneous correlation across panels. This table reports the results of using alternative contributions to systemic risk: (1) Net Shapley Value at the end of the quarter (baseline); (2) Net Shapley Value using the alternative approach at the end of the quarter; (3) sum of the Net Shapley Value for the corresponding quarter; and (4) Gross Shapley Value the end of the quarter. All dependent variables are measures on basis points. The results presented correspond to the estimated coefficient and the robust standard errors. The symbol *** (**) denotes that the variable is significant at 1% (5%).

	(1)	(2)	(3)	(4)
	Coefficient [SE]	*Coefficient [SE]*	*Coefficient [SE]*	*Coefficient [SE]*
Log market value $_{t-1}$	-4.16*	-4.56*	-35.82	-50.56***
	[2.51]	[2.51]	[27.72]	[14.09]
Log of squared market value $_{t-1}$	0.09	0.1	0.52	1.36***
	[0.08]	[0.08]	[0.92]	[0.45]
Commercial paper $_{t-1}$ */TA*	30.62	21.28	551.55	126.32
	[31.56]	[31.72]	[346.68]	[119.26]
Loan to banks $_{t-1}$ */TA*	19.71	27.56	181.18	613.85***
	[44.78]	[45.01]	[514.13]	[161.47]
Total loans $_{t-1}$ */TA*	9.67***	9.97***	110.01***	44.83***
	[2.84]	[2.86]	[32.80]	[14.29]
Non-interest to interest income $_{t-1}$	0.79	0.92	10.47	-1.51
	[0.83]	[0.83]	[7.80]	[2.24]
Correlation with S&P500 $_{t-1}$	2.36	2.35	75.40**	-2.96
	[2.89]	[2.89]	[35.22]	[12.94]
Net balance to bank $_{t-1}$ */TA*	477.97***	447.92***	6,174***	2,015***
	[95.60]	[92.88]	[1,162]	[505.89]
Net balance to non-bank $_{t-1}$ */TA*	-23.38	-29.04	-309.18	-133.57
	[17.40]	[17.74]	[200.89]	[82.80]
Leverage $_{t-1}$	0.15***	0.14***	2.43***	0.67***
	[0.04]	[0.04]	[0.51]	[0.23]
Maturity mismatch $_{t-1}$	0.21	1.2	-15.88	28.75**
	[2.62]	[2.65]	[32.46]	[11.58]
Total deposits $_{t-1}$ */TA*	-18.16***	-18.41***	-272.39***	-91.69***
	[3.47]	[3.47]	[38.30]	[13.23]
Non-performing loans $_{t-1}$ */Total loans*	136.40***	136.01***	1,589***	621.52***
	[44.56]	[44.18]	[473.29]	[208.39]
Aggregate systemic risk measue $_{t-1}$	67.13***	67.34***	217.16***	-81.61***
	[16.82]	[16.91]	[47.27]	[15.53]
Aggregate systemic risk measue $_{t-2}$	-27.54*	-28.04*	-82.16*	35.82**
	[16.51]	[16.59]	[44.88]	[15.67]
Credit derivatives $_{t-1}$ */TA*	34.33***	34.09***	519.29***	157.80***
	[8.22]	[8.26]	[115.95]	[35.51]
Interest rate derivatives $_{t-1}$ */TA*	-11.51***	-11.52***	-145.13***	-79.00***
	[2.78]	[2.78]	[35.40]	[12.78]
Foreign exchange derivatives $_{t-1}$ */TA*	93.58***	95.98***	1,096***	491.97***
	[24.68]	[24.79]	[235.50]	[94.39]
Equity derivatives $_{t-1}$ */TA*	-39.55	-33.33	-525.38	57.15
	[43.21]	[43.06]	[511.51]	[224.77]
Commodity derivatives $_{t-1}$ */TA*	-26.29**	-26.08**	-413.13**	-223.01***
	[12.36]	[12.38]	[170.97]	[66.36]
Constant	46.06**	49.83**	526.94**	516.99***
	[19.82]	[19.78]	[215.78]	[110.02]
Time Effects	Yes			
Number of Observations	2947	2947	3038	2947
Number of Groups	91	91	91	91
Min. Observations per Group	13	13	14	13
Avg. Observations per Group	33.2	33.2	33.4	33.2
Max. Observations per Group	36	36	37	36
R-squared	0.4904	0.4907	0.5795	0.4252

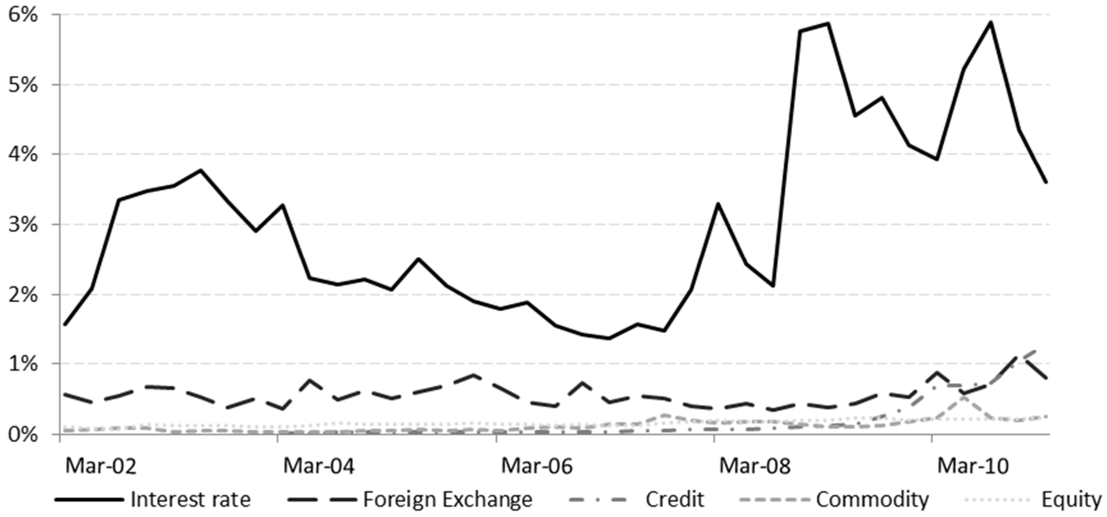

Figure 1: Banks' holdings of derivatives relative to total assets. This figure depicts the average ratio across banks of the fair value of derivatives holdings relative to total assets. The figure includes the following types of derivatives: interest rate, foreign exchange, credit, equity and commodity. The ratio is reported in percentages.

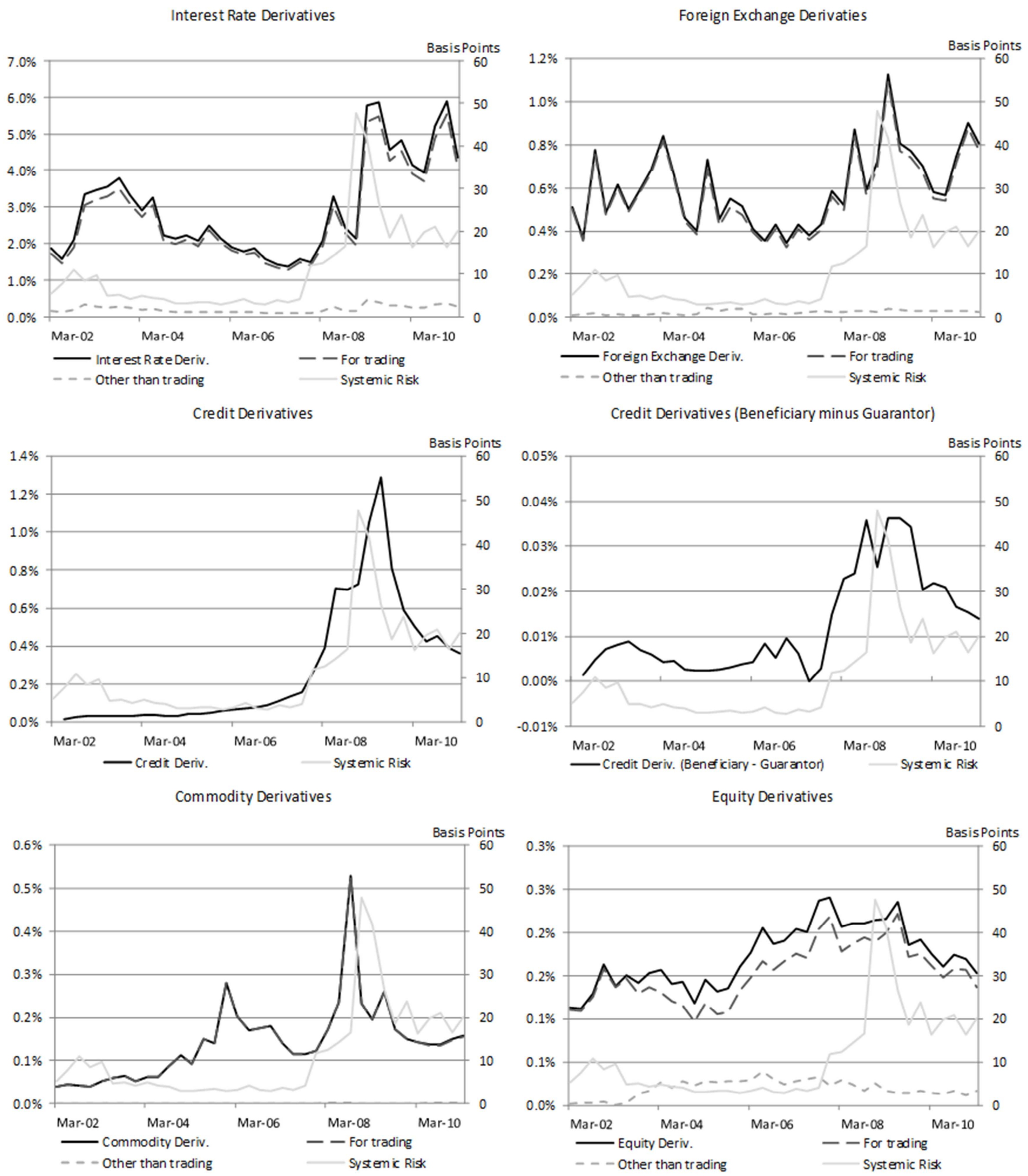

Figure 2: Systemic risk measure and banks' holdings of derivatives held for trading and for purposes other than trading relative to total assets. This figure depicts the average ratio across banks of the fair value of derivatives held for trading and for purposes other than trading relative to total assets (in percentages) in addition to the banks' average contribution to systemic risk (in basis points). The systemic risk measure is the average Net Shapley value across the 91 bank holdings (right axis). The figure includes the following types of derivatives (by order of appearance): interest rate, foreign exchange, credit, equity and commodity. In the case of credit derivatives, we report the average holdings relative to total assets and the average difference between the fair value of credit derivatives in which the banks act as beneficiary (buy protection) and those in which they act as guarantor (sell protection). The series corresponding to the average bank holdings of derivatives are lagged one period (*t-1*) and the systemic risk measure is depicted at period *t* such as they appear in the paper regressions.