DERIVATIVES HOLDINGS AND SYSTEMIC RISK IN THE U.S. BANKING SECTOR

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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, connectedness, substitutability, and other balance sheet information. Using a sample of 91 U.S. bank holding companies from 2002 to 2011, we compare six measures of systemic risk and find that the Net Shapley Value outperforms the others. Then, using this measure of systemic risk as the dependent variable, we find that the fair value of banks' holdings, for trading purposes, of foreign exchange derivatives in a given quarter increase the banks' subsequent individual contributions to systemic risk whereas these holdings of interest rate and equities as well as the total position in commodities derivatives decrease the banks' contribution to systemic risk. Bank's holdings of credit derivatives increase its contribution to systemic risk when the bank is net protection buyer. While foreign exchange derivatives increase and interest rate, equity and commodities derivatives decrease systemic risk in all time periods, we find that before the subprime crisis credit derivatives decreased systemic risk whereas after the crisis increased it. Therefore in the wake of the subprime crisis credit derivatives seemed to change their role from shock absorbers to shock issuers.

Keywords: Systemic risk; derivatives; Shapley value

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1. Introduction

Since the beginning of the current financial and economic crisis, the concern about systemic risk has increased up to becoming one of the priorities of the regulatory authorities. These authorities have 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 be in charge of identifying systemic risk, preventing regulatory loopholes, and making recommendations jointly with existing regulatory authorities. The concerns about systemic risk have also been extended to the 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 analyze and understand the determinants of the banks' contribution to systemic risk. This information would help them 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 banks' impact on systemic risk. Additionally, securities markets 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.

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 hedging purposes justified by theory supporting the rationality of hedging decisions at the 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 the individual level, see Jaffe (2003) among others. However, another substantial proportion of this growth is due to the proprietary trading activities by banks. Both activities, hedging and trading, are regarded by banks as potentially useful and profitable. However, it is well known that financial decisions that are rational at the individual level can have negative consequences at the level of the system. 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 is indeed 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 some 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 measure the banks' contributions to systemic risk we use the following six approaches: ΔCoVaR, ΔCoES, Asymmetric ΔCoVaR, Realized Systemic Expected Shortfall (SES), 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 Moreno, Rubia and Valderama, 2011). The Realized SES measures the propensity of bank *i* to be undercapitalized when the whole system is undercapitalized (see Acharya, Pedersen, Philippon and Richardson, 2011 a, b). 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). The NSV is obtained by subtracting from the GSV the VaR of the bank *i.*

We estimate the six previous measures for a subset of the 91 biggest U.S. bank holding companies for the period from 2002 to 2011. We then compute the correlation of the systemic risk measures with an index of systemic events and find that the NSV presents the closest association with the index.

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 period *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 commodities derivatives have a decreasing effect.
3. No. Derivatives held for trading have usually a significant effect, either positive (foreign exchange) or negative (interest rate, commodities) 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 foreign exchange, interest rate, equity and commodities derivatives influence systemic risk in all time periods in the same way.

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 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.

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 six measures: (i) ΔCoVaR, (ii) ΔCoES, (iii) Asymmetric ΔCoVaR, (iv) Realized SES, (v) Gross Shapley Value (GSV) and (vi) Net Shapley Value (NSV). The details about the characteristics and the estimation of the systemic risk measures can be found in Appendix A.2.

To rank the six measures we use an influential event variable (IEV) as in Rodriguez-Moreno and Peña (2011). This is a categorical variable that captures the main events observed and policy actions taken during the financial crisis. 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 $j = 1, \dots, 6$ and $i = 1, \dots, 91$) and then estimate the McFadden R-squared. Next, we compute the average McFadden R-squared across banks and select the measure with the highest goodness of fit. Details on the procedure to compare the systemic risk measures can be found in Appendix A.3.

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 perform a very similar output for different banks independently of the bank risk profile. To give an example, the estimation of CoVaR for every bank *j* (equations A.2.1.1-A.2.1.3) is conducted 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 *j* as explanatory variables. By conducting the quantile regression analysis we find that the coefficient of the market value of total financial assets of bank *j* is significant in 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=0.50). For this reason, we expect strong similarities across banks in terms of this systemic risk measure.[2]

Regarding the GSV, this measure for bank *j* considers the VaR of bank *j* as an additional element in estimating the individual contribution to systemic risk. The main drawback is that in non-stress periods (where the individual contribution to system risk is negligible due to the lack or systemic risk) this measure is governed by the evolution of the VaR of bank *j* which is a measure of the individual risk.[3]

In order to solve the drawback of the previous measure, we consider an alternative measure which is net of the impact of the individual value-at-risk (Net Shapley Value).

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[2] To quantify the strength of those similarities, for every considered measure we estimate pairwise correlation for the possible combinations of the 91 banks and find that the average correlation account to 0.98, 0.94 and 0.95 for the ΔCoVaR, ΔCoES and asymmetric CoVaR, respectively. These average correlation drop to 0.80 and 0.70 for the NSV and GSV measures, respectively.

[3] To show the magnitude 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 equal to 0.98 while this correlation drops to 0.75 using the NSV.

2.2. DETERMINANTS OF SYSTEMIC RISK

We implement a panel regression analysis in which we regress the individual bank *i*'s contribution to systemic risk in quarter *t* 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 the literature regarding the role of derivatives holding and their possible connections with systemic risk:

(1) The first question to ask is whether the banks' holdings of financial derivatives contribute to systemic risk. If this is indeed the case, then many other important questions spring to mind.

(2) The next obvious question to ask is whether this relationship is uniform across derivatives classes or there are differences in impact between foreign exchange and interest rates derivatives, say.

(3) Given that our databases allow us to distinguish between derivatives held for trading and for other purposes, the next question to ask is whether the impact on systemic risk is the same irrespective of the derivative being held for trading or for other purposes. This is important because derivatives held, possibly, for hedging reasons should decrease overall bank's risk whereas trading in derivatives may expose banks to additional sources of risk.

(4) Given the abrupt change in market conditions since July 2007 a pressing question is to study whether the relationship between derivatives 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, see Greenspan, 2005) 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 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 to whether this is indeed the case helps to understand the actual role of these controversial instruments.

(6) Additionally to the central focus in our paper, it seems natural to ask what other balance-sheet asset items are significant contributors to systemic risk, and in particular which are the ones with 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.[4] 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.

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

Our data set is composed by U.S. bank holding companies with total assets above $5billions 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 period or in the ongoing crisis period. Additional filters are banks for which we have information on their stock prices, banks that held at least one of the types of derivatives analyzed in this paper, and, we exclude banks that made default or were acquired before 2007.[5] Our final sample consists of quarterly information for 91 bank holding companies from March 2002 to June 2011.

Table 1 contains the identity of the 91 banks and some 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.1):

BANKS HOLDINGS OF DERIVATIVES

We consider five types of derivatives: credit, interest rate, foreign exchange, equity, and commodity. The effect of the holdings of derivatives on the banks contributions to systemic risk are studied on the basis of their total fair value (positive plus negative fair values) instead of their notional amount.[6] The use of the total fair value allow us to control for the total expositions to the derivatives counterparties which, at the same time, allow us to control by counterparty risk.[7,8]

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5 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.

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

7 Unlike in other securities, derivatives involve two possible positions and positive fair values mean negative fair values on the counterparty. Positive fair values are the sum of the total fair values of treatment of the underlying asset, to be recognized in the balance-sheet as either liabilities (negative fair value) or assets (positive fair values). According to the Dodd-Frank Act, the required information to private funds advised by investment advisers to guarantee a well monitoring of systemic risk in securities markets includes: amount of assets under management and use of

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 which are held for purposes other than trading. 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).

Previous literature suggests the possible role of credit derivatives as determinant of systemic risk; see Stulz (2004) and Acharya (2011). Moreover, the potential hedging offered by derivatives could also lead to banks to take more risk on the underlying asset which could destabilize the banking sector if markets are not perfectly competitive (Instefjord, 2005).

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 the convex, and that a positive relationship between size and systemic importance is a robust result. However, in our sample and given that the banks are all of considerable size the effect of this variable need not to be especially relevant because it has been a criterion for sample selection. The logarithm of the market capitalization (share price multiplied by the number of ordinary shares in issue) is used as the proxy for the size. This is a common practice in the finance (e.g. Ferreira and Laux, 2007) and the accounting (e.g. Bhen, Choi, and Kang, 2008) literature. We use market value instead of total assets to avoid any collinearity problem because the banks' total assets have been employed to define and standardize most of the variables. We add the squared of the size variable to our regression to control by any potential non-lineal relation between size and systemic risk.

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leverage, trading and investment positions, types of assets held, or trading practices, among others contracts.

[8] 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 or positive fair values.

INTERCONNECTEDNESS AND SUBSTITUTABILITY

Interconnectedness measures the degree at 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 the potential failed institutions. These two concepts are not easy to measure and there are scarce evidence quantifying their effects on systemic risk or banks contributions to 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, both dimensions could be grouped in a more general group: correlation of the bank with the financial sector and economy.

To control by these dimensions we employ several variables that could be more related to the interconnectedness dimensions and other more related to the substitutability dimensions. In the former 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 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).

We relate substitutability to the services that are provided by the banks and 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 as proxy for the non-core or non-traditional activities such as trading and securitization, investment banking, brokerage or advisory activities among others, 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) relative to total assets represent the bank core or traditional activities. We distinguish between loans to the financial system and the rest of the loans to study whether they have different effects on systemic risk. Finally, we use the ratio of the bank's commercial paper relative to total assets as a proxy for the activities through the payment and settlement system given that we do not have information on the interbank lending. As Cummins and Weiss (2010) state, the inter-bank lending and commercial paper markets were critical because there were no other significant sources of short-term credit for the shadow banks. These variables could also indicate to some extent the degree of interconnectedness of a given bank given that the larger the amount of loans the larger is the expositions of a given bank to their borrowers. The difficulty for defining proxies related to the bank degree of substitutability could be one of the reasons explaining the low number of studies quantifying the effect of this dimension on systemic risk.[9] We define the variables referred to interconnectedness relative to the bank total assets because otherwise it could mainly reflect size.

BALANCE-SHEET INFORMATION

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

One of the dimensions proposed by Acharya, Pedersen, Philippon, and Richardson (2011b) is leverage. It is not straightforward to measure the true leverage due to the limited market data in breaking down off- and on-balance-sheet financing. Our measure is:

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

[9] There is at least 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 Cummins and Weiss (2010) 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 we expect a positive effect of the substitutability dimension on the bank contribution to systemic risk.

As pointed out by Acharya and Thakor (2011) higher bank leverage creates stronger creditor discipline at individual bank level but it also creates greater levels of systemic risk. However, some empirical analyses have found a non-significant effect of leverage on systemic risk (see Brunnermeier et al., 2011; or López, Moreno, Rubia, and Valderrama, 2011). Mizrach (2011) shows that leverage as conventionally measured was not a reliable 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 with deposits taking are associated with a lower contribution to systemic risk. Total deposits could contribute to decrease systemic risk because they offer a better capacity of reaction to a shock.

Regarding the ratio of non-performing loans relative 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.

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. The interest rate derivatives, and foreign exchange derivatives, by this order, are the most frequent categories of assets in the banks portfolios. 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) what suggests a large interconnectedness of the banking system with the main industrial firms. 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 the 10%. Finally, regarding 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 is. 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 conduct the regression detailed in equation A.3.2 in Appendix A.3 on a weekly basis to rank the systemic risk measures. Panel B of Table 4 contains the average McFadden R-squared. Comparing the five weekly measures, we observe that the highest average McFadden R-squared is obtained by the NSV measure (0.21), followed by GSV (0.16), and the asymmetric CoVaR, ΔCoVaR and ΔCoES (0.14, 0.14 and 0.12, respectively).[10] Therefore our choice for the measure of systemic risk is NSV.

[10] Note that realized SES measure cannot be considered in this analysis because, by definition, it is a quarterly measure.

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

We address the first, second and sixth research questions 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 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. 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 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 in 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. Finally, the aggregate level systemic risk one quarter ago contributes positive and significantly to increase systemic risk but the effect of aggregate systemic risk does not go beyond one quarter before the current one.[11]

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 purposes other than trading using two different variables. In the case of credit derivatives we use the difference between the fair values of the holdings of credit derivatives in which the bank is the beneficiary (buys protection) and the holdings in which the bank is the 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 affect systemic risk and to a lesser extent the same applies to equity derivatives. We observe that as the bank acts as a net beneficiary when participating in the credit derivatives markets, its contribution to systemic risk increases. A bank acting as a beneficiary is exposed to counterparty risk. The concern of heightened counterparty risk around the Lehman Brothers collapse could explain this effect. Thus, this result may suggest the low quality of the protection purchased during the crisis period due to the high uncertainty about the potential default of the counterparties.

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

[11] 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.

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 analyzing the role of every derivative before and during the crisis in a separate way. We observe a negative effect of the holdings of credit derivatives on systemic risk before the subprime crisis but a positive and significant effect during the crisis which gives evidence in favor of the 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 the holdings of interest rates derivatives 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 commodities hedged systemic risk in both periods but only significantly so before the crisis.

5. Robustness Test

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

Alternative Indicators of Systemic Risk

We first test whether the results are influenced by the systemic risk indicators employed in our analysis or whether they are consistent for different definitions and estimations of systemic risk. Thus, we estimate the baseline regression in equation 1 for four additional systemic risk measures. The first two additional measures are related to the NSV. Thus, we first consider an alternative specification of the NSV in which we include an additional synthetic bank constructed as the weighted average of the remaining banks that are not used to estimate the measure (column 2).[12] 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

[12] See Section A.2.3 of Appendix A.2 for further details on this measure.

correspond to the GSV (column 4), and the fourth one is the realized SES (column 5). Results are reported in table 7.[13]

Comparing columns 1 and 2, we find similar results for both definitions of the NSV. Therefore, our results are robust to use the largest banks (column 1) or all banks (column 2) to define 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), we find similar results to the ones obtained for the baseline specification but some differences should be mentioned. The explanatory power of the regressors decreases for this specification (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.

For the realized SES specification we observe a very similar explanatory power of the regressors to the one obtained in the baseline specification. In general terms the signs are in agreement with the ones reported in column 1 but some differences are worth noting. The size now exhibits a significant concave shape in agreement with the results obtained by Brunnermeier et al. (2011). Loans to banks and depositary institutions, balances due to non-bank subsidiaries and maturity mismatch are now positive and significant. However, the leverage, the non-performing loans, and the holdings of commodity derivatives are not significant at any standard significance level.

Alternative Explanatory Variables

As in Brunnermeier et al. (2011) we also control by the lagged level of bank risk using the VaR instead of by the aggregate level of systemic risk one period ago. The VaR is defined in positive terms. In this case, the R-squared increases from 0.49 to 0.53. The effect of this variable is positive and significant at any standard level of significance. The signs and levels significance of the remaining explanatory variables are similar to

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[13] Regarding the co-risk measures, at the sight of the arguments posed on sections 2.1 and 4.1, we decide not to conduct robustness tests with them.

the ones in the baseline regression. Our results are robust to the use of the bank's VaR to control by the level of risk one quarter ago.

To control by the degree of concentration in the banking sector we include the Herfindahl-Hirschman index variable referred to the banks total assets. This variable has a non-significant effect at any standard level of significance and both the coefficients and levels of significance of the explanatory variables do not change with respect to the ones obtained in the baseline regression. [14]

6. CONCLUSIONS

The recent financial crisis has exposed the dangers lurking in the 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 the banks' balance-sheets. To address the extent to which this situation has increased systemic risk is the goal of this paper.

Using the Net Shapley Value as our proxy for systemic risk we find strong evidence of derivatives holding acting as leading indicators of systemic risk contributions. However their effects are not alike because credit and foreign exchange derivatives have an increasing effect on systemic risk whereas holdings of interest rate and commodities derivatives have a decreasing 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 commodities derivatives influence systemic risk in all time periods in the same way.

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

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

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.

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 with the 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 actually had 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 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.

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APPENDIX A.1

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.[15]

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.[16]

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: this variable is the difference between all balances and cash due to related banks[17] 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.[18]

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

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[15] 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).

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

[17] 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.

[18] 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.

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.

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 A.2

This appendix contains the details on the estimation of the six systemic approaches that we consider in this paper. The systemic risk measures (with the exception of the realized SES) 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.

A.2.1 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.[19] *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:

$$\begin{aligned} X_t^i &= \alpha^i + \gamma^i M_{t-1} + \varepsilon_t^i \\ X_t^{system} &= \alpha^{system|i} + \beta^{system|i} X_t^i + \gamma^{system|i} M_{t-1} + \varepsilon_t^{system|i} \end{aligned} \qquad (A.2.1.1)$$

where M_t^i is a set of state variables.[20] 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 A.2.1.1 have been estimated through quantile regression, we replace them into equation A.2.1.2 to obtain the *VaR* and *CoVaR*.

$$\begin{aligned} VaR_t^i(q) &= \hat{\alpha}_q^i + \hat{\gamma}_q^i M_{t-1} \\ CoVaR_t^i(q) &= \hat{\alpha}_q^{system|i} + \hat{\beta}_q^{system|i} VaR_t^i(q) + \gamma_q^{system|i} M_{t-1} \end{aligned} \qquad (A.2.1.2)$$

[19] 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.

[20] 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.

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., $q = 0.5$)

$$\Delta CoVaR_t^i(1\%) = CoVaR_t^i(1\%) - CoVaR_t^i(50\%) \quad (A.2.1.3)$$

On the basis of equation A.2.1.3 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.

A.2.2 Asymmetric CoVaR

López, Moreno, Rubio and Valderrama (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:

$$\begin{aligned} X_t^i &= \alpha^i + \gamma^i M_{t-1} + \varepsilon_t^i \\ X_t^{system} &= \alpha^{system|i} + \beta^{+system|i} X_t^i I_{(X_t^i \geq 0)} + \beta^{-system|i} X_t^i I_{(X_t^i < 0)} + \gamma^{system|i} M_{t-1} + \varepsilon_t^{system|i} \end{aligned} \quad (A.2.2.1)$$

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 A.2.2.1 is estimated using quantile regression at 1%. Then, $CoVaR_t^i$ is estimated according to equation A.2.2.2:

$$\begin{aligned} VaR_t^i(q) &= \hat{\alpha}_q^i + \hat{\gamma}_q^i M_{t-1} \\ CoVaR_t^i(q) &= \hat{\alpha}_q^{system|i} + \hat{\beta}_q^{-system|i} VaR_t^i(q) + \gamma_q^{system|i} M_{t-1} \end{aligned} \quad (A.2.2.2)$$

A.2.3 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,

$$GSV_i = \frac{1}{N} \sum_{n_s=1}^{N} \left[\frac{1}{c(n_s)} \sum_{\substack{S \supset i \\ |S| = n_s}} (\vartheta(S) - \vartheta(S - \{i\})) \right] \quad (A.2.3.1)$$

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).[21] This modification 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 and alternative way in which the system (16 banks) is composed by 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 *miscellaneous* bank, we take all the available information of the system (including the information contained in the small banks) but we create a. This alternative approach will be considered as a robustness test.

A.2.4 NET SHAPLEY VALUE OF VALUE-AT-RISK

We now extend the expression for the GSV for a given bank *i* as presented in equation A.2.3.1 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 ($n = 1, \dots, 4$). The possible subsystems and the GSV when we study the contribution of bank 1 to the risk of the economy would be:

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

$$
\begin{aligned}
GSV_1 = \frac{1}{4}\Big[& VaR(\{1\}) + \frac{1}{3} \\
& * \Big(\big(VaR(\{1,2\}) - VaR(\{2\})\big) + \big(VaR(\{1,3\}) - VaR(\{3\})\big) \\
& + \big(VaR(\{1,4\}) - VaR(\{4\})\big)\Big) + \frac{1}{3} \\
& * \Big(\big(VaR(\{1,2,3\}) - VaR(\{2,3\})\big) + \big(VaR(\{1,2,4\}) - VaR(\{2,4\})\big) \\
& + \big(VaR(\{1,3,4\}) - VaR(\{3,4\})\big)\Big) \\
& + \big(VaR(\{1,2,3,4\}) - VaR(\{2,3,4\})\big)\Big] \quad (A.2.4.1)
\end{aligned}
$$

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

[21] 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.

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:

$$NSV_i = GSV_i - \frac{1}{N} VaR_i \qquad (A.2.4.2)$$

A.2.5 Realized Systemic Expected Shortfall

The analytical expression of SES is the result of the combination of a theoretical model (which allow them to select the variables) with the standard management tool ES and takes the form,

$$SES^i = E\left[za^i - \varpi_1^i | W_1 < zA\right] \qquad (A.2.4.1)$$

where ϖ_1^i refers to the amount of equity capital, za^i refers to the target level that is, a fraction z of the total assets a^i. $W_1 < zA$ refers to the systemic event in which the whole system is undercapitalized because the aggregate banking capital (W_1) is bellow z times the aggregate assets of the banking system (A).

Note that setting the threshold capital z of equation 5 is challenging and implies strong assumption (i.e., z should be set every quarter at sector level instead of at individual level). Therefore, at this point we opt to follow Brunnermeier et al. (2011) who construct the realized SES measure as the stock return of financial institution i during the worst 5% market return days at calendar quarter t (we consider the MSCI value weighted as the reference for the market).

Appendix A.3

In this appendix we describe the methodology employed to compare the different systemic risk measures described in Appendix A.2. This comparison is carried out using the Rodriguez-Moreno and Peña's (2011) approach on the basis of an influential event variable (IEV). This is a categorical variable that captures the main events and political actions that have occurred during the financial crisis where the selected events and political actions are based on the Federal Reserve Bank of St. Louis' crisis timeline.[22] The IEV takes value 1 whenever there is an event, under the hypothesis that those events should increase systemic risk variables; and -1 whenever there is a political action, under the hypothesis that political actions should decrease systemic risk variables. Otherwise it takes value zero.

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

For each bank j 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 i for bank j (where $i = 1, \dots, 6$ and $j = 1, \dots, 91$) and then estimate the McFadden R-squared.

$$R^2 = 1 - \frac{ln\hat{L}(M_{Full})}{ln\hat{L}(M_{Intercept})} \quad (A.3.1)$$

where M_{Full} refers to the full model and $M_{Intercept}$ to the model without predictors, and $\hat{L}$ is the estimated likelihood.[23]

Next, we compute the average McFadden R-squared across banks and select the measure with the highest goodness of fit.[24] By doing that, we avoid penalizing those measures that provide leading information. We also avoid penalizing those events or political actions which have been discounted by the market before the event week. After that, we compute the average McFadden R-squared for each variable and bank. Finally, we choose those variables that provide better average fit.

$$IEV_t = \alpha + \beta SystemicRiskMeasure_{i,j,t-k} + \varepsilon_t \quad (A.3.2)$$

where i refers to the considered measure (i.e., NSV, GSV, $\Delta CoVaR$, $\Delta CoES$ and asymmetric $\Delta CoVaR$), j refers to bank under analysis ($j = 1, \dots, 91$) and k refers to the number of considered lags in the regression.

[23] 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.
[24] Results do not change when other lags are considered.

TABLES

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. Panel A reports the descriptive statistics of six systemic risk measures in basis points: Net Shapley value (NSV), Gross Shapley Value (GSV), Co-risk measures (ΔCoVaR and ΔCoES), asymmetric ΔCoVaR, and realized systemic expected shortfall (SES). For the first five measures quarterly measures are calculated as the last week of the corresponding quarter while for the realized SES approach quarterly measures are estimated as the average stock return of financial institution i during the worst 5% market return days at calendar quarter t. Panel B reports the average McFadden R-squared for the following systemic risk measures: (1) Net Shapley Value; (2) Gross Shapley Value; (3) ΔCoVaR; (4) ΔCoES; (5) asymmetric ΔCoVaR. For each systemic risk measure and bank, we compute multinomial regressions in which we modify the number of lags of the independent variable up to two weeks. Then we calculate the average of the McFadden R-squared for each measure.

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
Realized SES	268.94	186.84	262.50	3469.47	-907.93	3154

Panel B

	Net Shapley value	*Gross Shapley value*	*Delta co-value-at-risk*	*Delta co-expected-shortfall*	*Asymmetric Delta co-value-at-risk*
Average McFadden R-squared	0.2072	0.1610	0.1368	0.1162	0.1371

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 by 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)	(2)	(3)
	Coefficient [SE]	*Standardized coefficient*	*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 (IR), foreign exchange (FE), equity (EQ) and commodity (CO) 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 basis points. Our database is formed by 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 by 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 by 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; (4) Gross Shapley Value the end of the quarter; and (5) realized SES. 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)	(5)
	Coefficient *[SE]*	*Coefficient* *[SE]*	*Coefficient* *[SE]*	*Coefficient* *[SE]*	*Coefficient* *[SE]*
Log market value $_{t-1}$	-4.16	-4.56	-35.82	-50.56***	194.82***
	[2.51]	[2.51]	[27.72]	[14.09]	[65.45]
Log of squared market value $_{t-1}$	0.09	0.1	0.52	1.36***	-6.52***
	[0.08]	[0.08]	[0.92]	[0.45]	[2.11]
Commercial paper $_{t-1}$ /TA	30.62	21.28	551.55	126.32	-761.09
	[31.56]	[31.72]	[346.68]	[119.26]	[717.99]
Loan to banks $_{t-1}$ /TA	19.71	27.56	181.18	613.85***	3,414***
	[44.78]	[45.01]	[514.13]	[161.47]	[1,276]
Total loans $_{t-1}$ /TA	9.67***	9.97***	110.01***	44.83***	189.79***
	[2.84]	[2.86]	[32.80]	[14.29]	[56.59]
Non-interest to interest income $_{t-1}$	0.79	0.92	10.47	-1.51	-20.26
	[0.83]	[0.83]	[7.80]	[2.24]	[13.13]
Correlation with S&P500 $_{t-1}$	2.36	2.35	75.40**	-2.96	-55.12
	[2.89]	[2.89]	[35.22]	[12.94]	[62.81]
Net balance to bank $_{t-1}$ /TA	477.97***	447.92***	6,174***	2,015***	6,438***
	[95.60]	[92.88]	[1,162]	[505.89]	[2,179]
Net balance to non-bank $_{t-1}$ /TA	-23.38	-29.04	-309.18	-133.57	1,356***
	[17.40]	[17.74]	[200.89]	[82.80]	[450.30]
Leverage $_{t-1}$	0.15***	0.14***	2.43***	0.67***	-0.17
	[0.04]	[0.04]	[0.51]	[0.23]	[0.72]
Maturity mismatch $_{t-1}$	0.21	1.2	-15.88	28.75**	103.61
	[2.62]	[2.65]	[32.46]	[11.58]	[54.38]
Total deposits $_{t-1}$ /TA	-18.16***	-18.41***	-272.39***	-91.69***	-348.73***
	[3.47]	[3.47]	[38.30]	[13.23]	[58.36]
Non-performing loans $_{t-1}$ /Total loans	136.40***	136.01***	1,589***	621.52***	680.48
	[44.56]	[44.18]	[473.29]	[208.39]	[863.51]
Aggregate systemic risk measue $_{t-1}$	67.13***	67.34***	217.16***	-81.61***	115.71***
	[16.82]	[16.91]	[47.27]	[15.53]	[18.34]
Aggregate systemic risk measue $_{t-2}$	-27.54	-28.04	-82.16	35.82**	-37.36**
	[16.51]	[16.59]	[44.88]	[15.67]	[18.58]
Credit derivatives $_{t-1}$ /TA	34.33***	34.09***	519.29***	157.80***	877.33***
	[8.22]	[8.26]	[115.95]	[35.51]	[245.29]
Interest rate derivatives $_{t-1}$ /TA	-11.51***	-11.52***	-145.13***	-79.00***	-206.16***
	[2.78]	[2.78]	[35.40]	[12.78]	[69.66]
Foreign exchange derivatives $_{t-1}$ /TA	93.58***	95.98***	1,096***	491.97***	1,857***
	[24.68]	[24.79]	[235.50]	[94.39]	[406.81]
Equity derivatives $_{t-1}$ /TA	-39.55	-33.33	-525.38	57.15	812.41
	[43.21]	[43.06]	[511.51]	[224.77]	[1,137]
Commodity derivatives $_{t-1}$ /TA	-26.29**	-26.08**	-413.13**	-223.01***	-514.19
	[12.36]	[12.38]	[170.97]	[66.36]	[362.75]
Constant	46.06**	49.83**	526.94**	516.99***	-1,324***
	[19.82]	[19.78]	[215.78]	[110.02]	[498.68]
Time Effects			Yes		
Number of Observations	2947	2947	3038	2947	3038
Number of Groups	91	91	91	91	91
R-squared	0.4904	0.4907	0.5795	0.4252	0.4967