Is systemic risk pro-cyclical?

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January 15, 2017

Abstract

This paper investigates the pro-cyclicality of systemic risk, defined according to Brownlees and Engle (2012) as SRISK. Using a sample of US Bank Holding Companies over the period 2006-2016, we show that leverage pro-cyclicality translates into systemic risk: banks become more interconnected during booms and decrease their degree of interconnection during bursts. Moreover, using structural equations to tackle the interplay between systemic risk and leverage, we show that the level of systemic risk pro-cyclicality differs among four groups of banks identified in terms of liquidity and capital shortage. Banks that had access to the liquidity facilities activated by the Federal Reserve (e.g. Discount Window and Term Auction Facility) show a higher degree of pro-cyclicality of systemic risk; this is motivated by their lower cost of financing that allows them to increase debt at least in the short-run. Banks approaching or below the regulatory capital threshold (e.g. banks under regulatory pressure) and banks that participated in the Capital Purchase Program (CPP) show a lower degree of pro-cyclicality of systemic risk. Finally, banks with the status of TBTF unexpectedly show no difference in the degree of pro-cyclicality of systemic risk with respect to the baseline group.

JEL Classification Numbers: G21, G18, G28, E58.

Keywords: banks, Federal Reserve, LOLR, pro-cyclicality, SIFIs, systemic risk.

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1 Introduction

The recent financial crisis has shown how strong is the linkage among the real and financial sector. A vast amount of literature highlighted how periods of economic booms are forerun by unexpected growth in lending and how the opposite happens during crisis: a phenomenon known as pro-cyclicality of credit (Berger and Udell, 2004; Bikker and Metzemakers, 2005; Bertay et al., 2015; Gambacorta and Mistrulli, 2004). Moreover, under Basel II capital framework, both empirical and theoretical papers shown that the source of pro-cyclicality in lending arises (among others) from current capital requirements (Andersen, 2011; Repullo and Suarez, 2013). During recessions, when the value of equity decreases because losses erode bank's capital, banks might either increase capital or reduce risk-weighted assets in order to satisfy more stringent capital requirements. Even if the decision is twofold, difficulties faced by banks in raising capital during crises and debt-overhang hypothesis lead them to reduce their main assets via credit rationing. Thus, as stressed by the BCBS and FSF (2009), in order to mitigate this source of pro-cyclicality, Basel III introduced counter-cyclical capital requirements.

In addition to the pro-cyclicality of credit, recent literature has investigated the interaction between the asset and liability side via the so-called leverage pro-cyclicality (Fostel and Geanakoplos, 2008; Adrian and Shin, 2010b; Huizinga and Laeven, 2012; Baglioni et al., 2013; Damar et al., 2013; Beccalli et al., 2015; Amel- Zadeh et al., 2015; Acharya and Ryan, 2016). Along different time periods and different countries, banks (especially investment banks) are shown not to use a passive management for leverage; instead, they are increasingly shifting towards active management and pro-cyclical behaviours, that means to amplify the asset side via more debt during booms (and contracting it, via deleveraging, during burst). The milestone in this field are the findings from Adrian and Shin (2010, 2013): when assets are evaluated at *fair value* an increase in market price would decrease "quasi-market leverage ratio"[1] and, for those banks which operate through leverage or VaR targeting, this leaves room to build up debt. Their empirical findings show that banks' balance sheets expand by borrowing more during booms and contract during bursts (leverage is pro-cyclical). Furthermore, the recent financial crisis has drawn our attention on another phenomenon: the degree of interconnection among banks and their systemic dimension. Particularly, a bank is considered "systemic" when its distress or failure may threat the financial stability and impairs the functioning of the financial system as a whole with significant adverse effects on the broader economy (Freixas et al., 2015). As long as the increase in the value of assets makes banks larger and more interconnected (i.e. via an increase in the interbank debt) and banks do not completely internalise costs of their fragilities it is worthwhile studying implications of leverage procyclicality on systemic risk. That is, active management of leverage might create a negative externality and this fragility may propagate among banks decreasing overall stability. During the last decade both micro- and macro-prudential regulation become highly active on this topic identifying some banks as Systemically Important Financial Institutions (SIFIs), monitoring these banks via stress test (SCAP in the US), considering pro-cyclical capital requirements, limiting banks' activities and increasing the transparency of information (Dodd-Frank Act).

Following the evidence on leverage pro-cyclicality and the attention devoted by regulators to systemic banks, the main contribution of this paper is to show that the pro-cyclical behaviour of banks does not concern just their leverage but also their degree of interconnectedness with the financial system and their systemic contribution within the financial sector (i.e. pro-cyclicality of systemic risk). Moreover, we differentiate among four groups of banks characterized by either liquidity or capital shortage to investigate

[1] Quasi-market leverage ratio is defined as $\frac{A_{fv}}{E_{fv}} = \frac{A_{fv}}{A_{fv} - D_{acc}}$.

the effects on the pro-cyclicality of leverage and systemic risk. We focus on such banks to empirically investigate the strongest objection linked to the Federal Reserve's programs used to address liquidity shortage: the fear of moral hazard, as access to a liquidity facility may lead banks to opt for bolder policies with less liquidity self-protection (e.g. lower reserves) and, in the event of a liquidity crisis, to choose to incur debt from the Federal Reserve to avoid default on private debts and preserve creditworthiness. First, we exploit the exogenous variation in the characteristics of banks requiring funds from the Federal Reserve and find that banks that participate in Lender of Last Resort programs (*LOLR*), like Discount Window and Term Auction facility, are more likely to increase their short-run indebtedness even with other sources of funding (like Federal Reserve's repo and interbank debt): for these banks the degree of leverage pro-cyclicality is even higher than that of banks in our baseline model. The increased reliance on short-term funding (worsening liquidity fragilities) directly translates into a higher systemic contribution in the quarter following the access to these facilities (although with differences among these two programs), that means higher systemic risk pro-cyclicality. Second, banks identified by regulators (Basel Committee on Banking Supervision and Federal Reserve Board) as Domestic or Global Systemically Important Banks increase debt in the short-run via repos: this immediately translates into leverage pro-cyclicality. However our evidence shows an unexpected result on their degree of interconnectedness following an increase in the market value of assets: if fixed-effect regression shows pro-cyclicality of systemic risk for this group of banks, structural equation model does not confirm this result once we account for endogeneity of leverage. Third, banks under regulatory pressure, defined as banks with core capital below 8%, not only do not increase their leverage (at least in the short-run) but even decrease it during assets expansion. Moreover, our evidence confirms that the deleveraging process translates into systemic risk: the pressure to be compliant with stricter capital requirements leads these banks to decrease the pro-cyclicality of systemic risk with respect to the control group. Fourth, banks that have taken part in the Treasury's Capital Purchase Program, similarly to banks under capital pressure, reduce leverage in the short-run (immediately following Treasury's participation in their capital) with respect to the baseline group following an increase in assets-value, whilst showing a lower elasticity to systemic risk pro-cyclicality with respect to the control group.

In more detail, our first set of tests replicates the fixed-effects model by Adrian and Shin (2010) and, using quarterly data from a sample of 1635 US Bank Holding Companies (BHCs) from 2006 to 2016, our baseline model confirms that leverage is pro-cyclical. Furthermore, we consider four sub-samples of banks: those participating in Federal Reserve's liquidity injections - *LOLR* -, those designated as – *SIFIs* -, those under regulatory pressure - *Reg. Pressure*- and those participating in Treasury's Capital Purchase Program - *CPP banks* -. Our findings reveal that the degree of leverage pro-cyclicality increases for banks that rely on Federal Reserve's liquidity facilities and for SIFIs; for CPP banks leverage is still pro-cyclical but lower than the control group; whereas leverage is counter-cyclical for banks under regulatory pressure. In our second set of tests, we use again fixed-effects regressions to check for the pro-cyclicality of systemic risk. Our findings show that systemic risk is pro-cyclical. Moreover, our results reveal that the degree of systemic risk pro-cyclicality increases for banks that rely on Federal Reserve's liquidity facilities and for SIFIs; whilst systemic risk is counter-cyclical for banks under regulatory pressure; for banks participating into the Treasury's CPP program systemic risk is still pro-cyclical but lower than the control group. Our third set of test, given the multidimensional effects of pro-cyclical behaviour, employ structural equation model (Three Stage Least Squares - 3SLS - regressions). The aim is to study how the effects on procyclicality of leverage and procyclicality of systemic risk interact among them. In particular, we cannot neglect the fact that under general economic theory both the increase in assets and the increase in leverage positively affect the increase in systemic risk and running two separate regressions would lead to a mis-specified model. Thus, to tackle endogeneity of the increase in leverage, we perform a structural equation model via 3SLS. Controlling for a set of explanatory variables, our structural equation model allows us to examine the effect of an increase in the fair value of assets on the change in systemic risk disentangling the effects of the increase in leverage and in assets. Again, SRISK is found to be pro-cyclical: the links among banks (in terms of their interconnectedness) increase during booms and decrease during bursts. Moreover, structural regression leads to an economically and statistically large difference between banks participating in the Federal Reserve's liquidity programs or banks participating into Treasury's CPP program vs. banks that do not. In particular, leverage is pro-cyclical for banks which participated in the Term Auction Facility program while it is counter-cyclical for banks which participated in the Discount Window; however, for both type of borrowers systemic risk increases following the increase in fair value of assets but some differences come to light when we consider the mediated effect of leverage. Structural equations show that leverage is counter-cyclical for banks participating in the Treasury's CPP program but systemic risk decreases following the increase in assets with respect to banks in the control group. Finally, differences come to light among SIFIs and banks under regulatory pressure vs. banks not belonging in these sub-samples: SIFIs confirm leverage pro-cyclicality, however structural equation do not show systemic risk pro-cyclicality for this group of banks; whilst regulatory constrained banks evidence counter-cyclical leverage but pro-cyclical systemic risk in the structural equation.

Our findings are relevant both for regulators and supervisory authorities interested in monitoring banks' behaviour because of the implications in terms of possible macro-prudential policies to mitigate systemic risk. In particular, our results touch different aspects of current banking regulation: they relate to the new international regulatory framework -Basel III- and to the extra capital requirements for Too Big To Fail banks, to the designated procedures in order to evaluate capital adequacy to conduct bank business (known as stress test), and to the increase in information disclosure provided by the Dodd-Frank Act. Moreover, we refer to the appropriateness of the liquidity programs provided by the Federal Reserve because they could create moral hazard, enabling banks to borrow more as a result of the access to these facilities. Even the magnitude of extra capital requirements for systemically important banks is relevant: in fact, if current requirements are sufficient to counter the increase in systemic risk, it could be that more stringent requirements might have negative effects. Thereafter, the results of our analysis lead to two types of considerations. First, the evidence that the participation in banks' capital by the Treasury (through CPP program) is seen by the market as a positive signal, alleviating additional borrowing by banks. Second, our results show (surprisingly) that the attention of regulators should not be directed to banks that are capital constrained (for which we show that an increase in assets value does not involve any increase in leverage) but to well-capitalized banks, having the incentives to borrow and increase systemic risk.

The remainder of the paper is organised as follows. In Section 2, we review the literature. In Section 3, we provide motivations, describe the methodology and the identification strategy. In Section 4 we describe the data. In Section 5, we investigate whether leverage and systemic risk are pro-cyclical and we report results from structural equation model showing whether banks belonging to the sub-samples of SIFIs, as well as banks that rely on Federal Reserve's liquidity or Treasury's capital injections and banks under regulatory pressure exacerbate or alleviate systemic contributions in the US. Section 6 concludes.

2 Literature Review

Our study relates to three main streams of literature concerning the pro-cyclicality of leverage, the measurement of systemic risk and the current safeguards to face the financial crisis in terms of regulation, capital requirements and liquidity injections.

After the financial crisis, a vast research has been carried out on the pro-cyclicality in banking considering especially the role of leverage (Adrian and Shin, 2010a; Adrian and Shin, 2010b; Baglioni et al., 2013; Damar et al., 2013; Beccalli et al., 2015; Tasca and Battiston, 2016). The milestone in this field has been the work of Adrian and Shin (2010a) showing that when balance sheets are continuously marked-to-market, changes in asset price appear immediately as changes in net worth and this would algebraically lead to a decrease in leverage; however, active financial intermediaries adjust the size of their balance sheets increasing debt (especially via repos): a phenomenon known as leverage procyclicality. Moreover, Adrian and Shin (2010b) find that US commercial banks had an a-cyclical leverage between 1997 and 2008, whilst the five major "pure" investment banks have a strong pro-cyclical leverage. Baglioni et al. (2013), analysing a large sample of European banks, show that pro-cyclical leverage appears to be entrenched in the behaviour of those banks for which investment banking prevails over the traditional commercial banking activity. Damar et al. (2013) using Canadian data show that positive co-movements in bank leverage and assets are associated with leverage pro-cyclicality having as a driver funding in the wholesale market (mitigated by its relative liquidity); moreover, authors show that banking-sector leverage pro-cyclicality can forecast volatility in the equity market. Whilst Beccalli et al. (2015) investigating the role of off-balance sheet securitisation on US banks show that, as soon as GAAP accounting rules allowed for an under-estimation of on-balance sheet items from securitisation, effective leverage (taking into account off-balance sheet securitisation) is strongly pro-cyclical. Tasca and Battiston (2016) model the systemic risk associated with the balance-sheet amplification mechanism in a system of banks with interlocked balance sheets and with positions in real-economy-related assets. Their framework integrates a stochastic price dynamics with an active balance-sheet management aimed to maintain the Value-at-Risk at a target level and show that a strong compliance with capital requirements does not increase systemic risk unless the asset market is illiquid (in this case, even a weak compliance with capital requirements increases significantly systemic risk).

In terms of interconnectedness, the last decade has seen a steady stream of attempts to measure systemic risk in an aggregate way (Acharya et al., 2010; Billio et al., 2010; Adrian and Brunnermeier, 2011; Acharya et al., 2012; Allen et al., 2012; Castro and Ferrari, 2014). Acharya et al. (2010) develop a model showing that systemic risk is equal to the product of three components: the real social costs of a crisis per dollar of capital shortage, the probability of a crisis and the expected capital shortfall of a particular firm in a crisis. Acharya et al. (2012), focusing on this third component, model the systemic expected shortfall (SES) as the propensity to be undercapitalised when the system as a whole is undercapitalised. They capture in a single measure size, leverage, interconnectedness and the co-movement of the financial firm's assets with the aggregate financial sector in a crisis and validate their findings empirically showing the ability of SES to predict the outcome of stress tests performed by regulators and the decline in equity valuations of large financial firms during the crisis. Billio et al. (2010) study systemic risk from the point of view of interconnectedness among hedge funds, banks, brokers, and insurance companies. They propose five measures of systemic risk based on statistical relations among the market returns of these four types of financial institutions and they validate their results using correlations, cross-autocorrelations, principal components analysis, regime-switching models, and Granger causality tests. Adrian and Brunnermeier (2011) propose ΔCoVar as a measure for systemic risk. CoVaR is the value at risk (VaR) of

the financial system conditional on institutions being under distress (where they define each institution contribution to systemic risk as the difference between the VaR of the financial system conditional on institution being under distress and the CoVaR in the median state of the institution). Allen et al. (2012) derive a measure of aggregate systemic risk (CATFIN) that complements bank-specific systemic risk measures by forecasting macroeconomic downturns six months into the future using out-of-sample tests. They perform the analysis on US, European, and Asian bank data where CATFIN measure for both large and small banks forecasts macroeconomic declines. Castro and Ferrari (2014), using ΔCoVaR proposed by Adrian and Brunnermeier (2011) as a tool for identifying systemically important institutions, measure systemic risk by the price of insurance against financial distress. Results from their stress tests (based on ex ante measures of default probabilities and forecasted asset return correlations from high-frequency equity return data with macro-financial conditions) suggest that the theoretical insurance premium that would be charged to protect against losses that equal or exceed 15% of total liabilities (of 12 major US financial firms) stood at $110 billion in March 2008 and had an upper bound of $250 billion in July 2008.
In what concern the third stream of literature, we are interested in the current safeguards to face systemic risk in terms of regulation (Caruana, 2010; Brei and Gambacorta, 2014; Balasubramnian and Cyree, 2014; Bongini et al., 2015; Laseen et al., 2015; Moenninghoff et al., 2015), capital (Hart and Zingales, 2011; Bayazitova and Shivdasani, 2012; Black and Hazelwood, 2013; Berger et al., 2016a; Brownlees and Engle, 2016) and liquidity injections (Furfine, 2003; Armantier et al., 2015; Berger et al., 2015). Caruana (2010) analyses possible policies to mitigate systemic risk as a negative externality: according to their model, in the cross-sectional dimension regulators should implement policies that seek to limit interlinkages and common exposures, whilst to face the time-dimensions damages, banks have to build up capital and liquidity margins of safety during the upswing that can be drawn upon in the downturn. Hart and Zingales (2011) design a capital requirement for large financial institutions (LFIs) mimicking the operation of margin accounts. To ensure that LFIs are always solvent, LFIs have to maintain an equity cushion sufficiently large such that their own credit default swap price stays below a threshold level, and a cushion of long term bonds sufficiently large that, even if the equity is wiped out, the systemically relevant obligations are safe. If the CDS price goes above the threshold, the LFI regulator forces the LFI to issue equity until the CDS price moves back down. In what concern the relation between the Treasury's Capital Purchase Program and systemic risk, Bayazitova and Shivdasani (2012) study the effects and the incentives of banks to participate in the Capital Purchase Program (CPP). The authors show that stronger banks opted out of participating in CPP and that equity infusions were provided to banks that posed systemic risk, faced high financial distress costs, but had strong asset quality. On the same line, Black and Hazelwood (2013), studied the effects of TARP capital injections program on bank risk-taking by analysing the risk ratings of banks' commercial loan originations during the crisis. Their results indicate that, relative to non-TARP banks, the risk of loan originations increased at large TARP banks but decreased at small TARP banks. From the regulatory point of view, Brei and Gambacorta (2014) analyze how the new Basel III leverage ratio and risk-weighted regulatory capital ratio behave over the cycle. Using data from 14 advanced economies for the period 1995–2012 they find that the Basel III leverage ratio is significantly more counter-cyclical than the risk-weighted regulatory capital ratio. Balasubramnian and Cyree (2014) investigate whether or not market discipline on banking firms changed after the Dodd-Frank Wall Street Reform and Consumer Protection Act (DFA) of 2010. When market discipline is improved, a lower discount for size on yield spreads, particularly for banks identified as too-big-to-fail (TBTF) or systemically important (SIFI) is observed. Using secondary market subordinated debt transactions authors find that the size

discount is reduced by 47% and TBTF discount is reduced by 94% after the DFA. In terms of market reaction towards regulatory changes, Bongini et al. (2015) investigate the reaction to the publication of the list of systemically important financial institutions (SIFI) and the new rules designed to address the too-big-to-fail problem of systemic banks. By applying event study methodology to a sample of 70 of the world's largest banks, results show that financial markets did not univocally react to the new regulation regarding SIFIs. However, markets discriminated between high and low capitalised banks and they correctly estimated the probable effects of the additional capital requirements. Along the same field but with different results, Moenninghoff et al. (2015) provide evidence on how the new international regulation on Global Systemically Important Banks (G-SIBs) impacts the market value of large banks. Analysing the stock price reactions for the 300 largest banks from 52 countries across 12 relevant regulatory announcements and designation events they observe that the new regulation negatively affects the value of the newly regulated banks. A cross-sectional analysis of the valuation effects with respect to government ownership of banks supports the view that the positive reaction to these designations can be attributed to a Too-Big-to-Fail (TBTF) perception by investors. These results further suggest that even though the individual components of the regulation have been effective, revealing the identities of G-SIBs eliminated ambiguity about the presence of government guarantees, and thereby may have run counter to the regulators' intent to contain the effects of TBTF. Laseen et al. (2015) analyze if stricter policy-interventions (an increase in interest rates) reduce systemic risk because output, inflation, asset prices should decrease. Their findings show that when asset prices decrease, returns decrease too and banks are unable to raise equity. This inability leads them to increases debt and subsequently systemic risk. Berger et al. (2016a) study how regulatory interventions and capital support affect the risk taking and liquidity creation of troubled banks and find that regulatory interventions and capital support both succeed in reducing bank risk taking. Brownlees and Engle (2016) using Tobit regression and data from the Treasury recapitalization program (TARP) assess the significance of SRISK as a predictor of Treasury's injections. Concerning Fed's liquidity facilities Furfine (2003) analyses how banks rely on standing facilities by central banks depending on how financial institutions lend to one another overnight. Author shows that the mere availability of central-bank-provided credit may lead to its use being greater than what would be expected based on the characteristics of the interbank market. By contrast, however, banks may perceive a stigma from using such facility -DW- (because the improper design of the facility might decrease a bank's incentive to participate), and thus borrow less than what one might expect, thereby reducing the facilities' effectiveness at reducing interest rate volatility. Empirical predictions of the model are then tested using data from the Federal Reserve's new primary credit facility (DW) and the US federal funds market. Armantier et al. (2015) provide empirical evidence for the existence, magnitude, and economic cost of stigma associated with banks borrowing from the Federal Reserve's Discount Window (DW) during the 2007-2008 financial crisis. In particular, authors find that banks were willing to pay a premium of around 44 basis points across funding sources to avoid borrowing from the DW. Whilst Berger et al. (2015) compare the Federal Reserve liquidity injections into banks during the recent financial crisis using the Discount Window and Term Auction Facility. Examining these facilities' use, findings show that: small bank users were generally weak (while large bank users were not) and the funds were weak substitutes to other funding sources. Overall, these facilities increased aggregate lending, enhancing lending at expanding banks and reducing decline at contracting banks (where small banks increased small business lending, while large banks enhanced large business lending). Loan quality only improved at small banks, while both left loan contract terms unchanged. Our study arises essentially by combining the above streams of literature together with the recent evidence on the increase in bank size and in interbank debt; particularly, we study how, given the high degree of interconnectedness of today's banking system, even a small fraction of banks with a pro-cyclical leverage can impose a large social cost in terms of systemic risk and interconnectedness.

3 Institutional background and identification strategy

Motivations. Provided that assets (A) are evaluated at *fair value* (even known as *marked to market*) and that debt (D) cannot be renegotiated in the short-run[2], in $t = 0$ the bank's balance sheet appears like:

$$A_0 = E_0 + D_{acc}$$

whilst for $t > 0$ it becomes:

$$A_{fv} = E_{fv} + D_{acc}$$

This is immediately translated into the definition of "quasi-market leverage ratio" and it is straightforward to see that an increase in assets should be associated with a decrease in leverage.

$$LEV = \frac{A_{fv}}{E_{fv}} = \frac{A_{fv}}{A_{fv} - D_{acc}}$$
$$\frac{\partial LEV}{\partial A_{fv}} = -\frac{D_{acc}}{(A_{fv} - D_{acc})^2} < 0$$

However, Adrian and Shin (2010), in their first seminal work on this topic, proved that an increase in *fair value* of assets leaves room for an increase in debt for banks which operate by way of leverage targeting: commercial banks. Moreover, leverage is pro-cyclical (or $\frac{\partial LEV}{\partial A_{fv}} > 0$) for those banks which actively manage leverage due to their incentives in increasing debt during financial bubbles: typically, investment banks. Secondly, they motivated their findings with the fact that banks target equity (in order to be solvent or to have a particular level of credit rating) as a function of VaR, like: $E_{fv} = \lambda VaR$.[3] Thus, an increase in assets (when they are valued at *fair value*) lead to an increase in debt from two perspectives: leverage targeting and from a decrease in the Unit Value at Risk. Figure 1 (in Section 7) shows how an increase (decrease) in assets is followed up by and increase (decrease) in leverage for the period under analysis, where the degree of co-movement among the two variables is stronger starting from the first quarter of 2010.

On the other side, the recent financial crisis has highlighted how the financial system's incentives to take ex-ante excessive correlated risks, mainly in credit booms and asset price bubbles, might have serious backlash against other financial intermediaries and the real economy. In fact, from leverage pro-cyclicality, if the adjustment in leverage through short-run debt occurs by interbank debt (correlated risk) it is easy to see how the previous problem may be exacerbated and how growth in bank assets and increased systemic risk are two sides of the same coin. In fact, imagine a boom where the assets of both banks double in size, but the pool of retail deposits stays fixed (as standard in the literature -Shin (2010)-, core liabilities grow slowly in line with household wealth). Then, the proportion of banking

[2] In fact if is easy to evaluate the market value of equity and the stock price (at least for listed firms), computing the value of debt is not so straightforward because only part of debt is traded and analysts should rely on total borrowings observed only in periodic accounts.

[3] Where VaR is defined as $Prob(A_{fv} < A_0 - VaR) = (1 - c)$.
Substituting this into the definition of leverage, we get:

$$LEV = \frac{A_{fv}}{E_{fv}} = \frac{A_{fv}}{\lambda VaR} = \frac{1}{\lambda}\frac{1}{V}$$

where V is defined as Unit Value at Risk ($V = \frac{VaR}{A_{fv}}$) and we can immediately see that:

$$\frac{\partial LEV}{\partial A_{fv}} = \frac{\partial LEV}{\partial V} * \frac{\partial V}{\partial A_{fv}} > 0$$

sector liabilities in the form of retail deposits must fall. In other words, rapidly expanding bank assets is mirrored by the increased cross-claims across banks (Shin, 2010; Faia and Ottaviano, 2015). Thus, during a boom when bank assets grow rapidly, intermediaries lend and borrow from each other much more than during normal periods: in this way solvency and liquidity often feed each other (Rochet and Vives, 2004; Diamond and Rajan, 2009). Figure 2 (in Section 7) shows the relation between the increase in assets and the increase in systemic risk for the period under consideration, and reveals that the magnitude of the co-movement among the increase in assets and systemic risk is larger starting from the third quarter of 2007. From the VaR perspective, as studied in depth by both empirical and theoretical works (Estrella, 2004; Gambacorta and Mistrulli, 2004; Repullo and Suarez, 2013), we saw that when Unit VaR decreases leverage increases, moreover, banks target their capital as a function of their individual risk without taking into account the social cost that they impose on the system: resulting, in this respect, as under-capitalised banks. Thus, banks with lower capital than the amount sufficient to conduct business have no buffers to face economic down-turn which might lead to higher systemic risk.

In order to consider the effects of leverage pro-cyclicality on systemic contribution of a bank we employ SRISK measure by Brownlees and Engle (2012). SRISK captures the capital shortfall of a bank conditional on a severe market decline as a function of its size, leverage and risk and it represents the amount of capital that a bank would need to raise in order to function normally. In particular, they define the Capital Shortfall as the cases in which banks do not meet regulatory capital requirements[4]:

$$CS = \kappa \mathbb{E}[A_{fv}|Crisis] - \mathbb{E}[E_{fv}|Crisis] > 0$$

where the first term represents the capital requirement (and κ the regulatory parameter) and the second term represents the actual capitalization. This is equivalent to (provided debt cannot be renegotiated):

$$CS = \kappa(D_{acc} + \mathbb{E}[E_{fv}|Crisis]) - \mathbb{E}[E_{fv}|Crisis] > 0$$

The authors define *Crisis* or *Systemic event* the market decline below a threshold C over a time horizon h: $\{R_{m,t+1:t+h} < C\}$ and SRISK the expected Capital Shortfall (for financial institution i) conditional on that event. Previous equation becomes:

$$SRISK_{i,t} = \mathbb{E}[CS_{i,t+h}|R_{m,t+1:t+h} < C]$$

The capital shortfall can be directly calculated by recognising that the book value of debt will be relatively unchanged during short time-periods while equity values fall by LRMES (Long Run Marginal Expected Shortfall). Incorporating previous equations:

$$SRISK_{i,t} = \kappa D_{acc} - (1-\kappa)\mathbb{E}[E_{i,t}|R_{m,t+1:t+h} < C]$$

or,

$$SRISK_{i,t} = \kappa D_{acc} - (1-\kappa)E_{i,t}(1 - LRMES_{i,t})$$

Recalling that $D_{acc} = E_{fv}(LEV - 1)$ and substituting we can write previous equation as:

$$SRISK_{i,t} = E_{i,t}[\kappa LEV_{i,t} + (1-\kappa)LRMES_{i,t} - 1]$$

where LEV is the quasi-market leverage ratio and LRMES is the Long Run Marginal Expected Shortfall.[5]

At this point it is straightforward to see that $SRISK_{i,t} = f(E_{i,t}; LEV_{i,t}; LRMES_{i,t})$ and it increases

[4] $\frac{E_{fv}}{A_{fv}} \geq \kappa$; where κ is the prudential level of equity relative to assets.
[5] That is, $-\mathbb{E}_t[R_{i,t+1:t+h}|R_{m,t+1:t+h} < C]$.

directly when leverage increases by $\frac{\partial SRISK_{i,t}}{\partial LEV_{i,t}} = \kappa E_{i,t} > 0$. Figure 3 (in Section 7) shows this evidence and how this relation becomes stronger over time. However, this represents a lower bound, because in this case we are assuming that the partial derivatives of $LRMES_{i,t}$ wrt to $LEV_{i,t}$ is zero, that is the co-movements between banks and market returns are not influenced by smaller change in leverage. At this point the aim of this paper is trying to see which is the effect of an increase in assets on systemic risk: on one hand, we would expect that larger banks contribute more to systemic risk because greater would be their social cost in case of failure (that is a positive impact on LRMES which would lead to an increase in systemic risk); on the other hand, considering that leverage should decrease following an increase in assets, by chain rule we would expect that:

$$\frac{\partial SRISK_{i,t}}{\partial A_{i,t}} = \frac{\partial SRISK_{i,t}}{\partial LEV_{i,t}} * \frac{\partial LEV_{i,t}}{\partial A_{i,t}} = \frac{-(\kappa E_{i,t})D_{acc}}{(A_{fv}-D_{acc})^2} < 0$$

Meanwhile, we cannot disregard findings from Adrian and Shin (2010) and the effects on Systemic Risk may be amplified once we consider that leverage is pro-cyclical: thus, an increase in assets would have a direct effect via an increase in LRMES and an indirect effect considering the increase in leverage. In other words, the higher the leverage of the bank, the higher are the incentives of the bank to be more interconnected.
With the purpose to analyze this combined effect we take the first order approximation of the percentage change in LEV relative to LEV_0 as A change around A_0 and the first order approximation of the percentage change in SRISK relative to $SRISK_0$ as LEV change around LEV_0. If we consider debt (D_{acc}) as constant we have:

$$\hat{lev} = (\frac{-D_{acc}}{A-D_{acc}})\hat{a}_{i,t}$$

While, when we consider the results from Adrian and Shin (2010) with respect to an increase in debt when assets increase, the log-linearisation would be:

$$\hat{lev} = \frac{D_{acc}}{D_{acc}-A}(\hat{d}_{i,t} - \hat{a}_{i,t})$$

Whilst the log-linearisation of SRISK results in:

$$sr\hat{i}sk = \hat{e}_{i,t} + \frac{1}{\Gamma}[\kappa LEV * \widehat{lev} + (1-\kappa)LRMES * \widehat{lrmes} + LEV * LRMES(\kappa - 2\kappa^2)\hat{\kappa}]$$

where Γ is defined as $[\kappa LEV + (1-\kappa)LRMES - 1]$.[6]
Now it is easy to see how an increase in leverage is immediately translate into an increase in systemic risk; however, since we are studying how pro-cyclicality of leverage in translated into pro-cyclicality of systemic risk the final effect may be exacerbated or mitigated depending on the other forces: LRMES, equity and capital regulation (κ).

With this purpose, we explore the interaction among SRISK and leverage for four sub-samples of banks. First, we look at those banks that have participated into Federal Reserve's liquidity injection programs geared for individual depository institutions and for the banking system as a whole by providing a reliable

[6]Imposing the SRISK measure=0 is easy to see that when LRMES increases, equity should increase to satisfy the threshold.

backup source of funding (Discount Window[7] and Term Auction Facility).[8] Both facilities concern collateralised lending with some differences: DW represented an overnight facility (mainly renewed) whilst TAF had 28-84 days maturity, DW was a tap program -that is, credit has no limits provided that banks had sufficient collateral- while TAF was auction-based (with a precise amount offered by the Federal Reserve, a minimum number of participants in the auction and limits on the amount each bank can bid) implying differences in the price of credit. Figure 5 (Section 7) shows that rates under TAF (were banks had to bid for funds) were perfectly in line with rates on the market, whilst DW rate was on average 60bp above the market (on average, not distinguishing between primary and secondary credit). As stated by Bayazitova and Shivdasani (2012) these capital injections may be considered a multiplier for LRMES, that is capital needed by those banks during the crisis. Secondly, we investigate the sub-sample of banks defined by regulators as Global-Systemically Important Financial Institutions or Domestic-Systemically Important Financial Institutions: on one hand, these banks are those identified by the regulators for having the largest capital shortfall ($[\frac{\partial SRISK}{\partial LRMES}|Sifi] > [\frac{\partial SRISK}{\partial LRMES}|Others]$) but, on the other hand, they are subject to higher capital requirements and continuous monitoring via stress test (Supervisory Capital Assessment Program). Moreover, banks which are considered as *systemic* have incentives in seeking greater dimension and interconnection in order to get an implicit insurance represented by the status of TBTF or TITF. Thirdly, we investigate how leverage pro-cyclicality translates into pro-cyclical systemic risk for the sub-sample of banks defined to be under "regulatory pressure" (*Reg. Pressure*). We specify these banks as those having a ratio between equity and risk weighted assets below the regulatory lower bound ($\frac{E}{RWA} < \kappa$) and we define as a threshold for $\kappa = 8\%$. Lastly, we concentrate our analysis on banks participating into the Treasury's Capital Purchase Program (CPP). As part of the first stage of the TARP program, the U.S. Treasury announced on October 13, 2008, that it would invest directly in equity of financial institutions. On October 14, 2008, CPP was announced, allocating $250 billion for purchases of preferred stock of U.S. financial institutions.[9] Under CPP, the U.S. Treasury purchased non-voting preferred stock, and banks could apply for this capital injection in amounts between 1% and 3% of their risk-weighted assets (CPP infusions took the form of preferred stock in order to be attractive to banks by virtue of being non-dilutive to common shareholders). Under CPP-TARP program the U.S. Treasury would also receive warrants with a ten-year life to purchase common stock for an amount equal to 15% of the preferred equity infusion. The dividend on the preferred stock was set at 5%, but it would rise to 9% after three years. However, CPP infusions forbade dividend increases on common shares until the preferred shares were repaid.[10]

[7]Starting from the revision of August 2007, the Discount Window provides liquidity under three programs: Primary credit (at a rate 50bp above FOMS -Federal Open Market Committee target rates- is a "no asked question" for sounder banks), Secondary credit (at a rate 100bp above the FOMC has the aim to solve liquidity problems at bank level and cannot be use for expansion of borrower assets) and the seasonal credit. 82% of banks in our sample relied on Primary credit. Generally the FOMC rate ranged from 0.25 to 0.50 bp and the corresponding primary rate and secondary rates from 0.75 to 1 and from 1.25 to 1.50 respectively.

[8]Even if the Court (endorsed by Bernanke) sustained that information on borrowers from these funds should not be released, by fear of negative consequences in the financial markets, Bloomberg LLP encouraged their disclosure under Freedom of Information Act (FOIA); data on DW are published quarterly with two years lag starting from 22nd July 2010 whilst TAF was active from December 2007 to March 2010 and information on borrowers have been released in the second quarter of 2010 under the Dodd-Frank Consumer Protection Act.

[9]On this day, nine financial institutions —Citigroup, Wells Fargo, JPMorgan, Bank of America, Goldman Sachs, Morgan Stanley, State Street, Bank of New York Mellon, and Merrill Lynch—received an aggregate infusion of $125 billion. Other banks had until November 14, 2008, to apply for CPP funds from the U.S. Treasury. Moreover on 19th December 2008, the US Treasury Department purchases a total of $27.9 billion in preferred stock in 49 US banks under the Capital Purchase Program.

[10]Along with CPP, government guarantees on new bank debt issues and an increase in FDIC guarantee of non-interest bearing transaction accounts were also unveiled on October 14, 2008. The bank debt guarantee was finalised on November

3.1 The identification strategy

Leverage pro-cyclicality. In the first stage of the analysis, in the spirit of Adrian and Shin (2010), we replicate their model testing the following equation:

$$\Delta ln(Lev_{i,t}) = \alpha + \beta_1 ln(Lev_{i,t-1}) + \beta_2 \Delta ln(TA_{i,t}) + \alpha_i + \alpha_t + \epsilon_{i,t} \quad (1)$$

where $\Delta ln(Lev_{i,t})$ and $\Delta ln(TA_{i,t})$ represent the increase in leverage and assets from *t-1* and *t* for bank *i*. That is, when assets are evaluated at *fair value*, if banks actively manage their leverage we expect a positive coefficient for β_2. We test this hypothesis via fixed-effect regression with bank fixed effects (in order to take into account cross-sectional differences among banks) and year-quarter fixed effects in order to consider quarter seasonality and time trends. We perform robustness test controlling for Federal Reserve district fixed effects. Since we are interested in the effects on changes in leverage resulting from changes in assets, following Adrian and Shin (2010b), the panel regression is performed in first-differences. Running a regression in first-differences wipes out time invariant omitted variables using the repeated observations across time. As long as $E[\Delta ln(TA_{i,t})|\Delta\varepsilon_{it}] = 0$ the estimator is unbiased and consistent and this assumption is less restrictive than the assumption of weak exogeneity required for unbiasedness using the FE estimator in levels. Several researchers argue that the use of differenced-equation for modelling purpose is problematic and one of the main reason include the presumed biases that result if the correlation between the initial level of a dependent variable and its change is not explicitly modelled; for this reason, and as consolidated in the literature (Imbens and Wooldridge, 2009), we include as a predictor the lagged-level of the dependent variable (typically referred to "stability component"). Moreover, under mean-reversion, the higher the leverage in the previous period the lower will be the increase this year. Dynamic models of behaviour have a possible justification for the inclusion of initial level of the dependent variable on the right-end side of a change equation: they guarantee unconfoundedness and eliminate autocorrelation in the model.[11]
As robustness, considering "accounting" leverage (not taking into account assets valued at *fair value*) we expect that leverage is counter-cyclical: we test this hypothesis with regression (2).

$$\Delta ACCLev_{i,t} = \alpha + \beta_1 ln(ACCLev_{i,t-1}) + \beta_2 \Delta ln(TA_{i,t}) + \alpha_i + \alpha_t + \epsilon_{i,t} \quad (2)$$

$H1_n$: the coefficient β_2 in models (1) and (2) has the same sign meaning that an increase in the market value of total assets does not lead to an increase in leverage.

Following on, motivated by Figures 6(a),7(a), 8(a) and 9(a) in Section 7, we investigate if differences in pro-cyclicality of leverage are not only due to the preferences among investment or commercial banking activities (Adrian and Shin, 2010b; Baglioni et al., 2013), but also to liquidity problems that banks are suffering or have suffered during the financial crisis and/or the regulatory framework that they have to be compliant with. Particularly, Figures 6(a) and 7(a) show that for the groups of banks participating into Federal Reserve's liquidity injection programs and for *SIFIs* banks, the increase in assets leads to an increase in leverage greater than the pro-cyclicality observed for the baseline group, whereas Figure 9(a) shows that for *CPP banks* leverage is still pro-cyclical but the magnitude is expected to be lower than in the baseline group. Surprisingly, Figure 8(a) exhibits counter-cyclical leverage for the group of

21, 2008, as the Temporary Liquidity Guarantee Program (TLGP).

[11] Particularly, we assume that the state-art time t is a function of the initial level of the system: such models are termed "non-ergodic" in the sense that the past cannot be forgotten and we should take into account previous conditions.

banks under *regulatory pressure* defined as banks with a ratio of equity over risk weighted assets below 8%. In this respect, we test hypothesis 2 via the following set of regressions.

$$\Delta ln(Lev_{i,t}) = \alpha + \beta_1 ln(Lev_{i,t-1}) + \beta_2 \Delta ln(TA_{i,t}) + \beta_3 * I + \beta_4 \Delta ln(TA_{i,t}) * I + \alpha_i + \alpha_t + \epsilon_{i,t} \quad (3)$$

Where I represents an indicator variable for different sub-samples of banks: those participating into Federal Reserve's liquidity injection programs (*LOLR*), banks identified as Systemically Important Financial Institutions (*SIFIs*), banks under regulatory pressure (*Reg. Pressure*) and banks participating into the Treasury's Capital Purchase Program (*CPP banks*).

$H2_n$: Banks belonging to sub-samples of LOLR, SIFIs, Reg. Pressure and CPP banks are not different in terms of pro-cyclicality of leverage; thus, coefficients β_3 and β_4 should be not statistically significant in all specifications of regression (3).

Economic theory (Kiyotaki and Moore, 1995; Kiyotaki and Moore, 2002) and anecdotal evidence suggest that booms are periods characterised by an over-evaluation of assets whilst during burst prices decrease. If previous equations are confirmed, we expect that banks increase their leverage in "good periods" while they deleverage in "bad periods" showing a positive coefficient for β_2. However, once we test that the growth rate of assets and the growth rate of leverage move in the same direction (both during booms and during bursts) their magnitude might be different. Figure 1 (Section 7) shows how the overlapping between the change in leverage and assets differs along years and quarters. During downturn, being compliant with the regulatory framework, the squeeze in wholesale funding and the gradual drawdown of line of credits previously committed are all motivations that might sum up making the deleveraging process more severe. In order to check for differences among the crisis and no-crisis period we test equation (4) along two sub-periods. The same hypothesis is tested for banks belonging to sub-samples of *LOLR*, *SIFIs*, *Reg. Pressure* and *CPP banks*.

$$\begin{aligned} Crisis : \Delta ln(Lev_{i,t}) &= \alpha + \beta_1 ln(Lev_{i,t-1}) + \beta_2 \Delta ln(TA_{i,t}) + \alpha_i + \alpha_t + \epsilon_{i,t} \\ No-crisis : \Delta ln(Lev_{i,t}) &= \alpha + \beta_1 ln(Lev_{i,t-1}) + \beta_2 \Delta ln(TA_{i,t}) + \alpha_i + \alpha_t + \epsilon_{i,t} \end{aligned} \quad (4)$$

$H3_n$: Banks do not show differences in terms of the magnitude of the coefficient associated to the growth rate of total assets among the crisis and no-crisis period.

As stated by a growing literature (Diamond and Rajan, 2005; Crotty, 2009) and confirmed by the financial crisis, liquidity shortages played a major role in the propagation of the financial crisis. During booms, short-term debt has been a way to boost balance sheets and increase leverage: typically short-term debt is cheaper due to short maturity and because it is usually collateralised. In order to test this hypothesis we analyze how previous results change when we proxy the increase in assets specifically as an increase of different kinds of short-term debt. We consider, among others, the change in the logarithm of repurchase agreements with other banks (*repo*), repo signed with the US central bank (*FedRepo*), short-term deposits in other banks as measure of wholesale financing (*Interbank*), standing issue of commercial paper (*Com.Pap.*) and participation in Federal Reserve's liquidity injection programs (*LOLR*, like Term Auction facility and Discount Window)[12]. In what concern short-term financing, Figure 4 shows that, before the crisis -the third quarter of 2007-, during the "boom" period there has been an increase in all kinds of short-term debt: repo, repo with the Federal Reserve and commercial papers. However, we notice that,

[12] When LOLR figures as dependent variable we exclude it from the set of regressors.

starting from the fourth quarter of 2007, the wholesale market started to fluctuate with a negative spike in the third quarter of 2008 when the interbank market began to freeze showing a reduction in *repo* and *reverse repo* -red lines-; meanwhile there has been a decrease in the credit granted by banks to the Federal Reserve via a contraction in reverse repo having as counterpart the US central bank (*FedReverseRepo*). During the same period, banks continued to rely on commercial paper financing -*Com.Pap.*- and to be short-term indebted with the Federal Reserve (*FedRepo*) evidencing a positive spike exactly in the fourth quarter of 2008. While, starting from the last quarter of 2008 the deleveraging process concerned even repo and commercial paper financing confirming a decrease in short-term financing via "conventional ways". Moreover, Figure 4 shows a downward spike in *Repo* and an increase in *FedRepo* exactly after the activation of Term Auction facility program (2007q4). Thus, enlarging the possibilities of short-term financing with respect to Adrian and Shin (2010b), whom consider mainly *repo* financing, we take into account issuing of commercial paper, the injection of liquidity from the Federal Reserve -via the DW or TAF programs- and the interbank market as alternative sources of funding in the short-run. We perform this analysis testing the following regression:

$$\begin{aligned}\Delta Lev_{i,t} =& \alpha + \beta_1 ln(Lev_{i,t-1}) + \beta_2 LOLR_{i,t} + \beta_3 \Delta ln(repo_{i,t}) + \\ & \beta_4 \Delta ln(FedRepo_{i,t}) + \beta_5 \Delta ln(Com.Pap._{i,t}) + \beta_6 \Delta ln(Interbank_{i,t}) + \alpha_i + \alpha_t + \epsilon_{i,t}\end{aligned} \tag{5}$$

$H4_n$: We exclude as one of the drivers of the growth rate of leverage the increase in short-term financing via repos, repos with the Federal Reserve, commercial papers, wholesale debt or participation in Fed's liquidity injection programs.

Moreover, this prediction is supported by the path in interest rates. Figure 5 shows that bid-rates on TAF were perfectly in line with rates on commercial paper and federal funds rates but borrowing from this program had the advantage of "anonymous borrower" (at least until the Dodd-Frank Act become effective in July, 21st 2010) making it a first-best solution for banks trying to avoid the disclosure of their name as Federal Reserve's borrower (Cyree et al., 2013). The aim of regression (5) is to verify, controlling for the increase in repo, if there has been an increase in leverage subsequent the applications to DW or TAF programs or other short-term borrowings and how this is translated in the degree of leverage pro-cyclicality. In other words, we investigate if these sources of short-term debt feed each other or they are substitutes in the market for liquidity.
To summarise, as short-term funding tends to be the cheapest way to increase debt it is reasonable to predict that the increase in leverage happens via short-term borrowing. In this way, the growth in non-core liabilities via short-term debt are all consequences of the rapid growth of bank assets during boom. To the extent that the ratio of non-core to core liabilities reflects the stage of the financial cycle, it also reflects the degree of risk-taking by the banking sector and the extent of under-pricing of risk. Risk is being "under-priced" in the sense that banks take cues from current buoyant market conditions to take on additional exposures, without taking sufficiently account of the fallout to the rest of the economy when the bubble eventually bursts (negative externality). The possibility that banks take account of their own short-term objectives without taking account of the spillover effects of their actions on other banks and on the economy as a whole, lead us to conduct the analysis on systemic risk pro-cyclicality.

Systemic risk pro-cyclicality. Laeven et al. (2015) motivate the presence of agency conflicts in large organizations and "too big to fail" considerations to prove that individual and systemic risk are inversely related to bank capital. Consistently with their findings, in the second stage of the analysis we test whether the increase in fair value of assets causes a shift in the risk appetite of financial institutions.

The motivation for this question arises from the evidence that on one hand, larger banks aim at reaching the *status* of TBTF or TITF in order to benefit from the implicit guarantee associated with public rescue (Rochet, 1996; Demsetz and Strahan, 1997) but, on the other hand, the increase in market value of assets may be associated with a reduction in systemic risk as long as banks increase their capital, their diversification, their liquidity buffer and reduce their degree of interconnection: that is, when an increase in assets does not increase LRMES. We test pro-cyclicality of systemic risk by the following equation.

$$\Delta SRISK_{i,t} = \alpha + \beta_1 ln(SRISK)_{i,t-1} + \beta_2 \Delta ln(TA)_{i,t} + \alpha_i + \alpha_t + \epsilon_{i,t} \qquad (6)$$

$H5_n$: the coefficient β_2 in model (6) is not statistically significant meaning that an increase in assets valued at fair value does not lead to an increase in systemic risk.

Following we ask whether the degree of pro-cyclicality among fair value of assets and systemic risk (if any) is the same along four sub-samples of banks. As before, we investigate the effects on banks participating into Federal Reserve's liquidity injection programs (*LOLR*), *SIFIs*, low capitalised banks (*Reg. Pressure*), and banks which relied on TARP funds (*CPP banks*).

$$\Delta ln(SRISK_{i,t}) = \alpha + \beta_1 ln(SRISK_{i,t-1}) + \beta_2 \Delta ln(TA_{i,t}) + \beta_3 * I + \beta_4 \Delta ln(TA_{i,t}) * I + \alpha_i + \alpha_t + \epsilon_{i,t} \qquad (7)$$

$H6_n$: Banks do not show differences in the degree of pro-cyclicality of systemic risk along the four groups of banks.

As for pro-cyclicality of leverage we test whether an increase in total assets has different effects on the increase in systemic risk depending on the period under consideration. Figure 2 (Section 7) shows that the overlapping between changes in assets and changes in systemic risk is not homogenous: particularly, it seems that the relation becomes stronger after the adoption of International Accounting Standard Rules with some differences among the crisis (downturn) and no-crisis periods (upturn).

$$\begin{aligned} Crisis: \Delta ln(SRISK_{i,t}) &= \alpha + \beta_1 ln(SRISK_{i,t-1}) + \beta_2 \Delta ln(TA_{i,t}) + \alpha_i + \alpha_t + \epsilon_{i,t} \\ No-crisis: \Delta ln(SRISK_{i,t}) &= \alpha + \beta_1 ln(SRISK_{i,t-1}) + \beta_2 \Delta ln(TA_{i,t}) + \alpha_i + \alpha_t + \epsilon_{i,t} \end{aligned} \qquad (8)$$

$H7_n$: Banks do not show differences in terms of direction and magnitude of the effects of the growth in assets on systemic risk among the crisis and no-crisis period.

Moreover, large BHCs, while better diversified than small BHCs, may have used their diversification advantage to operate with lower capital ratios and pursue riskier activities (Demsetz and Strahan, 1997). As previous evidence has shown that banks targeting leverage have space for increasing debt when *fair value* of assets increases, symmetrically this happens for systemic risk. Defining systemic risk (as in Brownlees and Engle, 2012) as the price of the negative externality of banks when their equity value falls below the Basel-II compliant threshold (*Capital Shortfall*) we can notice that banks may target their systemic risk.

$$SRISK_{i,t} = min[0; CS_{i,t}]$$

$$SRISK_{i,t} = min[0; E_{fv} - \kappa(E_{fv} + D_{acc})]$$

Which, recalling the quasi-market leverage ratio, may be written as:

$$SRISK_{i,t} = min[0; \frac{E_{i,t}}{A_{i,t}} - \kappa \frac{(E_{i,t} + D_{acc})}{A_{i,t}}]$$

$$SRISK_{i,t} = min[0; \frac{1}{Lev_{i,t}} - \kappa]$$

When κ is equal to Basel II capital requirement (8%), this might be evaluated as a short put option having as a strike price κ and as underlying $\frac{1}{Lev_{i,t}}$. Thus, we can predict that as long as $\frac{1}{Lev_{i,t}}$ is below the regulatory threshold there is room for banks to increase leverage without increasing systemic risk. We test this hypothesis via regression (9) for all our sub-samples of banks.

$$\begin{aligned} Lev < 12.5\% &: \Delta ln(SRISK)_{i,t} = \alpha + \beta_1 ln(SRISK_{i,t-1}) + \beta_2 \Delta ln(TA_{i,t}) + \epsilon_{i,t} \\ Lev \geq 12.5\% &: \Delta ln(SRISK)_{i,t} = \alpha + \beta_1 ln(SRISK_{i,t-1}) + \beta_2 \Delta ln(TA_{i,t}) + \epsilon_{i,t} \end{aligned} \tag{9}$$

$H8_n$: Banks do not show differences on the degree of pro-cyclicality of systemic risk depending on the relation among leverage and the regulatory capital threshold.

Thus we expect evidence for systemic risk pro-cyclicality when the inverse of time-varying leverage is above the regulatory capital threshold, while below it banks might have pro-cyclical leverage still targeting systemic risk to zero.[13]

Structural equation. To properly study the pro-cyclicality of systemic risk we need to take into account the results from Adrian and Shin (2008). Given that the growth rate in assets, $\Delta ln(TA_{i,t})$, affects both the growth rate of leverage and the growth rate of systemic risk via the growth rate of leverage, we need to shape these effects on two endogenous variables to avoid spurious correlation.[14] In order to tackle this issue, we perform firstly a simultaneous equation model (allowing for correlation among dependent variables) and secondly a structural equation model (via Three Stage Least Squares)[15].

Particularly, we model the simultaneous equations in order to check for the mediation effect of leverage on systemic risk, introducing the effect of our main exogenous variable, $\Delta ln(TA_{i,t})$, on both endogenous variables and considering that the error terms of $\Delta ln(Lev_{i,t})$ and $\Delta ln(SRISK_{i,t})$ might be correlated. In regression (10), we model $\Delta ln(TA_{i,t})$ to affect both leverage and systemic risk allowing for correlation among our dependent variables and for different effects depending on sub-samples of banks (*LOLR, SIFIs, Reg. Pressure* and *CPP banks*). With simultaneous equations we estimate unknown parameters by minimising the difference among observed and implied covariance matrix via maximum likelihood estimation. The number of observations allows for model specification (resulting in unique estimates) whereas disentangle the effect of the exogenous increase in assets depending on different sub-samples of banks allows for model identification. In this way we include indicator variables for each sub-sample in order to consider attrition among groups.

$$\begin{cases} \Delta ln(Lev_{i,t}) = \alpha + \beta_1 ln(Lev_{i,t-1}) + \beta_2 \Delta ln(TA_{i,t}) + \beta_3 * I + \beta_4 \Delta ln(TA_{i,t}) * I + \epsilon_{i,t} \\ \Delta ln(SRISK_{i,t}) = \alpha + \beta_1 ln(SRISK_{i,t-1}) + \beta_2 \Delta ln(TA_{i,t}) + \beta_3 * I + \beta_4 \Delta ln(TA_{i,t}) * I + \epsilon_{i,t} \end{cases} \tag{10}$$

In order to confirm our results we made explicit comparison with a competing model controlling for exogenous variation (Duncan, 1975). In this respect, we perform a structural equation model via Three Stages Least Squares (3SLS) which allows for leverage endogeneity and for Granger causality test with panel data. Three-Stages Least Squares (3SLS) estimates a system of structural equations, where $\Delta(SRISK_{i,t})$ equation contains, among the explanatory variables, the endogenous variable $\Delta(Lev_{i,t})$ which is the de-

[13]Put in another way, we can see that the bank safety-condition in terms of Capital Shortfall ($E_{i,t} - \kappa(E_{i,t} + D_{acc}) \geq 0$) is expressed as: $E_{i,t} \geq \frac{\kappa}{1-\kappa} \frac{1}{1-LRMES_{i,t}} * D_{acc}$.

[14]It is straightforward sustaining that the movement in systemic risk and leverage represents a perfect case of cointegration however, as before, expressing regressions as first-differences allows for a proper specification in terms of covariance stationary (VECM form).

[15]We report results from structural equation model, results from simultaneous equations are available upon request.

pendent variable from another equation in the system.[16] This model is perfectly suited to the case in which a variable is the sum of an exogenous variable and a dependent variable (which might appear as an explanatory variable in some equations). The effects of the increase in the value of total assets on the endogenous variable $\Delta(Lev_{i,t})$ is identified by the exogenous variation in the log-level of leverage in the previous period, and macro-economic or financial indicators which might affect the path in this variable. Particularly, we shape the path for the change in leverage with the level of the Treasury rate (*Treasury rate*), the percentage change in GDP (*GDP*), the average rate paid by banks on commercial paper in order to proxy the cost to increase debt via commercial paper (*CP rate*), the average rate of return of public government indebtedness on the market proxied by the MSCI 10y Gov. Bond index (*Bond Index*), the logarithm of securities pledged as collateral (*Pledged Sec.*) and a dummy variable distinguishing among the crisis and no-crisis periods (*crisis*); while the effects of the increase in the fair value of assets on the endogenous variable $\Delta(SRISK_{i,t})$ is identified by the exogenous variation of the autoregressive term of the dependent variable (in logarithm), a dummy variable indicating if the Dodd-Frank Act is entered into force (*DFA*), the percentage change in GDP with respect to the previous quarter (*GDP*), the CPI index in order to control for US inflation (*Cpi*), the change in the return and volatility of the US market proxied by the log-differenced value of the total return index of the S&P500 (*S&P*) and the VIX (*Vix*) respectively, and a dummy variable distinguishing among the crisis and no-crisis periods (*crisis*). Among the set of exogenous regressors for the change in systemic risk we further consider the logarithm of the share of assets in the form of loans to US banks (*Loans US banks*) -in order to proxy interconnectedness with the banking system-, and the share of domestic to consolidated assets (*Domestic A.*). The description of the exogenous variables in the vector $\mathbf{X_{i,t}}$ is explained in the following section.

$$\begin{cases} \Delta ln(Lev_{i,t}) = \alpha + \beta_1 ln(Lev_{i,t-1}) + \beta_2 \Delta ln(TA_{i,t}) + \beta_3 * I + \\ \qquad \beta_4 \Delta ln(TA_{i,t}) * I + \beta_5 \mathbf{X_{i,t}} + \epsilon_{\mathbf{i,t}} \\ \Delta ln(SRISK_{i,t}) = \alpha + \beta_1 ln(SRISK_{i,t-1}) + \beta_2 \Delta ln(Lev_{i,t}) + \beta_3 * I + \\ \qquad \beta_4 \Delta ln(TA_{i,t}) * I + \beta_5 \Delta ln(Lev_{i,t}) * I + \beta_6 \mathbf{X_{i,t}} + \epsilon_{\mathbf{i,t}} \end{cases} \tag{11}$$

4 Data

Dataset. We collect quarterly data from US BHCs filling the FRY-9C from January 2002 to March 2016 and we extend this dataset in three directions. Firstly, we merge data with information on systemic risk measures as published monthly by VLAB Stern School of Business. Secondly, we include information based on the participation in the Discount Window, Term Auction Facility and Capital Purchase Program implemented by the Federal Reserve and the Treasury respectively. Thirdly, we use information on large banks as defined by the Federal Reserve Statistical Release and SIFI *status* as released by the Financial Stability Board and the Basel Committee on Banking Supervision.

Initially, our dataset includes 6,104 BHCs for the years under consideration. However, we narrow it considering only consolidated balance sheets of banks with total assets greater than 500 million of dollars filling the "BHCK" fields.[17] Thus, our final dataset comprises observations for 1635 BHCs from January 2006 to March 2016 and Table A2 in the Appendix provides details about states in which they are located.

[16] All dependent variables are explicitly taken to be endogenous to the system and are treated as correlated with the disturbances in the system's equations. Further, because some of the explanatory variables are the dependent variables of other equations in the system, the error terms among the equations are expected to be correlated.

[17] Beginning March 31, 2006, the FR Y-9C filing threshold was increased from $150 million to $500 million or more and FR Y-9SP filing threshold was increased from $150 million to banks with total consolidated assets of less than $500 million.

Table A3 provides the distribution of Federal Reserve districts designated to supervise the banks in the sample.[18] In order to compare the effects on leverage and systemic risk pro-cyclicality, using the same sample of banks, we exclude financial institutions that are not publicly traded because SRISK measure is based on stock market equity returns.

In order to proxy the systemic risk contribution we use the indicator proposed by Brownlees and Engle (2012) -SRISK-. The pros of this indicator encompass both the use of market prices and accounting data to infer the riskiness of an institution by measuring capital reduction following a systemic event: market prices are readily available and allow for real time measurement of risk while accounting data allows for a direct link with leverage pro-cyclicality.[19] Particularly, this measure consists of two parts: first, the cost for the society of a systemic crisis measured per dollar of capital shortage in the entire financial sector (this implies measuring the probability of a systemic crisis and the external costs of such a crisis), and a second part, which is the firm's anticipated contribution to the capital shortage in that sector (that is, measuring the expected capital shortfall of a firm in a crisis). VLAB (NY Stern School of Business) provides monthly systemic risk measures for a wide set of financial institutions including bank holding companies, insurance companies, money market funds, mutual funds, structural investment vehicles and hedge funds. From January 2006 to March 2016 VLAB has computed SRISK monthly measures for 178 institutions per year; we exclude from our analysis insurance, private equity, real estate and asset management companies leaving us with a sample of 95 institutions. Particularly, excluding those institutions we pass from a sample of 20911 bank-month observations to a sample of 14188 bank-month observations. Moreover, data were originally on a monthly basis and they have been aggregated as quarter-average leaving us with a sample of 3361 SRISK bank-quarter observations for 110 Bank Holding Companies.

The seriousness of the recent financial crisis entailed that the Federal Reserve joined the fray. The US central bank intervened with a series of programs in its role of Lender Of Last Resort (LOLR) with the aim to alleviate liquidity problems in the short run.[20]Among them, DW (Discount Window) and TAF (Term Auction Facility) were addressed to depository institutions, saving and commercial banks. The Discount Window is a "no ask question" program (for Primary Credit), the interest rate is fixed in advance by the Federal Reserve according to the federal funds rate (FOMS, Federal Open Market Committee target rate), with no limits on the amount borrowed (provided collateral and shortcut on it); while TAF is auction-based and there are limits on the bid and on the amount offered. Provided that both programs offer liquidity in the short-term, the main difference among them is that DW is an overnight lending facility while TAF is a term one (once the bank got funds with TAF, the borrower cannot repay them before the maturity, in other words, the borrower is obliged to pay interests on these funds at least for 28 days). Moreover, TAF has been created with the idea that approaching collectively at the auction, banks could avoid the "stigma" associated to DW financing (Armantier et al., 2015). The reason why we include these programs in the analysis is to address the strongest objection linked

[18]We exclude from the analysis financial institutions belonging to Charter type (RSSD9048) of insurance broker or insurance companies (code 550), Employee Stock Ownership Plan (code 610), securities broker or dealer (code 700), utilities company and credit card companies without commercial bank charters (codes 710 and 720).

[19]For the sake of completeness we should point out that there are different measures of systemic risk proposed in the literature: one of them is CoVar by Adrian and Brunnermeier (2011). However, CoVar measures are not explicitly sensitive to size or leverage, moreover CoVar has a lot of cross-sectional variation but it is quite stationary in the time-series dimension.

[20]In some cases, the government parties provided capital and agreed to provide certain loss protections and liquidity supports for specific institutions. On November 23, 2008, the U.S. Department of the Treasury, the Federal Reserve, and the FDIC jointly announced that the U.S. government would provide support to Citigroup to contribute to financial market stability. The same happened for Bank of America on January 16, 2009.

to these programs: in particular, the fear of moral hazard, because access to a liquidity facility may lead banks to opt for bolder policies with less liquidity self-protection (e.g. lower reserves) and, in the event of a liquidity crisis, to choose to incur debt from the Federal Reserve to avoid default on private debts and preserve creditworthiness. For what concern data on Discount Window, they are published quarterly with two years lag from the first quarter of 2010 (thus our dataset contains data up to March 2014). Particularly, the original data comprise information on 11,448 DW operations conducted from July 2010 to March 2014. Their distribution is provided in Figure A1 (in the Appendix section): among them 8070 took part in the form of primary credit, 2,836 in the form of seasonal credit and 542 in the form of secondary credit. However, we exclude from the sample credit unions, thrifts and borrower banks which do not belong to bank holding companies (we match banks based on ABA number of commercial banks which are part of BHCs). Provided that 91% of banks asked for funds more than once during each quarter, the dummy variable equals one if the BHC participated in the facility at least once in the quarter; thus we collapse daily data by the creation of a dummy variable equals 1 if the bank participated in the DW program in the quarter of analysis and zero otherwise. Once we exclude multiple accesses in the facility we remain with 6,774 borrower-quarter observations (which become 2,927 when we exclude from the analysis banks which are not part of a bank holding company). TAF was active from December, 12th 2007 to March, 8th 2010 and data were release on December 2010 under the Dodd-Frank Act. Banks participated in this facility 4214 times. Even in this case banks asked for funds more than once during each quarter: collapsing multiple accesses and excluding banks which are not part of a bank holding company, the dummy variable TAF is equal to 1 in 427 cases. In the first stage of the analysis we do not distinguish among the two facilities and we create the indicator variable $LOLR$ equals to one if the bank asked for DW or TAF funds in the quarter of analysis and zero otherwise. Table A4 in the Appendix provides a summary for TAF and DW operations, distinguishing by primary, secondary and seasonal facility.

In order to analyze risk-taking incentives we pay special attention to the sub-sample of banks defined as Systemically Important Financial Institutions (SIFIs). As a regulatory response to the revealed vulnerability of the banking sector in the financial crisis of 2007–08, and attempting to come up with a solution to solve the "too big to fail" interdependence, the Financial Stability Board (jointly with the Basel Committee) has identified factors for assessing whether a financial institution is systemically important: its size, its complexity, its interconnectedness, the lack of readily available substitutes for the financial infrastructure it provides, and its global (cross-jurisdictional) activity. The analysis started in November 2009 and the first official version of the G-SIBs list was published by FSB in November 2011 (and has been marginally updated each year in November). Basel III requires that all identified G-SIBs no later than March 2018, shall operate with a minimum Total Capital Adequacy Ratio comprising: min (8.0%, 8.5%, 9.0%, 9.5%, 10.5%) high quality Tier1 Capital (Common Equity Tier 1 Capital)[21], max 2% Tier2 capital (Subordinated capital), max 1.5% Additional Tier1 capital (Hybrid capital, i.e. Contingent Convertibles aka CoCos). In addition on February 2, 2015 the FSB issued a finalised document that defines a global standard for minimum amounts of Total Loss Absorbency Capacity -TLAC- to be held by G-SIBs.[22] Moreover, in the United States the financial regulator put towards domestic systemically

[21] This requirement towards G-SIBs depends on an indicator-based measure of size, interconnectedness, complexity, non-substitutability and global reach, elevating it to be 1.0% or 1.5% or 2.0% or 2.5% or 3.5% higher, compared to the similar Basel III capital requirement at 7% towards banks not contained in the list.

[22] Moreover, Basel III regulation in addition also introduced a potential counter-cyclical capital buffer, which can be enforced by national authorities on top of the noted Total Capital Adequacy Ratios, with demands of up till 2.5% extra Common Equity Tier1 capital towards all financial institutions (incl. SIBs), during years where the total lending in the specific nation starts to grow faster than the national GDP.

institutions special attention on different dimensions. The Financial Stability Oversight Council (FSOC) does not designate any banks or bank holding companies as systemically important, but the Dodd-Frank Act in the statute imposes heightened supervision standards for specific banks: any bank holding company with a balance sheet larger than 50 billion$ is subject to the Comprehensive Capital Analysis and Review (CCAR) whilst DFAST requirements (Dodd-Frank Act Stress Tests) apply to a broader range of financial companies with total assets over $10 billion.[23] Despite the lack of any official D-SIB designation, banks being subject to the USA Stress Test (CCAR) can be considered to be D-SIBs in the United States.[24] Secondly, All G-SIBs and D-SIBs with headquarters in USA, are also required to submit an updated emergency Resolution Plan each year to the Board of Governors of the Federal Reserve System. Table A5 in the Appendix includes all financial institutions identified as systemically important by the FSB (Global-SIBs) and by the national regulator (the so-called Domestic-SIBs) and we define the dummy variable *SIFIs* equal to 1 in the quarter in which the G-SIBs or D-SIBs *status* is acquired and it stays 1 unless that bank is removed from the list.

Given that for the introduction of Basel III the period of consideration represents a "transition period" because banks have to be fully-compliant with Basel III capital requirements by March 2018 we devote special attention on the sub-sample of banks defined to be under regulatory pressure (*Reg. Pressure*). Particularly, we define banks to be under regulatory pressure when the ratio of Common Equity capital over risk weighted assets (RWA) is below Basel II capital requirement of 8%. In fact, if Basel II regulation (under Pillar I) requires that Total Capital over RWA should be greater or equal than 8%, our index (*Reg. Pressure*) represents the distance from the total capital requirements by common equity; moreover the minimum Basel III requirements will include a 7% Common Equity Tier 1 by January 2019. This dummy variable is equal to 1 if the indicator for bank i at time t has a value below 8%. The distribution along time of the CE/RWA, Total Capital Ratio is provided in Figure 10.Table 1, in Section 8, provides the distribution of the dummy variable *Reg. Pressure* along time, showing that for 3832 bank-quarter observations this indicator is equal to 1. The description of the FR-Y9C fields to compute this variable is provided in Table A1 in the Appendix.

Lastly, we focus on banks which have participated into the Treasury's CPP program to investigate the effects of capital shortage. Through the CPP, Treasury purchased preferred stock from qualifying financial institutions aiming at strengthening their capital bases, increasing CPP participants' capacity to lend to U.S. businesses and consumers and to support the U.S. economy. Treasury initially committed more than a third of the total TARP funding, $250 billion, to the CPP, which was later reduced to $218 billion in March 2009. At the end of the investment period for the program, Treasury had invested approximately $205 billion under the CPP. Under this voluntary program, Treasury provided capital to 707 financial institutions in 48 states: the first investment was made on October 26th 2008 (to Bank of America) while the final investment was made in December 2009; however, we do not consider Treasury's investments in all 707 because we exclude Small BHCs and commercial banks which are not part of BHCs from the analysis.[25] The indicator variable *CPP banks* is equal to one for the quarter in which the bank

[23]The regulator set the selection criteria, establish hypothetical adverse scenarios and oversee the annual tests. Banks showing difficulty under the stress tests are required to postpone share buybacks, curtail dividend plans and, if necessary, raise additional capital.

[24]The group of banks being stress tested was identical throughout 2009-13, except for MetLife Bank ceasing its banking and mortgage lending activities in 2012 - and therefore subsequently leaving the group of supervised entities. In 2014 the stress test was expanded from 18 to 30 banks, as a result of a phase-in of the provisions of the Board's Dodd-Frank Act stress test rules, only making the additional 12 entities subject to this stress test starting from 2014.

[25]Respondent to 2015 Survey about use of CPP funds banks declared that they have increased securities purchased (ABS, MBS, etc.), make other investments, increased reserves for non-performing assets, reduced borrowings, increases charge-offs, purchased another financial institution or purchased assets from another financial institution, held as non-leveraged

under consideration has outstanding capital in the form of CPP preferred stock. The distribution along time for this indicator is provided in Table 1 (Section 8).

Variables. In the baseline model we define the increase in assets as the change from previous quarter of the logarithm of Total Assets (including those valued at *fair value*). In the same way, we compute the change in leverage ratio ($\Delta ln(Lev_{i,t})$) as the quarterly log-differenced leverage for bank i at time t (with respect to the previous quarter) and the change in systemic risk, $\Delta ln(SRISK_{i,t})$, as the quarterly log-differenced leverage for bank i at time t (with respect to the previous quarter). Since both leverage and systemic risk are represented by ratio and percentage respectively, in order to avoid negative-bias due to logarithm of percentages between 0 and 1, we adjust the SRISK indicator by shifting of 1 the measure before computing the logarithm; we did not the same for leverage because the minimum value in the sample for leverage is 1 (as reported in the summary statistics).

Concerning the drivers for the increase in leverage, we consider the log-differenced change between two subsequent quarters in the following variables representing short-term debt: issue of commercial paper (*Com.Pap.*), repos (*repo*), repos having as counter-party the Federal Reserve (*FedRepo*), interbank-debt (both borrowed money from other commercial banks in the United States and balances due to subsidiaries) -*Interbank*- and participation into Federal Reserve's liquidity facilities (*LOLR*). When we consider the set of feasible drivers for systemic risk, we add to short-term debt forces, accounting variables which proxy riskiness on the asset side. In particular, we consider the log difference of derivatives in bank's portfolio (*Derivatives*) and the distance from the "traditional" banking activity proxied by the log difference of securities over TA (*Investment b.*); whilst, in order to consider bank-specific riskiness we employ the log-differenced value of the Z-score (*Z-score*). We use the log-difference in *Tier2* to proxy the adjustment towards regulatory capital with Tier2 and the log-differenced value of loans commitments to proxy the riskiness of liquidity draw-up on the assets side. The FRY-9C codes are described in the Appendix (Table 1).

In what concerns the vector of macro variables used as controls in the structural regression we employ a set of interest rates in order to proxy the relative advantage of increasing debt. We consider the average rate on commercial papers (*CP rate*) and the average rate paid on treasury bond (*Treasury rate*). The series are provided from the Federal Reserve Bank of St. Louis (report H15[26]) and they have been transformed in order to take the difference from the previous quarter. In order to proxy average productivity and growth we use the current dollar percentage change of GDP at national level (*GDP*) from World Bank and the change in the Consumer Price Index at the State level from the US Bureau of Labor Statistics (*Cpi*) in order to proxy inflation. In order to proxy market-sentiment we use the log-differenced value of the total return of S&P500 (*S&P*) and the MSCI US benchmark 10Years government bond index (*Bond Index*). Daily return for these indices are provided by Datastream and they have been averaged over the quarter. Moreover, to take into account market volatility we use the log-differenced value of the VIX index for quarter t: as before, daily return have been averaged over the quarter (*Vix*). Further, we consider two events in the period under consideration: we use as definition of *Crisis*, the period from the fourth quarter of 2007 to the second quarter of 2009 as done by the Federal Reserve Bank of St. Louis and the dummy *DFA* which represents the introduction of the Dodd-Frank Act on October 2010. Along with macro- control variables, in the specification of the structural equation estimated via 3SLS, we use bank-specific variables in order to control not only for state-time characteristics which impact all banks but even for heterogeneity across banks. These refer to the log differenced value at

increase to total capital.

[26]Board of Governors of the Federal Reserve System (US), Effective Federal Funds Rate, retrieved from FRED, Federal Reserve Bank of St. Louis; *https://fred.stlouisfed.org/series/FEDFUNDS*.

time t for bank i of the logarithm of securities pledged as collateral -*Pledged Sec.*- (in the pro-cyclical leverage equation), while in the pro-cyclical SRISK equation we control for the ratio of domestic assets over consolidated assets (*Domestic Assets*) as provided by the Federal Reserve Statistical Release, and finally for the share of loans to US banks (*Loans US banks*) in order to proxy interconnectedness with the banking system.

5 Results

5.1 Summary statistics

Table 2 provides summary statistics for the main variables considered in the analysis both for the whole sample and for four sub-samples of banks: those that had access to liquidity facilities (*LOLR*), *SIFIs*, banks under regulatory pressure (*Reg. Pressure*) and banks participating in the CPP program (*CPP banks*). In order to avoid mis-leading results due to changes in accounting regulation from local GAAP to IAS/IFRS system and different thresholds of BHCs reporting, we use data starting from the first quarter of 2006 up to the first quarter of 2016 (41 quarters). Data for assets are expressed in million of dollars and we report log-variables and their Δ (log-differenced value with respect to the previous quarter). Number of observations reduced from 41244 to 40529 because in this way we lose the observation in the first period for each bank.

First and second row of each panel show that, on average, SIFI banks are larger than banks participating in Federal Reserve's liquidity and the Treasury's Capital Purchase programs (*LOLR* and *CPP banks* respectively) and both are larger than banks under regulatory pressure. In what concerns the growth rate in assets, the third row of each panel shows that Treasury's participated banks and *SIFIs* are those with the higher growth rate with respect to banks with liquidity shortages and banks under regulatory pressure. Moreover, *LOLR* banks and banks under regulatory pressure are those with high variability in the growth rates and present fat tails towards negative growth rates.

Concerning leverage ratio, the reduction in number of observations is due to the number of listed banks because we consider the sample of banks for which we have information on systemic risk. Banks highly leveraged in our sample are those participating in Federal Reserve's liquidity injection programs and SIFIs, whilst those under regulatory pressure and *CPP banks* are marginally less leveraged. However, all banks in our sub-samples are more leveraged than banks in the control group. Interestingly, when we consider the growth rate of leverage we see that banks in the whole sample and banks under regulatory pressure have a humble growth rate of leverage, but *CPP banks* and banks participating in Federal Reserve's liquidity injections programs have the higher growth rate in leverage; thus, LOLR banks are not only the more leveraged banks in our analysis but also those which are increasing debt even further. Surprisingly, SIFIs have, on average, a deleveraging process with a negative growth rate of leverage.

In what concerns systemic risk, as standard in the literature for percentages, we operated a marginal change adding 1 to the original measure of SRISK (in terms of distribution there are no differences except the shift to the right). This transformation allow us to exclude mis-leading results due to negative values of ln(SRISK) for all values between 0 and 1. Table 2 shows that banks under regulatory pressure and SIFIs are those with larger systemic risk with respect to *CPP banks* and banks which participate in the Federal Reserve's liquidity facility. Systemic risk in all sub-groups is larger than in the whole sample. However, when we consider the growth rate of systemic risk results are quite different: SIFIs are those with the lower growth rate (even smaller than the growth rate of the overall sample), whilst *LOLR* banks have the larger growth rate in systemic risk followed by banks under regulatory pressure and banks participating in the Treasury's Capital Purchase Program.

Table 3 reports results from differences in mean across sub-samples. Panel A shows differences among $LOLR$ banks and banks did not participate into Federal Reserve's liquidity programs. Results show that, on average, nonetheless $LOLR$ banks experienced a lower increase in assets with respect to the control group they had a greater increase in leverage and systemic risk (all differences are statistically significant at 1% level of significance). Moreover, distinguishing among the two liquidity facilities allows us to disentangle the effects of Discount Window from Term Auction Facility programs: differences show that for banks participating in the overnight program (DW), assets growth less than in the control group and leverage decreases with respect to the control group, while for banks participating in the auction-based facility (TAF) assets growth more than in the control group, and they increase leverage more than in the control group. Concerning *SIFIs*, Table 3 shows that these banks have a greater increase in leverage with respect to the control group; however, they do not show any difference in the growth rate of systemic risk. Banks under regulatory pressure, *Reg. Pressure*, show a larger growth rate in assets and systemic risk with respect to the control group but a non-statistically significant difference in the growth rate of leverage. Lastly, CPP banks show a decrease in the growth rate of assets and a decrease in leverage with respect to banks which did not participate in the Treasury's CPP program (however, last difference is not statistically significant). Table 4 provides results from correlation analysis and confirms the positive and statistically significant correlation among $\Delta ln(TA)$ and $\Delta ln(Lev)$ which is equal to 0.0649 and between $\Delta ln(Lev)$ and $\Delta ln(SRISK)$ which equals 0.326 (significant at all statistical level). This (possibly) lead to correlation between $\Delta ln(TA)$ and $\Delta ln(SRISK)$ of 0.0932 significant at all levels of significance. Distinguishing among sub-samples, correlation analysis in Panel B of Table 4, shows that SIFIs are those banks for which the correlation among the growth rate of assets and leverage and the correlation among the growth rate of systemic risk and leverage are the larger.

5.2 Empirical analysis

Pro-cyclical leverage. Table 5 reports results from the analysis on leverage pro-cyclicality via fixed-effect regressions controlling for year-quarter, bank and Federal Reserve District fixed effects.[27] Particularly, column (1) confirms results from Adrian and Shin (2010): controlling for the logarithm of leverage in the previous period, the increase in assets, when evaluated at fair value, leads to an increase in leverage in the same quarter. That is, banks are far from being passive and they actively manage their balance sheets increasing leverage during booms and decreasing it during bursts. Columns (2) proves the same result controlling for Federal Reserve district fixed effects: with this specification the overall significance of the regression increases substantially and the degree of pro-cyclicality shift from 14% to 23%; that is, a one percent increase in assets leads to a 23 basis points increase in debt (Adrian and Shin (2010) showed that the increase in debt took place mainly via the increase in short-term liabilities). However, endorsed from evidence in Figure 1, we test if the adjustment in leverage in the short-run is different during the crisis and no-crisis period. Results from column (3) and (4) report that the de-leveraging process during the crisis is more severe than the pro-cyclicality during booms: when fair value of assets decreases by one percent, leverage decreases by almost 43 basis point, while the increase in fair value of assets allows for an increase in leverage of almost 10 bp.

Pro-cyclicality for sub-samples. Evidence from Figures 6(a), 7(a), 8(a), 9(a) leads us to analyze if

[27]Results from Hausman specification test, available upon request, favour FE in place of RE for specification (1) and (2) of Table 5 with a χ^2 statistic of 121.14*** and 176.15*** respectively.

there are differences among sub-groups of banks in their degree of leverage pro-cyclicality. In particular we test this hypothesis among four groups and results are shown in Table 6. Banks participating into Federal Reserve's liquidity programs, column (1), show a more-pronounced pro-cyclical effect of leverage; in fact, their interaction coefficient ($\Delta ln(TA_t) * LOLR$) is positive and statistically significant with respect to the baseline model. This result suggests that these banks, not only ask for funds at the central bank, but they increase their debt even further perhaps benefiting from lower cost of funding after borrowing from these facilities. Column (2) shows results for banks identified by the Financial Stability Board and the Basel Committee on Banking Supervision as "Systemically Important Financial Institutions".[28] These banks, although show a reduction in leverage *per se* -as confirmed by summary statistics-, show pro-cyclicality of leverage and seem to be the category with strongest pro-cyclical behaviour. That is, higher capital requirements which they must be compliant with by 2019, lead them to decrease leverage *per se* but, at the same time, these banks are those which take more advantage when there is an increase in asset value by increasing debt during booms and decreasing it during bursts. One of the reasons for this evidence could be associated to the trade-off of their *status*: on one hand, they have to be compliant with higher capital requirements, on the other hand, they benefit from the TBTF *status* which increases their creditworthiness and allows them to benefit from cheaper sources of funding. Column (3) tests our prediction for the set of banks considered under regulatory pressure: this group identifies banks with a "$Equity/RWA$" ratio below 8%. Consistently with economic intuition, banks that have to be compliant with tougher capital regulation not only show that leverage is not pro-cyclical but show that the interaction coefficient is negative and larger than that in the baseline group ($\Delta ln(TA_t) * Reg.Pressure$). Intuitively, during booms they use proceeds from the increase in equity in order to deleverage with a negative slope overall. Results from column (4) report coefficients for banks which have participated into Treasury's Capital Purchase Program. Interestingly, CPP banks show a negative coefficient for the interaction term however, the net effect is still positive. This evidence suggests that banks increasing their share-offering having as counter-party the Treasury, operate during booms via deleveraging. The net effect appears to be still positive even if very mild with respect to the baseline group.

Motivated by the evidence that bank's leverage management might be different along time, Table 7 (Panel A and B) reports the same analysis distinguishing two different periods: crisis and no-crisis. Interestingly, for the group of $LOLR$ banks the coefficient associated to pro-cyclicality of assets is positive and in line with what found during the overall period; however, the same group shows that they did not deleverage during the crisis: when asset value fell down, they did not decrease leverage resulting in a non-statistically significant coefficient for $\Delta ln(TA_t) * LOLR$. In fact, these banks increased their leverage participating into Federal Reserve's liquidity facilities during the crisis. Concerning SIFIs and banks under regulatory pressure there are no differences among the crisis and no-crisis period except in the magnitude, which plays a significant role. If during booms SIFIs increase their leverage by 35 basis points following an increase of one percentage point in assets value, during the crisis they operate strongly via deleveraging reducing by almost 5% their leverage when assets value decrease by 1%; analogous story happened for banks under regulatory pressure (*Reg. Pressure*): they operate with a counter-cyclical leverage during booms -reducing debt following an increase in assets value- and increasing debt during the crisis when assets value decrease. However, due to the difficulties in raising equity during the crisis their degree of counter-cyclicality is stronger during bursts. Lastly, *CPP banks* show a negative coefficient associated to the interaction variable $\Delta ln(TA_t) * CPP$ although the net effect is mild but still positive during the boom; during the crisis period CPP banks show a counter-cyclical leverage increasing their debt more than the increase in equity when assets value decreases. The fact that banks

[28] As stated before we do not distinguish from Domestic and Global Sibs (D-Sibs and G-Sibs).

tend to increase debt during downturns could be explained by standard corporate finance theories like debt overhang and pecking order theory.

In order to check for possible drivers of previous evidence we perform a fixed effects regression substituting the growth rate of assets with acceptable candidates for the increase in short-term debt. Even if previous literature suggests that banks actively manage their liability side via repos (as the best candidate for short-term debt), our hypothesis is that it is not always the case. In fact, Table 8, shows that for the whole group in our sample, column (1), the increase in leverage is mainly due to the increase in interbank funding with a positive coefficient of 0.1976; Columns (2), (3), (4) and (5) show that this evidence is not validated for all sub-groups under analysis. Particularly in column (2), banks which took part in the Federal Reserve's liquidity injection programs, that is banks that borrow short-term fundings from Discount Window and Term Auction Facility, show an increase in repo funding having as counter-party the Federal Reserve, a heavier reduction in repos as funding source and, more than others, they rely on interbank fundings. This evidence is at odds with what has been shown from Adrian and Shin (2010): our analysis confirms that banks increase their short-term financing but repo is not the main source (at least for this group of banks). Column (3) provides results for the group of SIFI banks. For this sub-sample results show that the adjustment in leverage happens via traditional short-term debt (repos) which goes with the participation into Federal Reserve's liquidity injection programs and both act as substitutes of commercial paper (for which SIFIs show a deleveraging process). Results from column (4) report the coefficients for the group of banks under regulatory pressure (*Reg. Pressure*): in line with results from previous regressions, these banks do not increase debt in the short-run; at the same time, the fact that none of these coefficients report a negative and statistically significant contributing factor to the decrease in debt means that the deleveraging process happened substantially via an increase in equity. Banks participating into the Treasury's CPP program, coherently with results from Table 6 and 7 show mixed results: on one hand, they increase their solidity from the equity injections following CPP preferred stocks but, on the other hand, evidence shows mixed directions on short-term debt. Column (5) shows positive coefficients associated with an increase in interbank debt and repos having as counter-party the Federal Reserve and a deleveraging process in commercial paper. This evidence does not allow a unique prediction for CPP banks where the prevailing effect will depend on the relative magnitude of these countervailing forces.

Pro-cyclical systemic risk. In this section we test if periods of booms, via the increase in assets, are associated with a shift in the risk appetite of BHCs measured by the change in systemic risk. In Table 9, the baseline model, column (1) shows that when assets increase, as expected, banks become more "systemic" increasing their systemic risk. However, distinguishing our sample by sub-groups contrasting results appear. In particular, banks participating into Federal Reserve's liquidity injection programs, column (2), show that systemic risk increases during booms; these results are in line with evidence in Table 8: banks participating in LOLR programs, not only increase their short-term debt with Discount Window or Term Auction Facility, but also increase interbank debt and repos with the Federal Reserve. When the increase in leverage happens via the interbank market, this more likely will foresee the increase in their systemic riskiness. Interestingly, column (3) shows the effects of the increase in assets for SIFI banks: they exhibit a pro-cyclical behaviour with respect to systemic risk; that is, an increase in assets value is associated to a positive growth of systemic risk in the same quarter validating the hypothesis that even if banks increase their capital in order to be compliant with tougher capital requirements, the increase in leverage, its composition, and in the interlinkages among banks have a positive effect on the growth rate of systemic risk. This evidence is in line with results from Table 8 (column (3)) showing that SIFIs increased repos and their indebtedness with the Federal Reserve from LOLR programs. Columns

(4) and (5) show that systemic risk is counter-cyclical for banks under regulatory pressure and for banks which have participated into Capital Purchase Program even if their net effect is different. That is, taking into account both the interaction variable and the baseline group we notice that banks under regulatory pressure ($\Delta ln(TA_t) * Reg.Pressure$) react from an increase in the fair value of assets with a decrease in the growth rate of systemic risk or, in other words, in order to be compliant with more stringent capital requirement they neither increase leverage during booms nor their degree of systemic risk. Whilst, for banks participating into CPP program the interaction coefficient is still negative but does not compensate the one in the baseline model.

At odds with results from leverage pro-cyclicality, Table 10 shows differences among the crisis and no-crisis period in the degree of systemic risk pro-cyclicality for the same sub-samples of banks. Panel A shows that, during booms, LOLR banks do not increase their systemic risk more than in the baseline group following the increase in assets value; however Panel B shows that they reduce their interlinkages more than the baseline group during the crisis. The opposite happens for SIFI banks, for which the increase in systemic risk following the increase in assets is confirmed during the boom period, while during the crisis period no statistically significant differences emerge with respect to the baseline group. That is, SIFIs do not reduce their interconnectedness when assets value decreases. For the sub-sample of banks under regulatory pressure Table 10 shows in Panel A that these banks do not increase their systemic risk during bubbles, however Panel B shows that during burst they reduce systemic risk following the increase in assets value. Banks participating into the Treasury's CPP program show that systemic risk increases when assets value increase during boom (Panel A), whilst their systemic risk contribution increases also when assets value fall down (Panel B). In Table 11 we study the effects of systemic risk pro-cyclicality on two sub-sample of banks: those with a leverage ratio below 12.5% and above 12.5%. Following our prediction in Equation (9), the idea is to test if there are differences among high leveraged and low leveraged banks because under a threshold of 12.5% banks have room for a pro-cyclical leverage without impact systemic risk. This is so because the underlying, in the short-put option (the inverse of quasi-market leverage), does not reach the strike price implied by Basel capital requirements. Results exhibit that for all banks in our sub-samples results of previous tables are confirmed in Table 11 as long as the leverage ratio is greater than 12.5%. Thus, even if the degree of leverage pro-cyclicality and systemic risk pro-cyclicality is different across groups they have a unique behaviour in what concern targeting systemic risk.

Table 12 analyses a set of feasible drivers for systemic risk pro-cyclicality. Column (1) shows that systemic risk increases following the reduction in Tier2, whilst it increases when bank-specific riskiness increases -*Z-score*. Moreover, pro-cyclicality of systemic risk for *LOLR* banks goes on the assets side riskiness with an increase in derivatives and when banks increase their liquidity exposure loans commitments (*Loans Comm.*). Column (2) shows for *SIFIs* that systemic risk increases when increase short term debt in the form of *repo*, when they meet capital requirements with Tier2 instruments and when they are exposed to liquidity shortages on the asset-side. Both LOLR and banks under regulatory pressure increase systemic riskiness following a reduction in securities (*Investment b.*), even if their motivations might be different: for LOLR banks could be associated to a shift from trading securities to collateralised securities, while for banks under regulatory pressure could be explained by the increase in fire-sales of assets. It is important to notice that banks under regulatory pressure increase their systemic riskiness following an increase in their business *Z-score*. As before, for banks have participated in the Treasury's CPP programs, column (4), no clear results come to light both as liabilities and assets components. **Structural model.** Previous results might be mainly driven by endogeneity of leverage, to its pro-cyclical behaviour and to the interplay with specific drivers related to systemic risk. Thus, we perform structural equation via three stages least squares (3SLS) in order to take into account this source of endogeneity. As before, when assets value increase we should expect a negative effect in quasi-market value of leverage, leading to a decrease in systemic risk. However, the total effect on systemic risk, is due to the interplay of different factors. We test our previous hypothesis in Table 13 and 14 where the reference group is described at the top of each column. For each sub-sample, controlling for the same set of exogenous variables, we provide results for two different system of equation replacing $\Delta ln(TA_t)$ with $\Delta ln(Lev_t)$ in systemic risk equation. Table 13 provides results for banks which have participated into the Federal Reserve's liquidity facilities distinguishing among Term Auction Facility and Discount Window. For all of the them the baseline model shows a pro-cyclical behaviour of leverage, that is, leverage increases following the increase in assets value. However, the contrasting evidence of the mediated effect of leverage on systemic risk for LOLR interaction term lead us to further split the sample among the two facilities. Particularly, columns (3) and (4) show that leverage is pro-cyclical for banks participating into the auction-based liquidity facility, whilst for banks which rely on Discount Window leverage is counter-cyclical meaning that when assets value increases they reduce short-term debt. Moreover, Panel 2 shows that pro-cyclicality of systemic risk is confirmed: the increase in assets value (as well the increase in leverage) lead "*per se*" to an increase in systemic risk, nonetheless differences among the two groups persist. For banks participating in the Term Auction Facility program the degree of systemic risk pro-cyclicality due to the increase in assets value is larger than for banks participating into the Discount Window program; however, the mediated effect of leverage shows that for TAF banks an increase in leverage leads to a smaller increase in systemic risk than the control group; while, for DW banks an increase in leverage leads to a larger increase in systemic risk with respect to the baseline model. Last evidence is in line with the perceived "stigma" associated to banks which borrow from the DW program (Brunnermeier, 2009). Armantier et al. (2015) proved how banks participating in the Discount Window are perceived as financial constrained by market participants with negative return on the market. The exogenous variables in the leverage equation confirm expected effects: for example, banks are reluctant to increase leverage when rate on commercial paper is sufficiently high (increasing their cost of debt), while the higher rate on Treasury securities confirms assets expansion via leverage during boom period. Systemic risk equation shows that periods of greater vulnerability in the market are associated to higher growth rate in systemic risk -as proved by the positive coefficient of Vix-, that systemic risk increases for banks borrowing from Discount Window which lend to other US banks and that systemic risk increases when returns on the market are particularly high (as confirmed by the positive coefficient of $S\&P$). Moreover, results show the reduction in systemic risk following the introduction of the Dodd-Frank Act and that a larger share of domestic assets is not related to a larger systemic risk, but that systemic risk grows more for banks exposed in the international markets (contrary to international diversification theory).

Concerning SIFI banks, Table 14 shows that when assets value increases, leverage is pro-cyclical confirming previous results; however, structural equation reveals contrasting results with Table 9: provided that the increase in leverage and in assets value both lead to an increase in systemic risk, the group of SIFIs does not show any significant difference with respect to the control group with reference to the increase in assets. On the other hand, the larger pro-cyclicality of systemic risk for this group of banks in evidenced by the mediation effect: when leverage increases, systemic risk increases more than in the baseline group. Columns (3) and (4), provide results for regulatory constrained banks: as shown in previous tables, leverage for this group of banks is counter-cyclical; that is, they react to an increase in assets with a reduction in leverage. Moreover, when we disentangle the direct effect of the increase in assets and the mediated effect of the increase in leverage on pro-cyclicality of systemic risk, evidence shows contrasting results. In particular, following an increase in assets banks under regulatory pressure increase their systemic riskiness more than in the control group; while, following an increase in leverage, systemic risk for this sub-sample of banks increases less than in the baseline group. Finally, for the sample of bank participating in the Treasury's CPP program, columns (5) and (6) confirm a counter-cyclical leverage with respect to the baseline group. For what concern pro-cyclicality of systemic risk an increase in total assets lead to a reduction in systemic risk with respect to the control group, while the increase in leverage amplifies the increase in systemic risk with respect to the baseline model.

5.3 Interaction among programs

As we pointed out before, during the financial crisis to maintain confidence in the financial system and to ensure that banks continued to supply loans and avoid panic in the economy, Federal Reserve and Treasury officials became convinced that a systematic approach to financial system solvency risk was needed. Beyond expanding Fed lending programs and bailouts in response to some individual failures, for which they evaluate pertinence case by case, they have created specific capital injections and liquidity programs: among them the Treasury's Capital Purchase Program, the Federal Reserve's Term Auction Facility and renewed the Discount Window lending facility.
Moreover, in November 2013, the Treasury estimated the eventual nominal gains on all CPP investments declaring it would be roughly $16 billion (U.S. Government Accountability Office, 2014) and that the program had succeeded in improving banks' capital levels, thereby enhancing their ability to borrow and lend: but, which are the consequences of the increased "borrowing ability"? In this section we analyze whether the reliance on both liquidity and capital injection programs might have unforeseen consequences on systemic riskiness. From the bank's management point of view, the implicit moral hazard which arises from the presence of these facilities, might result in more risk taking in the future. While, from the market point of view, in presence of expectations of government support (bailouts), market prices may inaccurately reflect systemic risk. In particular, given the goal of each liquidity/capital program we considered, we investigate whether the joint-participation in both programs lead to reverse effects. Lender of Last Resort programs from the Federal Reserve where especially addressed to banks which face liquidity shortages in the short-run, whilst the Treasury advocates CPP funds for all non-financially stable banks in order to restore their capital levels and improve lending ability. In more detail, we conduct previous analysis on three groups of banks. Firstly, we consider banks which both participate into the Federal Reserve's liquidity facility and issued preferred stock bought from the Treasury. On 707 institutions which participate into the CPP program in 2009, we have information on 43 of them which borrowed money from the Federal Reserve as well. Collateralised lending to banks relies upon the use of relatively high-quality assets to make government loans less risky to the central bank or taxpayers. This form of assistance can be effective in resolving pure liquidity problems (where banks lack cash but their problems do not reflect a significant increase in their risk of insolvency). Collateralised lending does not work, however, when bank illiquidity is a symptom of substantially increased default risk of the bank (Calomiris and Khan, 2015). In such circumstances, the use of collateralised lending can actually exacerbate the liquidity problems of a bank by effectively subordinating the bank's depositors to the central bank or government lender (as depositors' claims become effectively junior to the new lender and are backed by relatively risky assets). Under such circumstances, a collateralised loan that raises the riskiness of deposits might even cause a depositor run rather than prevent one. Secondly, we ask whether CPP funds are really suited for all banks and we investigate if, for high-leveraged banks (especially those with fixed income bond), the participation to CPP program might exacerbate the "debt-overhang"

hypothesis (Calomiris and Khan, 2015). In fact, when banks are close to the failure, managers and shareholders prefer to gamble for their rebirth investing in high-return/high-volatility projects. CPP arises in the form of preferred stock purchases. Any purchases of securities (such as preferred stock) had to be accompanied by the granting of warrants (which allow future purchases of stock from the bank at a pre-established price) to ensure that taxpayers shared in the upside potential of recipient institutions. The presence of the Treasury, in the form of preferred-stock investor, push away existing shareholders from the bank's residual claim leading them to further ask for riskiness behaviour. Secondly, and with these respect, we conduct previous analysis on those banks which participated in the CPP program and were highly leveraged (with a Tier1 Capital ratio below the median). Lastly, we investigate how our results change for banks which have participated in the CPP program in 2009 and did not buy-back preferred shares in the same year. Participants that did not exit CPP early were relatively weak, had larger loan losses, and increasingly displayed problems in paying dividends and maintaining profitability (U.S. Government Accountability Office, 2013b). Are there any effects in terms of pro-cyclicality of systemic risk? Table 15 reports in column (1) and (2) results from structural equation for the group of banks which jointly participated in the Treasury's Capital Purchase Program and in the Federal Reserve's Term Auction Facility. Differently from our prediction, evidence shows that both programs reached their scope: that is leverage is counter-cyclical (meaning that the increase in capital more than compensate for the increase in debt), whilst both assets and the mediated effect of leverage are counter-cyclical on those banks with respect to the control group. Columns (3) and (4) exhibit results for banks participating in the CPP program which a Tier1 Capital Ratio below the median (among these banks). Evidence show that they do not manage actively leverage increasing debt when assets value increases but decreasing it; however, when a Low Capitalised banks further increases debt, systemic risk reacts in a pro-cyclical way more than in the control group. Coherently with gambling incentives for risky assets (Acharya and Steffen, 2015), when assets value increases systemic risk is pro-cyclical with respect to the control group. Lastly, banks which participated in the Treasury's Capital Purchase Program in 2009 and did not pay-back preferred shares in the same year show no differences in procyclicality of leverage with respect to the control group (in line with the increase in capital) and no pro-cyclical systemic risk due to the increase in assets value. Furthermore, when these banks increase leverage the mediated effect on riskiness show a pro-cyclical systemic risk.

6 Conclusions

The new capital regulatory framework -Basel III-, the increase in information disclosure required by the Dodd-Frank Act and the extra capital requirements for SIFIs all imply the need to investigate the pro-cyclicality of leverage beyond what done by Adrian and Shin (2010). Their empirical findings show that banks' balance sheets expand by borrowing more during booms and contract during bursts (so-called leverage is pro-cyclical). Using quarterly data from a sample of 1635 US Bank Holding Companies (BHCs) from 2006 to 2016, our baseline model confirms that leverage is pro-cyclical. However, some differences come to light along the different groups of banks characterized by capital and liquidity shortage. Leverage is pro-cyclical for the group of banks participating into the Federal Reserve's liquidity injections program and for SIFIs, whilst, it is counter-cyclical for banks under regulatory pressure (those with a ratio of equity over RWA below 8%) and for those banks participating in the Treasury's CPP program. Results are confirmed when we discriminate among crisis and no-crisis periods for all sub-samples of banks (expect for CPP banks which show a pro-cyclical leverage during the crisis).

Besides, the recent financial crisis led regulators to call for more stringent capital requirements for TBTF banks, to monitor the degree of interconnection in the financial markets and to purposely, monitor bank's capital adequacy via stress test by the fear that the distress of a financial institution impairs the functioning of the financial system. As long as the increase in the value of assets makes banks larger and more interconnected (i.e. via an increase in the interbank debt) and banks do not completely internalise the costs of their fragilities, it is worthwhile studying implications of leverage procyclicality on systemic risk. Thus, on the same sub-samples of banks, we study the effects of the increase in assets value on systemic risk pro-cyclicality. Our results reveal that the degree of systemic risk pro-cyclicality increases for banks that rely on Federal Reserve's liquidity facilities and for SIFIs; whilst systemic risk is counter-cyclical for banks under regulatory pressure and, for banks participating into the Treasury's CPP program systemic risk is still pro-cyclical but lower than the control group.
However, we cannot neglect the fact that under general economic theory both the increase in assets and the increase in leverage positively affect the increase in systemic risk and running two separate regressions would lead to a mis-specified model. Thus, to tackle endogeneity of the increase in leverage, we perform a structural equation model via 3SLS. Controlling for a set of exogenous variables, our structural equation model allows us to examine the effect of an increase in the fair value of assets on the change in systemic risk disentangling the effects of the increase in leverage and in assets. Our results show again that SRISK is pro-cyclical: the links among banks (in terms of their interconnectedness) increase during booms and decrease during bursts. Moreover, structural regression leads to an economically and statistically large difference between banks participating in the Federal Reserve's liquidity programs or banks participating into Treasury's CPP program. In particular leverage is pro-cyclical for banks which have participated in the Term Auction Facility while it is counter-cyclical for banks which have participated in the Discount Window. However, for both type of borrowers systemic risk increases following the increase in assets with respect to the baseline group, while for auction-based borrowers the increase in leverage leads to a smaller increase in systemic risk with respect to the control group. Discount Window borrowers show opposite results: the sensitivity of the increase in systemic risk following the increase in leverage is larger than in the control group, coherently with evidence on "stigma" for these borrowers. Structural equations confirm that leverage is counter-cyclical for banks under regulatory pressure and banks participating in the Treasury's CPP program, but evidence on systemic risk pro-cyclicality for these sub-samples of banks show contrasting results. CPP banks show a lower degree of systemic risk pro-cyclicality with respect to the control group, while regulatory constrained bank evidence a larger increase in systemic risk following the increase in total assets. Finally, differences come to light for SIFIs: they confirm leverage pro-cyclicality in the structural equation, however when we take into account endogeneity of leverage, results do not show systemic risk pro-cyclicality for this group of banks.
The results of this work might have implications in terms of regulatory capital requirements, state-aid in the form of capital, liquidity provisions by the Federal Reserve and mandatory disclosure of information. That is, the analysis shows that the banks that get into debt through the Term Auction Facility show leverage pro-cyclicality but have no implications in terms of pro-cyclical systemic risk; while banks which borrow through the Discount Window are those that suffer the most in terms of systemic risk; as demonstrated by Armantier et el. (2015), Discount Window borrowers suffer negative reactions on the market as a result of participating in this facility with negative implications in terms of SRISK. In this way, the liquidity provision from the US Central bank and the disclosure of Discount Window borrowers are two opposing forces which go against each other for the financial wealth of the bank. On the contrary, as regards the effects on systemic risk pro-cyclicality, the extra capital requirements for SIFIs or their compliance to the Supervisory Capital Assessment Program demonstrate to achieve the

objectives of the regulators. Although TBTF banks confirm pro-cyclical leverage, there are no effects on pro-cyclicality of systemic risk. Finally, for what concerns implications in terms of financial fragility and interconnectedness (as a result of the increase in the value of assets), our results prove that the regulator's attention should be directed to well-capitalised banks and not to those under regulatory pressure.

7 Graphs and Figures

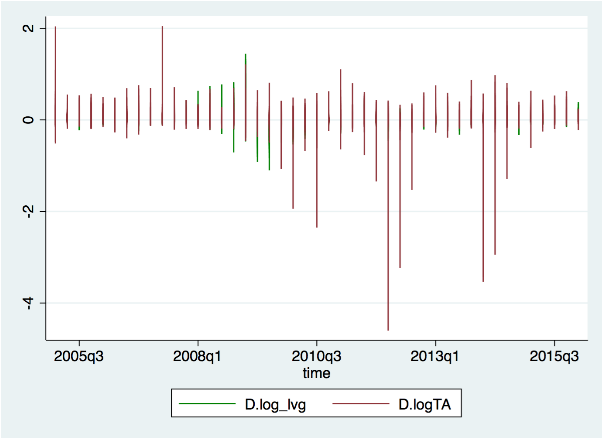


Figure 1: Changes in assets and leverage over time

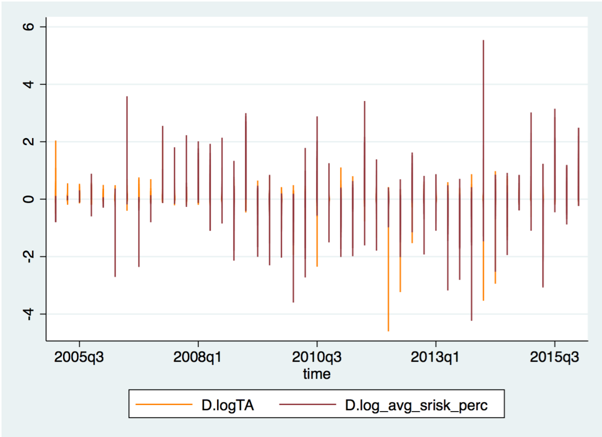


Figure 2: Changes in assets and SRISK over time

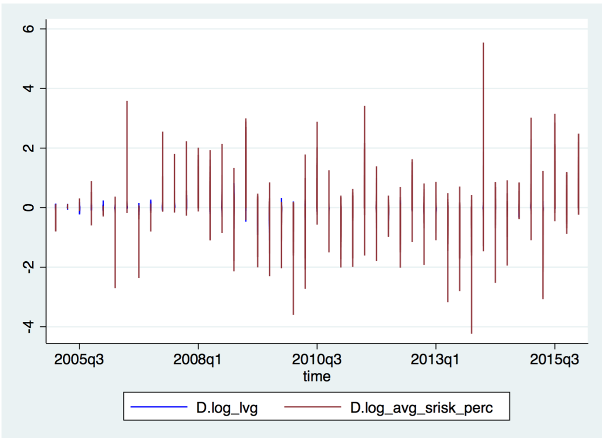


Figure 3: Changes in leverage and SRISK over time

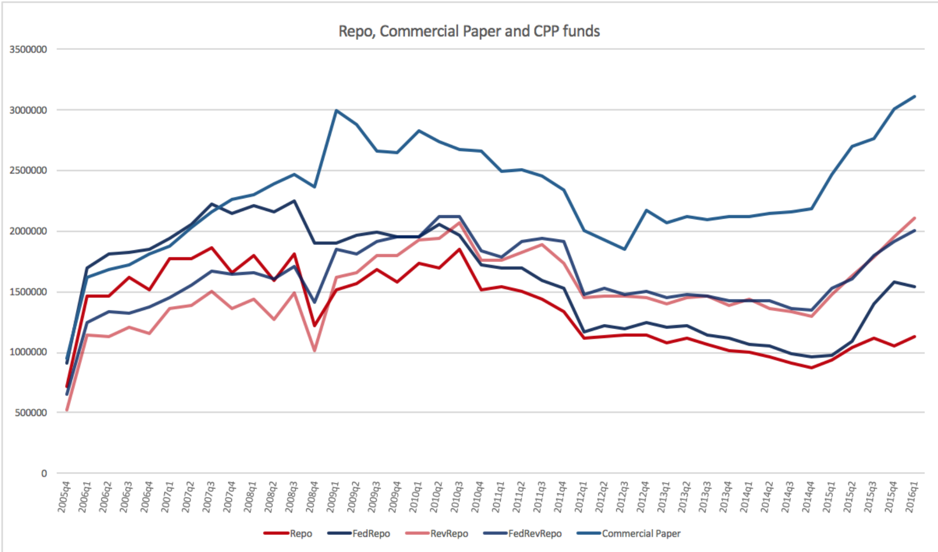


Figure 4: Short-term financing

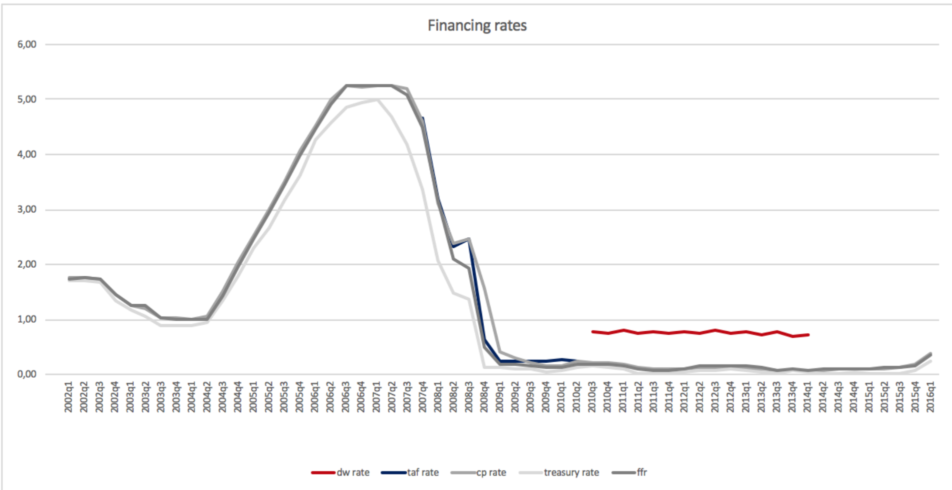
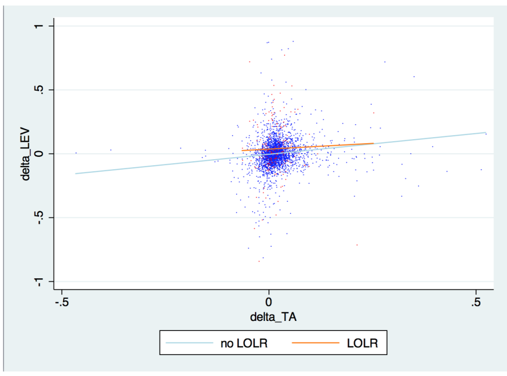
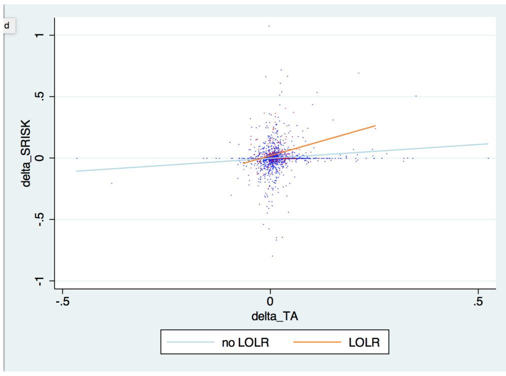


Figure 5: Short-term financing rates

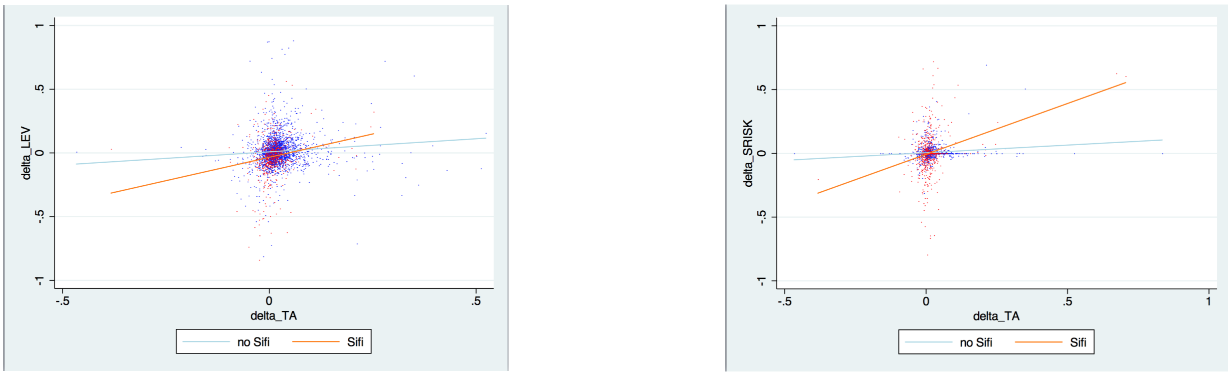


(a) Pro-cyclical leverage



(b) Pro-cyclical srisk

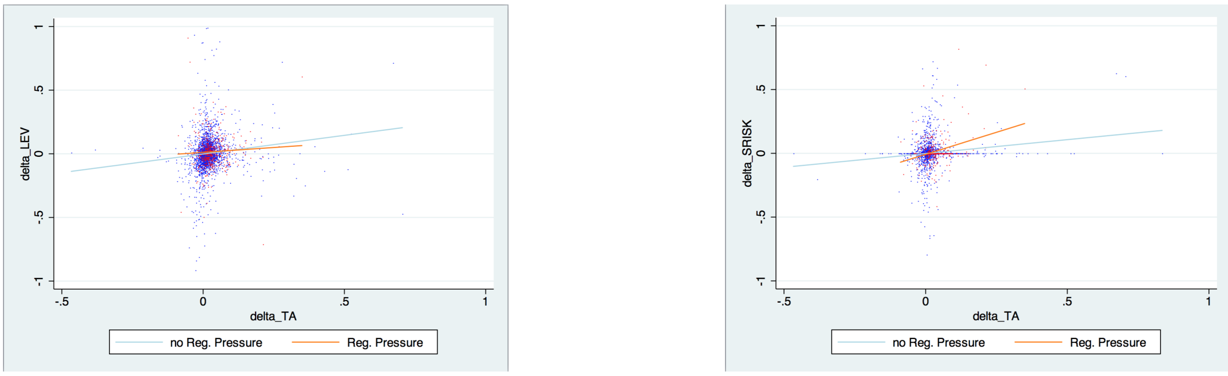
Figure 6: Banks participating in LOLR facilities



(a) Pro-cyclical leverage

(b) Pro-cyclical srisk

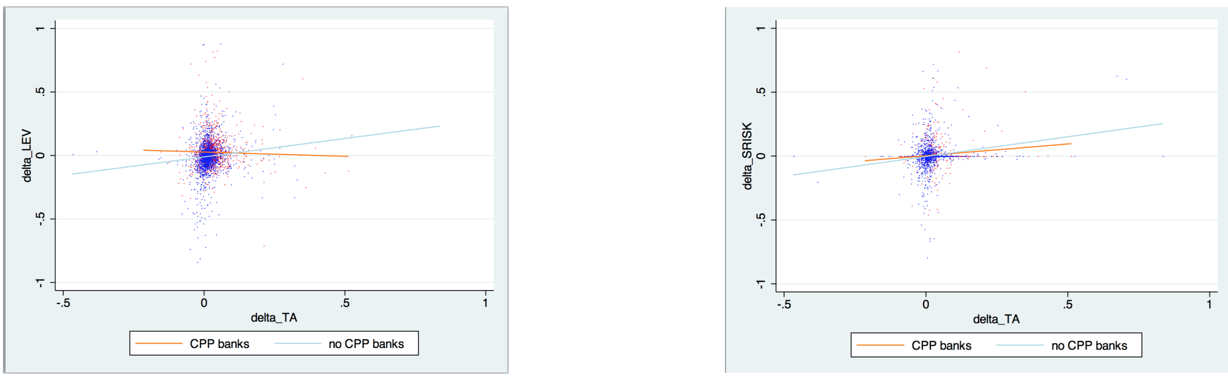
Figure 7: Banks identified as Sifi



(a) Pro-cyclical leverage

(b) Pro-cyclical srisk

Figure 8: Banks under Regulatory Pressure



(a) Pro-cyclical leverage

(b) Pro-cyclical srisk

Figure 9: Banks participating in the Treasury's Capital Purchase Program

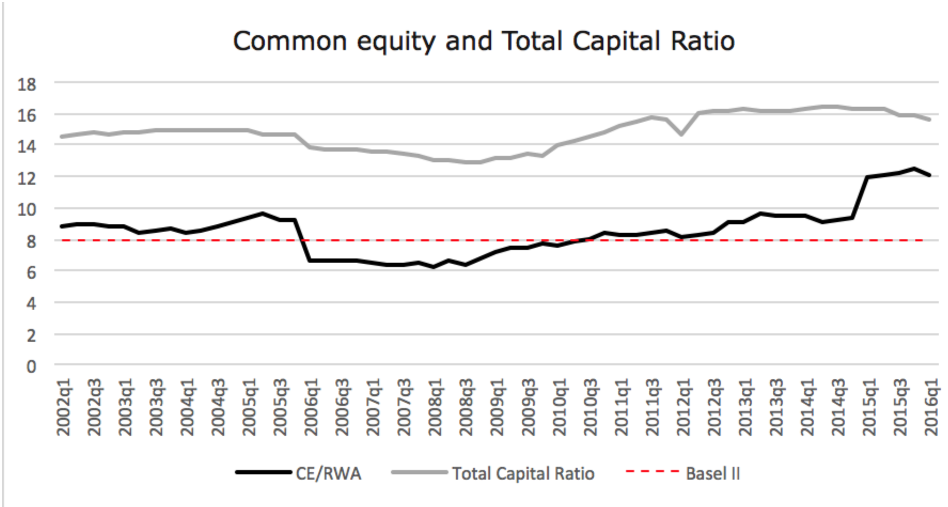


Figure 10: Common Equity ratio and Total Capital Ratio (BS RWA)

8 Tables

Table 1: Sub-samples of banks

Year	LOLR	Sifi	Reg. Press	CPP banks	LOLR & Sifi	LOLR & REG	LOLR & CPP	Sifi & REG	Sifi & CPP	REG & CPP
2006			481							
2007	5		426			2				
2008	71		497			14				
2009	130	18	525	291	13	22	43	5	7	95
2010	336	18	471	248	2	52	43	4	9	97
2011	571	18	390	220	4	73	46	5	4	81
2012	584	18	325	159	7	57	30	3	4	60
2013	681	19	300	108	9	75	25	2	2	47
2014	100	31	258	61	2	14	6	1	1	26
2015		31	91	20				1	1	2
2016		31	68	13						2
Tot.	2478	184	3832	1120	37	309	193	21	28	410

This table reports the distribution by year for different categories of banks. First column reports banks had access to LOLR facilities, the second column reports banks belonging to the group of Systemically Important Financial Institutions, the third column reports regulatory constrained banks (*Reg. Pressure*) and the fourth column shows the distribution for banks participating into the Treasury's CPP program. Other columns report their intersections.

Table 2: Summary statistics

Variable	Obs	Mean	Std.	Min	Max
			All		
Total Assets	41244	1.60E+07	1.01E+08	376	2.55E+09
ln(TA)	41244	14.221	1.448	5.930	21.659
$\Delta ln(TA)$	40592	.0128	.068	-4.602	2.048
Lev.	3361	7.959	6.825	1.020	100.000
ln(Lev.)	3361	1.887	.598	.020	4.605
$\Delta ln(Lev.)$	2995	.007	.146	-1.225	1.444
SRISK	3361	1.716	2.558	1.000	21.867
ln(SRISK)	3361	.223	.583	.000	3.085
$\Delta ln(SRISK)$	2995	.004	.111	-1.703	1.877
			LOLR		
Total Assets	1861	3.40E+07	2.02E+08	160627	2.52E+09
ln(TA)	1861	14.492	1.656	11.987	21.647
$\Delta ln(TA)$	1843	.006	.087	-3.235	.705
Lev.	195	13.345	13.520	1.130	100.000
ln(Lev.)	195	2.273	.813	.122	4.605
$\Delta ln(Lev.)$	187	.063	.291	-.915	1.331
SRISK	195	2.631	3.667	1.000	17.810
ln(SRISK)	195	.486	.813	.000	2.880
$\Delta ln(SRISK)$	187	.042	.124	-.244	.694
			SIFIs		
Total Assets	757	4.12E+08	5.71E+08	4.20E+07	2.52E+09
ln(TA)	757	19.180	1.060	17.553	21.647
$\Delta ln(TA)$	751	.010	.054	-.383	.705
Lev.	614	10.838	8.267	2.363	100.000
ln(Lev.)	614	2.240	.496	.860	4.605
$\Delta ln(Lev.)$	610	-.018	.201	-1.101	1.444
SRISK	614	3.136	4.037	1.000	19.957
ln(SRISK)	614	.646	.869	.000	2.994
$\Delta ln(SRISK)$	610	.001	.167	-1.232	1.077
			Reg. Pressure		
Total Assets	12265	1.28e+07	1.15e+08	4888	2.30E+09
ln(TA)	12265	13.945	1.163	8.495	21.557
$\Delta ln(TA)$	12052	.008	.086	-4.602	.9771
Lev.	367	10.574	9.671	1.766	100.000
ln(Lev.)	367	2.173	.548	.569	4.605
$\Delta ln(Lev.)$	361	.017	.169	-1.101	.912
SRISK	367	3.101	4.330	1.000	19.957
ln(SRISK)	367	.579	.906	.000	2.994
$\Delta ln(SRISK)$	361	.024	.138	-.414	1.407
			CPP banks		
Total Assets	10164	1.45e+07	1.17e+08	67728	2.55E+09
ln(TA)	10164	14.231	1.347	11.123	21.647
$\Delta ln(TA)$	10034	.015	.054	-.382	2.048
Lev.	576	11.050	10.027	1.070	100.000
ln(Lev.)	576	2.164	.662	.067	4.605
$\Delta ln(Lev.)$	567	.053	.254	-.9141	1.444
SRISK	576	1.640	2.161	1.000	17.817
ln(SRISK)	576	.254	.519	.000	3.085
$\Delta ln(SRISK)$	567	.025	.123	-.421	1.407

Table 3: Differences in mean

	N(Others)	Mean(Others)	N(I)	Mean(I)	Diff.	se	t	p-value
				LOLR				
$\Delta ln(TA)$	38749	.0131	1843	.0058	-.0073	.0023	-3.5225	.0000
$\Delta ln(Lev)$	2808	.0029	187	.0634	.0605	.0214	2.8217	.0053
$\Delta ln(SRISK)$	2808	.0017	187	.0416	.0398	.0093	4.2843	.0000
				DW				
$\Delta ln(TA)$	39069	.0131	1523	.0029	-.0102	.0023	-4.323	.0000
$\Delta ln(Lev)$	2903	.0074	92	-.0164	-.0238	.0089	-2.6705	.0087
$\Delta ln(SRISK)$	2903	.0044	92	-.0016	-.0060	.0069	-.8794	.3811
				TAF				
$\Delta ln(TA)$	40272	.0127	320	.0198	.0070	.0034	2.0417	.0419
$\Delta ln(Lev)$	2900	.0023	95	.1407	.1384	.0397	3.4850	.0007
$\Delta ln(SRISK)$	2900	.0016	95	.0834	.0818	.0157	5.2113	.0000
				SIFIs				
$\Delta ln(TA)$	39841	.0103	751	.0128	.0024	.0019	1.231	.2184
$\Delta ln(Lev)$	2385	-.0176	610	.0129	.0306	.0086	3.5724	.0004
$\Delta ln(SRISK)$	2385	.0009	610	.0051	.0041	.0070	.5879	.5568
				Reg. Pressure				
$\Delta ln(TA)$	28540	.0145	12052	.0087	-.0057	.0008	- 6.7165	.0000
$\Delta ln(Lev)$	2634	.0085	367	.0170	.0085	.0111	.7694	.4421
$\Delta ln(SRISK)$	2634	.0037	367	.0242	.0204	.0088	2.3060	.0217
				CPP banks				
$\Delta ln(TA)$	38276	.0133	2316	.00347	-.0098	.0012	- 7.7137	.0000
$\Delta ln(Lev)$	2419	.0114	576	-.0113	-.0227	.0273	-.8307	.4071
$\Delta ln(SRISK)$	2419	.0055	576	.0121	.0065	.0089	.7378	.4614

Table 4: Correlation matrix

Panel A: Correlation -whole sample-

	(1)								
	Total Assets	ln(TA)	$\Delta ln(TA)$	Lev.	ln(Lev.)	$\Delta ln(Lev)$	SRISK	ln(SRISK)	$\Delta ln(SRISK)$
Total Assets	1	0.456***	0.00295	0.280***	0.302***	-0.0173	0.829***	0.831***	0.0554**
ln(TA)	0.456***	1	0.0300***	0.272***	0.375***	0.00269	0.500***	0.585***	0.0434*
$\Delta log(TA)$	0.00295	0.0300***	1	-0.0923***	-0.101***	0.0643***	-0.0615***	-0.0574**	0.0932***
Lev.	0.280***	0.272***	-0.0923***	1	0.433***	0.259***	0.134***	0.172***	0.0995***
ln(Lev.)	0.302***	0.375***	-0.101***	0.433***	1	0.129***	0.359***	0.462***	0.0860***
$\Delta ln(Lev)$	-0.0173	0.00269	0.0643***	0.259***	0.129***	1	-0.0178	-0.000869	0.326***
SRISK	0.829***	0.500***	-0.0615***	0.134***	0.359***	-0.0178	1	0.937***	0.0913***
ln(SRISK)	0.831***	0.585***	-0.0574**	0.172***	0.462***	-0.000869	0.937***	1	0.135***
$\Delta ln(SRISK)$	0.0554**	0.0434*	0.0932***	0.0995***	0.0860***	0.326***	0.0913***	0.135***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Panel B: Correlation by groups

	LOLR		**SIFIs**		**Reg.Pressure**		**CPP banks**	
	$\Delta ln(Lev.)$	$\Delta ln(SRISK)$	$\Delta ln(Lev.)$	$\Delta ln(SRISK)$	$\Delta ln(Lev.)$	$\Delta ln(SRISK)$	$\Delta ln(Lev.)$	$\Delta ln(SRISK)$
$\Delta lnTA)$	-0.1262	0.4337	0.1084	0.2571	0.0563	0.1786	0.0962	0.1599
$\Delta ln(Lev.)$	1	0.2817	1	0.3608	1	0.1894	1	0.3378

Table 5: Procyclicality of leverage

	(1)	(2)	(No-crisis)	(Crisis)
	$\Delta ln(Lev_t)$	$\Delta ln(Lev_t)$	$\Delta ln(Lev_t)$	$\Delta ln(Lev_t)$
	b/se	b/se	b/se	b/se
$ln(Lev_{t-1})$	-.0330***	-.0357***	-.0270***	-.0651***
	(.0048)	(.0059)	(.0044)	(.0163)
$\Delta ln(TA_t)$	.1440***	.2364***	.0920*	.4072**
	(.0527)	(.0642)	(.0502)	(.1637)
Constant	.0675***	.0764***	.0468***	.1748***
	(.0098)	(.0123)	(.0091)	(.0357)
Year– Quarter FE	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes
Fed Reserve district FE	No	Yes	Yes	Yes
Observations	2907	2214	1635	579
No. of groups	80	77	76	56
R^2	.0516	.1168	.0693	.0899
F-test	59.81***	105.48***	87.28***	43.69***

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

This table reports panel regressions of quarterly leverage growth rates on the lagged level of leverage and the growth rates of assets distinguishing by crisis and no-crisis periods. Results are robust with Federal Reserve district fixed effects.

Table 6: Pro-cyclicality of leverage by groups

	(1) $\Delta ln(Lev)$ b/se	(2) $\Delta ln(Lev)$ b/se	(3) $\Delta ln(Lev)$ b/se	(4) $\Delta ln(Lev)$ b/se
$ln(Lev_{t-1})$	-.1693***	-.1185***	-.1337***	-.1328***
	(.0102)	(.0107)	(.0097)	(.0112)
$\Delta ln(TA_t)$	.1441*	.2240***	.3889***	.4898***
	(.0742)	(.0693)	(.0686)	(.0988)
LOLR	.1432***			
	(.0127)			
$\Delta ln(TA_t) * LOLR$	.4220***			
	(.1520)			
SIFIs		-.0358***		
		(.0130)		
$\Delta ln(TA_t) * SIFIs$		.4475*		
		(.2372)		
Reg. Pressure			.0251	
			(.0165)	
$\Delta ln(TA_t) * Reg.Pressure$			-1.2979***	
			(.2119)	
CPP banks				.0089
				(.0087)
$\Delta ln(TA_t) * CPP$				-.3848***
				(.1301)
Constant	.3192***	.2366***	.2566***	.2500***
	(.0197)	(.0199)	(.0192)	(.0198)
Year-Quarter FE	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes
Observations	2907	2907	2907	2907
No. of groups	80	80	80	80
F-test	228.33***	216.41***	255.19***	217.59***

Robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

This table reports panel regressions of quarterly leverage growth rates on the lagged level of leverage, the growth rates of assets and the interactions between the growth in assets and a dummy for four groups: banks participating into Federal Reserve's liquidity programs, SIFIs, regulatory constrained banks and banks participating into the Treasury's CPP program. Results are robust with Federal Reserve district fixed effects.

Table 7: Pro-cyclicality of leverage by groups during the crisis

	Panel A: no-crisis				Panel B: crisis			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
	$\Delta ln(Lev)$	$\Delta ln(Lev)$	$\Delta ln(Lev)$	$\Delta ln(Lev)$	$\Delta ln(Lev)$	$\Delta ln(Lev)$	$\Delta ln(Lev)$	$\Delta ln(Lev)$
	b/se	b/se	b/se	b/se	b/se	b/se	b/se	b/se
$ln(Lev_{t-1})$	-.1878***	-.1326***	-.1545***	-.1440***	-.2837***	-.2194***	-.2001***	-.5303***
	(.0116)	(.0120)	(.0111)	(.0125)	(.0265)	(.0322)	(.0249)	(.0445)
$\Delta ln(TA_t)$	.1871**	.2642***	.4057***	.5964***	.2601	.5376***	.9526***	1.0092***
	(.0819)	(.0761)	(.0748)	(.1130)	(.2454)	(.1881)	(.2057)	(.2311)
LOLR	.1403***				.2932***			
	(.0136)				(.0361)			
$\Delta ln(TA_t) * LOLR$	.3723**				.5760			
	(.1632)				(.3628)			
SIFIs		-.0612***				.0805*		
		(.0144)				(.0482)		
$\Delta ln(TA_t) * SIFIs$		.3572**				4.8702***		
		(.1562)				(1.5339)		
Reg. Pressure			.0523***				.0725	
			(.0189)				(.0664)	
$\Delta ln(TA_t) * Reg.Press.$			-1.4258***				-2.2479***	
			(.2562)				(.5360)	
CPP banks				-.0089				.1624***
				(.0098)				(.0341)
$\Delta ln(TA_t) * CPP$				-.4929***				-1.3775**
				(.1450)				(.6214)
Constant	.3669***	.2842***	.3060***	.2971***	.5775***	.4783***	.4339***	1.1280***
	(.0231)	(.0231)	(.0226)	(.0229)	(.0546)	(.0630)	(.0543)	(.0892)
Year-Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fed Reserve district FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1635	1635	1635	1635	579	579	579	579
No. of groups	76	76	76	76	56	56	56	56
F-test	337.74***	230.95***	250.61***	228.91***	155.61***	94.88***	98.501***	188.43***

Robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

This table reports panel regressions of quarterly leverage growth rates on the lagged level of leverage, the growth rates of assets and the interactions between the growth in assets and four groups: banks participating in Federal Reserve's liquidity programs, SIFIs, banks under regulatory pressure and banks participating in Treasury's CPP program.

Table 8: Drivers for ΔLev

	(1)	(2)	(3)	(4)	(5)
	$\Delta ln(Lev_t)$	$\Delta ln(Lev_t)$	$\Delta ln(Lev_t)$	$\Delta ln(Lev_t)$	$\Delta ln(Lev_t)$
	b/se	b/se	b/se	b/se	b/se
$ln(Lev_{t-1})$	-.1305***	-.1316*	-.2330***	-.0564	-.1438***
	(.0172)	(.0674)	(.0247)	(.0368)	(.0214)
$\Delta ln(repo_t)$	-.0824	-.9108**	.5253**	-.1707	-.0011
	(.1191)	(.4075)	(.2406)	(.2004)	(.1458)
$\Delta ln(FedRepo_t)$	.0083**	.0310***	.0151	-.0007	.0098***
	(.0035)	(.0110)	(.0104)	(.0048)	(.0038)
$\Delta ln(CP_t)$	-.0089*	-.0293	-.0340*	.0037	-.0109*
	(.0051)	(.0190)	(.0180)	(.0090)	(.0057)
$\Delta ln(Interbank_t)$	.1976***	.6425**	.3130	.0853	.1700**
	(.0604)	(.2829)	(.2536)	(.1326)	(.0685)
LOLR	.0682***		.1167**	-.0292	.0419
	(.0263)		(.0531)	(.0794)	(.0299)
Constant	.0672	-.3382**	.4265**	.0084	.1304**
	(.0441)	(.1588)	(.1841)	(.0650)	(.0508)
Year-Quarter FE	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes
Fed Reserve district FE	Yes	Yes	Yes	Yes	Yes
Observations	1958	162	548	260	1405
No. of groups	74	38	23	29	67
R^2	.0480	.0735	.1308	.0353	.0634
F-test	78.94***	18.92***	132.03***	8.80	68.12***

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

This table reports panel regressions of quarterly leverage growth rates on the lagged level of leverage, the growth rates of repo, repo with the Federal Reserve, the issue of Commercial paper, wholesale funding and participation in the Fed's liquidity programs. Results are robust with Federal Reserve district fixed effects.

Table 9: Pro-cyclical systemic risk

	(1)	(2)	(3)	(4)	(5)
	$\Delta ln(SRISK_t)$	$\Delta ln(SRISK_t)$	$\Delta ln(SRISK_t)$	$\Delta ln(SRISK_t)$	$\Delta ln(SRISK_t)$
	b/se	b/se	b/se	b/se	b/se
$ln(SRISK_{t-1})$	-.0087**	-.0115***	-.0079**	-.0097***	-.0088**
	(.0035)	(.0035)	(.0038)	(.0035)	(.0036)
$\Delta ln(TA_t)$	.1956***	.0739*	.1667***	.2270***	.2606***
	(.0403)	(.0438)	(.0418)	(.0432)	(.0551)
$\Delta ln(TA_t) * LOLR$		.6937***			
		(.1026)			
LOLR		.0359***			
		(.0086)			
$\Delta ln(TA_t) * SIFIs$			.4367***		
			(.1561)		
SIFIs			-.0020		
			(.0057)		
$\Delta ln(TA_t) * Reg.Press.$				-.2756**	
				(.1138)	
Reg. Pressure				.0176***	
				(.0062)	
$\Delta ln(TA_t) * CPP$					-.1459*
					(.0807)
CPP banks					-.0006
					(.0046)
Constant	.0025	.0024	.0025	.0004	.0028
	(.0024)	(.0024)	(.0026)	(.0025)	(.0035)
Year-Quarter FE	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes
Observations	2907	2907	2907	2907	2907
No. of groups	80	80	80	80	80
F-test	31.69***	104.50***	39.83***	41.94***	35.65***

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

This table reports panel regressions of quarterly systemic risk growth rates on the lagged level of systemic risk, the growth rates of assets and the interactions between the growth in assets and three groups: banks participating into Federal Reserve's liquidity programs, SIFIs, banks under regulatory pressure and banks which have participated into the Treasury's CPP program.

Table 10: Pro-cyclicality of systemic risk by groups –Crisis and no-crisis periods–

	Panel A: no-crisis				Panel B: crisis			
	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)
	$\Delta ln(SRISK_t)$	$\Delta ln(SRISK_t)$	$\Delta ln(SRISK_t)$	$\Delta ln(SRISK_t)$	$\Delta ln(SRISK_t)$	$\Delta ln(SRISK_t)$	$\Delta ln(SRISK_t)$	$\Delta ln(SRISK_t)$
	b/se	b/se	b/se	b/se	b/se	b/se	b/se	b/se
$ln(SRISK_{t-1})$	-.1459***	-.1499***	-.1426***	-.0055	-.1956***	-.1898***	.0144*	.0201**
	(.0348)	(.0367)	(.0371)	(.0065)	(.0169)	(.0199)	(.0092)	(.0080)
$\Delta ln(TA_t)$	.0662*	.0024	.0440*	.0850*	.1839**	.5676***	.5140***	.6562***
	(.0353)	(.0236)	(.0255)	(.0485)	(.0905)	(.0734)	(.0794)	(.0799)
$\Delta ln(TA_t) * LOLR$	-.0866				.8158***			
	(.0780)				(.1340)			
LOLR	.0093				.0765***			
	(.0091)				(.0144)			
$\Delta ln(TA_t) * SIFIs$		.5164***				.0986		
		(.1459)				(.4380)		
SIFIs		.0186				.0514***		
		(.0122)				(.0180)		
$\Delta ln(TA_t) * Reg.Press.$			.3132				.6586***	
			(.3397)				(.2186)	
Reg. Pressure			-.0018				.0194	
			(.0095)				(.0144)	
$\Delta ln(TA_t) * CPP$				.3553**				-.4312**
				(.1631)				(.2125)
CPP banks				-.0200***				-.0218**
				(.0061)				(.0108)
Constant	.0395***	.0349***	.0389***	.0034*	.0537***	.0529***	.0054	.0141**
	(.0099)	(.0079)	(.0115)	(.0018)	(.0065)	(.0065)	(.0059)	(.0065)
Year-Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1924	1924	1924	1924	579	579	579	579
No. of groups	76	76	76	76	56	56	56	56
F-test	11.9753***	16.7390***	17.0693***	15.3625***	65.45***	44.72***	82.40***	78.27***

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

This table reports panel regressions of quarterly systemic risk growth rates on the lagged level of systemic risk, the growth rates of assets and the interactions between the growth in assets and four groups: banks participating in Federal Reserve's liquidity programs, SIFIs, banks under regulatory pressure and banks participating in the Treasury's CPP program. Results are robust with Federal Reserve district fixed effects.

Table 11: Targeting SRISK

	LOLR		SIFIs		Reg. Pressure		CPP	
	(Lev<12.5%) $\Delta ln(SRISK_t)$	(Lev≥ 12.5%) $\Delta ln(SRISK_t)$	(Lev<12.5%) $\Delta ln(SRISK_t)$	(Lev≥ 12.5%) $\Delta ln(SRISK_t)$	(Lev<12.5%) $\Delta ln(SRISK_t)$	(Lev≥ 12.5%) $\Delta ln(SRISK_t)$	(Lev<12.5%) $\Delta ln(SRISK_t)$	(Lev≥ 12.5%) $\Delta ln(SRISK_t)$
	b/se	b/se	b/se	b/se	b/se	b/se	b/se	b/se
$ln(SRISK_{t-1})$	-.0609	-.0131***	-.0634	-.0097**	-.0972**	-.0109***	-.0630	-.0997***
	(.0425)	(.0037)	(.0437)	(.0040)	(.0484)	(.0038)	(.0427)	(.0088)
$\Delta ln(TA_t)$	-.0204	.0782	-.0225	.1894***	-.0244	.2686***	.0041	.2690***
	(.0462)	(.0505)	(.0467)	(.0476)	(.0442)	(.0495)	(.0979)	(.0595)
$\Delta ln(TA_t) * LOLR$	-.0465	.7121***						
	(.1727)	(.1107)						
LOLR	.0003	.0385***						
	(.0088)	(.0095)						
$\Delta ln(TA_t) * SIFIs$			-.0156	.4600***				
			(.1475)	(.1710)				
SIFIs			-.1330**	.0001				
			(.0625)	(.0062)				
$\Delta ln(TA_t) * Reg.Press.$					.0169	-.3505***		
					(.5839)	(.1227)		
Reg. Pressure					.0000	.0185***		
					(.)	(.0067)		
$\Delta ln(TA_t) * CPP$							-.0330	-.1572*
							(.1096)	(.0957)
CPP banks							-.0007	.0170***
							(.0072)	(.0055)
Constant	.0188	.0033	.0447	.0027	.0268	.0006	.0196	.0167***
	(.0255)	(.0027)	(.0285)	(.0029)	(.0297)	(.0028)	(.0262)	(.0040)
Observations	200	2585	200	2585	200	2585	200	2585
No. of groups	26	66	26	66	26	66	26	66
R^2	.1149	.1310	.1262	.2160	.1690	.2740	.1191	.2131
Year-Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 12: Drivers for SRISK

	(1) LOLR b/se	(2) SIFIs b/se	(3) Reg. Pressure b/se	(4) CPP banks b/se
$ln(SRISK_{t-1})$	-.2508***	-.2182***	-.0884***	-.7117***
	(.0627)	(.0504)	(.0133)	(.1292)
Interbank	.9531*	.0015	.7819	.1913***
	(.5303)	(.2364)	(.5257)	(.0631)
Investment b.	-.1279*	.3137	-.2052**	.7288
	(.0690)	(.5744)	(.0841)	(.6450)
Derivatives	.1350**	-.1806	.0843	-.1060***
	(.0503)	(.1303)	(.1421)	(.0072)
Repo	-.7132	.3614*	.1050	.2679*
	(.4937)	(.1887)	(.1167)	(.1331)
FedRepo	.6058***	-.1395	.2930**	.5322*
	(.2154)	(.0903)	(.1153)	(.2741)
Com. Pap.	-.1442*	-.8134	-.8455	-.7797*
	(.0825)	(.4868)	(.8029)	(.4428)
Tier 2	-.2107***	.1559*	-.2618	-.8561
	(.0548)	(.0849)	(.7686)	(.8147)
Z-score	.2333*	.2895	.1874***	-.2980
	(.1186)	(.2647)	(.0178)	(1.6967)
Loans Comm.	.8678***	.8992**	.0314	.1431
	(.2710)	(.3925)	(.2977)	(.1541)
Constant	.2119***	.1451***	.0898***	.2911***
	(.0621)	(.0494)	(.0088)	(.0553)
Year-Quarter FE	Yes	Yes	Yes	Yes
Bank FE	Yes	Yes	Yes	Yes
Observations	123	444	154	157
No. of groups	33	22	20	26
R^2	.5136	.3071	.1978	.6825
F-test	51.4588***	28.6814***	70.2789***	110.2008***

Robust standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 13: Structural equation

	(1)	(2)	(3)	(4)	(5)	(6)
	LOLR	LOLR	TAF	TAF	DW	DW
	b/se	b/se	b/se	b/se	b/se	b/se
$\Delta ln(Lev_t)$						
$ln(Lev_{t-1})$	-.0934***	-.1023***	-.0555***	-.0878***	-.0836***	-.1080***
	(.0190)	(.0189)	(.0155)	(.0165)	(.0188)	(.0193)
$\Delta ln(TA_t)$	.0804**	.9555**	.8601***	.7880***	.1665***	.8920*
	(.0485)	(.4852)	(.0310)	(.0353)	(.0405)	(.4837)
$\Delta ln(TA_t) * I$	.1556**	.6409***	.3942**	.4790**	-.1362***	-.1702**
	(.0750)	(.0747)	(.1993)	(.1991)	(.0431)	(.0747)
I	.0448*	.0474*	-.0260	-.0353	.0909	.0792***
	(.0252)	(.0250)	(.0459)	(.0458)	(.0554)	(.0301)
Treasury rate	.1087***	.1158***	.0799**	.1490***	.1866***	.1126***
	(.0412)	(.0410)	(.0331)	(.0366)	(.0320)	(.0411)
CP rate	-.0775**	-.0858**	-.0517*	-.1229***	-.1491***	-.0815**
	(.0383)	(.0382)	(.0303)	(.0336)	(.0297)	(.0382)
GDP	-.0044	-.0046	-.0018	-.0027	-.0048	-.0038
	(.0050)	(.0050)	(.0051)	(.0051)	(.0043)	(.0049)
Bond I.	.3268***	.3122***	.3335***	.2816***	.3429***	.3319***
	(.0711)	(.0707)	(.0666)	(.0694)	(.0603)	(.0705)
Crisis	.2748***	.2802***	.2811***	.3352***	.3588***	.2665***
	(.0394)	(.0392)	(.0317)	(.0340)	(.0331)	(.0392)
Pledged Sec.	-.0035	-.0027	-.0044	-.0022	-.0017	-.0032
	(.0039)	(.0039)	(.0036)	(.0038)	(.0032)	(.0038)
Constant	-1.8055***	-1.7054***	-1.9226***	-1.5532***	-1.9511***	-1.8073***
	(.4554)	(.4527)	(.4268)	(.4457)	(.3824)	(.4513)
$\Delta ln(SRISK_t)$						
$ln(SRISK_{t-1})$	-.0277***	-.0268***	-.0199**	-.0282***	-.0258***	-.0256***
	(.0074)	(.0083)	(.0079)	(.0079)	(.0074)	(.0086)
$\Delta ln(TA_t)$		.1871***		.2529***		.1905***
		(.0343)		(.0267)		(.0354)
$\Delta ln(Lev_t)$	.6236***		.6595***		.7796***	
	(.0701)		(.0432)		(.0697)	
$\Delta ln(TA_t) * I$	.9291**	.6464**	.4700**	.6597***	.1017***	.1135*
	(.4672)	(.2675)	(.1773)	(.1610)	(.0139)	(.0588)
$\Delta ln(Lev_t) * I$	-.4447***	.1791**	-.1697**	-.1695***	.4612***	.2939***
	(.1152)	(.0732)	(.0954)	(.0548)	(.0986)	(.0758)
I	.0408**	.0379**	.0207	.0096	.0832*	.0473**
	(.0176)	(.0191)	(.0405)	(.0366)	(.0470)	(.0237)
Cpi	.0002	-.0010	.0004	-.0015	.0010	-.0010
	(.0011)	(.0012)	(.0012)	(.0012)	(.0011)	(.0012)
Vix	.1234***	.1125***	.1457***	.1264***	.1173***	.1151***
	(.0201)	(.0222)	(.0220)	(.0215)	(.0224)	(.0233)
S&P	.0877**	.1224***	.0693	.1388***	.0617	.1145**
	(.0401)	(.0443)	(.0424)	(.0410)	(.0399)	(.0458)
GDP	-.0062*	-.0090**	-.0089**	-.0106***	-.0046	-.0087**
	(.0036)	(.0039)	(.0045)	(.0040)	(.0038)	(.0040)
Loans to US	.0010	.0029	.0022	.0016	.0010	.0033*
	(.0018)	(.0019)	(.0019)	(.0019)	(.0017)	(.0020)
Domestic A.	-.0010**	-.0008	-.0008*	-.0009*	-.0010**	-.0008
	(.0005)	(.0005)	(.0005)	(.0005)	(.0005)	(.0005)
DFA	-.0434*	-.0334	-.0646***	-.0279	-.0486**	-.0349
	(.0226)	(.0247)	(.0248)	(.0246)	(.0228)	(.0257)
Crisis	-.0676***	.0133	-.1190***	.0429**	-.1267***	-.0003
	(.0199)	(.0198)	(.0216)	(.0176)	(.0271)	(.0209)
Constant	-.3982*	-.5806**	-.3666	-.5654**	-.3335	-.5540**
	(.2325)	(.2535)	(.2493)	(.2517)	(.2328)	(.2634)
Observations	2356	2356	2356	2356	2356	2356
R^2	.1265	.1420	.1380	.1426	.2937	.1502
log(likelihood)	862.9754	791.5210	812.9312	808.6965	1005.9339	760.3719

Table 14: Structural equation

	(1) SIFIs b/se	(2) SIFIs b/se	(3) Reg. Pressure b/se	(4) Reg. Pressure b/se	(5) CPP banks b/se	(6) CPP banks b/se
$\Delta ln(Lev_t)$						
$ln(Lev_{t-1})$	-.0314*	-.0669***	-.0806***	-.1027***	-.0453**	-.0971***
	(.0177)	(.0177)	(.0152)	(.0164)	(.0187)	(.0186)
$\Delta ln(TA_t)$	.1791***	.1604***	.15204***	.1770***	.2853***	.2606***
	(.0345)	(.0360)	(.0303)	(.0348)	(.0450)	(.0451)
$\Delta ln(TA_t) * I$	.2587**	.1867*	-.4565***	-.4872***	-.1984**	-.2076**
	(.1067)	(.1039)	(.0976)	(.1022)	(.0959)	(.0935)
I	-.0252	-.0235	.1126***	.1376***	.0273	-.0132
	(.0173)	(.0194)	(.0169)	(.0360)	(.0255)	(.0323)
Treasury rate	.1000***	.1515***	.0818**	.1203***	.0996**	.1057***
	(.0353)	(.0362)	(.0319)	(.0353)	(.0395)	(.0382)
CP rate	-.0714**	-.1258***	-.0523*	-.0969***	-.0728**	-.0926***
	(.0326)	(.0335)	(.0292)	(.0323)	(.0362)	(.0350)
GDP	-.0045	-.0056	-.0083*	-.0095**	-.0047	-.0056
	(.0050)	(.0048)	(.0047)	(.0048)	(.0055)	(.0053)
Bond I.	.2848***	.2452***	.3247***	.2606***	.3002***	.2639***
	(.0708)	(.0695)	(.0625)	(.0664)	(.0805)	(.0809)
Crisis	.2874***	.3313***	.2747***	.2978***	.2703***	.2682***
	(.0333)	(.0334)	(.0309)	(.0336)	(.0381)	(.0378)
Pledged Sec.	-.0025	-.0014	.0019	.0021	-.0071	-.0026
	(.0038)	(.0039)	(.0035)	(.0037)	(.0044)	(.0043)
Constant	-1.6985***	-1.3805***	-1.9113***	-1.4638***	-1.7044***	-1.3945***
	(.4505)	(.4429)	(.4009)	(.4264)	(.5101)	(.5078)
$\Delta ln(SRISK_t)$						
$ln(SRISK_{t-1})$	-.0258***	-.0304***	-.0150*	-.0244***	-.0192**	-.0171**
	(.0084)	(.0083)	(.0082)	(.0081)	(.0075)	(.0076)
$\Delta ln(Lev_t)$	.4929***		.6860***		.3674***	
	(.0653)		(.0468)		(.0504)	
$\Delta ln(TA_t)$		.1389***		.1019***		.1477***
		(.0272)		(.0266)		(.0313)
$\Delta ln(TA_t) * I$	-.1419	-.1998	.4994***	.1641*	-.2413***	-.2259***
	(.09336)	(.9398)	(.0907)	(.0871)	(.0791)	(.0579)
$\Delta ln(Lev_t) * I$	.1961**	.1750***	-.1680**	-.1413**	.5317***	.4548***
	(.0827)	(.0495)	(.0740)	(.0625)	(.0839)	(.0702)
I	-.0024	-.0196	-.0062	.0558*	-.0376**	-.0514**
	(.0142)	(.0153)	(.0324)	(.0302)	(.0171)	(.0221)
Cpi	.0007	-.0001	.0019	-.0009	.0032***	.0037***
	(.0012)	(.0012)	(.0012)	(.0012)	(.0012)	(.0013)
Vix	.1385***	.1230***	.1462***	.1002***	-.0862**	-.0850**
	(.0234)	(.0216)	(.0169)	(.0212)	(.0360)	(.0368)
S&P	.0141	.0536	-.0052	.0775**	-.0073	.0235
	(.0358)	(.0349)	(.0356)	(.0338)	(.0359)	(.0363)
GDP	-.0065	-.0083**	-.0033	-.0084**	-.0074*	-.0088**
	(.0040)	(.0037)	(.0042)	(.0039)	(.0038)	(.0038)
Loans US banks	.0035*	.0033*	.0023	.0024	.0020	.0015
	(.0018)	(.0018)	(.0018)	(.0018)	(.0017)	(.0017)
Domestic A.	-.0009*	-.0009*	.0003	-.0001	-.0017***	-.0017***
	(.0005)	(.0005)	(.0005)	(.0005)	(.0005)	(.0005)
DFA	-.0439**	-.0233	-.0527**	-.0135	-.0377	-.0258
	(.0221)	(.0220)	(.0224)	(.0219)	(.0229)	(.0233)
Crisis	-.0843***	.0263	-.1141***	.0542***	-.0475**	.0132
	(.0223)	(.0177)	(.0213)	(.0177)	(.0221)	(.0194)
Constant	-.2060	-.3716*	-.3989*	-.5011**	-.1997	-.5446**
	(.2160)	(.2182)	(.2241)	(.2208)	(.2390)	(.2522)
Observations	2356	2356	2356	2356	2356	2356
R^2	.5800	.8882	.1649	.1148	.1908	.1095
log(likelihood)	832.2851	874.1461	898.5421	885.2198	770.6308	802.5549

Table 15: Structural equation

	(1)	(2)	(3)	(4)	(5)	(6)
	CPP & TAF	CPP & TAF	CPP & Low Cap.	CPP & Low Cap.	CPP & Nr	CPP & Nr
	b/se	b/se	b/se	b/se	b/se	b/se
$\Delta ln(Lev_t)$						
$ln(Lev_{t-1})$	-.2231***	-.2115***	-.1905***	-.2754***	-.0554***	-.0878***
	(.0491)	(.0429)	(.0482)	(.0687)	(.0165)	(.0161)
$\Delta ln(TA_t)$	.2080	.2482*	.7627***	.6938***	.2181***	.1931***
	(.1350)	(.1431)	(.2274)	(.2608)	(.0347)	(.0358)
$\Delta ln(TA_t) * I$	-.5133***	-.5496***	-.8407***	-.8679***	-.1481	-.1827
	(.1486)	(.1569)	(.2321)	(.2727)	(.1492)	(.1449)
I	.0200	.0099	-.0489	.1010	.0173	.0201
	(.1134)	(.1096)	(.0681)	(.1074)	(.0189)	(.0183)
Treasury rate	.2191	.0344	-.4278	.3375	.0984***	.1423***
	(.7559)	(.6014)	(1.0608)	(1.2739)	(.0359)	(.0355)
CP rate	-.1904	-.2840	.8109	.6972	-.0681**	-.1153***
	(.5450)	(.4533)	(.7445)	(.9288)	(.0329)	(.0325)
GDP	.0171	.0159	.0361*	.0495*	-.0040	-.0051
	(.0160)	(.0160)	(.0197)	(.0256)	(.0051)	(.0049)
Bond I.	.2232	.0970	.2713	1.0645*	.3356***	.2872***
	(.2092)	(.1999)	(.3075)	(.5580)	(.0721)	(.0702)
Crisis	.1085***	.1107***	.7592***	.8347***	.2901***	.3292***
	(.0123)	(.0117)	(.1347)	(.1770)	(.0338)	(.0332)
Pledged Sec.	-.0076	-.0132	-.0532**	-.0248	-.0036	-.0011
	(.0116)	(.0109)	(.0227)	(.0259)	(.0038)	(.0037)
Constant	-.7805	.0903	-.5563***	-.5725	-.1954***	-.1611***
	(.4011)	(.3299)	(.0386)	(.3539)	(.0462)	(.0459)
$\Delta ln(SRISK_t)$						
$ln(SRISK_{t-1})$	-.1839***	-.1947***	-.0850***	-.2400***	-.0231***	-.0284***
	(.0507)	(.0515)	(.0198)	(.0597)	(.0076)	(.0076)
$\Delta ln(Lev_t)$	.1087**		.1490*		.5087***	
	(.0526)		(.0885)		(.0439)	
$\Delta ln(TA_t)$		.5702***		.6130***		.1361***
		(.0542)		(.0577)		(.0278)
$\Delta ln(TA_t) * I$	-.3345***	-.1362**	.8132***	.2863***	-.9727	-.1524
	(.0215)	(.0645)	(.1034)	(.0591)	(.7967)	(.1250)
$\Delta ln(Lev_t) * I$	-.2009***	-.2227***	.0758***	.6701***	.3686***	.3625***
	(.0551)	(.0327)	(.0089)	(.1985)	(.1074)	(.0998)
I	-.2967	-.4828	.0049	-.1914	.0036	.0078
	(.3510)	(.4498)	(.0196)	(.1804)	(.0157)	(.0158)
Cpi	.0336	.0365	.0035	.0015	.0007	-.0002
	(.0335)	(.0359)	(.0054)	(.0408)	(.0012)	(.0011)
Vix	.3018	.0943	.1100***	.3048*	.1243***	.1026***
	(.2229)	(.2390)	(.0250)	(.1771)	(.0206)	(.0203)
S&P	-.7330	-.6353	-.0329	-.7071	.0701*	.1207***
	(.9479)	(.9519)	(.1596)	(1.3361)	(.0400)	(.0393)
GDP	-.0214	.0109	-.0009	-.0894*	-.0070*	-.0088**
	(.0506)	(.0632)	(.0071)	(.0514)	(.0040)	(.0038)
Loans US banks	.0401	.0428	.0086**	.0142	.0029	.0025
	(.0269)	(.0261)	(.0042)	(.0248)	(.0018)	(.0018)
Domestic A.	-.0172**	-.0144	-.0002	-.0229**	-.0008	-.0008
	(.0083)	(.0089)	(.0016)	(.0106)	(.0005)	(.0005)
DFA	-.1719	-.1752	-.0209	-.0988	-.0562**	-.0352
	(.2363)	(.2421)	(.0357)	(.2381)	(.0232)	(.0230)
Crisis	.1481***	.3128***	.0753	-.5509	-.0799***	.0366**
	(.0566)	(.0627)	(.0490)	(.3747)	(.0207)	(.0172)
Constant	-.1663	-.2885	-.4411	.9048	-.4401*	-.6634***
	(.3769)	(.4121)	(.6943)	(.5580)	(.2374)	(.2419)
Observations	193	193	223	223	292	292
R^2	.3430	.3401	.6047	.5944	.2000	.0692
log(likelihood)	-222.5835	-223.5616	140.4171	-57.4290	822.6377	858.8783

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Appendix

Table A1: Bank Holding Company data definition and construction

Dataset	FRY-9C	Name
ln(TA)	BHCK3368	QUARTERLY AVERAGE OF TOTAL ASSETS
ln(Tafv)	BHCKG502	TOTAL ASSETS MEASURED AT FAIR VALUE ON A RECURRING BASIS
ASSETS_TAOBD_0RWA	BHCKB696	TOTAL ASSETS, DERIVATIVES, AND OFF-BALANCE SHEET ITEMS BY RISK WEIGHT CATEGORY - 0%
ASSETS_TAOBD_20RWA	BHCKB697	TOTAL ASSETS, DERIVATIVES, AND OFF-BALANCE SHEET ITEMS BY RISK WEIGHT CATEGORY - 20%
ASSETS_TAOBD_50RWA	BHCKB698	TOTAL ASSETS, DERIVATIVES, AND OFF-BALANCE SHEET ITEMS BY RISK WEIGHT CATEGORY - 50%
ASSETS_TAOBD_100RWA	BHCKB699	TOTAL ASSETS, DERIVATIVES, AND OFF-BALANCE SHEET ITEMS BY RISK WEIGHT CATEGORY - 100%
ln(repo)	BHCKB995	SECURITIES SOLD UNDER AGREEMENTS TO REPURCHASE
ln(FedRepo)	BHCK3353	QUARTERLY AVERAGE OF FEDERAL FUNDS PURCHASED AND SECURITIES SOLD UNDER AGREEMENTS TO REPURCHASE
ln(Com.Pap.)	BHCK2309	COMMERCIAL PAPER
ln(Interbank)	BHCK3190 + BHCK6555 + BHCK5043	
Other banks	BHCK3190	OTHER BORROWED MONEY
Sub. Vs Unrelated	BHCK6555	DEBT MATURING IN ONE YEAR OR LESS THAT IS ISSUED TO UNRELATED THIRD PARTIES BY BANK SUBSIDIARIES
Sub. Banks	BHCK5043	BALANCES DUE TO SUBSIDIARY BANKS OF THE BANK HOLDING COMPANY, GROSS
CAPITAL_QE	BHCK3519	QUARTERLY AVERAGE OF EQUITY CAPITAL
RISK_kCPPps	BHCKG234	ISSUANCES ASSOCIATED WITH THE U.S. DEPARTMENT OF TREASURY CAPITAL PURCHASE PROGRAM: SENIOR PERPETUAL PREFERRED STOCK OR SIMILAR ITEMS
RISK_kCPPcs	BHCKG235	ISSUANCES ASSOCIATED WITH THE U.S. DEPARTMENT OF TREASURY CAPITAL PURCHASE PROGRAM: WARRANTS TO PURCHASE COMMON STOCK OR SIMILAR ITEMS

Table A2: Number of banks by states

State	Code	N. of BHCs	Perc.
Alaska	AK	1	0.06%
Alabama	AL	25	1.53%
Arkansas	AR	23	1.41%
Arizona	AZ	4	0.24%
California	CA	97	5.93%
Colorado	CO	21	1.28%
Connecticut	CT	22	1.35%
District of Columbia	DC	1	0.06%
Delaware	DE	8	0.49%
Florida	FL	80	4.89%
Georgia	GA	69	4.22%
Hawaii	HI	6	0.37%
Iowa	IA	37	2.26%
Idaho	ID	5	0.31%
Illinois	IL	111	6.79%
Indiana	IN	41	2.51%
Kansas	KS	36	2.20%
Kentucky	KY	28	1.71%
Louisiana	LA	29	1.77%
Massachusetts	MA	60	3.67%
Maryland	MD	18	1.10%
Maine	ME	14	0.86%
Michigan	MI	36	2.20%
Minnesota	MN	32	1.96%
Missouri	MO	51	3.12%
Mississippi	MS	23	1.41%
Montana	MT	7	0.43%
North Carolina	NC	45	2.75%
North Dakota	ND	11	0.67%
Nebraska	NE	16	0.98%
New Hampshire	NH	6	0.37%
New Jersey	NJ	47	2.87%
New Mexico	NM	8	0.49%
Nevada	NV	8	0.49%
New York	NY	73	4.46%
Ohio	OH	41	2.51%
Oklahoma	OK	27	1.65%
Oregon	OR	9	0.55%
Pennsylvania	PA	86	5.26%
Rhode Island	RI	4	0.24%
South Carolina	SC	24	1.47%
South Dakota	SD	15	0.92%
Tennessee	TN	45	2.75%
Texas	TX	117	7.16%
Utah	UT	8	0.49%
Virginia	VA	44	2.69%
Vermont	VT	6	0.37%
Washington	WA	35	2.14%
Wisconsin	WI	48	2.94%
West Virginia	WV	9	0.55%
Wyoming	WY	6	0.37%
	Others	12	0.73%
Total		1635	100.00%

This table reports the distribution of banks by US states (exception of District of Columbia which is in the list). Banks located in insular area and Commonwealth are within the category "Others".

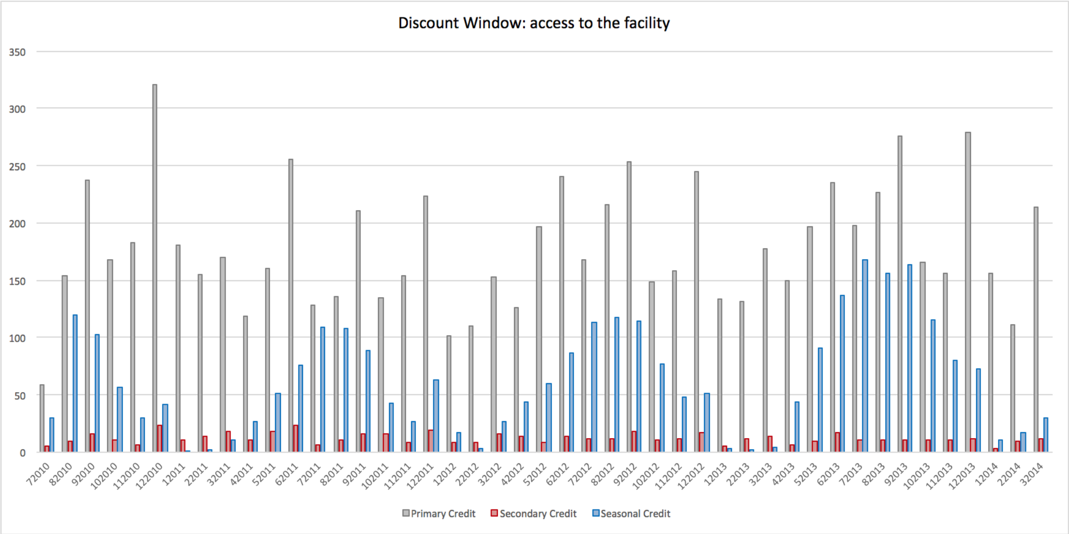

Figure A1: Discount Window

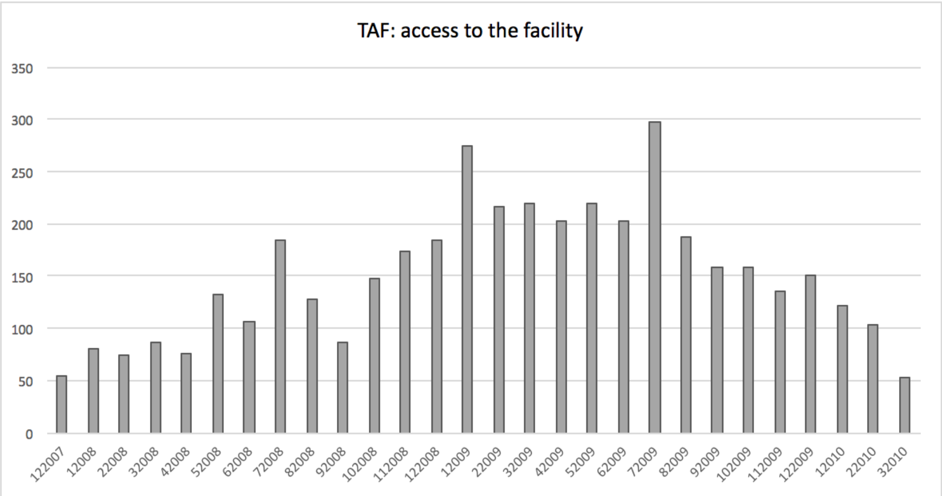

Figure A2: Term Auction Facility

Table A3: Fed districts

Fed district	**District code**	**N. Of BHCs**	**Percentage**
Boston	1	103	6.300%
New York	2	127	7.768%
Philadelphia	3	90	5.505%
Cleveland	4	70	4.281%
Richmond	5	140	8.563%
Atlanta	6	244	14.924%
Chicago	7	241	14.740%
St. Louis	8	122	7.462%
Minneapolis	9	76	4.648%
Kansas City	10	123	7.523%
Dallas	11	125	7.645%
San Francisco	12	174	10.642%
Total		1635	

Table A4: Facilities distribution

PRG_type	Freq.	Percent	Cum.
Primary Credit	2,411	71.19	71.19
Seasonal Credit	259	7.72	79.63
Secondary Credit	257	7.66	87.27
TAF	427	12.73	100.00
Total	3,354	100.00	

This table reports the distribution of Discount Window and Term Auction Facility.

Table A5: G-SIBs and D-SIBs

Type of SIFI	**Name**	**Stress test**	**SIFI**	**Capital Req.**
DSIB	Ally Financial	2009		
DSIB	American Express	2009		
GSIB	Bank of America	2009	2011	12.0% (CET1=min.8.5%)
GSIB	Bank of New York Mellon	2009	2011	11.5% (CET1=min.8%)
DSIB	BB&T	2009		
DSIB	BBVA Compass	2014		
DSIB	BMO Financial Corp.	2014		
DSIB	Capital One Financial	2009		
GSIB	Citigroup	2009	2011	12.5% (CET1=min.9%)
DSIB	Comerica	2014		
DSIB	Discover Financial Services	2014		
DSIB	Fifth Third Bank	2009		
GSIB	Goldman Sachs	2009	2011	12.0% (CET1=min.8.5%)
DSIB	HSBC North America Holdings	2014		
DSIB	Huntington Bancshares	2014		
GSIB	JP Morgan Chase	2009	2011	13.0% (CET1=min.9.5%)
DSIB	KeyCorp	2009		
DSIB	M&T Bank	2014		
DSIB	MetLife	2009 to 2012		-
GSIB	Morgan Stanley	2009	2011	12.0% (CET1=min.8.5%)
DSIB	Northern Trust	2014		
DSIB	PNC Financial Services	2009		
DSIB	RBS Citizens Financial Group	2014		
DSIB	Regions Financial	2009		
DSIB	Santander Holdings USA	2014		
GSIB	State Street	2009	2011	11.5% (CET1=min.8%)
DSIB	SunTrust Banks	2009		
DSIB	U.S. Bancorp	2009		
DSIB	UnionBanCal	2014		
GSIB	Wells Fargo	2009	2011	11.5% (CET1=min.8%)
DSIB	Zions	2014		

This table reports the list of banks designated as Domestically-SIBs or Globally-SIBs. The column "Stress Test" indicates the year starting from which they are subject to stress test, whilst the column "SIFI" indicates the year in which banks have been designated as G-SIBs and the last column indicates their specific capital requirements.