Financial Disintermediation and Financial Fragility

Kosuke Aoki* Kalin Nikolov†

University of Tokyo European Central Bank

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Abstract

This paper investigates how the growth of non-bank sources of credit affects the susceptibility of the financial system to crisis. We study two main ways in which loans come to be held by non-banks: direct market funding (e.g. through corporate bonds) and shadow banking (off-balance sheet operations of the banks in our model). The paper finds that the growth of corporate bond markets can increase banking fragility although it also diminishes the impact of banking crises. This is because corporate bond markets provide an alternative financing source for the real economy, reducing its dependence on bank credit. Shadow banking allows higher financial system leverage and thus increases bank fragility even further. Because it relies on bank capital for its operations, the shadow banking sector provides no funding diversification and cannot offset the real economy impact of a banking crisis.

*Department of Economics, University of Tokyo, Japan. Email: kaoki@e.u-tokyo.ac.jp

†Research Department, European Central Bank, Frankfurt-am-Main, Germany. Email: kalin.nikolov@ecb.int

1 Introduction

Non-bank credit sources for firms and households have grown rapidly in the last couple of decades. Before the crisis, this process of disintermediation was seen as a benign or even beneficial phenomenon. Greenspan (1999) called the market for mortgage securitisations a useful 'spare tire' which insulated the US economy from the worst effects of the housing bust in the early 1990s. Having a diverse set of funding sources helped to maintain aggregate credit supply in the face of a contraction in bank lending.

The recent financial crisis has changed researchers' and policy-makers' views of securitisation and the repo market. These products and markets are seen by many as major culprits behind the leverage boom-bust cycle of the 2000s. In this paper we investigate which view is right? Does the growth of non-bank finance sources increase or decrease financial instability? Are they a 'spare tire' which contributes to the stability of aggregate credit supply or a source of systemic risk?

To answer the questions of the paper, we modify the limited commitment model with financial intermediation we developed in our earlier research (Aoki and Nikolov (2011)) by adding non-bank credit sources. Following the growing literature on rational bubbles in models of credit frictions[1], we show in Aoki and Nikolov (2011) that, when the banking system is exposed to such asset price bubbles, this creates financial fragility and creates the possibility of large banking losses and a credit crunch whenever the bubble collapses.

In Aoki and Nikolov (2011) we relied on moral hazard driven by government guarantees for banks in order to motivate the increase in systemic risk during bubbly episodes. Without a financial safety net, banks refrained from

[1] For example Caballero and Krishnamurthy (2006), Kocherlakota (2009), Ventura (2012),Martin and Ventura (2012), Martin and Ventura (2011), Farhi and Tirole (2011).

buying risky assets in equilibrium because their traditional activities were very profitable in an environment of binding bank balance sheet constraints. These constraints led to a shortage of bank intermediation services and a spread between lending and deposit rates, creating what is known as 'bank franchise' value. In line with the findings of the literature on bank competition and risk taking (Vives (2011), Hanson et al. (2011), Gropp et al. (2011) and Corbae and D'Erasmo (2013)), our model implies that this 'bank franchise value' prevents financial institutions from undertaking risky investment strategies.

In this paper we show how the expansion of non-bank credit erodes financial intermediaries' unique role in the financial system and reduces their 'franchise values'. As a result they 'search for yield' by taking more risks by starting to hold the risky bubble. This exposes the economy to the risk that the bubble collapse will trigger a banking crisis.

We consider the impact of two (deliberately extreme) types of financial innovation which allow direct lending in a hitherto bank-dominated financial system and ask whether such innovations make the financial system more crisis prone. Firstly, we examine the effect of the growth of what we call 'the corporate bond market'[2]. In our model, we implement this by allowing certain financial transactions to be conducted outside the banking system. We think of these as non-bank sources of finance (most notably high grade corporate bonds or simple securitisation products) whose supply does not depend on the financial condition of banks.

The second financial innovation we consider is what we call 'shadow banking'. Here we have in mind the multiple ways in which banks structure fi-

[2]There is now a growing literature on this topic. De Fiore and Uhlig (2011) study the determinants of the split between bank and bond finance in a DSGE model with financial frictions. Adrian et al. (2012), De Fiore and Uhlig (2012) and Gertler and Karadi (2012) show that the presence of corporate bond finance acted like a 'spare tire' for the corporate sector during the financial crisis.

nancial transactions in order to evade capital regulation. This is motivated by the compelling empirical evidence in Acharya et al. (2012) that regulatory arbitrage stimulated the growth of Asset Backed Commercial Paper (ABCP) conduits during the 2000s. The balance sheets of these conduits were effectively insured by sponsoring banks but without the associated capital charge that a traditional financial institution would have had to make.

Our treatment of shadow banking is somewhat more extreme in its emphasis on regulatory arbitrage compared to other recent papers on shadow banking (Goodhart et al. (2012), Alessandri et al. (2012), Gennaioli et al. (2012) and others). However, our approach captures two important aspects of shadow banking that are crucial for the purposes of our paper. It expands aggregate financial system leverage and its operations depend on the health of the banking system[3].

We find that both of the innovations we consider increase banking sector risk taking and financial fragility although shadow banking has a substantially greater impact on systemic risk. The impact of both innovations on risk-taking work through the 'franchise value' channel discussed above. The expansion of corporate bond market erodes the banking system's unique position in credit intermediation and reduces lending spreads in equilibrium. The growth of shadow banking increases the financial system's effective leverage and expands credit supply, depressing lending spreads in the process. Bank profitability from traditional lending activities declines and, as a result, financial institutions increase their holdings of risky bubbles. This exposes banks to large

[3] There has been substantial work on the shadow banking system in the finance literature. For example, Gorton (2010) argues that the shadow banking system undertakes maturity transformation without access to lender of last resort or deposit insurance. This left it vulnerable to classic bank runs. In addition, many authors (for example Pozsar et al. (2012) and Gai et al. (2011)) have stressed the complex and inter-connected nature of the shadow banking system and the dangers that this poses for systemic risk. While these are undoubtedly very important issues, we do not tackle them in this paper but leave their integration into our framework for future research.

losses when the bubbles burst.

However, we find that, in line with recent historical experiences, the impact of shadow banking on financial fragility is greater. This occurs for two reasons. First, shadow banking increases financial system leverage and drives lending spreads even lower. This happens because leverage expands the rate of return on banks' own net worth for given loan spreads. In equilibrium, therefore, higher leverage leads to lower spreads. In contrast, the corporate bond market has a small or even negative impact on bank leverage, which helps to contain the decline in lending-deposit spreads. As a result, bank holdings of the bubble asset are greater when the shadow banking system grows and the collapse in bank net worth and lending during the bust is that much greater.

Second, even though banks become more fragile under both the 'corporate bond' and the 'shadow banking' scenario, the risks for the real economy increase more under the latter. While the expansion of the corporate bond market increases risks in the banking sector, it also helps to insulate firms from fluctuations in bank credit supply as highlighted by Greenspan (1999). So the growth of bank-independent sources of finance makes a banking crisis more likely but less costly. In contrast, the 'shadow banking' economy has no 'spare tire' against bank losses and the associated loan supply contraction. Because the supply of credit from the shadow banking sector depends on the financial health of sponsoring financial institutions, it collapses together with credit supply from the traditional financial sector. In fact, due to its higher leverage, the financial system contracts even more sharply in the 'shadow banking' economy.

The paper is structured as follows. Section 2 provides some motivating observations based on US data, section 3 introduces the baseline economic environment with non-bank credit, section 4 describes the bubbly equilibrium of the economy. Section 5 goes in more detail into the conditions under which banks hold the bubble asset and become exposed to the bubble's collapse. Section 6 uses numerical simulations to show how our two types of financial innovations increase banking sector fragility. Finally, section 7 concludes.

2 Financial Innovations and Bank Profitability in the US

In order to motivate our work, in this section we document a number of interesting facts about the US financial system over the past thirty years. The key message of this section is that traditional commercial banks have found themselves increasingly competing with other finance providers since 1980. Figure 1 shows how the corporate bond market has grown relative to commercial bank credit since the Second World War. Despite recent volatility in the size of the outstanding stock of corporate bonds relative to bank loans, we can clearly see that it has risen by 10-15 percentage points since the early 1980s.

Since the corporate bond market expanded credit supply to high grade corporates, this market became increasingly difficult for banks to compete in, leading them to move into hitherto under-developed real estate lending. Figure 2 shows how around the time when the corporate bond market grew very sharply, banks switched their portfolios away from commercial and industrial loans (which fell from 40% to 17% of total loans) towards real estate loans (which rose from 25% to around 60% of total loans).

Banks, however, continued to face competition from further financial innovation. Securitisation started to grow in earnest around 1990 as shown by the expanding balance sheets of ABS issuers and broker-dealers (Figure 3). The growth of these 'shadow bank' entities was especially rapid after 2003. For example ABS issuers ' balance sheets expanded from around 30% of commercial bank assets in 2003 to 45% of bank assets in 2007, before collapsing back to 25% during the crisis. The growth of ABS increased the competition banks faced in the mortgage market which by then had become their largest source of lending business.

Such rapid financial innovation, de-regulation and growth in competition affected banks' profitability. FDIC data presented in Figure 4 sheds more light on banks' profitability over this period. Net interest income declined as a percentage of bank equity from a peak of over 50% in the late 1980s to 25% in recent years. At the same time, banks started to lend to more risky borrowers as evidenced by the growing loss provisions. After accounting for loss provisions, net interest income peaked in 1980 at 50% and declined sharply to almost 10% during the crisis. One important factor which allowed banks to maintain profitability is the growth of non-interest income. The figure shows that it grew until 2000 but has been declining as a share of bank equity since then.

This brief and simple look at the US financial sector since 1980 reveals two key phenomena about the interaction of the banking system and non-bank sources of funds. First of all, the commercial banking sector has experienced an increasingly competitive environment and this has forced it to adapt by shifting towards real estate financing and relying increasingly on non-interest income. Secondly, even though these shifts in business models allowed banks to maintain profitability, this came at the expense of higher risk as evidenced by the volatile equity returns (Figure 5) and higher loss provisions. Furthermore, the data highlight the fact that the supply of these different sources of external finance have not all proved durable under stressed financial conditions. While the corporate bond market increased the funds it provided to the real economy, the ABS sector contracted strongly since 2007.

In the rest of this paper, we outline a model environment which can link these phenomena in a consistent framework. We show that the decline in bank profitability and the increase in bank risk-taking can be naturally linked to the growth in non-bank funding sources observed in the data. Finally, we argue that the durability (or lack thereof) of non-bank credit sources in times of crisis can be usefully linked to the dependence of these funding sources on the banking system itself.

3 The Model

The main aim of this paper is to study the risks to financial stability posed by fragile exuberance in financial and credit markets. We assume an environment with limited commitment in which fragile rational bubble equilibria exist and look at how the real economy reacts to regime switches between bubbly and fundamentals-only equilibria. The bubble asset we will refer to frequently from now on is a durable but intrinsically useless asset which is in fixed aggregate supply. Its fundamental value is zero but, as we show in Aoki and Nikolov (2011), under certain conditions[4], there exist equilibria in which expectations can be coordinated on a positive valuation of this intrinsically useless asset.

The economy is populated with three kinds of agents: entrepreneurs with heterogenous productivities, workers and banks. Low productivity entrepreneurs become savers and high productivity entrepreneurs become borrowers in equilibrium. Borrowing and lending can be intermediated by banks. In addition to this we consider two kinds of direct funding sources. One is corporate bond markets in which savers can enforce loans without banks. The other is a

[4] We also discuss the condition in Section 5 of this paper.

shadow banking system in which banks charge to savers fees for guaranteeing enforcement of loans on behalf of them.

3.1 Entrepreneurs

Each entrepreneur is endowed with a constant returns to scale production function which converts labor h_t into output in the next period y_{t+1}.

$$y_{t+1} = a_t^i h_t, \tag{1}$$

where a_t^i is a productivity parameter which is known at time t.

In each period some firms are productive ($a_t^i = a^H$) and the others are unproductive ($a_t^i = a^L < a^H$). Each entrepreneur shifts stochastically between productive and unproductive states following a Markov process. Specifically, a productive entrepreneur in this period may become unproductive in the next period with probability δ, and an unproductive entrepreneur in this period may become productive with probability $n\delta$. This probability is independent across entrepreneurs and over time. This Markov process implies that the fraction of productive entrepreneurs is stationary over time and equal to $n/(1+n)$, given that the economy starts with such population distribution. We assume that the probability of the productivity shifts is not too large:

$$\delta + n\delta < 1. \tag{2}$$

This assumption implies that the productivity of each agent is persistent.

Entrepreneurs are ex-ante identical and have log utility over consumption streams

$$U^E = E_t \sum_{t=0}^{\infty} \beta^t \ln c_t \tag{3}$$

Entrepreneurs purchase consumption (c_t), bubbles (m_t^e) at price μ_t, they borrow amount b_t^l from banks (negative b_t^l means that the household places deposits with banks) and they borrow b_t^m directly from savers. They also pay wages to the workers they hire $w_t h_t$ in order to receive future revenues $a^i h_t$ which the government taxes at rate τ_t after deducting debt repayments. w_t and h_t denote real wage and labor respectively.

$$\begin{aligned} c_t + w_t h_t + m_t^e \mu_t - b_t^m - b_t^l &= \\ (1-\tau_t)\left(a^i h_{t-1} - R_{t-1}^i b_{t-1}^l - \widetilde{R}_{t-1}^i b_{t-1}^m + m_{t-1}^e \mu_t\right) &\equiv (1-\tau_t)\, z_t \end{aligned} \quad (4)$$

where z_t stands for entrepreneur's net worth. R_t^i is the bank loan/deposit interest rate which is equal to the loan rate R_t^l when the entrepreneur is a borrower and R_t^d when the household is a saver. $\widetilde{R}_t^i$ is the cost (return) of direct market loans for borrowers ($\widetilde{R}_t^l$) and savers ($\widetilde{R}_t^d$). $\widetilde{R}_t^l$ is equal to the interest rate on the market bonds for borrowers R_t^m while the return to the bond holder is given by:

$$\widetilde{R}_t^d = R_t^m - (1-\psi)\, p_t$$

where ψ is an index function which takes the value of 1 when savers can enforce marketable debt themselves and 0 when banks have a monopoly on debt enforcement and savers need to purchase enforcement guarantees from them in order to ensure they are repaid. p_t is the cost of bank guarantees per unit of the bond[5]. We will discuss these market arrangements in some detail

[5] Without a loss of generality, we assume that the savers do not pay the premium upfront but when the repayment with interest is received.

This assumption is not crucial for our results. It is however very convenient because it ensures the timing of interest income and non-interest income is the same. This is what will ensure that the 'shadow bank' economy has an equivalent real allocation to a pure bank intermediation economy with a looser balance sheet constraint - a result which will be established later on in the paper.

below.

3.2 Loan Market Arrangements

In our previous work we assumed that only banks could enforce debts while ordinary savers could not. As a result all loans were bank intermediated. In this paper we are interested in non-bank funding sources and for this reason we consider the impact of two innovations that allow direct lending between savers and the final borrowers.

3.2.1 The Corporate Bond Market

In one case, savers can directly enforce these loans without the involvement of financial institutions. We will refer to this case as the 'corporate bond economy' motivated by the ability of this market to operate with relatively limited bank involvement. This means that $\psi = 1$.

Banks still remain in existence in the corporate bond economy because we assume that they have superior loan enforcement skills that allow them to capture a larger fraction of a defaulting firm's revenues compared to ordinary savers.

More specifically, we assume that entrepreneurs with expected output $E_t y_{t+1}$ can pledge $\theta E_t y_{t+1}$ to banks but only $\theta (1-\chi) E_t y_{t+1}$ to savers. Hence firms face two collateral constraints in the corporate bond economy. One limits what they can borrow from the market

$$R_t^m b_t^m \leqslant \theta (1-\chi) E_t y_{t+1}, \tag{5}$$

where $R_t^m b_t^m$ is the promised repayment (including interest) to corporate bond investors. The other constraint limits their total (market plus bank) borrowing to the amount that can be enforced by banks with their superior enforcement technology

$$R_t^m b_t^m + R_t^l b_t^l \leqslant \theta E_t y_{t+1}, \tag{6}$$

This assumption is a simple way of capturing the intuition that some loans can be intermediated via a market - these are generally risk-free loans whose evaluation requires little special skill. Other loans, however, are not so easy to evaluate and they require the monitoring skills of bankers in order to distinguish good from bad loans. Our framework will ensure that banks and markets coexist in equilibrium even though it will turn out that bank loans will be a more expensive means of debt finance than corporate bonds[6].

3.2.2 Shadow Banking

In another case, which we will refer to as the 'shadow banking economy' throughout the paper, we assume that even though loans can be directly traded between borrowers and savers without necessarily going on banks' balance sheets, the enforcement of these loans requires special skills only bankers have. In other words savers cannot enforce loans at all. This means that $\psi = 0$. The only relevant constraint for entrepreneurs is, therefore, (6) which states that both market and bank loans are limited by banks' ability to collect debts from entrepreneurs.

Due to the lack of any saver enforcement power, direct loans will only

[6] Our set up in which bank and bond finance co-exist within the same firm is consistent with the variable investment scale version of the model in Holmstrom and Tirole (1997).

In reality, bank and bond finance do not always co-exist within the same firm. Young and small firms borrow mostly from banks while old and large firms borrow mostly from capital markets. In contrast, our firms utilise bond and bank finance in the same proportions regardless of firm size or age.

In a separate exercise which is available upon request, we develop a simple model in which firms gain access to the bond market only as they get older. When they are young, they are bank-dependent. We show that, as long as old and young firms do not differ in their average productivities, the choice of whether to model bank and bond finance as co-existing within the same firm does not matter for aggregte dynamics.

trade with the help of a bank guarantee which costs p_t per unit of bonds and, without a loss of generality, we assume that the savers pay the premium in the following period[7]. In our model, this guarantee[8] is a promise to purchase the bonds from savers and enforce repayment in the event that the borrower threatens to default[9]. In subsequent analysis we will demonstrate that the only reason such a market will exist is in order to provide avenues for regulatory arbitrage.

3.3 Banks

Bankers are risk neutral and live for a stochastic length of time. Once bankers receive an "end of life" shock, they liquidate all their asset holdings and consume their net worth before exiting. This shock hits with probability $1-\gamma$. Banks maximize the following objective function:

$$U^B = E_t \sum_{t=0}^{\infty} (\beta\gamma)^t \, c_t^B \tag{7}$$

subject to the following constraints explained below.

In each period the bank has net worth (n_t). It collects deposits (d_t) from the savers. Then it lends to the borrowers (b_t), purchases bubbles in non-negative quantities $(\mu_t m_t^b \geqslant 0)$, issues guarantees (s_t) on market debt or consumes (c_t^b). We assume that intermediation is entirely costless. The bank's balance sheet

[7] This assumption is not crucial for our results. It is however very convenient because it ensures the timing of interest income and non-interest income is the same. This is what ensures that the 'shadow bank' economy has an equivalent allocation to a pure bank intermediation economy with a looser balance sheet constraint - a result which will be established in this section.

[8] Our assumption on bank guarantees is inspired by the description in Acharya et al. (2012) of the way bank liquidity lines to ABCP vehicles were structured prior to the crisis.

[9] Here we assume that the regulatory constraint holds only 'ex ante'. If the guarrantees are called, the bank has to increase its balance sheet size beyond what is allowed by regulators. For simplicity (and also realistically) we assume that regulators exercise forebearance in such a situation and allow the bank to violate its capital adequacy ratios at least for one period.

constraint is given by

$$c_t^b + b_t + \mu_t m_t^b = n_t + d_t. \tag{8}$$

The evolution of net worth is given by

$$n_{t+1} = R_t^l b_t + \mu_{t+1} m_t^b - R_t^d d_t + p_t s_t. \tag{9}$$

when the bubble does not burst and by:

$$n_{t+1} = R_t^l b_t + \rho_{t+1} m_t^b - R_t^d d_t + p_t s_t. \tag{10}$$

when it does burst. ρ_{t+1} is the fraction of the banks' bubble investment which is guaranteed by the government. In the event of a bubble collapse, the government transfers these funds to the banks to compensate them for losses made. The parameter ρ_{t+1} is a simple means of capturing the explicit or implicit guarantees given by the government to the banking system.

Following Gertler and Karadi (2011), we model banks subject to limited commitment. More specifically, the banker may divert $1 - \lambda^m$ fraction of total liabilities. Once he diverts, a banker consumes the funds and closes his bank, remaining inactive until his 'death'. Savers will therefore restrict the amount they deposit with the intermediary, according to the following borrowing constraint which states that the value of diverted funds is less than or equal to the continuation value of the bank $V(n_t)$ which will be defined later on in section 4:

$$(1 - \lambda^m)(s_t + d_t) \leqslant V(n_t). \tag{11}$$

The liabilities on the left-hand side include both on-balance-sheet deposits (d_t) as well as off-balance-sheet guarantees (s_t) which turn into divertable deposits as soon as the guarantee is called in[10]. So for the purposes of the bank's balance sheet constraint, on and off-balance-sheet liabilities require the same amount of bank capital.

In addition to the above market capital constraint, the bank also faces a regulatory constraint[11] which is specified in terms of traditional bank liabilities d_t only:

$$(1-\lambda^r)d_t \leqslant V(n_t) \tag{12}$$

The bank maximizes (7) subject to (8), (9), (10), (11) and (12).

3.4 Workers

Unlike the entrepreneurs, the workers do not have access to the production technology nor any collateralizable asset in order to borrow. They maximize the following utility

$$U^W = E_t \sum_{t=0}^{\infty} \beta^t \left(c_t^w - \frac{h_t^{1+\eta}}{1+\eta} \right) \tag{13}$$

subject to their flow-of-funds constraint

[10] We are not trying to model rigorously the microfoundations for the borrowing constraint (11) but we have the following environment in mind.

Within every period, savers move first and divide their savings into conventional bank deposits and direct market loans to borrowers (backed by bank guarantees). Immediately after the bond market closes, borrowers have the opportunity to default on the bonds they just sold to savers. At this point, the deposit market can reopen in order to provide banks with funds with which to purchase the defaulted bonds from savers and enforce repayment.

Only after the closure of the deposit market, do banks have the opportunity to divert deposits, which at this point could potentially include bank guarantees as well as conventional deposits. This explains why the left hand side of (11) is specified in terms of $s_t + d_t$.

[11] Regulatory constraints are usually specified in terms of accounting definitions of equity:

$$(1-\lambda^r)\, d_t \leqslant n_t$$

In a note available upon request we show that all our results continue to hold if we consider a regulatory capital constraint in terms of accounting equity rather than the market value of equity.

$$c_t^w + m_t^w \mu_t - b_t^w = w_t h_t + m_{t-1}^w \mu_t - R_{t-1}^d b_{t-1}^w, \quad (14)$$

here superscript 'w' stands for 'workers'.

3.5 The Government

We assume that the only role for the government in this economy is to levy taxes on entrepreneurs and bail out the banking system when it makes losses. We assume that the government follows a balanced budget rule and does not issue government debt. Consequently taxes are only levied whenever bailout spending is necessary. For the rest of the time, taxation is zero.

4 Equilibrium

Following Weil (1987) we consider a stochastic bubble that persists with probability π. With probability $1-\pi$ the bubble bursts and its value reverts to zero. We assume this probability is constant over time. Also, we assume that once bubbles burst they never arise again.

In equilibrium, due to the difference in their productivity, productive entrepreneurs borrow from banks and unproductive entrepreneurs make deposits to banks. We focus on equilibria in which the productive entrepreneurs borrow up to their borrowing constraint[12].

4.1 Entrepreneurs' optimal behavior

The entrepreneurs' problem can be interpreted as a savings problem with uncertain returns. Since utility function is logarithmic and there is no labour

[12] This happens when the borrowing constraints are tight enough. See Aoki et al. (2009).

income or transfer income, entrepreneurs consume a constant fraction of net worth (z_t).

$$c_t = (1 - \beta)\, z_t. \tag{15}$$

and save the remaining β fraction[13].

High productivity entrepreneurs enjoy better returns on production so they are the ones who borrow in equilibrium. We focus on an equilibrium in which the overall borrowing constraint (6) binds. When $R_t^l > R_t^m$ (which will be the case in the corporate bond economy), entrepreneurs prefer to borrow as much as they can from corporate bond investors before going to banks for loans. Therefore constraint (5) binds too.

In the shadow bank economy savers cannot enforce debts and bank and market loans will be perfect substitutes in equilibrium. Hence $R_t^l = R_t^m$ and borrowers will be indifferent as to whether they borrow from banks or from the market.

Entrepreneurs' rate of return on wealth ($r(a^H)$) is given by[14]:

$$r(a^H) = \frac{a^H(1-\theta)}{w_t - a^H\theta\left(\left(1-\chi\right)/R_t^m + \chi/R_t^l\right)} \geqq R_t^l. \tag{16}$$

The denominator is the required downpayment for the unit labor cost which can be financed with market bonds and bank loans. The investment (employ-

[13] See, for example, Sargent (1987).

[14] This equation is a compact way of representing $r(a^H)$ in a way that holds in the corporate bond as well as in the shadow bank economy. (16) is written as it is in the corporate bond economy whereas, strictly speaking, in the shadow bank economy, the equation is

$$r(a^H) = \frac{a^H(1-\theta)}{w_t - a^H\theta/R_t^l}$$

However, (16) also holds in the shadow bank economy because $R_t^m = R_t^l$. So we reuse the same condition for compactness of exposition.

ment) of a productive agent is given by

$$h_t = \frac{\beta z_t}{w_t - a^H \theta \left((1-\chi) / R_t^m + \chi / R_t^l \right)}. \tag{17}$$

The entrepreneur saves a β fraction of wealth z_t and uses her entire savings as a downpayment for wage payments to the workers she hires.

Low productivity entrepreneurs are savers in equilibrium. They can make bank deposits or buy market bonds whose rates of return must be equalised in equilibrium:

$$R_t^d = R_t^m - (1-\psi) p_t$$

In addition, they have two other means of savings: unleveraged production and investing in bubbles. When

$$R_t^d > \frac{a^L}{w_t} \tag{18}$$

low productivity agents are inactive in production. However when the credit constraints on banks and borrowing entrepreneurs are tight enough, the productive entrepreneurs cannot absorb all national saving and the low productivity technology may be viable in equilibrium. In such case

$$R_t^d = \frac{a^L}{w_t} \tag{19}$$

Bubbles are risky. When savers invest in bubbles as well as deposits, the arbitrage condition for bubbles is determined by the savers' state-contingent wealth valuation

$$E_t \left[\frac{1}{c_{t+1}^L} \frac{\mu_{t+1}}{\mu_t} \right] = E_t \left[\frac{1}{c_{t+1}^L} \right] R_t^d, \tag{20}$$

where $1/c_{t+1}^L$ represents the shadow value of wealth at time $t+1$ of the entrepreneur who is unproductive at time t[15], where expectation operator is taken over whether bubble survives or crashes.

$$\mu_{t+1} = \begin{cases} \mu^b_{t+1} \text{ with probability } \pi \\ 0 \text{ with probability } 1-\pi \end{cases} \tag{21}$$

where μ^b_{t+1} is the market value of the bubble on survival.

As we showed in Aoki and Nikolov (2011), savers are the natural bubble holders when $R^l_t > R^d_t$ and when there is no financial safety net. They have the worst investment opportunities, which are dynamically inefficient for a large set of parameter values (see Aoki and Nikolov (2011) for more details).

4.2 Banks' optimal behaviour

Next, we characterise the optimal behaviour of a representative bank in our economy. The problem of the bank can be represented in recursive form as follows:

$$V(n_t) = \max_{c^b_t, d_t, b_t, m^b_t, s_t} \left\{ c^b_t + \beta E_t \left[\gamma V(n_{t+1}) + (1-\gamma) n_{t+1} \right] \right\} \tag{22}$$

$V(n_t)$ is the value of a bank with net worth n_t which chooses current consumption, deposits, bubbles and loans optimally. This value is equal to current consumption and the expected future discounted value of bank net worth $\beta E_t [\gamma V(n_{t+1}) + (1-\gamma) n_{t+1}]$. This value includes the continuation value of being a banker - this happens only if the banker survives with probability γ. With probability $1-\gamma$, the banker receives the death shock and consumes his entire net worth in the following period.

[15] Namely, it is given by

$$1/c^L_{t+1} = (1-\beta) Z^L_{t+1}$$

where Z^H_{t+1} is given by equation (A.9).

When $\psi = 1$ and savers do not need banks to enforce market bond repayment, banks' guarantees will be worthless ($p_t = 0$) and no guarantees will be issued ($s_t = 0$). Then the banks have only on-balance-sheet liabilities and their borrowing constraint is given by the tighter of the two constraints (11) and (12):

$$d_t \leqslant \min\left(\frac{1}{1-\lambda^m}, \frac{1}{1-\lambda^r}\right) V(n_t)$$

Here we assume that the regulatory constraint is tighter so in the economy where $\psi = 1$, banks operate with the leverage desired by regulators.

When $\psi = 0$, banks are needed in the enforcement of market bonds and this gives financial institutions the possibility of having off-balance sheet liabilities s_t. Since both debt guarantees and normal deposits attract the same market capital charge, the bank will charge a guarantee 'insurance premium' which is equal to the lending-deposit rate spread in equilibrium:

$$p_t = R_t^l - R_t^d. \tag{23}$$

The bank is then indifferent between lending to firms directly on-balance-sheet or indirectly off-balance-sheet. (11) becomes the only real balance sheet constraint for banks. Bankers choose the size of the shadow banking system (here given by guarantees s_t) to make sure that (12) is satisfied. This is given by the following condition:

$$s_t = \left(\frac{1}{1-\lambda^m} - \frac{1}{1-\lambda^r}\right) V(n_t). \tag{24}$$

When (24) holds, the regulatory capital constraint (12) no longer affects bank total leverage and aggregate lending. In other words, if unregulated shadow banks are set up in the model, regulation becomes a 'pure veil'[16]. It influences only the split between the regulated and unregulated sectors without affecting the real allocations in the economy[17]. This stark result captures well the spirit of the discussion of Tucker (2010) as well as the empirical evidence presented in Acharya et al. (2012). Faced with a strong profit motive for circumvention, the financial system will find ways in which to get around capital regulation regimes that focus on a narrow regulatory perimeter.

Finally note that our modelling set up is consistent with many different institutional structures in addition to the ABCP conduits we highlight in our discussion. For example, if lightly regulated entities (e.g. insurance companies such as AIG or Dexia) sell CDS protection to loan holders thereby allowing the latter to reduce their capital requirements, this would achieve exactly the same outcome. In practice, as argued by Acharya et al. (2012), the exact structure of the shadow banking system will be determined by the precise loopholes in individual country regulatory regimes. But the result is always the same: regulation becomes ineffective at preventing financial institutions from operating with very high levels of leverage. This is the important feature of reality our shadow bank model aims to capture.

[16] This result depends on the assumption that insurance premia are paid in arrears rather than in advance. Without such an assumption, the exact equivalence will change but the spirit of the analysis will be preserved.

[17] We assumed for simplicity that the regulatory constraint takes the same form as the constraint imposed by markets. Due to this assumption the regulatory constraint on leverage is time varying as the bank's value function changes over time. It may be more natural to assume that the regulatory constraint puts a constant upper bound on the bank's book leverage such as:

$$(1-\lambda^r)d_t \leqslant n_t \tag{25}$$

Even in this case, it continues to be true that borrowers are indifferent between borrowing from the traditional banking sector and from the shadow banking sector because the enforcement power is identical between the two. Also, the savers are indifferent between making deposits and buying the bank guarranteed bonds. Then, equation (23) holds and thus banks are indifferent between lending to firms directly on-balance sheet or indirectly off-balance sheet. Therefore the subsequent analysis will continue to hold even if we assume a more realistic regulation given by (25).

To summarise, the effect of shadow banking on financial intermediaries is to modify their collateral constraint in the following way:

$$\left(1-\widehat{\lambda}\right)\widehat{d}_t \leqslant V\left(n_t\right) \tag{26}$$

where

$$\widehat{\lambda} = \psi\lambda^r + (1-\psi)\lambda^m \tag{27}$$

and

$$\widehat{d}_t = d_t + s_t. \tag{28}$$

Note that $s = 0$ when $\psi = 1$ as discussed above.

Because of risk neutrality, we can guess that the value of the bank is a linear function of net worth n_t

$$V\left(n_t\right) = \phi_t n_t \tag{29}$$

When $R_t^l > R_t^d$, the balance sheet constraint (26) binds and consumption is postponed until death.

Our guess for $V\left(n_t\right)$ together with the bank's value function (22) imply that the bank chooses bubble and loan holdings according to the following first order condition:

$$E_t\left[\left(1-\gamma+\gamma\phi_{t+1}\right)\frac{\tilde{\mu}_{t+1}}{\mu_t}\right] = E_t\left[\left(1-\gamma+\gamma\phi_{t+1}\right)\right]R_t^l, \tag{30}$$

where

$$\tilde{\mu}_{t+1} = \begin{cases} \mu_{t+1}^b \text{ with probability } \pi \\ \rho\mu_t \text{ with probability } 1-\pi \end{cases} \tag{31}$$

where ρ is a parameter which governs the (explicit or implicit) financial safety net for banks. when the bubble bursts, banks receive a fraction ρ of their original bubble investment. This is due to a bailout payment from the government. The expectation operator is again taken over the bubble surviving or not. If equation (30) holds with strict inequality, then the bank will not invest in bubbles ($m_t^b = 0$). When the bank invests in bubbles (30) must hold with equality.

Finally, by substituting (11), (27), (29) and (30) into (22), ϕ_t satisfies

$$\phi_t = \frac{\beta E_t \left[(1-\gamma) + \gamma E_t \phi_{t+1}\right] R_t^l}{1 - \beta E_t \left[(1-\gamma) + \gamma E_t \phi_{t+1}\right] \frac{R_t^l - R_t^d}{1-\widehat{\lambda}}}. \tag{32}$$

This expression states that the value of a unit of net worth for a banker is equal to the value of the returns on its loan book (the numerator), suitably boosted by leverage (the denominator). The banker issues one unit of loans but the downpayment he has to make is only given by the denominator of (32) because he can pledge some of the future expected excess returns from intermediation ($\beta E_t \left[(1-\gamma) + \gamma E_t \phi_{t+1}\right] \frac{R_t^l - R_t^d}{1-\widehat{\lambda}}$) to depositors who finance a large part of the loan outlay. Note that the above formulas show that ϕ_t increases with ϕ_{t+1}. This implies that the current leverage depends on the future franchise value of the bank which is reflected by the leverage next period.[18] It also shows that ϕ_t is an increasing function of the spread $R_t^l - R_t^d$.

The direct impact of financial innovation on (32) works only through its impact on $\widehat{\lambda}$. We will start from a baseline case in which banks must keep all assets on-balance sheet and hence the regulatory capital constraint binds: $\widehat{\lambda} = \lambda^r < \lambda^m$. Since we assume in the corporate bond economy that all bank loans must be held on-balance sheet, this innovation does not impact (32) directly and $\widehat{\lambda} = \lambda^r$ continues to hold.

[18] See Nikolov (2010), who considers a similar problem for firms.

Once banks can shift assets off-balance sheet in the shadow banking economy, the borrowing constraint they face is the looser market constraint ($\widehat{\lambda} = \lambda^m > \lambda^r$) and this acts as a leverage shifter which directly affects (32) by raising all current and future values of ϕ_t. Of course, as we will demonstrate in the remainder of the paper, both of these financial innovations will affect the bank franchise value equation (32) indirectly through their impact on the equilibrium lending spread $R_t^l - R_t^d$.

4.3 Workers' optimal behaviour

Workers are risk-neutral and consequently their consumption-savings behaviour is a knife-edge one. When the loan interest rate is lower than the rate of time preference, workers want to borrow unlimited quantities. Because the workers cannot operate the production technology, they cannot pledge collateral to lenders. Hence workers cannot borrow.

Of course workers could save at the deposit rate but they only want to do this when

$$R_t^d \geqslant \beta^{-1}. \tag{33}$$

If this condition is not satisfied, workers will consume their entire net worth (financial wealth and labour income) and save nothing. Their labour supply h_t^s is given by

$$h_t^s = w_t^\eta. \tag{34}$$

Because ours is a limited commitment economy, we guess and verify that $R_t^d < \beta^{-1}$ at all times along the equilibrium paths we consider. Hence our workers are hand-to-mouth consumers at all times.

4.4 Aggregation and market clearing

The full set of aggregate equilibrium conditions is given in Appendix A.

5 Discussion: What Determines Bank Risk-Taking?

The bubble is the only risky asset in our model economy[19]. Therefore, bank risk-taking behaviour manifests itself in higher bubble holdings by banks. In Aoki and Nikolov (2011) we showed that asset price bubbles pose significant risks to economic and financial stability only when it is held by the banking system. In this section, we want to provide a discussion of what determines bank risk-taking via bubble purchases. This provides a link to our earlier work (Aoki and Nikolov (2011)) but also highlights the way in which the different financial innovations introduced in this paper affect bank risk-taking and financial fragility. The current section will show that the lending-deposit spread $(R_t^l - R_t^d)$ plays a major role in determining whether the bank is exposed to the risky bubble or not. This discussion is leading up to our simulation results in the next section where we demonstrate that market financing and shadow banking affect banks' risk taking behaviour differently due to their differential impact on the lending-deposit spread.

To understand banks' incentive to hold the bubble, it is actually instructive to start with a risk-premium representation of the arbitrage condition for

[19] In general, rational bubbles circulate when they are affordable and attractive. Affordability means that bubbles must not grow too fast. In the case of deterministic bubble in our model, the rate of return of bubbles must not be higher than the rate of economic growth which is unity. Aoki and Nikolov (2011) shows that this happens when θ is at an intermediate level. Conditions for attractiveness are discussed in detal in this Section.

savers' bubble holdings (equation (20)):

$$E_t\left[\frac{\mu_{t+1}}{\mu_t}\right] = R_t^d - \frac{cov_t\left[\frac{1-\tau_{t+1}}{c_{t+1}^L}\frac{\mu_{t+1}}{\mu_t}\right]}{E_t\left[\frac{1-\tau_{t+1}}{c_{t+1}^L}\right]} = R_t^d + \varkappa_t^L \tag{35}$$

where $\varkappa_t^L$ is the risk premium required by savers in order to hold the risky bubble. The excess return is increasing in savers' risk aversion and also in the covariance of consumers' marginal utility of consumption with the bubble return. The larger savers' bubble holdings are in relation to their total wealth, the more volatile their consumption becomes and the more correlated it becomes with the bubble return. Standard asset pricing arguments then imply that the required excess return on the bubble should increase.

When banks hold the bubble, the following condition should hold in equilibrium (this time based on equation (30)):

$$E_t\left[\frac{\widetilde{\mu}_{t+1}}{\mu_t}\right] = R_t^l - \frac{cov_t\left[\left(1-\gamma+\gamma\phi_{t+1}\right)\frac{\widetilde{\mu}_{t+1}}{\mu_t}\right]}{E_t\left[\left(1-\gamma+\gamma\phi_{t+1}\right)\right]} = R_t^l + \varkappa_t^B \tag{36}$$

where $\varkappa_t^B$ is the risk premium required by bankers.

It may seem surprising that the bankers who have linear period utility would require a risk premium in order to hold the bubble. This is due to the effect of binding borrowing constraints and the high and time varying value of internal funds that this brings about. The shadow value of wealth for bankers is given by $\left(1-\gamma+\gamma\phi_{t+1}\right)$ - a term whose time series behaviour is dominated by ϕ_{t+1}- the value of wealth for surviving bankers. Binding borrowing constraints for banks lead to an aggregate shortage of bank capital and a lending spread

($R^l > R^d$) in equilibrium. Then, being a banker is valuable, because it allows the enjoyment of the super-normal profits created by these spreads. ϕ_{t+1} is the net present value of these super-normal profits - the 'franchise value' of the bank.

Bankers would ideally like to transfer wealth to states of the world in which these super-normal profits are high - i.e. where ϕ_{t+1} is relatively high. Equation (32) shows that ϕ_{t+1} is high when the deposit-lending spread is high. And the spread is high during the financial crisis. This makes them risk-averse with respect to gambles that affect aggregate banking system net worth and hence the profits of normal banking activities. In the case of the bubble asset, the risk aversion of banks depends on whether the financial system as a whole is exposed to the bubble's bursting or not. This is the *'Last Bank Standing'* effect highlighted by Perotti and Suarez (2002). It makes banks require a high risk-premium for assets which deplete aggregate bank capital and leave good profit opportunities for surviving intermediaries after the crisis.

The expected return for banks also includes the anticipated bailout payment even when the bubble bursts. This means that equation (36) above can be alternatively expressed as:

$$E_t\left[\frac{\mu_{t+1}}{\mu_t}\right] = R_t^l - (1-\pi)\,\rho + \varkappa_t^B \tag{37}$$

where $(1-\pi)\,\rho$ is the expected value of any bailouts that accrue to a bank holding the bubble in the event of a bubble crash. Banks hold the bubble if the expected bubble return (including any bailout assistance) is higher than their alternative use of funds (the loan rate) and the risk premium required by the bank.

Substituting the savers' condition for holding bubbles into the banks' condition we get the following condition for bank bubble holdings:

$$(1-\pi)\,\rho + \varkappa_t^L - \varkappa_t^B = R_t^l - R_t^d \tag{38}$$

The left-hand side of the above equation summarises the channels discussed in our earlier paper Aoki and Nikolov (2011). The $\varkappa_t^L - \varkappa_t^B$ term arises due to risk sharing between savers and bankers. The more of the bubble is held by risk-averse savers, the higher the return they require for bearing the risk associated with it and $\varkappa_t^L$ increases. Other things equal, this higher expected return makes the bubble more attractive for banks who then share some of the risk with savers. This risk-premium is growing with banks' bubble holdings which expose them to a large drop in net worth when the bubble bursts. As explained above, binding credit constraints induce time variation in the value of bank capital $(1-\gamma+\gamma\phi_{t+1})$. This makes banks risk-averse with respect to assets which deliver large losses for the aggregate banking system. Finally, also on the left hand side of (38) we have the expected bailout term $((1-\pi)\,\rho)$ which is the classical moral hazard effect.

The lending spread $(R_t^l - R_t^d)$ term on the right-hand side of (38) is the 'Bank franchise value' channel we focus on in this paper. The presence of binding balance sheet constraints on banks introduces a wedge between lending and deposit rates and allows banks to earn rents on the loans it extends to the real economy. When the balance sheet constraint binds tightly, this lending-deposit spread is high and buying the risky asset becomes less attractive to the bank. There is no need for the bank to buy the bubble in order to earn a high return on its net worth. Its privileged position as a bank allows it to earn large profits with default-free loans only.

In the next section we will use numerical simulations to show that financial innovation and shadow banking both increase competition in the financial sector and drive down banks' lending spreads and franchise values. Holding all the terms on the left hand side of (38) fixed, this makes banks more willing to hold the bubble asset in equilibrium and increases the risks that a bubble collapse poses to banks' financial health. We find, however, that shadow banking reduces spreads and increases bank bubble holdings by a larger amount due to the fact that it expands aggregate financial system leverage further.

6 Non-Bank Credit and Financial Fragility

In this section we answer the central question of our paper: how does growing competition from different non-bank finance sources affect bank and macroeconomic fragility? To do this we compare the impact of the two financial innovations discussed in the paper - the growth of the corporate bond market and the growth of the shadow banking sector. Following our approach in Aoki and Nikolov (2011) the possibility of a financial crisis arises due to the presence of an asset price bubble, which can burst and damage the net worth of those economic agents who hold it.

Notice that emergence of direct finance between savers and borrowers does not increase the overall pledgeability of borrowers' assets. In both the corporate bond and shadow bank economy, total pledgeability is still given by the overall collateral parameter θ. Both mitigate frictions in financial intermediation. However, corporate bond finance does not rely on bank capital while the shadow banking sector (implicitly or explicitly) relies on bank capital. As is shown below this difference is crucial.

Since the analytical solution is not available, we discuss the properties of the model based on numerical simulations with a calibrated version of our model. The model calibration follows the methodology of Aoki and Nikolov (2011) and full details are available in Appendix B of this paper.

In order to study the effects of financial innovations on financial fragility, we take an economy which already has a bubble worth 10% of GDP and hit it with two additional shocks. The first is a shock which expands the ability of savers to lend directly to borrowers without the involvement of banks. This is our 'corporate bond market growth' scenario and it is implemented in our model by a decrease in χ to 0.846 from its baseline value of unity.

The second is a shock which allows banks to shift a quarter of their assets off-balance sheet through the mechanism described in Section 4. Both scenarios are calibrated so as to generate an increase in non-bank funding sources equal to 25% of commercial bank loans. This is the approximate increase in ABS between 2000 and 2006 as shown in Figure 3.

Our main interest is in the following questions. How does the invention of these new lending institutions affect existing financial institutions' incentives to take risk by holding bubbles? How does this affect the size of the downturn in the real economy when the bubble finally bursts? In particular, we want to think about Greenspan's 'spare tire' hypothesis: do these new markets and non-bank financial institutions provide a diversified source of funding for firms or not?

Figures 6 and 7 compare the evolution of the economy under the 'shadow bank' and 'corporate bond' scenarios. Figure 6 focuses on bank balance sheet variables, Figure 7 displays the evolution of bank net worth, credit supply and real output during our simulations. The financial innovations occur in period 2 of the simulations while the bubble collapses in period 5. Since our model is calibrated to the annual frequency, this implies that the boom lasts 3 years. All the numbers in the chart are scaled by the baseline in which the economy is in a bubbly equilibrium but no financial innovation shocks have occurred.

Figure 6 shows that the boom-time impact of the two innovations on bank leverage is very different. Shadow banking expands leverage by around a third relative to baseline while the growth of the corporate bond market decreases leverage during the boom period. The reason for this difference lies in the fact that the corporate bond market expansion encourages the growth of unleveraged direct loans from savers to borrowers. In other words demand for bank loans decreases. This squeezes bank profitability and reduces bank franchise values. Since the bank's collateral constraint depends on its charter value (a market value concept), this reduces leverage. Note that bank profitability also declines under the shadow banking simulation and this, *ceteris paribus*, decreases bank leverage too. However, the direct impact of the ability to shift assets off balance sheet where they are subjected to less stringent market based capital requirements dominates and consolidated financial system leverage expands.

This difference in bank leverage is reflected in the evolution of lending spreads. Bank lending margins ($R^l - R^d$) decline in both simulations but under shadow banking the decline is greater. The reason for this lies in the impact of leverage on bank profitability. When $R^l_t - R^d_t > 0$ higher leverage expands bankers' rate of return on inside equity n_t and, all else equal, makes their net worth grow faster in equilibrium. In equilibrium, bank capital cannot grow too fast and this is especially true under the shadow banking shock which increases the lending that can be supported by existing bank capital. In fact, bankers' net worth should decline in equilibrium which is why the fall in spreads is greater relative to the corporate bond simulation. When the corporate bond market grows, this also requires that the banking system should shrink. However, the decline in banks' leverage helps this adjustment to take place with a smaller fall in spreads.

As the last panel in Figure 6 shows, the different behaviour of bank leverage and spreads has a direct impact on banks' holdings of bubbly assets. Lower lending spreads makes holding bubbles more attractive for banks and therefore bank risk-taking increases more during the shadow bank simulation compared to the corporate bond one. This occurs both through greater holdings of risky (bubble) assets but also through higher leverage which makes bank net worth more sensitive to potential losses. Finally, in Figure 7 we can see that output and lending expand significantly during the boom before the bubble finally bursts in period 5 of the simulation.

The collapse of the bubble can be seen in Figure 6 where the bubble relative to GDP goes from just under 10% of annual output to zero in period 5. At this point, we assume that bank losses from bubble holdings alert the regulators to the high level of implicit leverage of the financial system. The result is the closure of the shadow banking system. In contrast, we assume that the corporate bond market survives.

We can see that bank losses and the closure of the shadow banking system lead to a significant decline in output relative to baseline. In contrast, the expansion of the corporate bond market largely offsets the impact of the bursting of the bubble and, as a result, output and lending do not experience a significant decline. Bank net worth collapses under both scenarios following the bubble's bursting but the credit crunch impact is much more pronounced under the shadow banking simulation. As Figure 6 shows, spreads increase very sharply when the crisis hits and this actually helps the banking system to recapitalise. However, output and lending remain significantly below the no-financial-innovation saver bubble baseline for more than twenty periods.

In contrast, the corporate bond simulation produces a much smaller increase in spreads (Figure 6) and no decline in aggregate lending and economic activity (Figure 7). This is both because banks were less exposed to the bubble and suffered a smaller decline in net worth (the first panel of Figure 7) but also because the corporate bond market continues to provide liquidity to borrowers while the shadow banking sector shuts down after the crisis.

7 Conclusions

This paper asks the question of how the growth of non-bank financing sources affects systemic risk. We find that the answer crucially depends on whether the availability and cost of these non-bank sources of finance is truly independent of the health of the banking sector. We contrast two deliberately extreme cases: one in which the non-financial sector improves its ability to enforce debts and another in which the banking sector shifts bank loans off balance sheet in order to circumvent regulation. In both cases, non-bank financing grows but only in the first case this growth can be sustained regardless of the level of bank capital.

Both of the shocks to the supply of non-bank credit sources we consider have the effect of expanding aggregate credit supply. This lowers lending-deposit spreads for banks and reduces their franchise values. As a result, bubbly assets become more attractive for banks and they increase their exposure to them. Banks do not hold bubbles forever in either of our simulations. Eventually, bank capital shrinks due to low profitability and this allows at least a partial recovery of loan-deposit spreads. At this point, profits from traditional activities recover sufficiently and financial institutions stop holding bubbles as a result. However, during the transition period, the banking system is vulnerable to a collapse in the bubble and risks to bank capital are high in both simulation exercises.

Where the two experiments differ very strongly is in the consequences of bank losses for the real economy. In the 'corporate bond' scenario, the fall in bank capital triggers only a very mild credit crunch because the corporate sector has an alternative source of funds to go to. This is the 'spare tire' highlighted by Greenspan (1999) - diversification of funding sources makes banks less important in providing funds to the real economy and this diminishes the costs of systemic banking crises. In contrast, the 'shadow banking' scenario features a more severe credit crunch. This happens for two reasons. Shadow banking allows the aggregate financial system to become more leveraged and therefore bank capital experiences a larger proportional decline due to the bubble's collapse.

Appendices

A Aggregate Equilibrium Conditions

Let the total supply of the bubble asset be normalized to 1. In other words,

$$m_t^e + m_t^b = 1, \tag{A.1}$$

where m_t^e and m_t^b, respectively, denote the shares of the bubble held by unproductive entrepreneurs and banks.

Let Z_t^H and Z_t^L, respectively, denote aggregate wealth of the productive and unproductive entrepreneurs. Then we can characterise the aggregate equilibrium as follows. From (17) the aggregate employment of the productive entrepreneurs is given by[20]:

$$H_t^H = \frac{\beta Z_t^H}{w_t - a^H \theta \left((1-\chi) / R_t^m + \chi / R_t^l \right)}. \tag{A.2}$$

When (18) holds, the unproductive entrepreneurs are indifferent between making deposits and producing, thus their aggregate saving is split as follows

$$H_t^L = \beta Z_t^L - D_t - B_t^M - m_t^e \mu_t \tag{A.3}$$

where D_t and B_t^M, respectively, denote aggregate deposits and aggregate directly traded loans.

Let us turn to banks. In the shadow banking economy, total loan supply is determined by banks' market borrowing constraint. Hence the aggregate

[20] Again, we use the aggregate condition from the corporate bond economy for compactness. It also holds (trivially) in the shadow bank economy because $R_t^m = R_t^l$.

quantities of deposits and bank guarantees are given by:

$$S_t + D_t = \frac{\phi_t}{(1-\lambda^m)}\gamma N_t. \tag{A.4}$$

where S_t denotes the aggregate off-balance sheet guarantees issued by banks. The split between on and off-balance-sheet activities is given by the regulatory constraint[21]:

$$D_t \leqslant \frac{\phi_t}{(1-\lambda^r)}\gamma N_t \tag{A.5}$$

Finally the size of the direct loan market is given by the supply of bank guarantees ($S_t = B_t^M$) and the aggregate balance sheet of the operating banks is given by

$$D_t + \gamma N_t = B_t^L + m_t^b \mu_t. \tag{A.6}$$

In the corporate bond economy, $S_t = 0$ and the size of the corporate bond market is determined by savers' loan enforcement abilities:

$$R_t^d B_t^M = \theta\,(1-\chi)\,a^H H_t^H \tag{A.7}$$

The bank's balance sheet constraint is determined by regulation: in other words (A.5) holds while (A.6) does not.

Let us turn to the transition of state variables. Note that the unproductive entrepreneurs become productive in the next period with probability $n\delta$ and the productive entrepreneurs continues to be productive with probability $1-\delta$. Their rates of return are given by (16) and (18). Therefore the net worth of

[21] Notice that $1-\gamma$ fraction of banks exits in each period and consumes their net worth. Therefore the aggregate net worth of the operating banks is given by γN_t.

the productive entrepreneurs evolves from (16) and (15) as

$$Z_{t+1}^H = (1-\delta)\frac{a^H(1-\theta)}{w_t - a^H\theta\left((1-\chi)/R_t^m + \chi/R_t^l\right)}\beta Z_t^H + n\delta\left[R_t^d\left(\beta Z_t^L - m_t^e\mu_t\right) + m_t^e\mu_{t+1}\right] \tag{A.8}$$

Similarly, the aggregate net worth of the unproductive entrepreneurs evolves as

$$Z_{t+1}^L = \delta\frac{a^H(1-\theta)}{w_t - a^H\theta\left((1-\chi)/R_t^m + \chi/R_t^l\right)}\beta Z_t^H + (1-n\delta)\left[R_t^d\left(\beta Z_t^L - m_t^e\mu_t\right) + m_t^e\mu_{t+1}\right] \tag{A.9}$$

From aggregating production function, aggregate output is given by

$$Y_t = a^H H_{t-1}^H + a^L H_{t-1}^L. \tag{A.10}$$

Finally, aggregate bank net worth is given by

$$N_{t+1} = \gamma\left[R_t^l B_t^l + m_t^b\mu_{t+1} - R_t^d D_t + (1-\psi)\left(R_t^l - R_t^d\right)S_t\right] \tag{A.11}$$

The markets for goods, labour, capital, loan and deposit must clear. Goods market clearing implies that aggregate saving must equal to aggregate investment.

$$\beta(Z_t^H + Z_t^L) + \gamma N_t = w(H_t^H + H_t^L) + \mu_t. \tag{A.12}$$

From (34), labour market clearing implies

$$w_t^\eta = H_t^H + H_t^L. \tag{A.13}$$

Now equations (19), (20), (30), (32), (A.1)-(A.13) jointly determine 17 variables R_t^d, R_t^l, w_t, H_t^H, H_t^L, Y_t, ϕ_t, D_t, S_t, B_t^L, B_t^M, Z_{t+1}^H, Z_{t+1}^L, N_{t+1}, μ_t, m_t^e, m_t^b

with three states Z_t^H, Z_t^L, N_t[22]. At $t = 0$, Z_0^H is given by (A.8).

Definition 1 *Competitive bubbly equilibrium without government is a sequence of decision rules* $\{H_t^H, H_t^L, Y_t, D_t, S_t, B_t^L, B_t^M, m_t^e, m_t^b\}_{t=0}^{\infty}$*, aggregate state variables* $\{Z_{t+1}^H, Z_{t+1}^L, N_{t+1}\}_{t=0}^{\infty}$ *and a price sequence* $\{R_t^d, R_t^l, w_t, \phi_t, \mu_t\}_{t=0}^{\infty}$ *such that: (i) entrepreneurs, banks and workers optimally choose decision rules* $\{H_t^H, H_t^L, Y_t, D_t, S_t, B_t^L, B_t^M, m_t^e, m_t^b\}_{t=0}^{\infty}$ *taking the evolution of aggregate states, prices and idiosyncratic productivity opportunities as given; (ii) the price sequence* $\{R_t^d, R_t^l, w_t, \phi_t, \mu_t\}_{t=0}^{\infty}$ *clears the goods, labor, capital, loan, bubble and deposit markets and (iii) the equilibrium evolution of state variables* $\{Z_{t+1}^H, Z_{t+1}^L, N_{t+1}\}_{t=0}^{\infty}$ *is consistent with the individual choices of entrepreneurs, banks and workers and with the exogenous evolution of productive opportunities at the individual firm level.*

B Calibration

We have 10 parameters $\{\eta,\ a^H/a^L,\ \delta,\ n,\ \theta, \chi,\ \gamma,\ \beta,\ \lambda^m, \lambda^r\ \}$ we need to calibrate before we proceed to examine the quantitative predictions of our model economy. For simplicity we set $\chi = 1$ in the baseline calibration thus having no market financing in the baseline economy.

There is little consensus regarding η, the Frisch elasticity of labour supply. Micro-data evidence suggests a value close to zero based on the labour supply behavior of primary earners. The real business cycles literature usually sets a much higher value in the region of 3 or even higher. The differences is justified by the presence of labour market frictions that ensure that aggregate labour is highly elastic even though individuals are relatively unwilling to vary their market hours over time. Gertler and Kiyotaki (2010) make this argument and

[22] By Warlas law one of these equations is redundant.

set the Frisch elasticity to 10 in their model. We pick a value of $\eta = 5$, which is within the range set in calibrating macro models.

a^H/a^L is an important parameter, whose value is also highly uncertain. As studies such as Bernard et al. (2003) and Syverson (2004) have documented, the dispersion of plant level productivity in US manufacturing is enormous, with the most productive plants having more than 4 times more productive compared to the least productive. But as Aoki et al. (2009) argue, it is hard to believe that such a huge dispersion of productivity levels is entirely due to the presence of credit constraints. More likely, inputs could be mismeasured in a number of ways. For example, intangible assets such as managerial quality could be an important missing input which could explain some of the huge differences in measured plant level TFP. Following Aoki et al. (2009) we set a value for $a^H/a^L = 1.1$ implying a substantial cross-sectional dispersion in plant level TFP in the model.

We calibrate the remaining 8 parameters in order to match the steady state predictions of the model in the absence of bubbles to 9 moments in the US data. These are (1) the real loan rate minus the growth rate of real GDP and minus intermediation costs; (2) the real deposit rate minus the growth rate of real GDP; (3) commercial bank leverage; (4) average corporate leverage; (5) average leverage for highly leveraged corporates; (6) the rate of return on bank equity; (7) the ratio of M2 to GDP; (8) the ratio of ABS issuers' balance sheets to the stock of commercial bank loans and (9) the ratio of total corporate bonds outstanding to the stock of commercial bank loans.

Calibration targets (1) and (2) deserve further discussion. For simplicity, in our model we assume there is no growth and no intermediation costs. In reality these two assumptions of course do not hold. Growth in the US economy has averaged close to 3% per annum since the second world war. Since we are interested in the dynamic efficiency of the investments of US savers and banks, we want to know whether the real return on these investments exceeds the economy's growth rate. This is why we subtract the real growth rate from the real return on deposits and loans.

In addition, when it comes to evaluating the dynamic efficiency of banks' loan investments, we need to take intermediation costs into account. FDIC data on US commercial banks' cash flow sources reveals that there are substantial intermediation costs (80% of those are labour costs). Here we assume that all of these costs arise due to loan issuance rather than deposit taking. This assumption is not entirely unreasonable given the labour intensive nature of arranging loans, monitoring them and then recovering them if they become non-performing. It does, however, err on the side of assuming that banks' real loan returns are more dynamically inefficient. We subtract these loan costs from banks' real loan returns to get the final numbers shown in Table A2 below. Full details of data sources and construction are available in Table A1:

Table A1:

Theor. concept	Data concept	Source
Real bank loan rate	Real prime loan rate-GDP growth-costs	FRB, Table H.15, FDIC, BEA
Real deposit rate	Real M2 own rate - GDP growth	FRED
Expected inflation	Average CPI inflation (All Urban Consumers)	FRED
Expected real GDP growth	Average real GDP growth (chained measure)	FRED
Deposit stock	M2	FRED
Nominal GDP	Nominal GDP	FRED
Bank leverage	Bank Debt Liabilities/Bank Net Worth	FRB, Table H.8
Average corporate leverage	Corporate Debt/Corporate Net Worth	Welch (2004)
Leverage of indebted corporates	Debt/Corp Net Worth for high leverage corporates	Welch (2004)
Bank rate of return on equity	Bank rate of return on equity	FDIC

Table A2: Model and data moments

Moment (Model concept)	Data	Model
Real deposit rate - real GDP growth (R^d)	0.950	0.971
Real loan rate - real GDP growth - costs/Assets (R^l)	0.982	0.982
Ratio of M2 to GDP (D/Y)	0.500	0.464
Bank leverage (D/N)	10.00	10.00
Average corporate leverage (L/Z)	0.500	0.530
Leverage of indebted corporates ($L/(sZ)$)	2.000	2.000
Bank rate of return on equity ($R_t^l + \frac{\phi_t \left(R_t^l - R_t^d\right)}{(1-\lambda)}$)	1.100	1.103

The parameter values that come out of our calibration exercise are given in Table A3 below.

Table A3: Baseline calibration

Parameter	Value
δ	0.177
n	0.039
a^H/a^L	1.100
η	5.000
θ	0.626
χ	1.000
λ^r	0.765
λ^m	0.000
γ	0.867
β	0.946

References

Acharya, V., Schnabl, P., Suarez, G., 2012. Securitisation without risk transfer. Journal of Financial Economics, forthcoming.

Adrian, T., Colla, P., Shin, H., 2012. Which financial frictions? parsing the evidence from the financial crisis of 2007-09. NBER Working Paper No. 18335.

Alessandri, P., Meeks, R., Nelson, B., 2012. Shadow banks and macroeconomic instability. Bank of England Mimeo.

Aoki, K., Benigno, G., Kiyotaki, N., 2009. Adjusting to capital liberalization. Working Paper, LSE.

Aoki, K., Nikolov, K., 2011. Bubbles, banks and financial stability. mimeo.

Bernard, A., Eaton, J., Jensen, B., Kortum, S., 2003. Plants and productivity in international trade. American Economic Review 93(4), 1268–1290.

Caballero, R., Krishnamurthy, A., 2006. Bubbles and capital flow volatility: Causes and risk management. Journal of Monetary Economics 53, 35–53.

Corbae, D., D'Erasmo, P., 2013. A quantitative model of banking industry dynamics. Mimeo.

De Fiore, F., Uhlig, H., 2011. Bank finance versus bond finance. Journal of Money, Credit and Banking, 1399–1421.

De Fiore, F., Uhlig, H., 2012. Corporate debt structure and the financial crisis. Mimeo.

Farhi, E., Tirole, J., 2011. Bubbly liquidity. Review of Economic Studies forthcoming.

Gai, P., Haldane, A., Kapadia, S., 2011. Complexity, concentation and contagion. Journal of Monetary Economics, 453–470.

Gennaioli, N., Shleifer, A., Vishny, R., 2012. Neglected risks, financial innovation and financial fragility. Journal of Financial Economics, 452–468.

Gertler, M., Karadi, P., 2011. A model of unconventional monetary policy. Journal of Monetary Economics, 17–34.

Gertler, M., Karadi, P., 2012. Qe1 vs. 2 vs. 3... a framework for analyzing large scale asset purchases as a monetary policy tool. Mimeo.

Gertler, M., Kiyotaki, N., 2010. Financial intermediation and credit policy in business cycle analysis. In: Woodford, M. (Ed.), Handbook of Monetary Economics. Elsevier.

Goodhart, C., Kashyap, A., Tsomocos, D., Vardoulakis, A., 2012. Financial regulation in general equilibrium. Mimeo.

Gorton, G., 2010. Slapped by the Indivisible Hand: the Panic of 2007. Oxford University Press.

Greenspan, A., 1999. Lessons from the global crises. Federal Reserve Board Mimeo.

Gropp, R., Hakenes, H., Schnabel, I., 2011. Competition, risk-shifting, and public bail-out policies. Review of Financial Studies, 2084–2120.

Hanson, S., Kashyap, A., Stein, J., 2011. The macroprudential approach to financial regulation. Journal of Economic Perspectives, 3–28.

Holmstrom, B., Tirole, J., 1997. Financial intermediation, loanable funds and the real sector. Quarterly Journal of Economics, 663–691.

Kocherlakota, N., 2009. Bursting bubbles: Consequences and cures. Working Paper, Federal Reserve Bank of Minneapolis.

Martin, A., Ventura, J., 2011. Theoretical notes on bubbles and the current crisis. IMF Economic Review 59 (1), 6–40.

Martin, A., Ventura, J., 2012. Economic growth with bubbles. American Economic Review 102(6), 3033–3058.

Nikolov, K., 2010. A model of borrower reputations as intangible collateral. Working paper, LSE.

Perotti, E., Suarez, J., 2002. Last bank standing: What do i gain if you fail? European Economic Review, 1599–1622.

Pozsar, Z., Adrian, T., Ashcraft, A., Boesky, H., 2012. Shadow banking. Federal Reserve Bank of New York Staff Report No 458.

Sargent, T., 1987. Dynamic Macroeconomic Theory. Harvard University Press, Cambridge, USA.

Syverson, C., 2004. Market structure and productivity: A concrete example. Journal of Political Economy 112 (6), 1181–1222.

Tucker, P., 2010. Shadow banking, financing markets and financial stability. Remarks to a BGC Partners Seminar, London.

Ventura, J., 2012. Bubbles and capital flows. Journal of Economic Theory 147(2), 738–758.

Vives, X., 2011. Competition policy in banking. Oxford Review of Economic Policy, 479–497.

Weil, P., 1987. Confidence and the real value of money in an overlapping generations economy. Quarterly Journal of Economics, 1–22.

Welch, I., 2004. Capital structure and stock returns. Journal of Political Economy 112 (1), 106–131.

Figure 1: US corporate bond stock as % of US commercial bank loans (Source: US Flow of Funds)

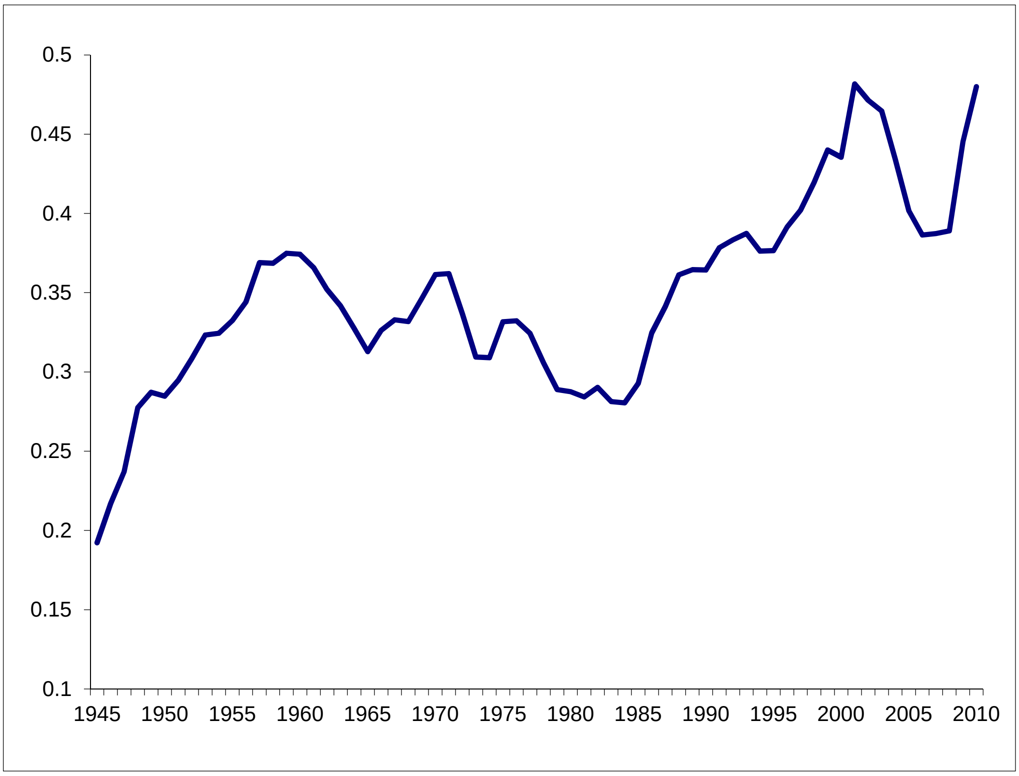

Figure 2: Commercial & Industrial and Real Estate loans as a % of total US commercial bank loans (Source: FDIC)

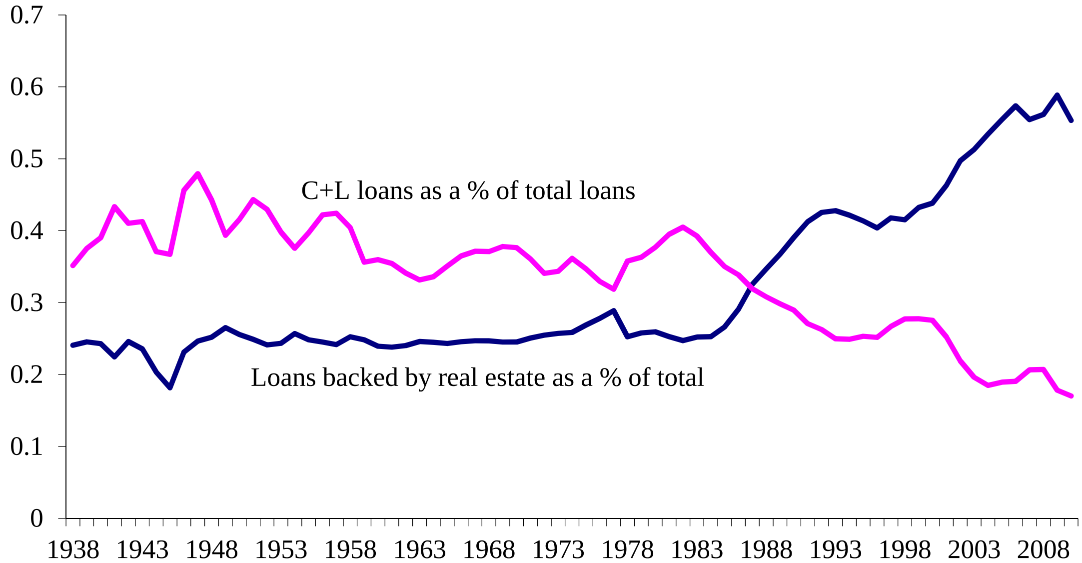

Figure 3: Assets of ABS issuers and Broker-Dealers as a proportion of US commercial bank loans (Source: US Flow of Funds)

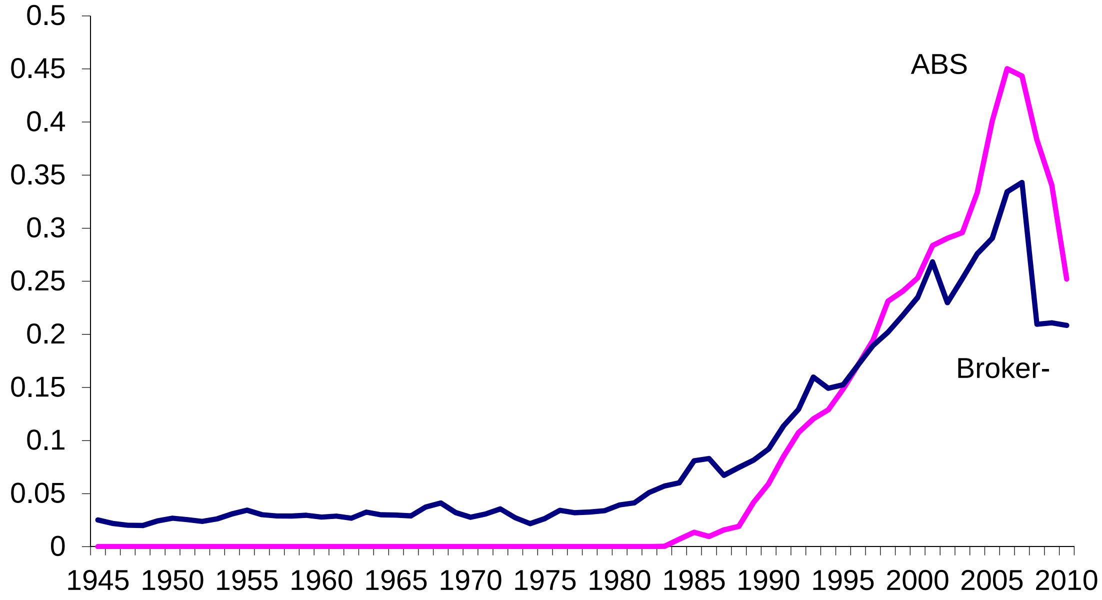

Figure 4: Sources of US Commercial bank profits (Source: FDIC)

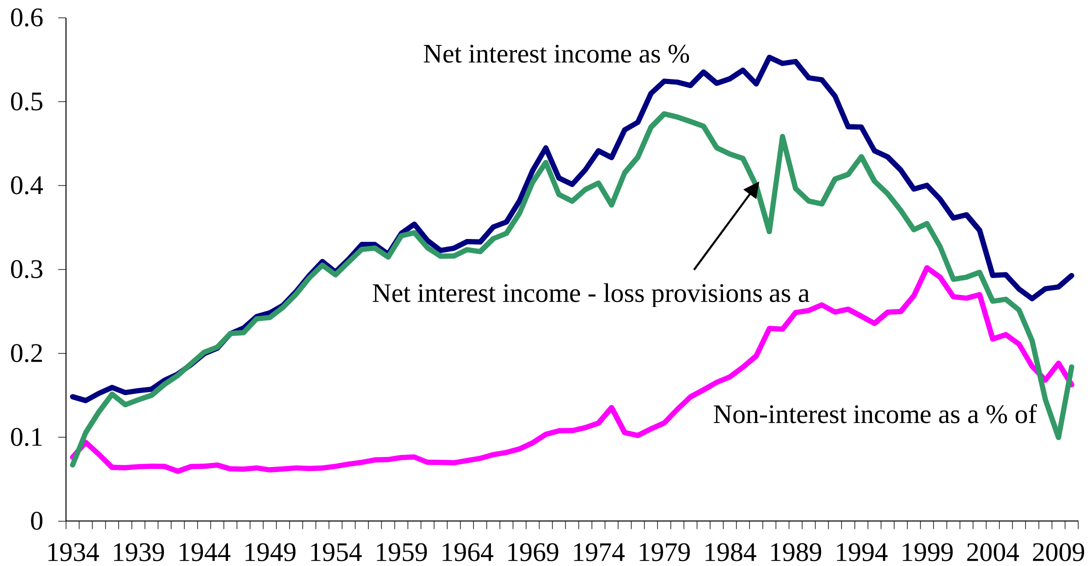

Figure 5: US Commercial banks' net profit as a % of total equity (Source: FDIC)

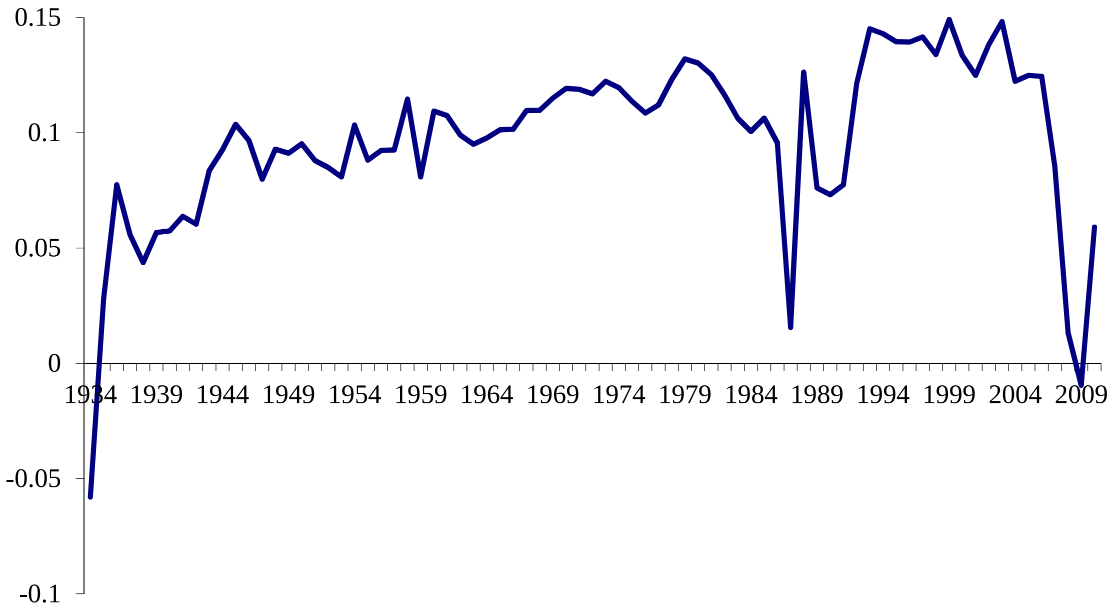

Figure 6: Bank leverage, lending spreads and bubble holdings
(All numbers apart from Bubble/GDP are relative to no-financial-innovation saver bubble baseline)

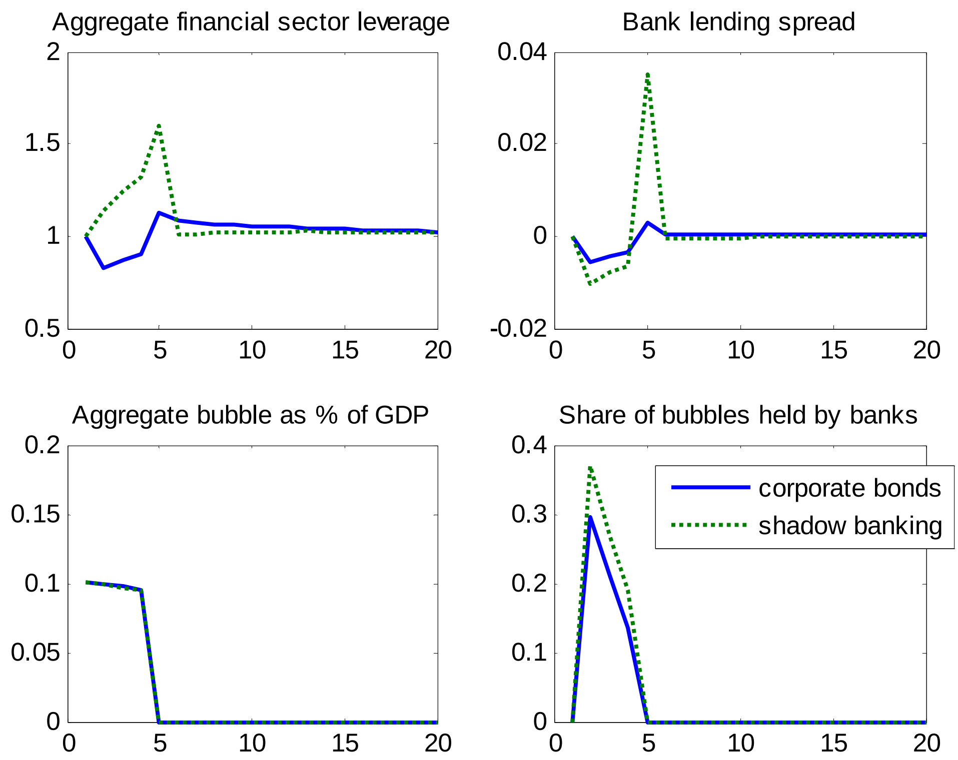

Figure 7: Bank net worth, output and credit supply
(All numbers apart from Bubble/GDP are relative to no-financial-innovation saver bubble baseline)