IMES DISCUSSION PAPER SERIES

Bubbles, Banks, and Financial Stability

Kosuke Aoki and Kalin Nikolov

Discussion Paper No. 2011-E-24

IMES

INSTITUTE FOR MONETARY AND ECONOMIC STUDIES

BANK OF JAPAN

2-1-1 NIHONBASHI-HONGOKUCHO
CHUO-KU, TOKYO 103-8660
JAPAN

IMES Discussion Paper Series 2011-E-24

September 2011

Bubbles, Banks, and Financial Stability

Kosuke Aoki* and Kalin Nikolov**

Abstract

This paper asks two main questions: (1) What makes some asset price bubbles more costly for the real economy than others? and (2)When do costly bubbles occur? We construct a model of rational bubbles under credit frictions and show that when bubbles held by banks burst this is followed by a costly financial crisis. In contrast, bubbles held by ordinary savers have relatively muted effects. Banks tend to invest in bubbles when financial liberalisation decreases their profitability.

Keywords: Rational bubbles; Financial Frictions; Financial Stability

JEL Classification: E32, E44

***** University of Tokyo (email: kaoki@e.u-tokyo.ac.jp)

** European Central Bank(email: kalin.nikolov@ecb.int)

We thank Henrik Borchgrevink, Wouter den Haan, Piti Disyatat, Martin Eichenbaum, Philipp Hartmann, Jonathan Heathcote, Xavier Freixas, Roman Inderst, Peter Karadi, Nobu Kiyotaki, Helene Rey, Victor Rios-Rull, Shigenori Shiratsuka, Harald Uhlig, Jaume Ventura, Christopher Waller, Philippe Weil, seminar and conference participants at the Bank of Japan, the European Central Bank, the University of Amsterdam and the Bank of England. Views expressed in this paper are those of the authors and do not necessarily reflect the official views of the Bank of Japan or the European Central Bank.

1 Introduction

The last decade has seen the dramatic rise and fall of world-wide housing prices, culminating in the financial crisis and 'Great Contraction' of 2008-2009. This brought the financial system to the brink of collapse and led to unprecedented official intervention. Currently, politicians and central bankers are busy putting the foundations of a new macro-prudential policy framework which is meant to make the financial system more stable and less prone to the kind of boom-bust cycle we experienced over the last five years.

Motivation and economic questions As Reinhart and Rogoff (2008) document in detail, there are many episodes of boom-bust financial cycles but not all of them result in a costly economic contraction. Some boom-bust cycles, such as those in Japan and the Scandinavian countries in the 1990s, and the subprime crisis of 2007-2009, led to banking crisis and a serious recession. But on other well known occasions such as the 1987 crash or the dot-com bubble of 1999-2000, the collapse of asset prices did not result in a banking crisis and a severe contraction of real economic activity. Figure 1 below illustrates the puzzle. Panel A of the figure compares the decline from peak of the S&P 500 during 2000-03 period with the fall of the value of the CDS on a pool of AAA-rated subprime RMBS since 2007. Panel B compares the behaviour of GDP growth over the two periods. The message of the figure should be clear. The 'dot com' crash was of a similar magnitude to the 'subprime crisis' while its output effects were small in comparison.

[Figure 1 here]

Why did the dot-com bubble not lead to a serious banking crisis while the subprime bubble did? Should policy react to any sharp increase in asset prices or are there occasions when the market can be left safely to its own devices even when financial prices look to have departed from fundamentals? These are the questions we ask in our paper. Some policy makers (most notably Mishkin (2008) and Mishkin (2009)) have argued that we should only worry about bubbles generated within the banking system. This view receives some support from the literature on 'early warning indicators of crisis' (Borio and Lowe (2002), Borio and Drehmann (2008), Alessi and Detken (2009) as well as many others). The literature shows that an asset price boom is far more likely to result in a costly output collapse when it is accompanied by a large increase in money, credit and bank leverage. In this paper, we formalise this idea and show that who owns bubbly assets indeed matters for financial and economic stability.

Model description In order to analyse the questions addressed above, we construct a model in which both banks and entrepreneurs are subject to credit frictions. Entrepreneurs differ in their productivity levels, and those with higher productivity become borrowers (and vice versa) in equilibrium. Following Kiyotaki and Moore (1997) they are subject to a collateral constraint when they borrow. Following Gertler and Karadi (2009), the amount of deposits a bank can collect depends on its net worth. When those credit frictions are severe enough, the interest rate is suppressed and bubbles can be traded once expectations are coordinated. Using this model, we compare the case in which banks hold bubbles and the case in which savers hold bubbles directly. While not modelled explicitly, we interpret bubbles held by banks as indivisible large bubbly assets, such as commercial real estate bubbles. Since it is much larger than a typical savings of savers, individuals cannot afford to buy it, but banks can do so by pooling savings of individuals. Bubbles held by individual savers can be interpreted, for example, bubbles attached to equities. Those are divisible and savers can buy them.

Results The main point of our paper is to formalise the intuition that asset bubbles held by banks (sometimes referred to as 'credit bubbles') are more dangerous than bubbles held by other investors who are less central in the credit allocation mechanism. When bank-held credit bubbles burst, banks become insolvent and need to be rescued by the government. The fall in their net worth causes a severe credit crunch and output collapse. In contrast, the effects of asset price busts on real activity are milder when savers directly hold bubbles. The intuition behind the result is simple. When savers hold bubbles it is those savers who suffer from capital loss. But because the net worth of savers is not central to the efficiency of financial intermediation, the costs of the bubble collapse remain private rather than 'systemic'. Borrowers and other banks do not suffer as a result of the savers' loss. In contrast, when banks hold bubbles, bursting of bubbles directly hit the banks' net worth possibly leaving them insolvent without government intervention. Because banks have a 'special' place in the financial system, this fall in bank net worth results in a 'systemic crisis', a credit crunch and a sharp decrease in investment and output.

In the final part of the paper, we explore the link between financial liberalisation and the tendency of banks to invest in bubbly assets. History contains many examples in which deregulation has led to the growth of non-bank financial intermediation and a decline in the profitability of traditional lending and deposit-taking activities. Very often, banks have reacted to such developments by trying to branch out into alternative lines of business with disastrous consequences. To model such a situation, we extend our framework by allowing direct intermediation via a 'corporate bond market' and examine banks' reaction to the growth of non-bank lending. We find that banks are much more likely to invest in bubbly assets following such a 'financial liberalisation'.

Literature review Motivated by the recent global economic stagnation following the subprime crisis of the US, there is growing literature on models of economic fluctuations that emphasise the role of credits. A number of papers incorporate various forms of credit frictions and study the way those frictions amplify the effects of technology and/or financial shocks (Kiyotaki and Moore (2009), Christiano et al. (2010), Gertler and Karadi (2009), Gertler and Kiyotaki (2010)). The literature finds the importance of credit shocks (shocks to net worth of borrowers or banks) but it is not easy to identify what they are in reality. An example of shocks that change the value of firms and bank net worth used in the literature is a shock that makes firms capital obsolete (Gertler and Karadi (2009), Gertler and Kiyotaki (2010)). However, it is not very obvious how such shocks indeed occurred during every boom-bust cycles. Instead, following Martin and Ventura (2010), our explanation of the crisis is based on changes in investor expectations rather than changes in technology and/or financial shocks. Collapse of bubbles in our model serves as credit shocks to the banking sector.

Our paper contributes to the recent growing literature on rational bubbles under credit frictions, pioneered by Ventura (2010) and subsequent work includes Caballero and Krishnamurthy (2006), Kocherkalota (2009), Arce and Lopez-Salido (2008), Martin and Ventura (2010), Farhi and Tirole (2010), Hirano and Yanagawa (2010). Ever since the seminal work of Tirole (1985), the 'rational bubbles' literature has been very interested in the question of whether bubbles are expansionary for aggregate economic activity or not. The traditional view was that bubbles replace excessive investment and therefore have a contractionary impact on total output. Subsequent papers have shown that when there are credit market imperfections, bubbles may have an expansionary effect through a variety of mechanisms that determine entrepreneurs' current net worth and access to leverage.

In Martin and Ventura (2010) the expansionary effect of bubbles arises because the anticipated profits from future bubble sales are collateralisable and allow entrepreneurs to increase borrowing in the current period. As a result more production to be undertaken by the most productive entrepreneurs, thereby increasing aggregate TFP. In Farhi and Tirole (2010) bubbles increase interest rates and actually reduce the leverage available to borrowing entrepreneurs through what Farhi and Tirole (2010) call the 'competition effect'. This is negative for investment. However there is a positive 'liquidity effect'. When entrepreneurs need a means of saving in between investment opportunities, the increase in interest rates makes them richer when the investment opportunity finally comes.

Our model contains some of the channels discussed in the literature as well as some novel ones. We have a 'liquidity effect' because bubbles enhance the rate of return of those saving in anticipation of future investment opportunities. We also have a 'competition effect' though it is somewhat less prominent than in Farhi and Tirole (2010) because bubbles simultaneously increase interest rates and reduce production costs (real wages in our case).

The new channels we introduce arise due to the presence of credit constrained financial intermediaries in our model. This offers several alternative and complementary mechanisms through which bubbles generate lending and output booms. In our model, limited financial market participation is key because it allows banks to borrow at the deposit rate in order to issue loans (or buy bubbles) whose rate of return is higher than the deposit rate. Following

Gertler and Karadi (2009) the net present value of such spreads (the franchise value of banks) is collateralisable and therefore changes in the spread increase banks' ability to collect deposits. During a bubbly episode, the net worth of borrowing entrepreneurs rises as they sell bubbles, increasing loan demand and pushing up loan-deposit spreads.As a result, the value of the bank (including the franchise value of future spreads) increases, leading to a rapid expansion of deposits. Thus, lending to entrepreneurs increases even in the case in which bubbles compete with 'real loans' in banks' portfolios. This channel is similar in spirit to the collateralisability of profits from future bubbles sales discussed in Martin and Ventura (2010) but the mechanism is different because it relies on the expansion of bank rather than corporate balance sheets. Our approach is complementary to theirs and, we believe, particularly useful for analysing financial stability issues.

Plan of the paper Section 2 introduces the economic environment, section 3 describes the bubble-free equilibrium and discusses the conditions for the existence of bubbles. Section 4 describes the bubbly equilibrium and uses a calibrated version of the model to discuss the effect of bubbles' emergence and collapse on financial stability. Finally, section 7 concludes.

2 The Model

The economy is populated with three kinds of agents. There are continuum of infinitely lived entrepreneurs and a continuum of infinitely lived workers both of measure 1. There is also a continuum of bankers who have finite lives and can die with probability $1-\gamma$ in any period, conditional on being alive in the previous period.

2.1 Entrepreneurs

Each entrepreneur is endowed with a constant returns to scale production function which converts labour 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

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

Entrepreneurs purchase consumption (c_t), bubbles (m_t) at price μ_t and bonds b_t. They also pay wage bills $w_t h_t$ in order to receive future revenues

$a^i h_t$. Here w_t denotes real wage. The budget constraint of the entrepreneurs is given by

$$c_t + w_t h_t + m_t \mu_t - b_t = a^i h_{t-1} + m_{t-1}\mu_t - R^i_{t-1} b_{t-1} \tag{4}$$

where R^i_t is the interest rate which is equal to the loan rate R^l_t when the entrepreneur is a borrower and R^d_t when he is a saver.

Due to limited commitment in the credit market, agents will only honour their promises if it is in their interests to do so. We assume that only a fraction of the value of the firm can be seized by creditors. Hence the collateral constraint is given by:

$$\begin{aligned} R^l_t b_t &\leqslant \theta y_{t+1} \\ &\leqslant \theta a^i h^i_t / w_t, \quad 0 < \theta < 1 \end{aligned} \tag{5}$$

They maximise (3) subject to (4) and (5).

2.2 Workers

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

$$U = E_t \sum_{t=0}^{\infty} \beta^t \left(c^w_t - \frac{h_t^{1+\eta}}{1+\eta} \right) \tag{6}$$

subject to her flow-of-funds constraint

$$c^w_t + m^w_t \mu_t - b^w_t = w_t h_t + m^w_{t-1}\mu_t - R^d_{t-1} b^w_{t-1}, \tag{7}$$

here superscript 'w' stands for 'workers'. In equilibrium, it is shown that workers do not save because the equilibrium deposit rate is low. Therefore they consume their labour income in each period.

2.3 Banks

We assume that savers cannot directly lend to borrowers and that lending is done by 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 all of them before exiting. This shock hits with probability $1-\gamma$.

Banks maximize the following objective function:

$$V\left(n_t\right)=c_t^b+\beta E_t\left[\gamma V\left(n_{t+1}\right)+(1-\gamma)\, n_{t+1}\right] \tag{8}$$

subject to a number of 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 (l_t), purchases bubbles (μ_t), or consumes (c_t^b). Therefore its balance sheet is given by

$$c_t^b+l_t+\mu_t m_t=n_t+d_t. \tag{9}$$

The evolution of net worth is given by

$$n_{t+1}=R_t^l l_t+\mu_{t+1} m_t-R_t^d d_t. \tag{10}$$

Following Gertler and Karadi (2009), we model banks subject to limited commitment. More specifically, the banker may divert $1-\lambda$ fraction of deposits. Once he diverts, he will close his bank and the savers can retain the remaining

λ fraction of deposits. Since the savers recognise the banker's incentive to divert funds, they will restrict the amount of deposit. Those assumptions imply the following borrowing constraint

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

The left hand side of equation (11) is the value when the banker diverts, while the right hand side is the value when he did not (i.e., the continuation value of the bank). We also assume that the bank cannot short m_t. The bank maximises (8) subject to (9), (10) and (11).

3 Equilibrium without bubbles

Before characterising an equilibrium with bubbles it is informative to characterise the equilibrium without bubbles because it provides us the condition under which bubbles circulate in the economy. In this section we set $\mu_t = 0$ at all times.

3.1 Optimal behaviour

The entrepreneur has a few choices of accumulating net worth. Let $R_t(a_t)$ be the maximum rate of return on the net worth from time t to $t+1$ for the entrepreneur with productivity $a_t = a^h$, a^L. Then it is given by

$$R_t(a_t) = \max\left\{R_t^d, \frac{a_t}{w_t}, \frac{a_t(1-\theta)}{w_t - \theta a_t / R_t^l}\right\}. \tag{12}$$

The first term in the right hand side is the deposit rate. The second term is the rate of return of bubbles. The third term is the rate of return on production without borrowing. The last term is the rate of return on production with maximum borrowing. By borrowing from banks secured by θ fraction of output, the entrepreneur can finance externally $\theta a_t / R_t^l$ amount (equation (5)). Therefore the denominator is the required downpayment for the unit labour cost. The numerator is the output after repaying debt.

Note that the last two rates of return in equation (12) are strictly higher for the productive entrepreneur than the unproductive entrepreneur, and the deposit rate and the rate of return of bubbles are the same for both. Therefore in equilibrium the unproductive entrepreneurs supply deposits and produce if and only if their rate of return of production is equal to the deposit rate. We focus our analysis on such case, namely,

$$R_t(a^L) = R_t^d = \frac{\gamma}{w_t}. \tag{13}$$

Intuitively, the borrowing constraints are tight enough so that the productive entrepreneurs cannot absorb all national saving. Then there is not enough demand for deposits. In such case the savers use both bank deposits and its own production technology to accumulate wealth.

The productive entrepreneurs borrow and produce, and their rate of return is given by

$$R_t(a^H) = \frac{a^H(1-\theta)}{w_t - \theta a^H / R_t^l} \geqq R_t^l. \tag{14}$$

Given the optimal choice of accumulating wealth, the budget constraint (4) can be written as

$$z_{t+1} = R_t(a_t)(z_t - c_t), \tag{15}$$

where

$$z_t = y_t - R_{t-1}^i b_{t-1}, \quad i = d, l \tag{16}$$

denotes the net worth of the entrepreneur at time t. Positive b_t implies that he borrows and the lending rate R_t^l applies to his debt. Similarly negative b_t represents deposit and R_t^d applies.

Since utility function is logarithmic, consumption decision is given by

$$c_t = (1 - \beta) z_t. \tag{17}$$

When $R_t(a^H) > R_t^l$ the productive entrepreneurs produce with their borrowing constraint binding. From (5) and (4) their employment is given by

$$h_t = \frac{\beta z_t}{w_t - a^H \theta / R_t^l}. \tag{18}$$

Regarding the workers, their labour supply h_t^s is given by

$$h_t^s = w_t^\eta. \tag{19}$$

They will not save and consume all their labour income when

$$R_t^d < \beta^{-1}. \tag{20}$$

Later we will verify this is true in the neighbourhood of the steady state equilibrium.

Finally, let us characterise the bank. When $R_t^l > R_t^d$, then credit constraint (11) binds and consumption is postponed until death. Guess that the value of the bank is a linear function of net worth n_t

$$V(n_t) = \phi_t n_t \tag{21}$$

Here ϕ_t can be interpreted as the bank's leverage. Then, with equation (11) binding, deposit is given by

$$d_t = \frac{\phi_t}{1-\lambda} n_t. \tag{22}$$

By substituting (21) and (22) into (8), ϕ_t satisfies

$$\phi_t = \frac{\beta \left[(1-\gamma) + \gamma\phi_{t+1}\right] R_t^l}{1 - \beta \left[(1-\gamma) + \gamma\phi_{t+1}\right] \frac{R_t^l - R_t^d}{1-\lambda}}. \tag{23}$$

Note that the above formulas show that ϕ_t increases when ϕ_{t+1} increases. This implies that the current leverage depends on the future franchise value of the bank which is reflected by the leverage next period.[1] It also shows that ϕ_t is an increasing function of the spread $R_t^l - R_t^d$.

3.2 Aggregation and market clearing

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 (18) the aggregate employment of the productive entrepreneurs is given by

$$H_t^H = \frac{\beta Z_t^H}{w_t - \theta a^H / R_t^l}. \tag{24}$$

When (13) holds, the unproductive entrepreneurs are indifferent between making deposits and producing, thus their aggregate saving is split as follows

$$H_t^L = \beta Z_t^L - D_t \tag{25}$$

where D_t denotes aggregate deposit.

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

Let us turn to banks. Under the banks binding borrowing constraint, the aggregate deposit is given by

$$D_t = \frac{\phi_t}{(1-\lambda)}\gamma N_t. \tag{26}$$

Notice that $1-\gamma$ fraction of banks exits in each period by liquidating all their net worth. Therefore the aggregate net worth of the operating banks is given by γN_t.The aggregate balance sheet of the operating banks is given by

$$D_t + \gamma N_t = L_t. \tag{27}$$

Let us turn on 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 (14) and (13). Therefore net worth of the productive entrepreneurs evolves from (14), (15) and (17) as

$$Z_{t+1}^H = (1-\delta)\frac{a^H(1-\theta)}{w_t - \theta a^H/R_t^l}\beta Z_t^H + n\delta R_t^d \beta Z_t^L. \tag{28}$$

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

$$Z_{t+1}^L = \delta\frac{a^H(1-\theta)}{w_t - \theta a^H/R_t^l}\beta Z_t^H + (1-n\delta) R_t^d \beta Z_t^L. \tag{29}$$

From aggregating production function, aggregate output is given by

$$Y_t = a^H H_{t-1}^H + a^L H_{t-1}^L. \tag{30}$$

Finally, aggregate bank net worth is given by

$$N_{t+1} = \gamma \left(R_t^l + \frac{\phi_t \left(R_t^l - R_t^d \right)}{(1-\lambda)} \right) N_t. \quad (31)$$

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

$$\beta(Z_t^H + Z_t^L) + \gamma N_t = w(H_t^H + H_t^L). \quad (32)$$

From (19), labour market clearing implies

$$w_t^\eta = H_t^H + H_t^L. \quad (33)$$

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

In equilibrium, equations (13), (23)-(33) jointly determine 12 variables R_t^d, R_t^l, w_t, H_t^H, H_t^L, Y_t, ϕ_t, D_t, L_t, Z_{t+1}^H, Z_{t+1}^L, N_{t+1}, given the state variables Z_t^H, Z_t^L, N_t.

3.3 Existence of bubbly equilibria

Now we characterise the deposit rate R_t^d and loan rate R_t^l in the steady state without bubbles and discuss when bubbles can circulate. In the steady state, all 12 endogenous variables are constant. Credit frictions suppress the interest rates and those rates are lower than β^{-1} when the credit constraints bind.[2] Similarly to Farhi and Tirole (2010), whether a bubbly steady state exists and who owns bubbles depend on whether the two interest rates are lower than the growth rate (which we assume is equal to 1) in the 'no bubbles' steady state.

In our economy, the severity of credit frictions is represented by two parameters, λ and θ. Figure 2a shows the region of λ and θ in which the deposit rate is less than one and low productivity agents produce in equilibrium (the red area). In this case, the savers (unproductive entrepreneurs) have incentive to buy bubbles in order to boost the rate of return they receive on their savings. The blue parts of the graph show parts of the parameter space where the economy is very credit constrained. At such low values of λ and θ low productivity entrepreneurs are active but wages are so low that even such inefficient projects deliver a rate of return greater than unity. As a result, savers have no incentive to hold bubbles in such economies. The white parts of the graph (very high values of λ and θ) shows parts of the parameter space where low productivity entrepreneurs do not produce because the financial system is well developed. Here again, the rate of return on deposits is greater than unity and savers have no incentive to hold bubbles. So it should be clear from Figure 2b that the conditions for the existence of bubbles is satisfied at intermediate levels of financial development.

[Figure 2a here]

[2] See Aoki et al. (2009)) for the general discussion of the relationship between the interest rate and credit frictions.

The red area of Figure 2b shows the region in which the loan rate is less than one. Then the banks have an incentive to buy bubbles. Since the deposit rate is always lower than the loan rate, the savers also have incentive to hold bubbles at these parameter values. It is natural that the part of the parameter space where banks bubbles can exist is more limited compared to the parts of the parameter space where saver bubbles exist. Because banks' borrowing constraints bind, this introduces a positive spread between lending and deposit rates. Hence the parameter space where bank bubbles exist is a subset of the space where savers have an incentive to invest in bubbly assets.

[Figure 2b here]

4 Equilibrium with bubbles

4.1 Competitive equilibrium with bubbles

In our model, either the banks, the savers, or both, can invest in bubbles. In what follows we analyse each ease separately. In this paper we restrict our attention to deterministic bubbles. In order to analyse the implications of who owns bubbles for the economy, it is sufficient to consider deterministic bubbles.[3]

When the banks hold bubbles, this must imply that they are indifferent between bubbles and loans

$$\frac{\mu_{t+1}}{\mu_t} = R_t^l, \tag{34}$$

otherwise, either bubbles do not circulate or lending becomes zero.[4] When the spread between the loan rate and the deposit rate is positive, bubbles are also

[3] In a companion paper Aoki and Nikolov (2011), we consider stochastic bubbles and draw implications for macroprudencial policy.

[4] As is discussed in the previous section, in this case we are prohibiting the entrepreneurs (and workers) from buying bubbles.

attractive to the savers. Firstly, we allow only banks to hold bubbles. In other words we assume limited participation. Even though not modelled explicitly, what we have in mind is the situation in which bubbles are attached to large indivisible assets such as commercial real estate. In such a case, individual savers cannot afford to buy bubbles because their savings are too small. However, the banks could buy bubbles by pooling savings from individual savers. Thus the pooling of small depositors' savings is one of the fundamental functions of financial intermediaries in our model. Another story we could tell is that bubbles are sometimes attached to assets which are not easy for individual savers to trade, due to transaction costs for example. Again, only banks will hold bubbles in such an environment.

When (34) holds, the banks value function ϕ_t is still given by equation (23) because bubbles and loans are perfect substitutes to them. For the same reason, the transition equation of the aggregate bank net worth remains the same as (31). Without loss of generality, we normalise the aggregate supply of bubbles equal to one. Then the aggregate value of bubble is equal to μ_t. The balance sheet of banks (equation (27)) is now given by

$$D_t = \gamma N_t = L_t + \mu_t. \tag{35}$$

Secondly, we allow both banks and savers to buy bubbles. This corresponds to a situation in which bubbles are attached to more divisible and standardised assets, such as equities. Then individual savers can afford to buy the bubble. This implies that the rate of return of bubbles must satisfy

$$\frac{\mu_{t+1}}{\mu_t} = R_t^d = \frac{\gamma}{w_t}.$$

We continue to focus our analysis on the case in which the savers produce by themselves as well as making deposits. It turns out that in such an equilibrium, only the savers hold bubbles as long as there is a positive spread between the deposit rate and the loan rate. This is because the savers' opportunity cost of holding bubbles is the deposit rate while the bank's opportunity cost is the loan rate which is higher than the deposit rate. The rate of return of bubbles is equal to the deposit rate, so the savers crowd out banks from bubbly asset markets.

Finally, if both the banks and the savers hold bubbles, this must imply that

$$\frac{\mu_{t+1}}{\mu_t} = R_t^d = R_t^l. \tag{36}$$

This means that the banks will compete with the savers only if their spread becomes zero. In Section 6 we analyse the situation in which (36) holds following a form of financial liberalisation.

For all the three cases, since a part of national savings is invested in bubbles, the goods market clearing (saving = investment) is modified as

$$\beta(Z_t^H + Z_t^L) + \gamma N_t = w(H_t^H + H_t^L) + \mu_t. \tag{37}$$

The other equilibrium conditions remain the same as Section 3.

Next, let us discuss the initial period when bubbles show up. We assume that the productive entrepreneurs will create bubbles. Suppose that bubbles μ_0 show up at time $t = 0$. This is pure gain for the productive entrepreneurs. Therefore their net worth equation (28) is given by

$$Z_0^H = (1-\delta)\frac{a^H(1-\theta)}{w_{-1} - \theta a^H / R_{-1}^l}\beta Z_{-1}^H + n\delta R_{-1}^d \beta Z_{-1}^L + \mu_0. \tag{38}$$

They sell bubbles to finance employment. Now equations (13), (23)-(26), (28)-

(31), (33), (34)-(37) determine 13 variables R_t^d, R_t^l, w_t, H_t^H, H_t^L, Y_t, ϕ_t, D_t, L_t, Z_{t+1}^H, Z_{t+1}^L, N_{t+1}, μ_t with three states Z_t^H, Z_t^L, N_t. At $t = 0$, Z_0^H is given by (28).

Definition 2 *Competitive equilibrium with bubbles is a sequence of decision rules* $\left\{H_t^H, H_t^L, Y_t, D_t, L_t\right\}_{t=0}^{\infty}$*, aggregate state variables* $\left\{Z_{t+1}^H, Z_{t+1}^L, N_{t+1}\right\}_{t=0}^{\infty}$ *and a price sequence* $\left\{R_t^d, R_t^l, w_t, \phi_t, \mu_t\right\}_{t=0}^{\infty}$ *such that: (i) entrepreneurs, banks and workers optimally choose decision rules* $\left\{H_t^H, H_t^L, Y_t, D_t, L_t\right\}_{t=0}^{\infty}$ *taking the evolution of aggregate states, prices and idiosyncratic productivity opportunities as given; (ii) the price sequence* $\left\{R_t^d, R_t^l, w_t, \phi_t, \mu_t\right\}_{t=0}^{\infty}$ *clears the goods, labour, capital, loan, bubble and deposit markets and (iii) the equilibrium evolution of state variables* $\left\{Z_{t+1}^H, Z_{t+1}^L, N_{t+1}\right\}_{t=0}^{\infty}$ *is consistent with the individual choices of entrepreneurs, banks and workers and with the exogenous evolution of productive opportunities at the individual firm level.*

As many other models of rational bubbles, our economy has many kinds of bubbly equilibria depending on agents' expectations. Our strategy is to look at a bubbly equilibrium that can at least qualitatively explain boom-burst cycles we observed in reality. Much literature on economic fluctuations search shocks such as productivity and credit shocks that can realistically explain data once those shocks are put into DSGE models. Conceptually we are doing a similar exercise but instead of fundamental shocks we are searching for expectational shocks (such as investor sentiments).

4.2 Calibration

Since the analytical solution is not available, we discuss the properties of the model based on numerical simulations. We have 8 parameters $\{\eta$, a^H/a^L, δ, n, θ, γ, β, λ $\}$ we need to calibrate before we proceed to examine the quantitative predictions of our model 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 behaviour 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 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 6 parameters in order to match the steady state predictions of the model in the absence of bubbles to 7 moments in the US data. These are (1) the real loan rate minus the growth rate of real GDP; (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 and (7) the ratio of M2 to GDP. Full details of data sources and construction are available in Appendix A. Table 1 below presents the values of the parameters chosen to match the moments.

Table 1: Baseline calibration

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

Table 2 below presents the moments in the model and the data.

Table 2: Model and data moments

Moment (Model concept)	Data	Model
Real loan rate - real GDP growth (R^l)	0.950	0.983
Real loan rate - real GDP growth (R^d)	0.998	0.997
Ratio of M2 to GDP (D/Y)	0.500	0.465
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 ($R_t^l + \frac{\phi_t(R_t^l - R_t^d)}{(1-\lambda)}$)	1.150	1.154

5 Banks' Bubble Holdings and Financial Stability

In this section we characterise the dynamics of the economy in which bubbles circulate. One of the key questions of our paper is how the impact of asset price bubbles on financial stability depends on who holds the bubble. So in the next subsections we examine the effects of the emergence and bursting of different bubbles. In all experiments we assume that the currently productive agents are endowed with intrinsically useless 'zero dividend' assets. We assume that the model is initially in a steady state in which investor sentiment regarding the future resaleability of these assets is pessimistic and so they have zero market value. In addition, we assume that investor sentiment suddenly changes and the 'bubble' asset starts to trade at a positive value.

5.1 The emergence and bursting of a bank-intermediated bubble

[Figure 3a here]

[Figure 3b here]

In our first experiment (described in Figures 3a and 3b above), we consider a situation in which investor sentiment shifts in favour of indivisible assets that can only be purchased by banks that pool the savings of many different small savers. Investor sentiment remains positive for ten periods and then turns negative again. At this point the bubble collapses. All the above events occur in a wholly unexpected (one time shock) fashion.

When the bubble first appears, productive entrepreneurs become very rich because they create and sell bubbles. This represents a pure wealth gain, and, because collateral constraints continue to bind under small enough bubbles, productive agents leverage up their increased net worth to raise borrowing and employment. Initially, banks' net worth is limited and this restricts the amount of loans they can supply while also purchasing bubbles from productive entrepreneurs. Therefore, the lending rate increases sharply, and, in order to compete with the loan rate, the bubble grows rapidly over time. For one period, banks make a huge profit due to the increased spread between the loan rate and deposit rate. In turn, this rise in current and expected future profitability increases the franchise value of the bank (represented by ϕ_t), relaxes the bank's collateral constraint and leads to a sharp increase in leverage. So the appearance of the bubble and the associated sharp rise in bank profitability and leverage allows banks to raise a lot more deposits and finance an increase in both lending and bubble holdings. Despite the fact that the bubble has to compete with loans in banks portfolios, its appearance leads to a 'crowding in' effect, which increases lending and investment in two ways. One is through the increase in investor net worth, leading to higher corporate borrowing capacity. The second is through the increase in the franchise value of the banks, leading to higher loan supply.

In subsequent periods, higher bank profits increase bank capital and allow for a rapid expansion of lending as the loan rate and bank leverage go down. As the productive entrepreneurs expand their employment, the employment of the unproductive entrepreneurs is crowded out. This improves the aggregate efficiency of the economy and TFP increases. As a result, output expands. A number of papers, starting with Kiyotaki and Moore (1997) have shown that when credit frictions prevent the most productive firms from purchasing all factors of production, the economy may experience endogenous credit cycles that look very similar to conventional technology shocks. This happens because, as the net worth and borrowing capacity of high productivity agents increases, they increase their productive activities at the expense of low productivity agents. This resource re-allocation improves aggregate efficiency and leads to an increase in output. More recently, Ventura (2010) and Martin and Ventura (2010) have applied this argument in the case of bubbles in economies with credit frictions. They show that the emergence of bubbles can lead to a large reallocation of resources towards more productive use, increasing economy-wide TFP. Conversely, the collapse of bubbles can shift resources into less productive firms, leading to a reduction in aggregate efficiency. Our model shares a similar property.

After ten periods in a 'bubbly equilibrium' we assume that investor sentiment suddenly and unexpectedly turns and the bubble collapses to zero. When the bubble bursts, the banks that own it experience a massive decline in their net worth. In our model the loss is so large that the banks become insolvent in the absence of government intervention. In order to prevent this we assume that the government gives them a bail out which it finances by raising lump sum taxes from all entrepreneurs in the model. In the interests of realism, we assume that the bail out is not large enough to maintain bank net worth. As a result, bank capital falls sharply and this leads to a credit crunch characterised by a spike in lending-deposit spreads and in bank leverage. High-productivity entrepreneurs' employment decreases sharply due to the credit crunch. Since the entrepreneurs do not hold bubbles their net worth is not directly affected by the collapse of bubbles. So the decrease in employment and output is driven entirely by the credit crunch.

5.2 The emergence and bursting of a 'saver bubble'

In the previous subsection we examined the behaviour of the economy under a bubble which is only held by the banking system. The emergence of such a bubble is initially very good for banks because it provides them with unique access to an alternative store of value, raising their profits and net worth in the process. But many real world bubbles do not fall under such a 'limited participation' description. For example equity bubbles can be held by any investor, no matter how small. This raises an important question. How much should we worry about such 'equity' as opposed to 'credit' bubbles?

In this subsection we experiment with the emergence and bursting of a 'divisible' bubble, which can be directly held by low productivity savers. We show that banks may or may not join in the bubble depending on their profitability. In what follows we compare the effects of a 'bank-held' bubble with the effects of a 'saver-held' bubble.

[Figure 4a here]

The most striking feature of the evolution of the real variables during the bubble's emergence is that the saver-held bubble does not lead to such violent fluctuations in output and TFP. The bursting of the bubble in period 10 hardly affects the path of output. Even without the bursting of the bubble, output would have been on a gentle downward trajectory. The collapse does very little to change the economy's course. This fits well with the experience during the 1998-2002 period. After a period of vigorous growth and very high investment, the collapse of the tech bubble led to a relatively mild recession in comparison with the Great Contraction. The model simulations confirm this hypothesis. Under the bank-held bubble, the bust leads to a big fall in the net worth of banks and a credit crunch that sharply reduces output and TFP. A bubble that is only held by unleveraged savers has none of these undesirable consequences for financial stability.

[Figure 4b here]

The differences between the evolution of financial variables allow us to gain a better understanding into why the real effects of the two types of bubbles are so different. During the bubble, bank balance sheets expand more dramatically when banks are directly involved (leverage and money to GDP ratios all increase substantially). Loans to the 'real' sector grow faster under the saver held case because they do not have to compete with bubbles on banks' balance sheets. But total bank assets (bubbles as well as 'real' loans) grow more rapidly under the bank-held bubble. Bank profitability is extremely strong under both scenarios underpinned by strong loan demand from entrepreneurs with sharply higher net worth due to the profits from their recent bubble sales. This, as well as higher leverage, is why banks' net worth increases by more when banks hold the bubbles.

Just like in the previous section, here we burst the bubble after 10 periods in order to examine its effects on the economy. The ratios of loans and money to GDP decline gradually when savers hold bubbles. The fall is much sharper when banks intermediate the bubble. The credit crunch leads a sharp increase in the price of credit. Hence the economy experiences another surge in bank leverage and bank profit margins. This helps bank capital recover after a period of restricted bank credit and money supply.

6 Banks' Franchise Values and Bubble Holdings

In the previous subsection, we noted that bubbles held by ordinary savers tend to have more benign effects on financial stability compared to 'bank bubbles'.

The reason for this lies in the behaviour of banks who choose not to purchase 'saver bubbles' even though they have the opportunity to do so. 'Saver bubbles' earn the same rate of return as deposits which is lower than the loan rate as long as the borrowing constraint on the banks is binding. So banks choose rationally not to buy these bubbles, instead focusing on their traditional (and much more profitable) activity - loans to entrepreneurs. As Gorton (2010) has emphasised, protecting banks from competition creates a 'franchise value' (the NPV of excess profits from 'traditional' banking activities) which prevents banks from investing in bubbly assets. Since 1980, however, financial markets have become increasingly de-regulated, putting pressure on bank profitability. At the same time, the frequency and severity of financial crises has risen, producing a number of historical episodes in which there seems to be some relationship between de-regulation and financial crisis. In this section we extend our model to allow for direct finance and examine how changes in this non-bank intermediation affects banks' profitability, franchise value and incentive to hold bubbles. It is shown that the financial liberalisation of this form endogenously induce the banks to invest in saver bubbles.

6.1 Financial Liberalisation and Banks' Franchise Value in the US

Before extending our model, we briefly review how the profitability of the US banks have been affected by financial liberalisation. In the US, traditional commercial banks have found themselves increasingly competing with other finance providers since 1980. Figure 5 below 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.

[Figure 5 here]

Banks responded to this development by concentrating on real estate lending. Figure 6 below 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).

[Figure 6 here]

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 9 below). The growth of these 'shadow bank' entities was especially rapid after 2003. For example ABS issuers' balance sheets expanded from around 30% of bank assets in 2003 to 45% of bank assets in 2007, before collapsing back to 25% during the crisis. The growth of ABS increased especially the competition banks faced in the mortgage market which by then had become their largest source of lending business.

[Figure 7 here]

FDIC data presented in Figure 8 below sheds more light on the effect of growing competition on banks' profitability. 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% declined sharply to almost 10% during the crisis. Non-interest income helped banks maintain profitability until 2000 but has been declining as a share of bank equity since then.

[Figure 8 here]

As well as increasing fee income, banks responded to the increased competition by cutting costs. The FDIC data shows that non-interest costs declined from 50% to 25% of bank equity. This helped their net return on equity climb to record levels before the financial crisis hit in 2008 (see Figure 9 below). With the benefit of hindsight, we now know that banks' strong profitability was driven by a combination of risky asset holdings and high leverage. In the next subsection we show that our model is capable of explaining qualitatively these features of the data.

[Figure 9 here]

6.2 The Model with Direct Finance[5]

In order to analyse the effect of direct finance on the equilibrium of our economy, we assume that ordinary savers are able to enforce debt repayments up to some fraction θ^m as follows:

$$R_t^m b_t^m \leqslant \theta^m y_{t+1}$$

where R_t^m is the interest rate on direct loans from savers (we can think of these as 'corporate bonds') and b_t^m is the quantity of direct loans. Banks still exist in this economy because they have superior intermediation technology which allows them to enforce debt repayments up to fraction θ^l as follows:

$$R_t^l b_t^l \leqslant \theta^l y_{t+1}$$

where R_t^l is the interest rate on bank loans and b_t^l is the quantity of bank loans.

[5]More details on the model with direct finance can be made available upon request.

It is easy to see that arbitrage by savers implies that corporate bond and bank deposits will be equalised:

$$R_t^d = R_t^m$$

while bank debt will remain more expensive. When the rate of return on the high productivity technology exceeds the cost of market finance

$$\frac{a^H}{w_t} > R_t^m$$

entrepreneurs will borrow up to the $\theta^m y_{t+1}$ limit from the corporate bond market. When

$$\frac{a^H}{w_t} > R_t^l > R_t^m$$

entrepreneurs will continue borrowing from banks up to the remaining $\left(\theta^l - \theta^m\right) y_{t+1}$ bank debt capacity after they have exhausted their market borrowing capacity. Firms always prefer to borrow from the market because it is cheaper but if their productive opportunities are good enough, bank borrowing is attractive too despite its higher cost. On the other hand, if

$$\frac{a^H}{w_t} > R_t^l = R_t^m$$

then they are indifferent between borrowing from banks and issuing corporate bonds.

6.3 A Financial Liberalisation Simulation

With the above brief outline of our direct finance economy in mind, we now continue to analyse the impact of a 'disintermediation shock' (an increase in

θ^m holding θ^l fixed) on banks' incentives to hold bubbles despite competition from ordinary savers. The experiment we conduct is the following. In the first period of the simulation the economy experiences positive investor sentiment and this leads to the emergence of a bubble which is held by savers but not by banks. Then two periods into the bubble, the economy experiences a 'disintermediation shock' which allows some direct lending between savers and borrowers. Two periods later, the bubble bursts and the degree of direct intermediation returns to its initial value of zero.

Figure 10 below displays the evolution of bank net worth and its portfolio composition under this scenario. We can see that the banks do not join in the bubble until direct intermediation starts to grow. At this point, banks purchase almost all of the available bubbles in circulation, allocating to them a sum equal to around three quarters of bank capital. In terms of absolute magnitudes, banks' bubble holdings remain small. Due to leverage, however, the presence of bubbles in bank portfolios leaves them very exposed to a loss of confidence in the bubble's future acceptance value. When the bubble finally collapses, bank net worth falls sharply, causing a credit crunch in the economy.

[Figure 10 here]

As Figure 11a below shows, the fall in bank capital leads to a contraction in the supply of credit and a re-allocation of employment from high to low productivity entrepreneurs. As a result, TFP declines and the only thing that prevents a big collapse in output is the fact that the decline in the efficiency of the economy's savings technology forces 'savers' to raise the amount they save through inefficient production.

[Figure 11a here]

But why did banks suddenly choose to invest into the bubble following 'financial liberalisation' whereas previously they had stayed on the sidelines of the boom? Figure 11b below provides some answers to this question by delving more deeply into the financial side of the model. In particular, the evolution of bank profit margins is key to understanding the reasons for this sudden change of bank behaviour.

When the bubble first appears, the rise in productive agents' net worth increases credit demand and boosts bank profit margins. Since traditional lending is so much more profitable than bubbles (which earn the deposit rate since 'savers' are able to hold them), banks rationally hold no bubbles on their balance sheets. However the growth of direct financing increases the supply of credit for borrowers as well as the supply of means of saving for savers. Higher loan and deposit supply brings bank profitability (as measured by loan-deposit spreads) down. As a result, the lending rate temporarily becomes equal to the deposit rate and the rate of return on bubbles[6]. At this point, financial intermediaries become indifferent between expanding their balance sheets on the margin because their capital constraint is slack. Lending to 'real entrepreneurs' is demand determined and fixed by entrepreneurs' net worth. So the only way in which banks can expand balance sheets is by issuing deposits to the unproductive agents and purchasing bubbles from them with the proceeds. Unproductive agents are themselves indifferent between deposits and bubbles and so would be happy to change their portfolios in this way without demanding a change in relative rates of return.

[Figure 11b here]

While the bubble continues, such a 'reshuffling' of the portfolios of banks and savers has no consequences for prices and real allocations. Therefore, the share of the bubble held by banks is indeterminate up until the point where

[6] Given sufficient time, the credit market liberalisation would increase the net worth of the corporate sector boosting credit demand. At this point, bank profit margins will recover to some extent although they will still remain below pre-liberalisation levels.

banks' balance sheet constraint starts to bind. In the above simulation, we have assumed that banks expand their balance sheets to buy bubbles as much as they can. Therefore, this experiment represents an upper bound on the risks to financial stability from 'saver bubbles'.

6.4 Poor bank profitability increases the risks of financial instability

Our model implies that 'saver bubbles' may or may not carry risks for financial stability, depending on the level of bank profitability. Less profitable banking systems are more likely to invest in bubbly assets and expose their net worth to a possible bubble collapse. Our model suggests several different channels through which profitability might be eroded leading to banks investing in bubbly assets: (i) an increase in bank competition[7]; (ii) relaxation of the bank's leverage constraint and (iii) weakness in corporate balance sheets. It is straightforward to see why these three factors would reduce banks' profits from corporate lending. (i) and (ii) increase the supply of loans and reduce the loan-deposit spread. (iii) reduces loan demand with the same downward impact on bank's lending margins. In all of these situations, poor profitability makes banks more willing to hold bubble assets.

[7]For the effects of bank competition on bank riskiness see (Boyd and De Nicolo (2009)). The literature identifies two offsetting channels. First of all, more bank competition implies a lower franchise value of the bank leading to more risk taking. But there is a second effect working in the opposite direction. More bank competition will lead to lower loan rates and this may reduce the riskiness of the bank's loan portfolio, making the bank safer overall.

Our model introduces some new channels linking banking sector competition with bank riskiness that have not hitherto been explored in the literature.

For us, more competition reduces profits from traditional lending and may tempt banks into investing in bubble assets. This increases the risk that the bubble may burst and reduce bank net worth. But there is an offsetting effect. More bank competition, reduces the value of the firm and, in the Gertler and Karadi (2009) framework, this leads to lower leverage. As a result, experiencing the same loan loss would have a smaller impact on bank capital.

6.5 Summary

Table 3 provides a summary of the main conclusions of our analysis.

Table 3. Types of bubbles and their propagation

	Bank bubble	Saver bubble
Banks hold bubbles	Boom: $\uparrow\uparrow$ D, Y, TFP (banks always hold) Bust: Very costly	Boom: $\uparrow$ D, Y, TFP (banks hold if $R^l = R^d$) Bust: Costly if big exposure
Banks do not hold bubbles	-	Boom: $\uparrow$ D, Y, TFP (banks don't hold if $R^l > R^d$) Bust: Not costly

7 Conclusions

In this paper we build a model in which rational asset price bubbles arise due to credit frictions. Our framework models financial intermediaries in an explicit manner in order to formalise the intuition that asset prices held by leveraged financial intermediaries pose the biggest threat to financial stability. In contrast, if unleveraged savers hold bubbles, the collapse of bubbles has relatively few consequences for financial intermediation and for the solvency of the banking system. We show that, in normal times, banks unique position in the financial system creates excess profits whose 'franchise value' prevents banks from investing in bubbly assets. Economic shocks that reduce these excess profits and consequently diminish banks' franchise values increase the likelihood that banks will hold bubbles. This explains why, historically, financial liberalisation and de-regulation are often followed by banking crises.

Our model provides a rich array of theoretical predictions regarding the impact of different types of bubbles on real and financial variables. These can be useful in interpreting the results of the growing literature on 'early warning indicators' of financial crises[8]. Most of the existing studies naturally utilise a largely atheoretic approach, focusing on finding robust crisis predictors without necessarily spelling out the underlying mechanism by which such predictors are related to the eventual occurrence of financial crisis. Our paper can provide some theoretical backing and interpretation behind some of these 'early warning signals' of financial instability. Our model implies that large bank balance sheet expansions signal the presence of a bubble in the economy. A thorough investigation into the early warning indicators is left for future research.

Finally, our paper also makes a contribution to the literature that attempts to explain why asset price bubbles tend to be expansionary in reality rather than contractionary as early rational bubble theories implied. We show that the presence of banks enhances bank excess returns which are collateralisable. We show that bubbles are therefore more likely to be expansionary in a framework that models banks explicitly.

[8] See, for example, Borio and Lowe (2002), Alessi and Detken (2009).

8 Appendix A: Data

In this section we provide details of the sources of the data used for calibrating the model. This is given in Table A1 below:

Table A1:

Theor. concept	Data concept	Source
Nominal bank loan rate	Prime loan rate	Federal Reserve Board, Table H.15
Nominal deposit rate	M2 own rate	FRED
Expected inflation	Average actual 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	Federal Reserve Board, Table H.8
Average corporate leverage	Corporate Debt/Corporate Net Worth	Covas and Den haan (2011)
Leverage of indebted corporates	Debt/Corporate Net Worth for the largest corporates	Covas and Den haan (2011)
Bank rate of return on equity	Bank rate of return on equity	Meh and Moran (2010)

References

Alessi, L., Detken, C., 2009. "real time" early warning indicators for costly asset price Boom/Bust cycles – a role for global liquidity. ECB Working Paper Series 1039.

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

Aoki, K., Nikolov, K., 2011. Rational bubblers under moral hazard. (in preparation).

Arce, O., Lopez-Salido, D., 2008. Housing bubbles. Banco de Espania Working Paper No. 0815.

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

Borio, C., Drehmann, M., 2008. Towards an operational framework for financial stability: 'fuzzy' measurement and its consequences. In: 12th Annual Conference of the Central Bank of Chile.

Borio, C., Lowe, P., 2002. Asset prices, financial and monetary stability: Exploring the nexus. BIS Working Paper 114.

Boyd, J., De Nicolo, G., 2009. Bank competition, risk and asset allocations. IMF Working Paper No. 09/143.

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

Christiano, L., Motto, R., Rostagno, M., 2010. Financial factors in economic fluctuations. ECB Working Paper No. 1192.

Covas, F., Den haan, W., 2011. The cyclical behavior of debt and equity finance. American Economic Review forthcoming.

Farhi, E., Tirole, J., 2010. Bubbly liquidity. Working Paper, Toulouse School of Economics.

Gertler, M., Karadi, P., 2009. A model of unconventional monetary policy. Working Paper.

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

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

Hirano, T., Yanagawa, N., 2010. Asset bubbles, endogenous growth, and financial crisis. Working Paper, University of Tokyo.

Kiyotaki, N., Moore, J., 1997. Credit cycles. Journal of Political Economy 102(2), 211–248.

Kiyotaki, N., Moore, J., 2009. Liquidity, business cycles and monetary policy. Working Paper, Princeton University.

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

Martin, A., Ventura, J., 2010. Theoretical notes on bubbles and the current crisis. working paper, CREI.

Meh, C., Moran, K., 2010. The role of bank capital in the propagation of shocks. Journal of Economic Dynamics and Control 34(3), 555–576.

Mishkin, F., 2008. How should we respond to asset price bubbles? Speech at the Wharton Financial Institutions Center.

Mishkin, F., 2009. Not all bubbles present a risk to the economy. Finantial Times article 9th November 2009.

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

Reinhart, C., Rogoff, K., 2008. This time is different: A panoramic view of eight centuries of financial crisis. Working paper, University of Maryland.

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

Tirole, J., 1985. Asset bubbles and overlapping generations. Econometrica 53 (6), 1499–1528.

Ventura, J., 2010. Bubbles and capital flows. Working Paper, CREI.

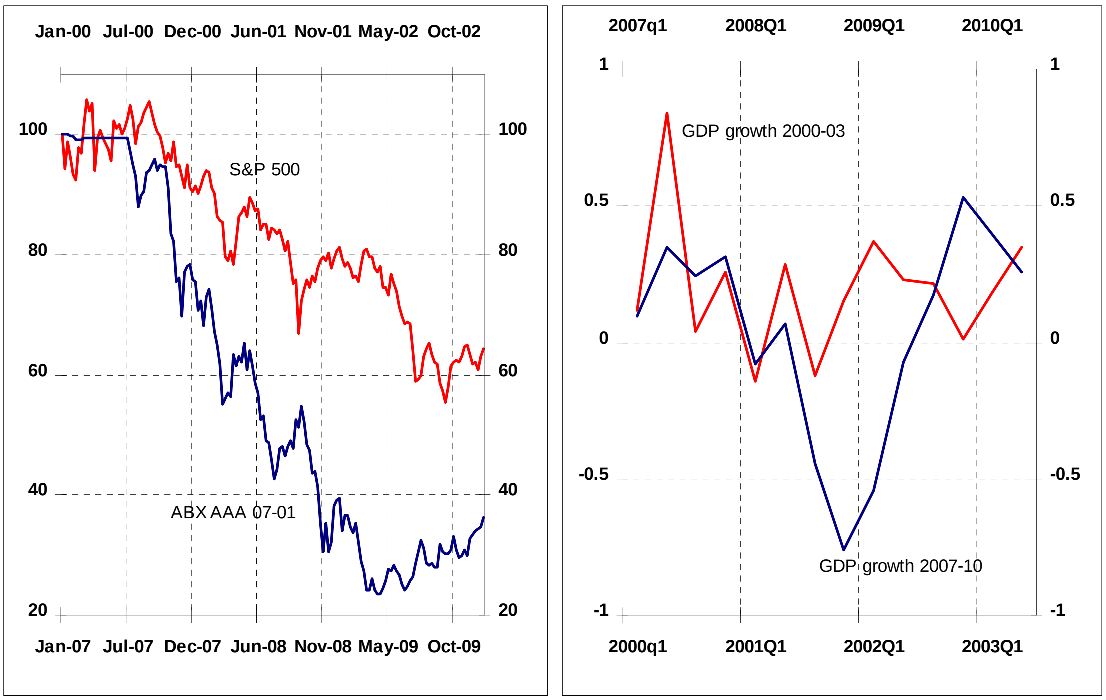

Figure 1. US asset prices and output

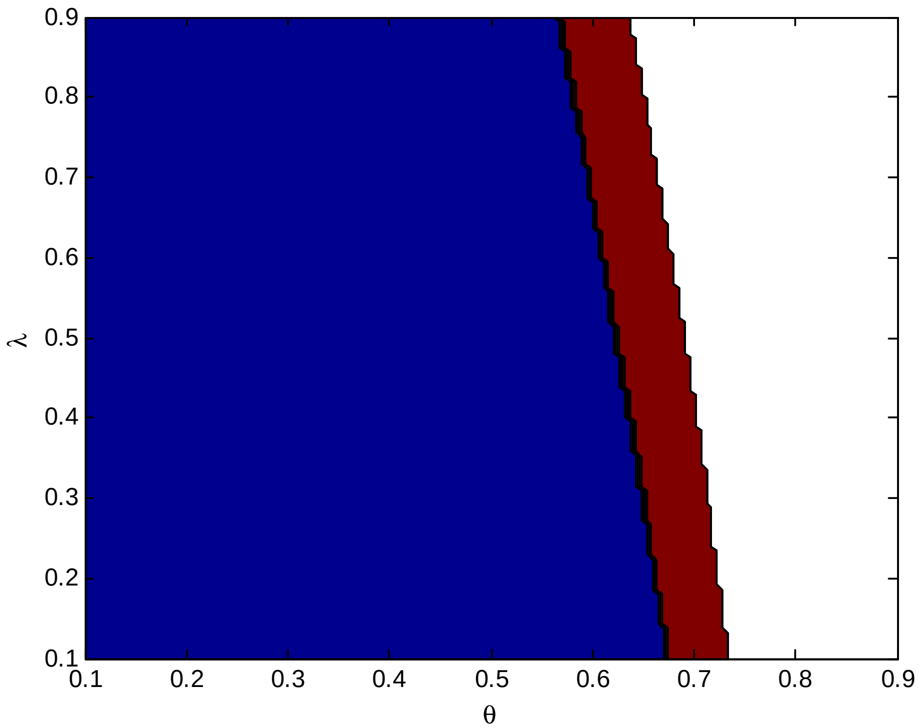

Figure 2a. Deposit rate less than one (red area)

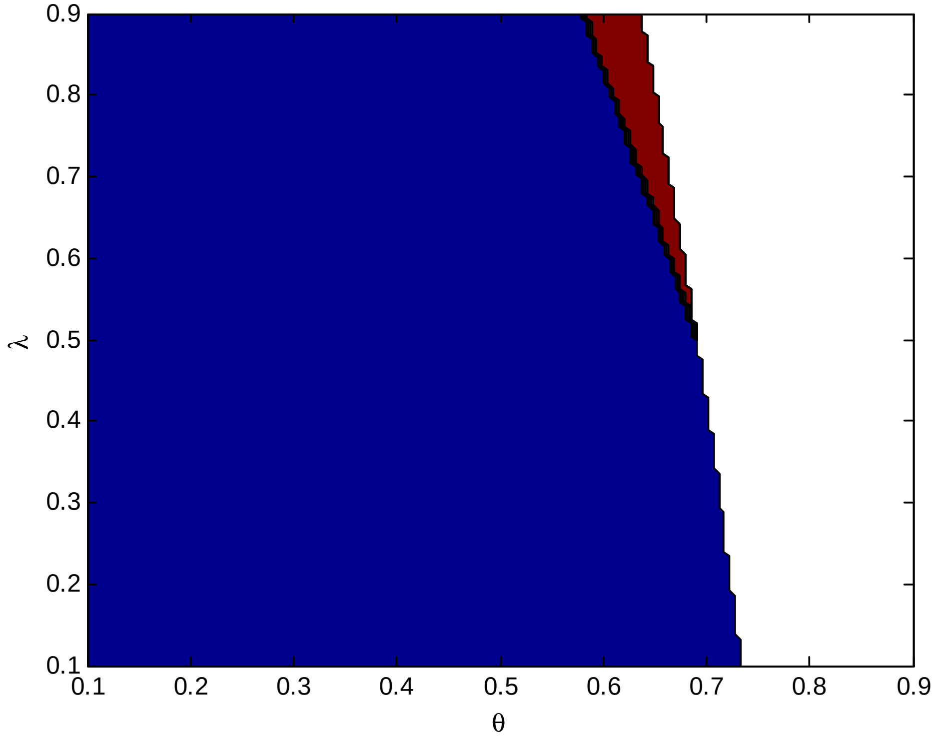

Figure 2b. Lending rate less than one (red area)

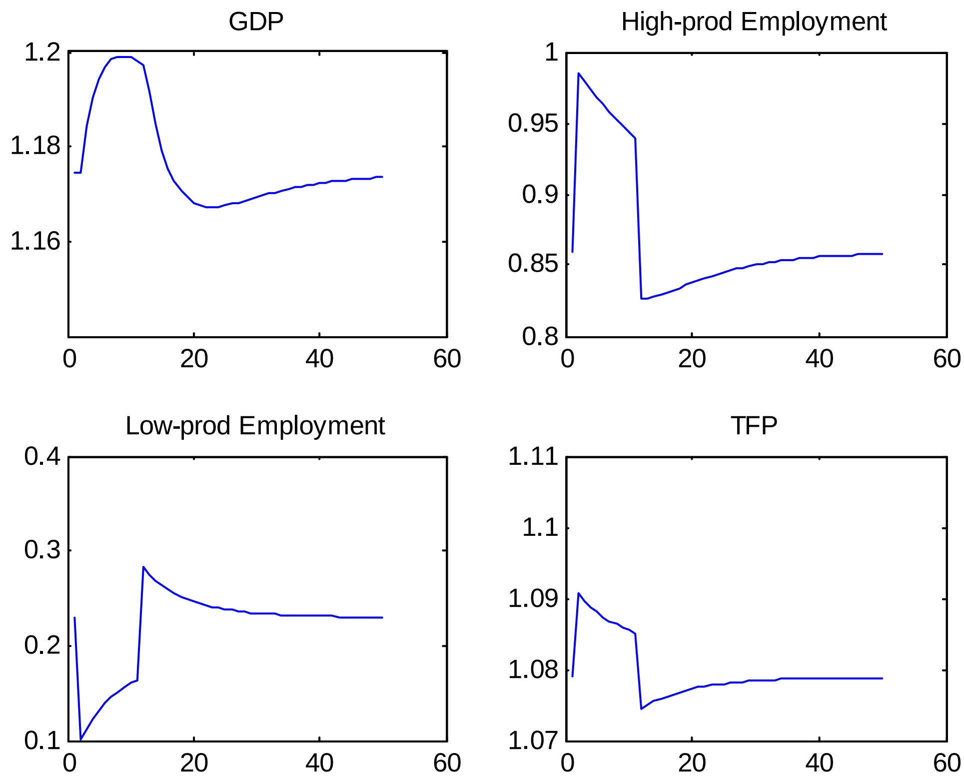

Figure 3a: Real variables: bank-bubble

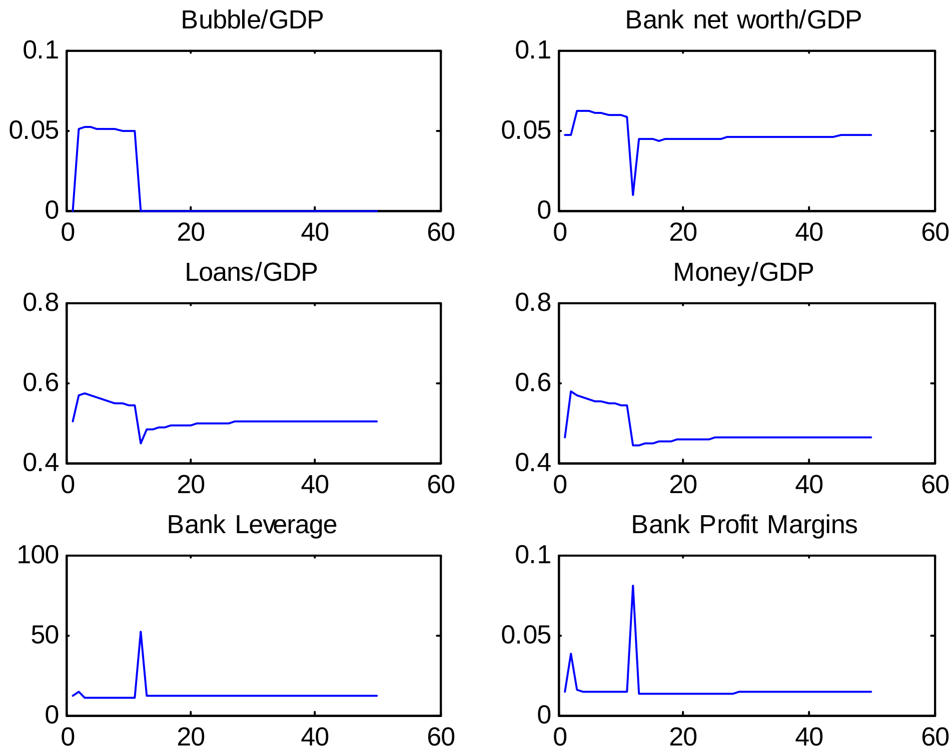

Figure 3b. Financial variables: bank-held bubble

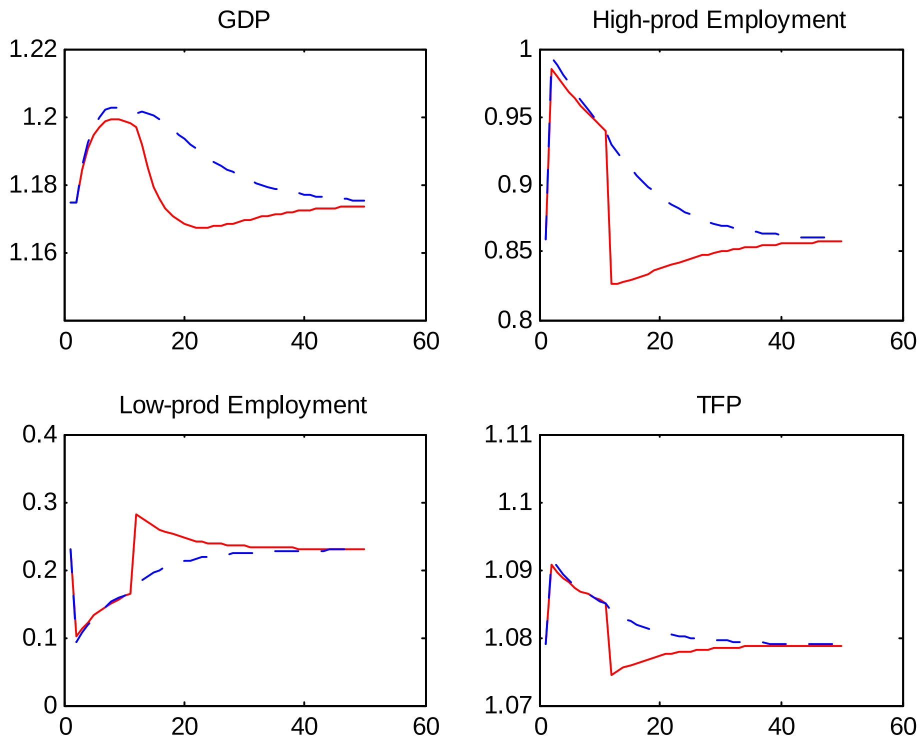

Figure 4a. Real variables: bank-held (solid) vs saver-held (dashed) bubbles

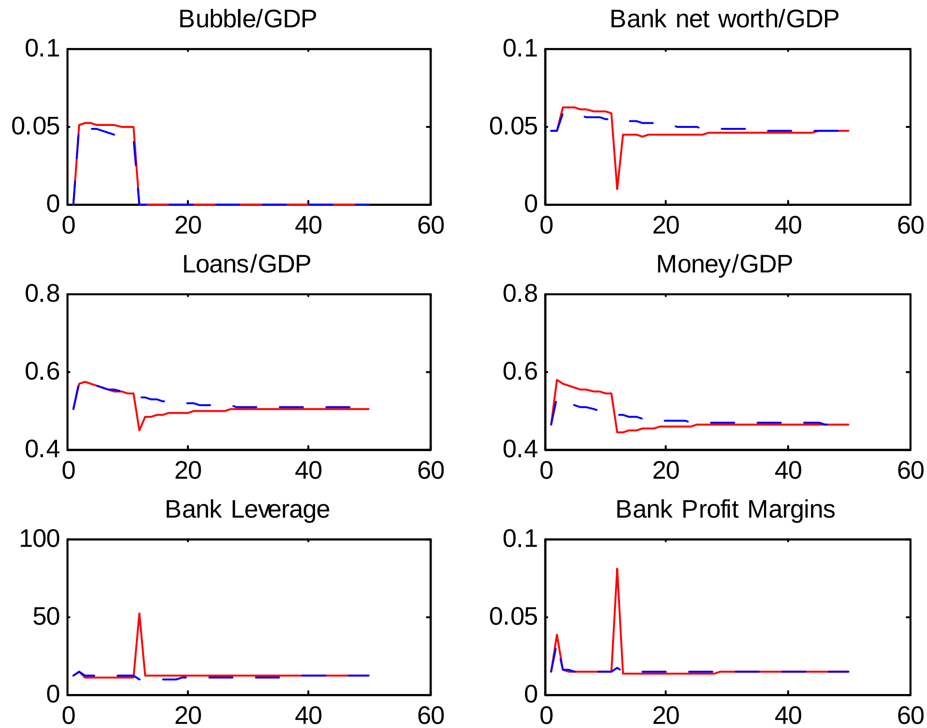

Figure 4b. Financial variables: bank-held (solid) vs saver-held (dashed) bubbles

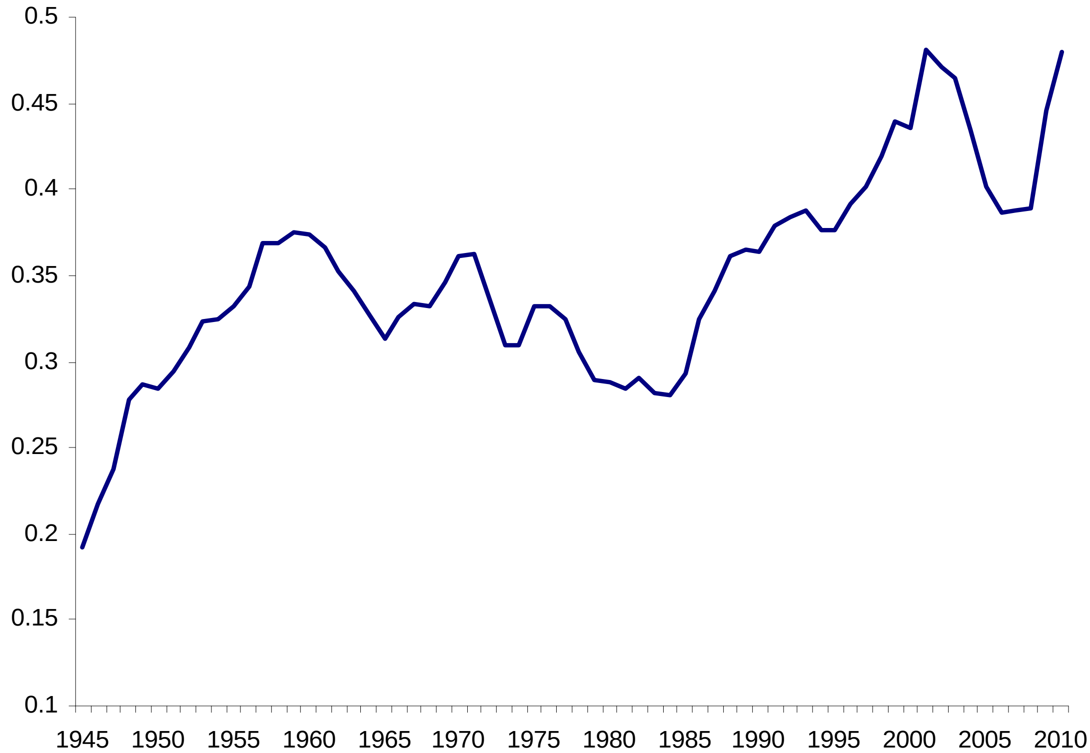

Figure 5: Corporate bond stock as % of commercial bank loans

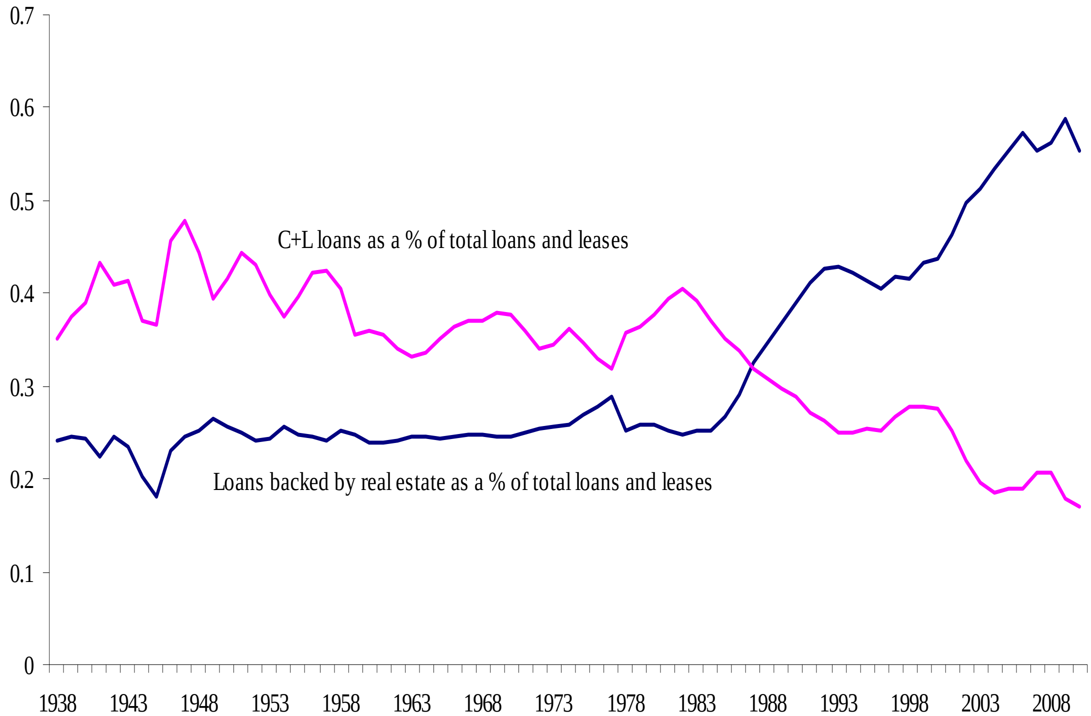

Figure 6: Commercial & Industrial and Real Estate loans as a % of total loans

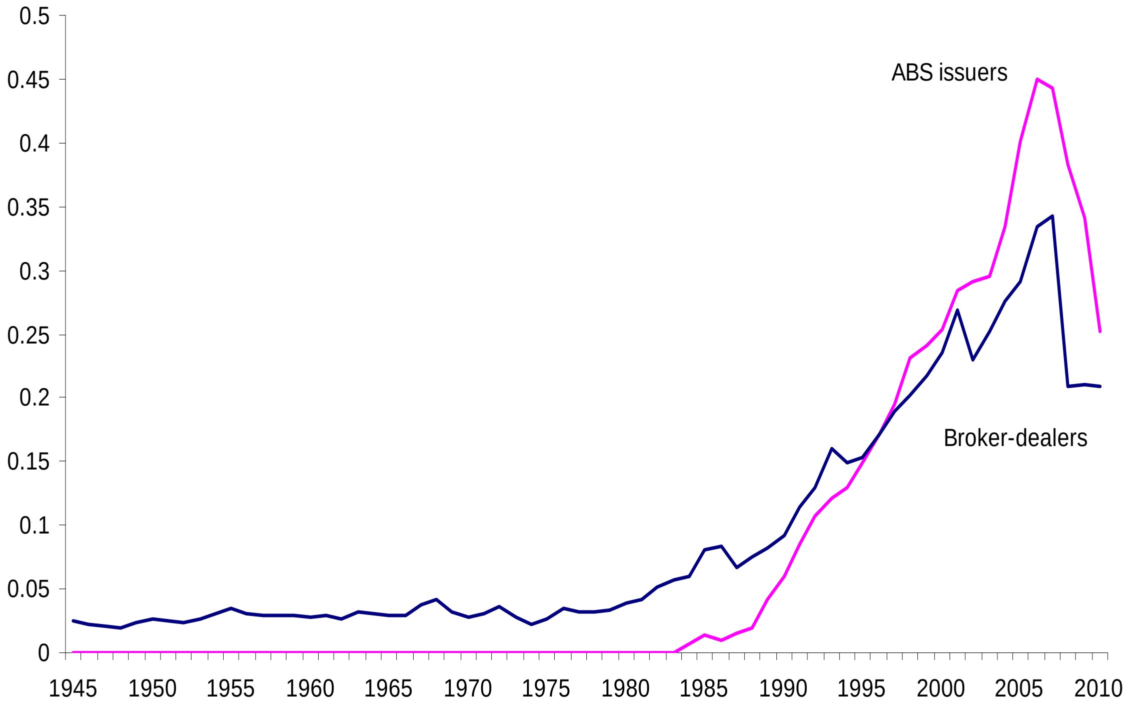

Figure 7: Assets of ABS issuers and Broker-Dealers as a % of commercial bank loans

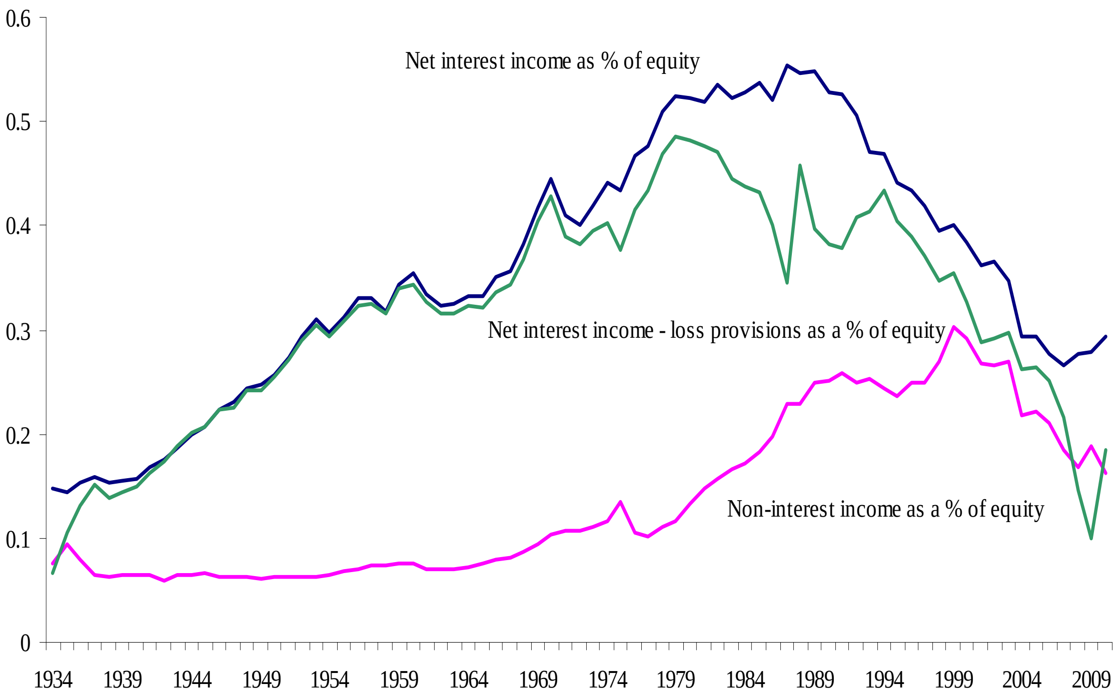

Figure 8: Sources of bank profits

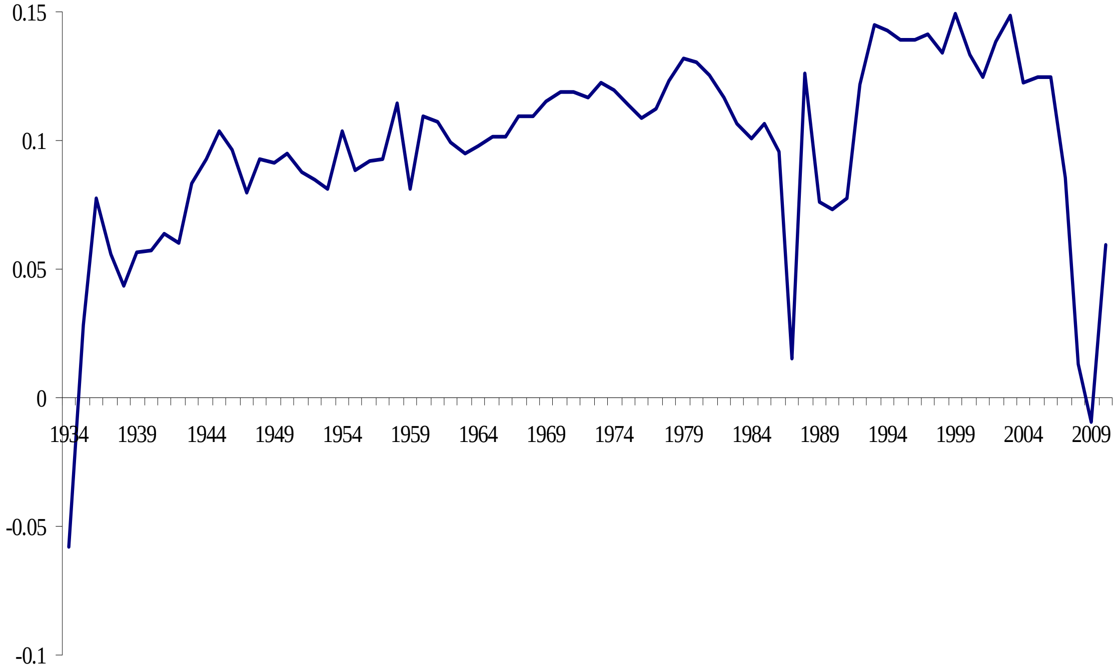

Figure 9: Banks ' net profit as a % of total equity

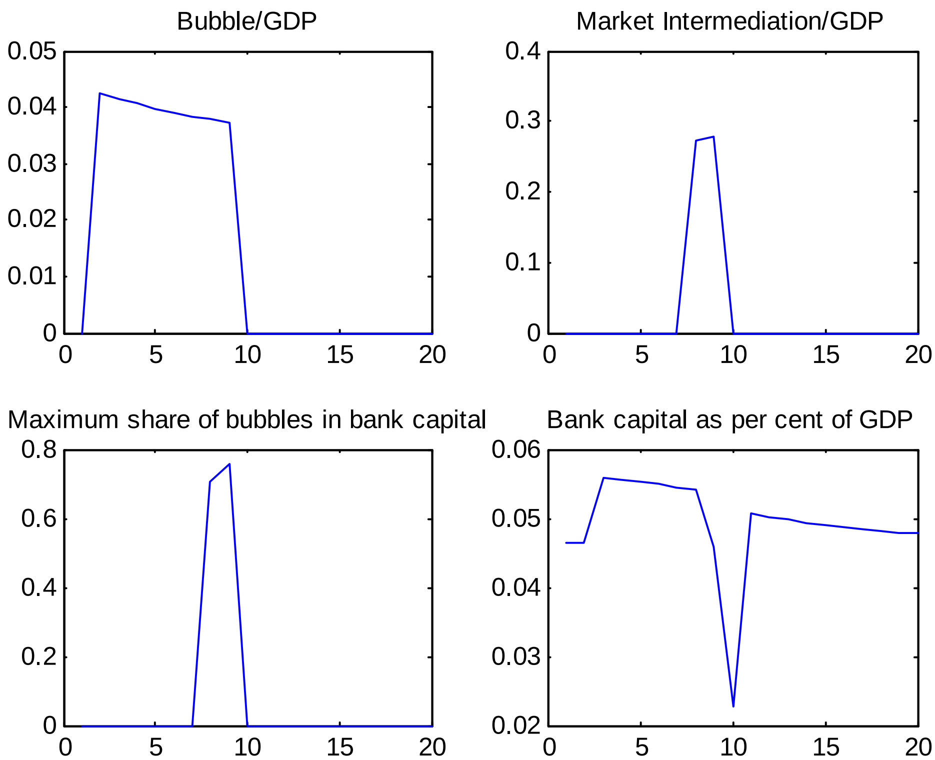

Figure 10: A boom in non-bank lending

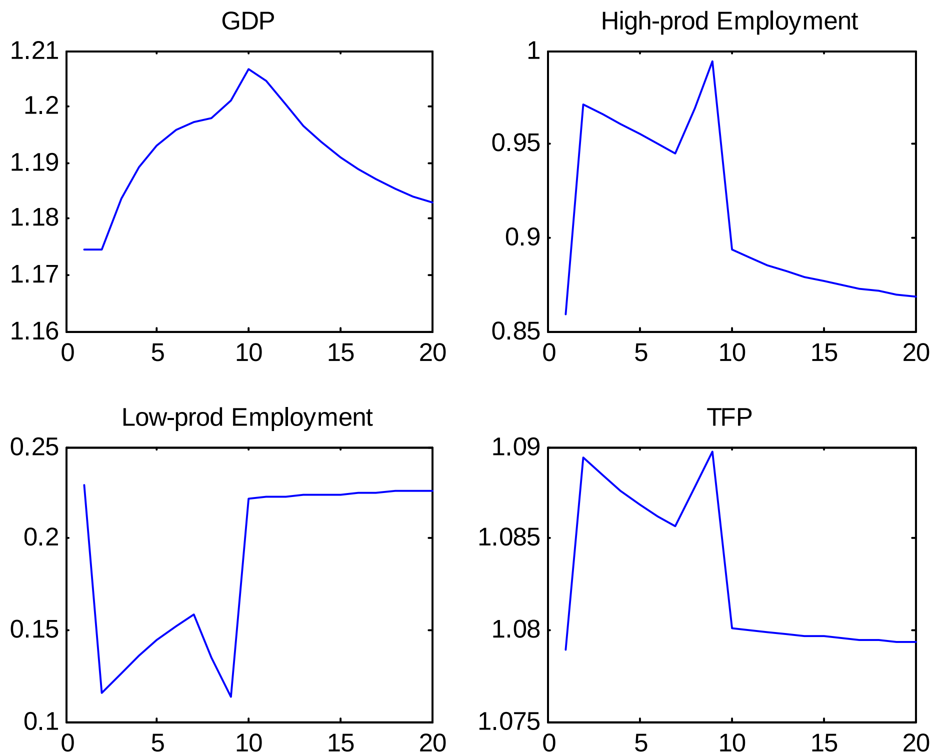

Figure 11a: Evolution of real variables during a boom in non-bank lending

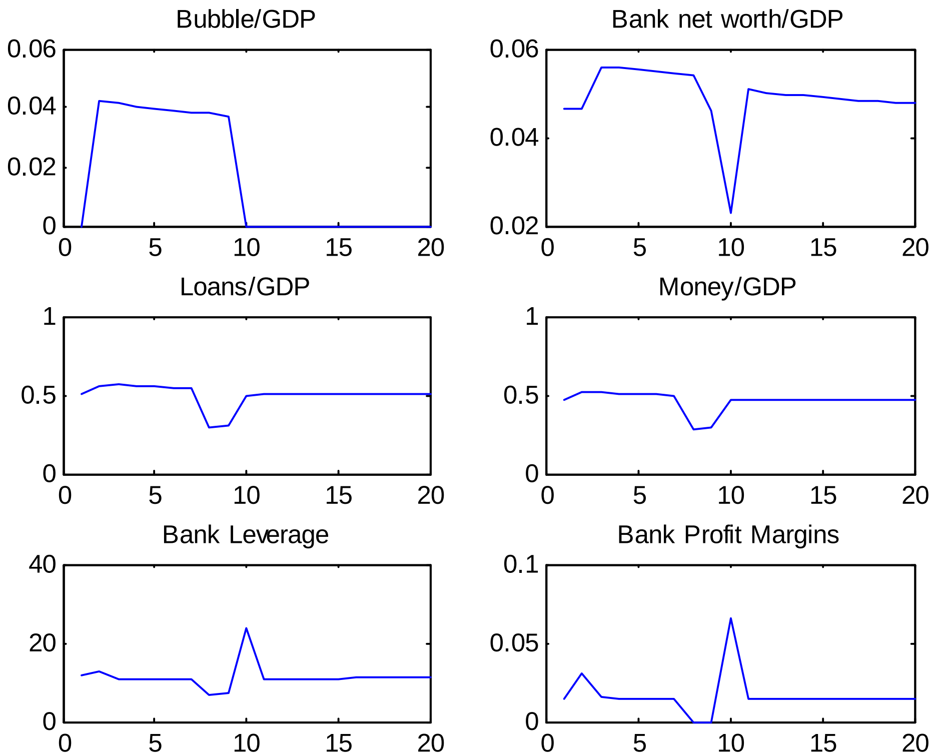

Figure 11b: Evolution of financial variables in a boom in non-bank lending