Bubbles, Banks, and Financial Stability

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VERY PRELIMINARY

April 2011 [First version: November 2010]

Abstract

This paper asks two main questions:

(1) What makes some asset price bubbles more costly for the real economy than others?

(2) What does theory have to say about the appropriate early warning indicators of dangerous bubbles?

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. Bank intermediated bubbles also lead to a strong expansion of money and credit, which explains why these variables are useful though noisy early warning indicator of future crises.

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 AAA-rated 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 main 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 formalize this idea and show that who owns bubbly assets indeed matters for financial and economic stability.

Model description In order to analyze 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 known as 'credit bubbles') are more dangerous than bubbles held by other investors who are less central in the credit allocation mechanism (we refer to these as 'saver-bubbles '). 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 other investors/savers directly hold bubbles. 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 lenders (the banks) do not suffer as a result of savers ' losses. In contrast, when banks hold bubbles, the bursting of bubbles directly hit the banks' net worth, possibly leaving the banking system 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.

Our paper also provides a theoretical justification for the usefulness of money, credit and bank leverage in predicting future crises. The emergence of all bubbles leads to a big boost in corporate net worth and demand for credit. As a result, the economy experiences a dramatic expansion of credit and bank leverage, consistent with the empirical evidence. Nevertheless, we also show that within our model it is difficult for a policy-maker to tell with confidence whether a bubble will result in a financial crisis or not. This is because money and credit expand more rapidly during the build up phase of a bank-held (as opposed to a saver-held) bubble but the differences are not large enough to allow for accurate forecasting. Our model implies that crisis prediction using aggregate data will remain an uncertain exercise.

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 lad 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 '. This explains why financial innovations that rapidly expand the total supply of credit can eventually lead to a systemic financial crisis.

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 emphasize the role of credits. Much literature incorporates various forms of credit frictions and how 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 occured 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.

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), Kocherlakota (2008), 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 8 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 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, if 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 and h_t denote real wage and labor respectively.

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

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 the household 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 maximize (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

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

subject to her flow-of-funds constraint

$$c_t^w + m_t^w \mu_t - b_t^w = w_t h_t + m_{t-1}^w \mu_t - R_{t-1}^d b_{t-1}^w, \tag{7}$$

here superscript 'w' stands for 'workers'. In equilibrium, it is shown that workers do not save because the equilibrium interest rate is low. Therefore they consume their labor 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:

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

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 recognize the banker's incentive to divert funds, they will restrict the amount of deposit. Those assumptions imply the following borrowing constraint

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

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 maximizes (8) subject to (9), (10) and (11).

3 Equilibrium without bubbles

Before characterizing an equilibrium with bubbles it is informative to characterize the equilibrium without bubbles. In this section we set $\mu_t = 0$ at all times.

3.1 Optimal behavior

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 labor 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[1],

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

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

[1] In Appendix XX we derive the condition for this to hold in the neighborhoold of the steady state without bubbles.

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 labor supply h_t^s is given by

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

They will not save and consume all their labor income when

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

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

Finally, let us characterize the bank. When $R_t^l > R_t^d$, then credit constraint (11) binds and consumption is postponed until death[2]. 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.[3] 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 characterize the aggregate equilibrium as follows. From (18) The aggregate employment of the productive

[2] **Need to show the conditions under which this is true.**
[3] See Nikolov (2010), who considers a similar problem for firms.

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.

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

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

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

$$\beta(Z_t^{H} + Z_t^{L}) + \gamma N_t = w(H_t^{H} + H_t^{L}) \tag{32}$$

From (19), labour market clearing implies

$$w_t^{\eta} = H_t^{H} + H_t^{L}. \tag{33}$$

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, labor, 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 en-*

trepreneurs, 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. Since the analytical solution is complicated and not very informative, we discuss the properties of the steady state based on numerical simulations. The parameter values we use are in line with Aoki, Benigno and Kiyotaki (2009) and are discussed in more detail in Appendix X.

3.3 Existence of steady state bubbles

It is useful to characterize 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.[4] 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 produc-

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

tivity 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]

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 subset of the space where savers have an incentive to invest in bubbly assets.

[Figure 2b here]

If both the loan and deposit rate are lower than one, we consider two cases. 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.

Secondly, we allow both banks and savers to buy bubbles. This corresponds to a situation in which bubbles are attached to more divisible and standardized assets, such as equities. Then individual savers can afford to buy the bubble. It turns out that in such a steady state, only savers hold bubbles while banks stay out. This is because 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. In the steady state equilibrium we consider, the rate of return of bubbles is equal to the deposit rate, so the savers crowd out banks from bubbly asset markets.

4 Equilibrium with bubbles

4.1 Calibration

We have 8 parameters $\{\eta, a^H/a^L, \delta, n, \theta, \gamma, \beta, \lambda\}$ 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 ($R_t^l + \frac{\phi_t\left(R_t^l - R_t^d\right)}{(1-\lambda)}$)	1.150	1.154

4.2 Competitive equilibrium with bubbles

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.[5] 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 normalize 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

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

Since a part of national savings is invested in bubbles, the goods market clearing (saving = investment) is modified as

$$\beta(Z_t^H + Z_t^L) + \gamma N_t = w(H_t^H + H_t^L) + \mu_t. \tag{36}$$

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

$$Z_0^H = (1-\delta)\frac{a^H(1-\theta)}{w_{-1} - \theta a^H / R_{-1}^l}\beta Z_{-1}^H + n\delta R_{-1}^d \beta Z_{-1}^L + \mu_0. \tag{37}$$

They sell bubbles to finance employment. Now equations (13), (23)-(26), (28)-(31), (33), (34)-(36) 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 four states Z_t^H, Z_t^L, N_t. At $t = 0$, Z_0^H is given by (28).

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

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, labor, 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).

5 Banks' Bubble Holdings and Financial Stability

In this section we characterize 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 suddently changes and the 'bubble ' asset starts to trade at a positive value.

5.1 The emergence and bursting of a bank-intermediated bubble

[Figures 3a and 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. Thus, similar to Ventura (2010) and Martin and Ventura (2010), bubbles are expansionary in our model.

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 Bubbles and TFP shocks

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 realocation 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.

This efficiency-enhancing effect makes it harder to spot bubbles reliably because, in terms of their output effects, they look like conventional TFP shocks. So in this subsection, we compare the effects of a boom-bust cycle driven by a bank-held bubble with a boom-bust cycle, driven by exogenous movements in aggregate technology. The Figure 4a below compares the evolution of real variables in the model under a bank-held bubble and under a conventional exogenous TFP shock.

[Figure 4a here]

The first thing to note is the remarkable similarity between the evolution of output and TFP during the boom phase under both experiments. But whereas the end of a TFP boom only returns aggregate technology to a around its starting level, the effects of the bursting of a bank-held bubble on aggregate TFP are more dramatic. As we argued above, this additional output volatility is largely due to the credit crunch that occurs following the collapse of the bubble.

Moving on to financial variables we see that their evolution is very different under the two scenarios. Bank leverage, bank profitability and the size of bank balance sheets relative to GDP increase much more sharply during a bubbly episode compared to a standard aggregate technology shock. When the bust comes, its effects on financial variables are dramatic in the case on the bubble but very limited in the case of ordinary TFP shock. When a bank-held bubble bursts, it wipes out the net worth of the banking system and the ratio of bank net worth to GDP falls very sharply. Bank balance sheets contract sharply and the ratios of money and credit to GDP fall substantially. Credit, in particular, undergoes a sharp decline because higher loan rates reduce credit demand. Bank leverage rises sharply on the back of improved bank profit margins. After a crisis period in which loan rates reach very high levels and deposit rates fall sharply, bank net worth recovers some way towards pre-crisis levels and the credit crunch begins to abate.

[Figure 4b here]

To clarify the evolution of financial variables under an ordinary TFP shock, we plot them by themselves in the Figure 5 below. Qualitatively, the series are somewhat similar to the ones that occur under a bank-held bubble. The improvement in aggregate technology generates an increased demand for liquidity from both investing and saving entrepreneurs. Because bank capital is pre-determined in the initial period of the shock, the higher liquidity demand leads to an increase in bank profits and a rise in the franchise value of the bank (which includes the NPV of future bank profits). The higher franchise value relaxes the bank's collateral constraint and allows it to expand leverage, loans and deposits. When the improvement in productivity reverses after 10 periods, the same process operates in reverse. Bank profits fall and bank balance sheets contract driven by lower demand for liquidity by entrepreneurs. The boom-bust cycle follows a familiar and intuitive pattern. But it is a very mild cycle that hardly leads to fluctuations in money and credit aggregates or in banks ' leverage and net worth, either during the boom or the bust phase of the cycle.

[Figure 5 here]

5.3 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 6a 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 6b 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 that can be 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 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 them, instead focusing on their traditional (and much more profitable) activity - loans to entrepreneurs. As Gorton (2007) has emphasized, 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.

[However, there exist a number of historical episodes in which financial liberalisation and the growth of non-bank financial intermediation pushed bank loan spreads down and encouraged banks to engage in new and riskier activities. Hoshi and Kashyap (2000) document the way financial liberalisation and the growth of the corporate bond market pressures on Japanese banks during the 1980s.

Adrian and Shin (200x), Gorton (2007) document the rapid growth of securitisation and repo financing during the 2000s. NEED TO SAY MORE HERE, MAYBE WITH A DATA CHART OR TWO]

All these episodes have the common feature that financial liberalisation increased competition among banks or between bank and bond intermediation, and therefore depressed loan spreads and pushed banks to branch out into riskier activities. In what follows, we extend our model of Section 2 to allow for direct finance. We then explore how the growth of direct intermediation affects the incentives of banks to hold bubbles.

6.1 The Model with Direct Finance[6]

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 a superior intermediation technology, which allows them to enforce debt repayments up to fraction θ^b 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.

It is easy to see that arbitrage by savers implies that corporate bond and

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

bank deposit yields 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,

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

borrowing entrepreneurs will borrow up 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 $\theta^m y_{t+1}$. Firms always prefer to borrow from the market first because it is cheaper but if their productive opportunities are good enough, bank borrowing is attractive too.

6.2 A Financial Liberalisation Simulation

With the above brief outline of our direct finance extension in mind, we now continue to analyse the impact of an '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.

Figure 7 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 approximately 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 and value. When the bubble finally collapses, bank net worth falls sharply, causing a credit crunch in the economy.

[Figure 7 here]

As Figure 8a 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 8a here]

But why did banks suddenly choose to invest into the bubble as direct intermediation grew whereas previously they had stayed on the sidelines of the boom? Figure 8b below provides some answers to this question by delving more deeply into the financial side of the model. In particular, as we argued above, the evolution of bank profit margins are 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 when '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. Banks temporarily[7] become borrowing unconstrained and the lending rate becomes equal to the deposit rate and the rate of return on bubbles. At this point, financial intermediaries become indifferent between expanding their balance sheets on the margin because their capital constraint is slack. Banks' 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 8b 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 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 during periods of rapid disintermediation.[8]

[7] 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.

[8] This section used a financial liberalisation scenario which relied on the growth of non-

7 Model-implied 'early warning signals' of crisis

In the last ten years, there has been a big increase in the number of researchers who have sought to learn about the empirical regularities in banking and more general financial crises. Now, following the 2008-09 financial crisis, the interest of policy-makers in developing empirical measures that can help in predicting the occurence of future banking crises is greater than ever. 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 occurence of financial crisis. Our paper can provide some theoretical backing and interpretation behind some of these 'early warning signals ' of financial instability.

7.1 Rapid growth in money, credit and bank leverage is likely to be associated with a bubble

Even though the evolution of output is similar between bubbles and genuine positive TFP shocks, the evolution of financial variables is very different. In particular, bank balance sheets (money, credit relative to GDP as well as bank leverage) expand much more rapidly under bubbles than under TFP shocks. This provides a justification for the threshold approach used by Borio and Lowe (2002), Alessi and Detken (2009) and others in identifying boom-bust

bank financial intermediation in order to generate bubble induced fragility into the banking system. We motivated this way of modelling financial liberalisation by appealing to the historial experiences of Japan in the 1980s as well as the well-publicised growth of the 'shadow banking system' over the last decade.

In a previous version of the paper we examine the effect of a 'financial liberalisation ' shock which increases the permissible leverage of financial institutions. The results (which are available from the authors upon request) are qualitatively very similar. Bank loan supply increases, drives loan profitability down and exposes banks to the possibility of holding 'saver bubbles '.

episodes. In our model, big increases in money, credit and bank leverage to GDP are likely to have their origins in bubbles and hence signal increased likelihood of future crisis.

7.2 Distinguishing between 'costly ' and 'harmless ' bubbles 'ex ante' is hard in the model

Bubbles on assets that can only be held by banks ('bank bubbles ') are more likely to have damaging consequences for financial stability compared to bubbles that can be held by other economic agents ('saver bubbles'). This is because banks will often choose not to invest in 'saver bubbles ' and will therefore remain unaffected by their bursting. But as we saw in section xx this is not always the case. When banks' profits from traditional business loans are low, they can be tempted to join in a 'saver bubble'. Can a policy-maker who cannot tell bubbles from real loans notice whether the banking system is engaged in a dangerous bubble or not just by looking at bank balance sheets? Our analysis showed that the same size bubble caused a sharper balance sheet expansion under a 'bank bubble'. But the difference is not as large as between bubbles and positive TFP shocks. So our policy maker would be able to tell that there is an unsustainable asset price boom somewhere in the economy but would not be sure whether the collapse of the bubble would lead to bank failures. This provides a reason why the literature on 'early warning signals ' has struggled to find really robust measures that can forecast crises with a high degree of confidence. For example Alessi and Detken (2009) and Kannan et al. (2009) both find that even their best early warning indicator is still subject to large Type I and Type II errors. In our model this is an unavoidable consequences of the fact that the different types of bubble we examine do not have hugely different implications for aggregate variables during the boom phase.

7.3 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[9]; (ii) growth of market based intermediation such as corporate bonds and asset backed securities (analysed in the previous section) (iii) relaxation of the bank's leverage constraint and (iv) weakness in corporate balance sheets. It is straightforward to see why these three factors would reduce banks ' profits from corporate lending. (i), (ii) and (iii) increase the supply of loans and reduce the loan-deposit spread. (iv) reduces loan demand with the same downward impact on banks' lending margins. In all of these situations, poor profitability makes banks more willing to hold bubbly assets.

[9]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.

7.4 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

8 Conclusions

In this paper we build a model in which rational asset prices 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. In particular, we find that large bank balance sheet expansions signal the presence of a bubble in the economy. However, it is more difficult within our model to be sure whether the bubble is held by banks or by ordinary savers. 'Bank bubbles' lead to bigger movements in bank balance sheets but the difference is not large enough to be used as a robust indicator

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

9 Appendix A:

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	Welch (2004)
Leverage of indebted corporates	Debt/Corporate Net Worth for the largest corporates	Welch (2004)
Bank rate of return on equity	Bank rate of return on equity	Meh and Moran (2009)

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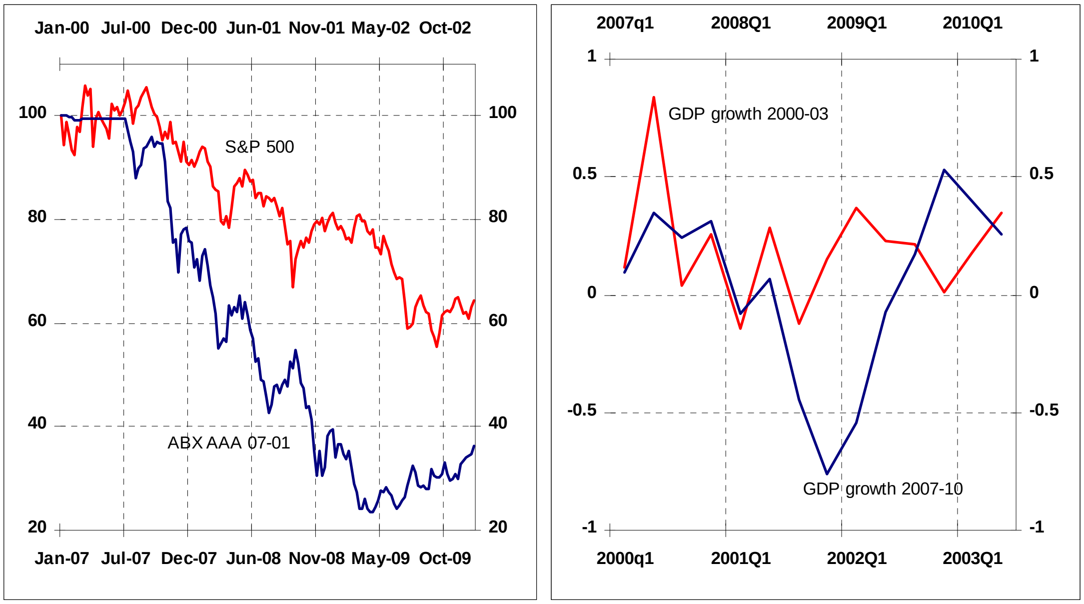

Figure 1. US equity prices and output

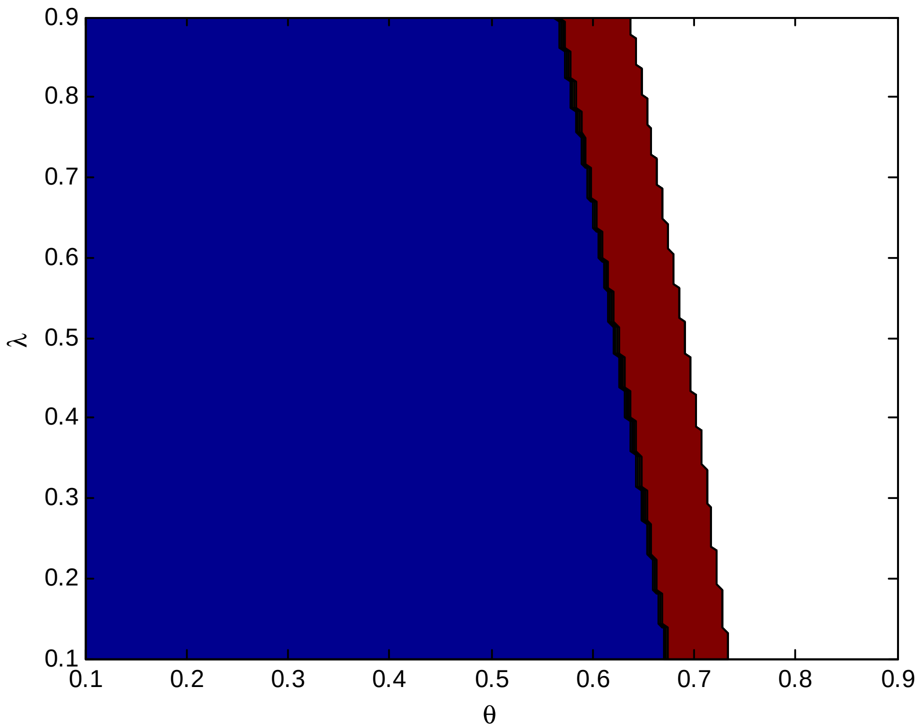

Figure 2a. Deposit rate less than one (red area)

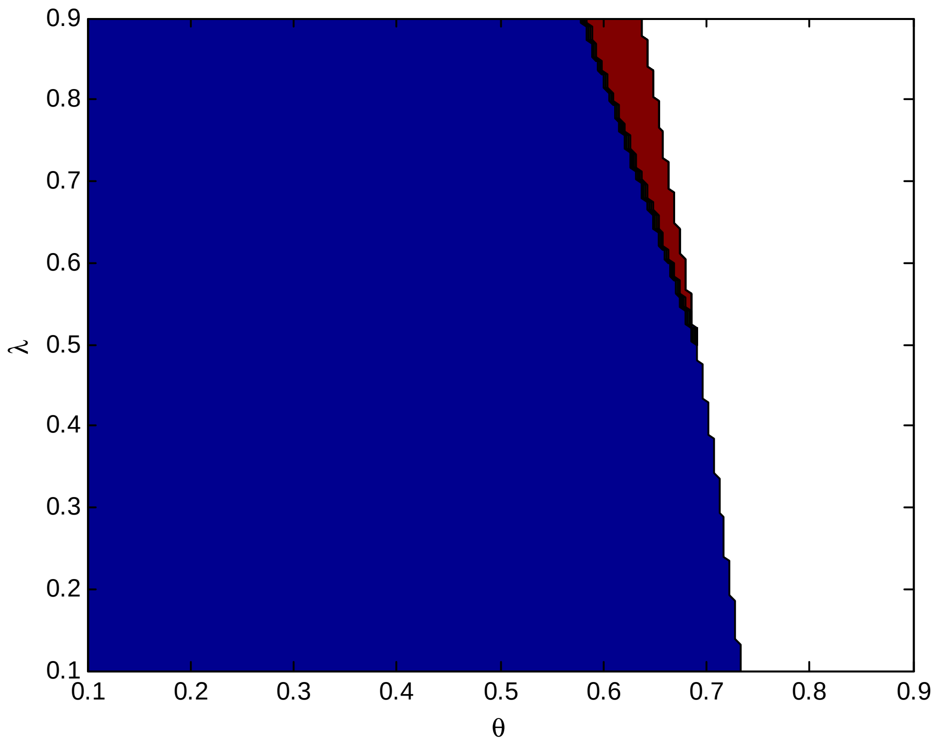

Figure 2b. Lending rate less than one (red area)

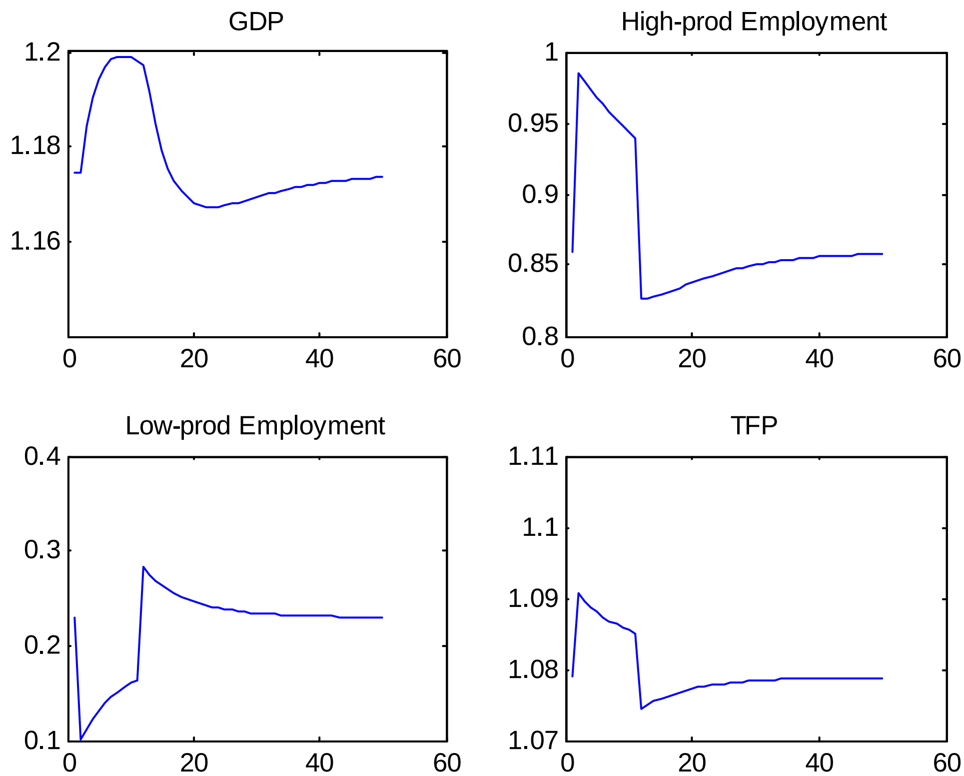

Figure 3a: Real variables: bank-bubble

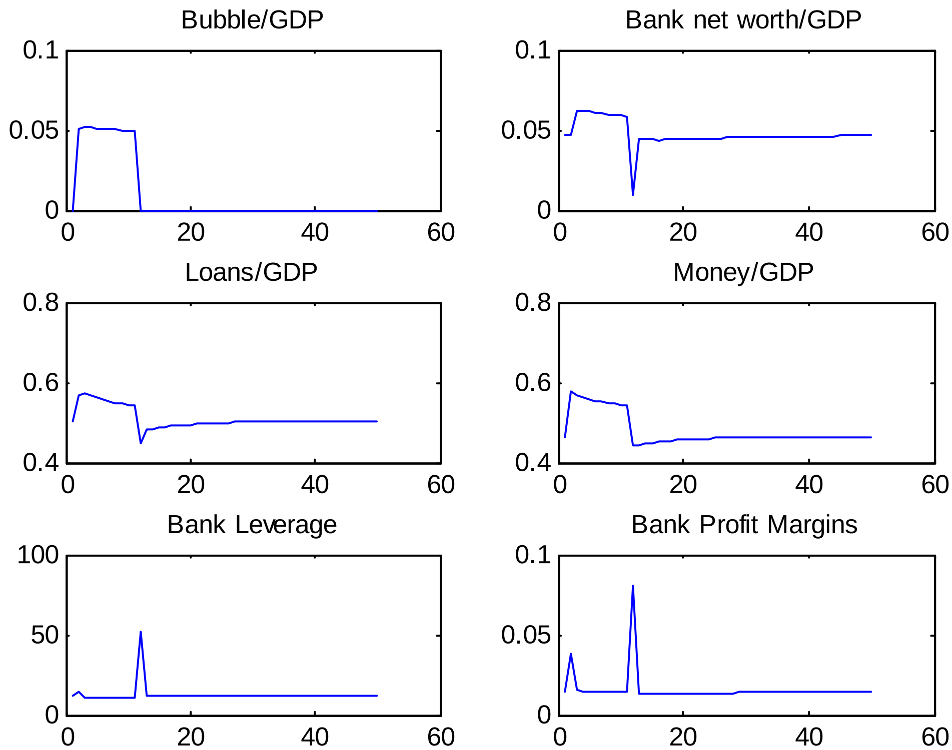

Figure 3b. Financial variables: bank-held bubble

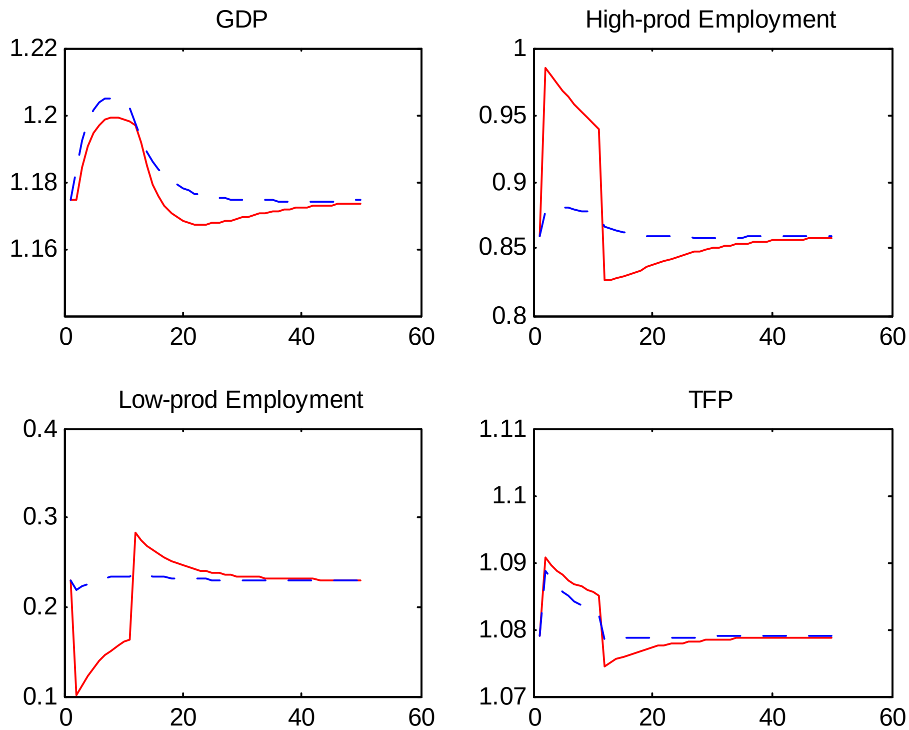

Figure 4a: Real variables: bank bubble (solid) vs TFP shock (dashed)

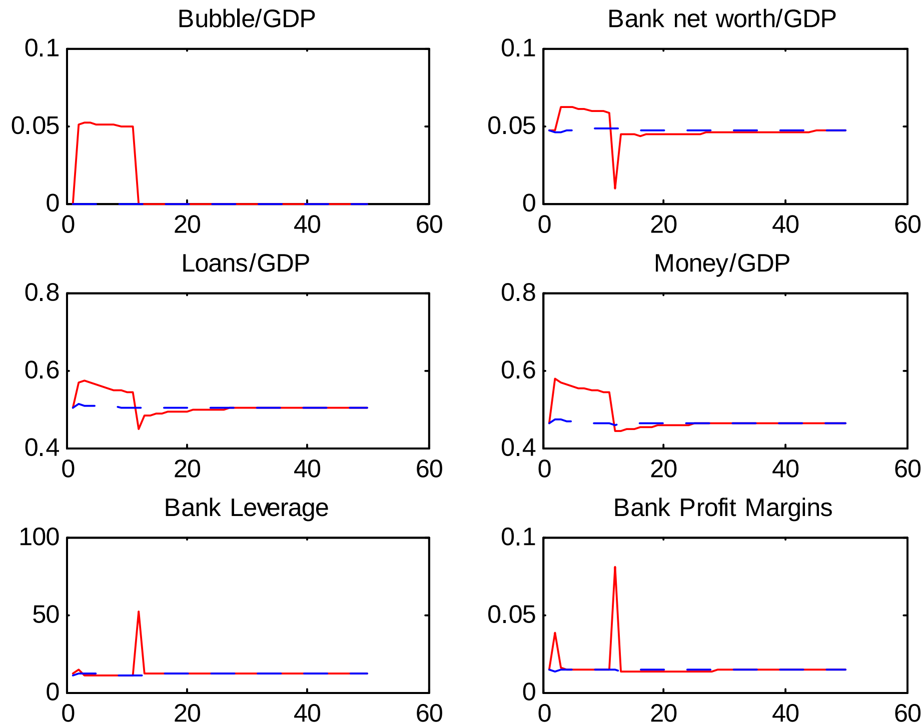

Figure 4b: Financial variables: bank bubble (solid) vs TFP shock (dashed)

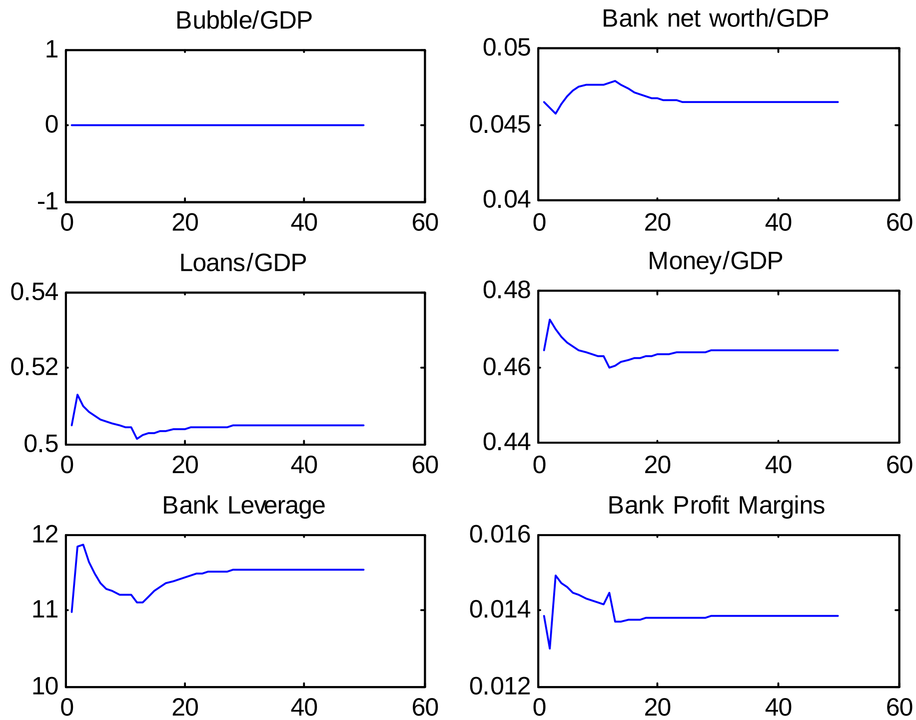

Figure 5. Financial variables under a TFP shock

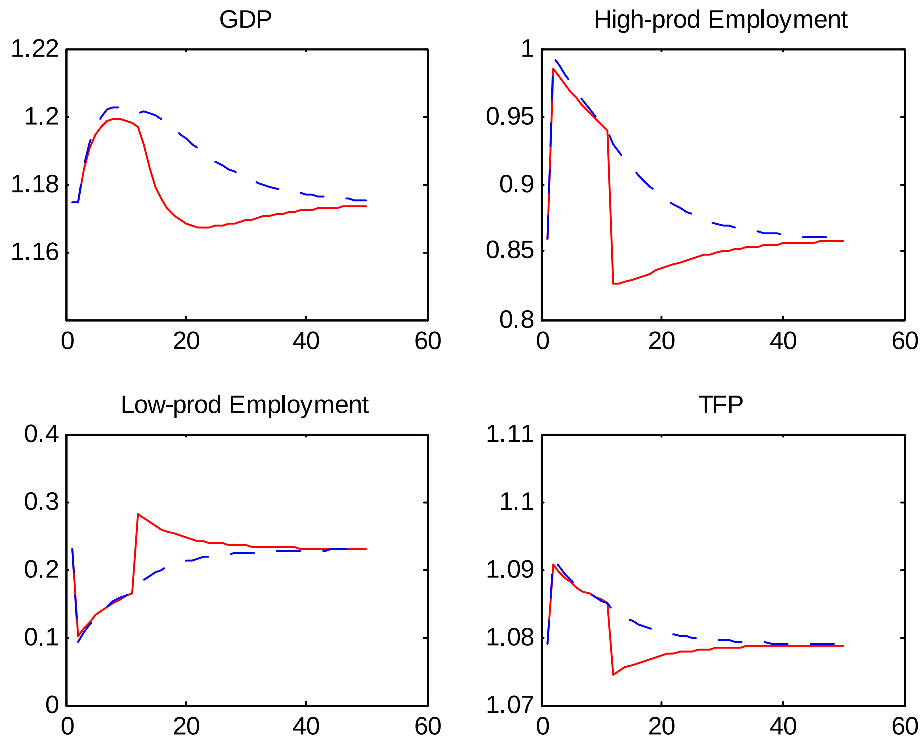

Figure 6a. Real variables: bank-held (solid) vs saver-held (dashed) bubbles

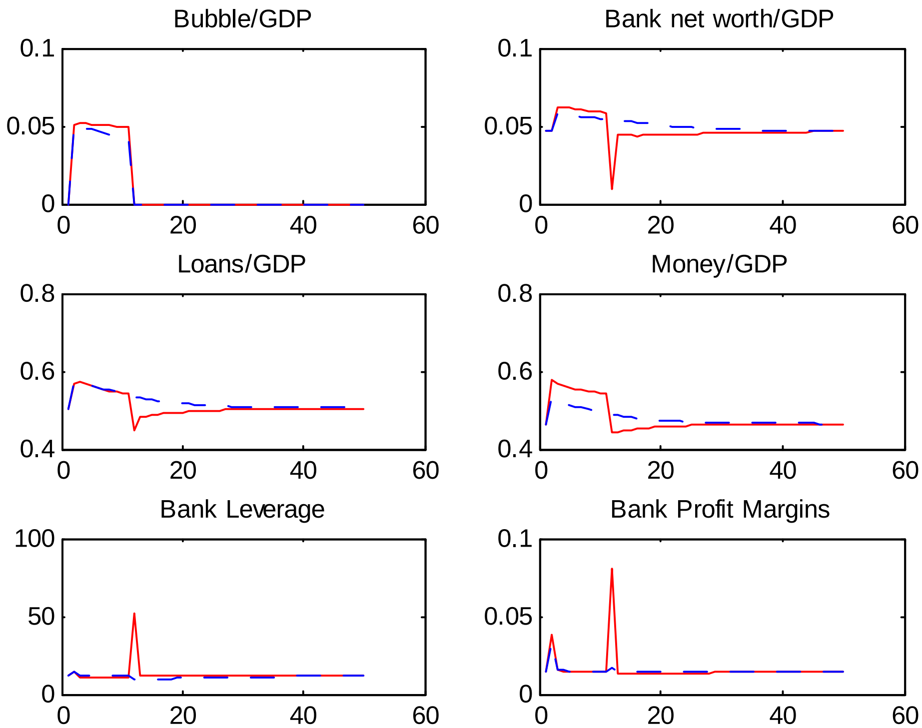

Figure 6b. Financial variables: bank-held (solid) vs saver-held (dashed) bubbles

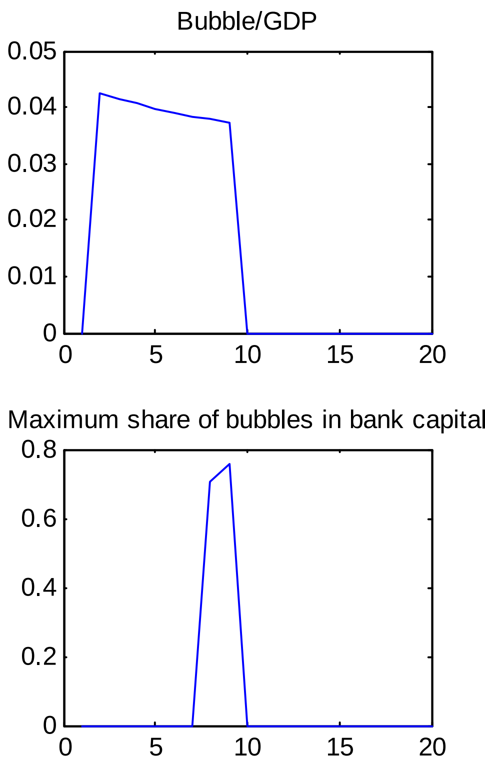

Figure 7: A boom in non-bank lending

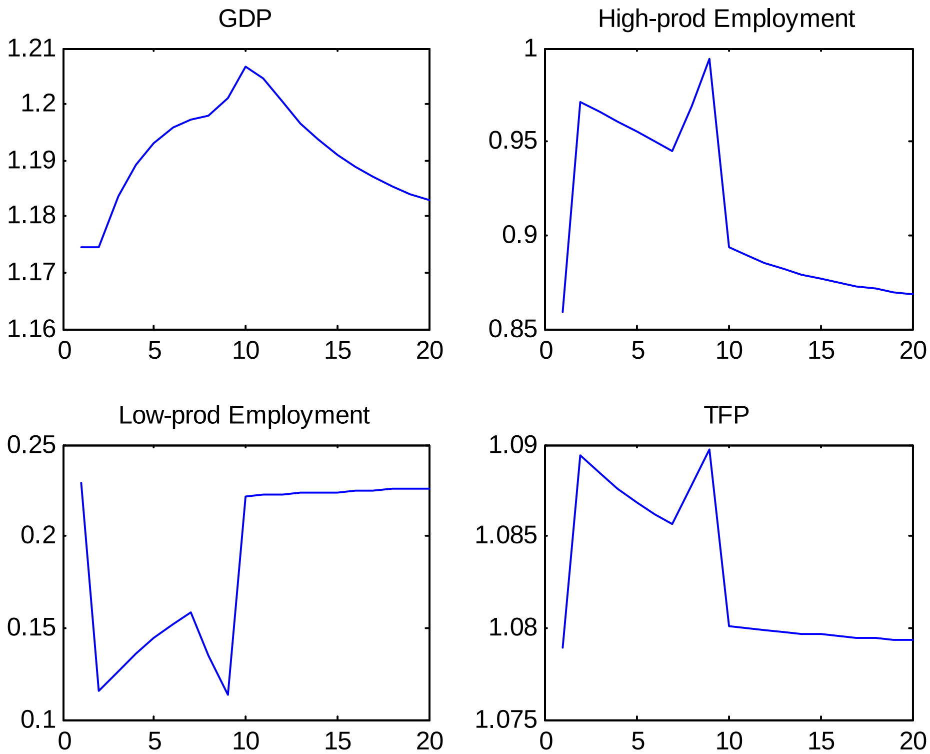

Figure 8a: Evolution of real variables during a boom in non-bank lending

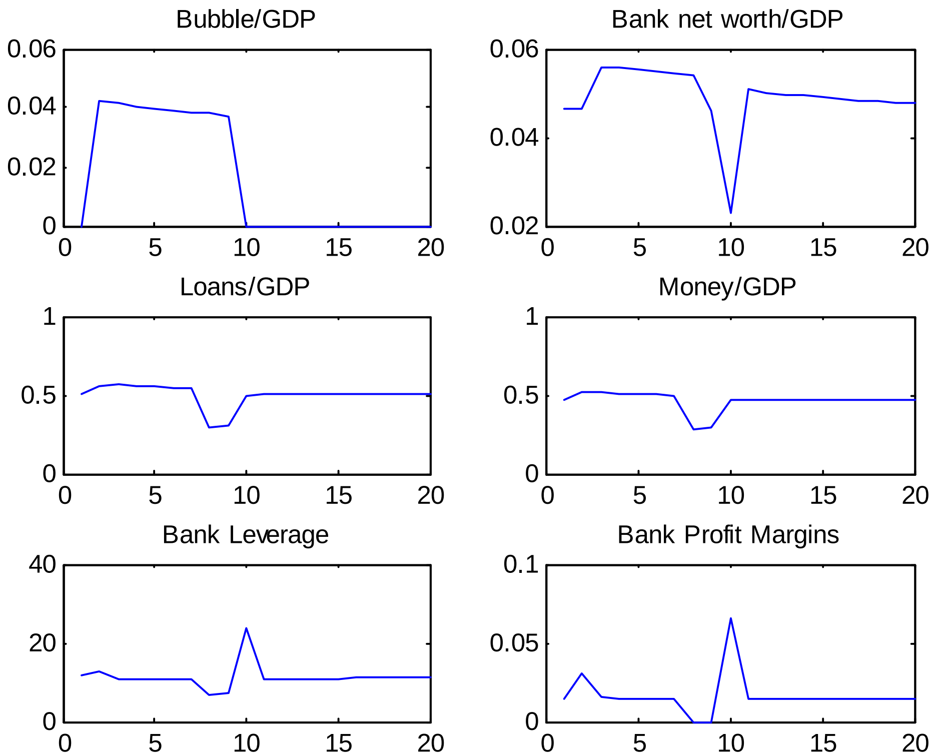

Figure 8b: Evolution of financial variables in a boom in non-bank lending