Bank Capital, Housing and Credit Constraints [1]

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This paper integrates household financing frictions with bank financing frictions and housing price fluctuations in a dynamic stochastic general equilibrium model. To our knowledge this is the first macroeconomic model to study this link. We use a 2 sided costly default framework in which the bank cannot fully diversify shocks to its borrowers to study the link between household and bank sectors' financial distress levels. The cyclical behaviour of the cost of the bank-depositors financing friction is determined by two main factors. On one hand, booms improve the financial health of the banks' borrowers which tends to reduce the cost of bank funding. On the other hand, consumption smoothing by savers and borrowers during booms increases the proportion of external financing in the banks' balance sheet which tends to increase the cost of bank funds. As a result of these opposing effects, the model matches procyclical profits and countercyclical leverage in the financial sector, as observed in the data, but the banking frictions in the model have an insignificant impact on the main macroeconomic aggregates such as output, consumption and investment. The other

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contribution of the paper is to develop a highly tractable model of households credit constraints with equilibrium default. The framework allows us to highlight a new mechanism for generating countercyclical external finance premia and default rates. In particular, consumption smoothing by borrowers limits the response of borrowing to movements in asset values and wages, generating countercyclical default rates.

1 Introduction

This paper develops a DSGE model of the interaction between financing frictions facing households and financial intermediaries. The 2008 financial crisis in the US and the UK as well as earlier financial crisis in Scandinavia and Japan in the early 1990's suggest the potential usefulness of building a quantitative framework to study the links between financial sector and household balance sheets. The usefulness of such a model is also supported by reduced form empirical evidence that loan rates may depend on the health of financial intermediaries' balance sheets and that housing wealth has a significant impact on consumption and debt levels[4]. Of course reduced form evidence may easily confound correlation and causality due to omitted variables bias. In particular because the financial health of banks and borrowers tends to be positively correlated, it is hard to tell for example if loans from banks in poor financial health are more expensive due to the state of the banks' balance sheets or the financial weakness of its borrowers. This makes it desirable to complement the existing evidence and ultimately base the analysis on a structural economic model. The main questions are:1. can we build a tractable DSGE framework to study this? 2. What is the quantitative importance of the interaction between household and bank balance sheets?

Following several recent DSGE models (starting with Kiyotaki and Moore 1997[33] and Iacoviello 2005[26]) our model features borrowers and savers distinguished by differences in their degree of impatience and limited enforcement frictions. This generates equilibrium lending with collateral. Our model adds bankers as the only agents in the economy capable of evaluating and monitoring loans to households. Banks finance impatient borrowers through debt contracts collateralised by borrower housing and wage income. We make three key assumptions. First, a borrower's collateral is subject to shocks. This provides borrowers with incentives to default on their loan repayments in bad states, requiring costly loan enforcement by the bank. Second, banks cannot fully diversify the shocks to their loan portfolios resulting from the shocks to borrower collateral, due to the need to specialize in a segment of borrowers. As a result they cannot guarantee depositors a safe rate of return. Because of asymmetric

[4] For examples of evidence on the effect of bank capital on loans see Hubbard et al (2002)[25], Peek and Rosengren(2000)[41] and Carlson et al (2008)[11]. For empirical evidence suggesting a strong effect of house prices on consumption and debt see Dynan and Kohn(2007)[18], Iacoviello and Minetti(2008)[27] and Case et al (2005)[13].

information about the realisation of bank loan revenues, the banks themselves would have an incentive to misreport their revenues and not repay depositors without some form of monitoring. This is where the third assumption comes into play: banks belong to a deposit insurance scheme that can monitor and enforce deposit repayments and diversify the loan portfolio risk of banks[5]. However these monitoring costs make deposits a relatively costly source of loan financing in comparison to the banks' own net worth (bank capital in the model).

These assumptions generate a potentially positive link between the default rates of borrowing households and banks. In combination with countercyclical borrower default rates, this can in theory amplify business cycle fluctuations. At the same time the desire to smooth consumption by borrowers and savers tends to make the deposits to loans ratio procyclical. This raises (lowers) the bank's leverage in a boom (recession), which increases (decreases) the financing frictions between the bank and depositors and tends to dampen fluctuations[6].

We solve the model and find that the effect of consumption smoothing by borrowers and savers dominates, and the overall effect on the extra cost of bank funding is small. This allows us to reproduce the empirical evidence of a procyclical bank leverage ratio and procyclical bank profits, but the impact of bank capital fluctuations on non-bank aggregates is insignificant. Thus, the financial friction modeled in this paper cannot rationalise claims that procyclical financial sector leverage amplifies fluctuations or that bank capital matters in response to shocks that are exogenous to the banking sector.[7] On the contrary, bank financing frictions dampen output fluctuations slightly due to the consumption smoothing effect on leverage. There are several caveats to the irrelevance of bank capital result. First, this version of the paper only examines linear approximations to the model's dynamics. It is quite possible that the effect of banking on output fluctuations is nonlinear, with stronger effects occurring for bigger shocks. Given the tractability of the model, this should be easy to explore using higher order perturbation approximations as in Schmitt-Grohe and Uribe (2004)[23]. We intend to pursue this direction in a future version of the paper. Second, in keeping with most of the litterature on financing frictions in DSGE models we do not have any maturity mismatch in banks' balance sheets. Third, while we allow for asymmetric information about the outcome of loans, we assume perfect information on the stochastic process of the shocks affecting the loans. Finally, we assume that financing frictions only affect household sec-

[5] Though we frequently refer to banks and call the intermediaries in the model bankers, the link between default rates on loans and on financial sector liabilities should be relevant to other financial intermediaries as long as these intermediaries provide some form of repayment guarantees to savers based on a portfolio of loans(e.g mortgage backed securities).

[6] This effect is similar to but different from the banking attenuator effect found by Goodfriend and McCallum(2007)[21] in a DSGE model of banking with a reduced form loan production function. There, The attenuation effect of banking on aggregate fluctuations was produced by a deposits in advance constraint on consumption that increased demand for deposits in booms. The effect that we find does not rely on modeling the inside money role of bank deposits.

[7] This does not exclude the possibility that bank financing frictions may matter for model dynamics in response to exogeneous shocks to the costs of monitoring banks, but the exogeneity of such a shock is doubtful.

tor borrowing. Meh and Moran (2008)[38] find significant effects of bank capital dynamics on output responses in a model where financing frictions affect capital producing firms. This suggests that results may be different in a version of the model where a subset of firms also faces similar credit constraints.

In addition to studying the interaction of bank and household financial distress, the paper develops a highly tractable alternative framework to study the effects of household credit frictions in DSGE models that allows for equilibrium default while preserving the assumption of risk averse/consumption smoothing households and banks, in contrast to the risk neutral borrowers in Bernanke, Gertler and Gilchrist (henceforth BGG1999)[7] and in the Holmstrom Tirole model (1997)[24]. This should make the analysis easier to compare to standard business cycle models, as well as providing potentially more realistic and less extreme borrower asset dynamics than those obtained in previous models with risk neutral agents. Furthermore, it may eventually allow us to examine the effects of precautionary savings on borrowers and banks by using higher order approximations of the model's dynamics. Naturally this tractability comes at a cost: we use a large family insurance arrangement as in Lucas (1990)[32] or Shi (1997)[43] to facilitate aggregation. We see this as a useful assumption at least as a first step, while acknowledging the value of eventually studying these issues in a more realistic heterogenous agent model.

By preserving the assumption of risk averse borrowers, the model develops a new mechanism for explaining the countercyclicality of external finance premia. Consumption smoothing by borrowers reduces fluctuations in their desired loan size relative to fluctuations in the value of collateral. The resulting countercyclicality in leverage translates into countercyclical default rates and external finance premia. Note that a similar argument could be made for financially constrained firms: the desire to smooth dividends or entrepreneur consumption can help generate a countercyclical firm level external finance premium.

Our model of banks is inspired by several theoretical papers that emphasize the effect of limited bank loan diversification and the ability of bank capital to reduce asymmetric information frictions between banks and depositors(See for example Williamson (1986) [48],Winton (1995)[49], Krasa and Villamil (1992)[35], Valencia (2006)[47]). Williamson (1986) shows how an intermediated lending arrangement using banks can reduce loan monitoring costs if the bank can diversify away idiosyncratic loan risks. Krasa and Villamil (1992) show that even with imperfect loan diversification and monitoring costs that are increasing in the size of the bank intermediated lending can be more efficient in terms of overall monitoring costs than direct lending. Winton (1995) shows how in the presence of imperfect loan risk diversification, bank capital can reduce information frictions between the bank and depositors. The main competitor to the asymmetric information framework is Holmstrom and Tirole's bank capital model (1997)[24] and its extensions to a DSGE framework (Meh and Moran 2007[37],2008[38] and Aikman and Paustian 2006[2]), where bank capital plays a role of giving the bank incentives to monitor firms before their returns are realised. The Holmstrom and Tirole story may be relevant for firm level credit frictions but it is hard to apply to households: it is plausible that banks implicitly monitor the efforts of businesses to ensure they can repay the loans through the terms of the loan for example or through monitoring of firms' transactions accounts held at the banks. However, one does not observe financial intermediaries monitoring the effort of households to improve their probability of repaying the loan. Instead, it seems more realistic to focus on borrower monitoring and contract enforcement when the borrower is in financial distress and cannot fully repay the loan.

Models of bank capital that use the Holmstrom-Tirole model find that bank capital movements can amplify fluctuations, though the quantitative importance of the effect is sensitive to other features of the model[8].

Our paper is also related to the literature on household financing frictions in DSGE models. Most of the literature follows Kiyotaki and Moore (1997)[33] and Iacoviello (2005)[26] in using a combination of differences in household impatience rates in combination with hard borrowing constraints using housing as collateral. These models have found an important role of household borrowing constraints in business cycle dynamics(see for example Iacoviello and Neri (2008)[28] and Monacelli (2008)[40]). In contrast to our framework, these papers assume an always binding hard borrowing constraints in their analysis of shocks. The soft borrowing constraint that we use, where interest rates increase smoothly in the size of the loan, is more likely to bind even for larger shocks than the hard borrowing constraint. In addition, it allows us to realistically incorporate time varying leverage ratios for households. [9]Recent extensions of Iacoviello's model such as Gerali et al(2008)[20] and Andres and Arce (2008)[3] include a non trivial role for banks, but they focus on other issues ,such as the role of imperfect competition in banking or the role of rigid loan interest rates, and ignore bank capital.

The next section develops the model used in the paper. Section 3 presents the numerical results obtained with the model, and section 4 concludes.

2 The model

The model consists of the following agents:

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[8]Aikman and Vlieghe(2004) [1]find a very small contribution of bank capital movements to output fluctuations, while Meh and Moran (2008)[38] find a larger contriubtion.

[9]The only other framework allowing for equilibrium default of households in a DSGE model with aggregate shocks is the model of Aoki et al(2004)[4]. They adapt the BGG framework to housing by positing the existence of a special class of risk neutral home owners that rent housing to households. The financing frictions in their model apply to these risk neutral home owners (the equivalent of entrepreneurs in BGG) as opposed to the risk averse households. In order to model an effect of housing wealth on household consumption they are forced to adopt an ad-hoc dividend payment rule between home owners and households as well as assuming rule of thumb consumers that simply consume all their wealth each period.

Finally there is an emerging heterogeneous agent litterature modeling housing collateralised loans in general equilibrium(see for example Silos(2005)[44] and Iacoviello and Pavan(2008)[29]) using hard borrowing constraints. These models provide a much richer picture of the interaction of aggregate shocks and credit constraints by allowing for a non-degenerate distribution of assets, but they're much harder to solve and it may be difficult to extend them to allow for other modeling features.

- patient households with a relatively high discount factor that lend to banks and own all non financial firms in the economy.
- impatient households with a lower discount factor that borrow from banks to finance housing and consumption subject to financing frictions.
- bankers that take deposits from patient households and lend to impatient households subject to financing frictions with respect to depositors.
- perfectly competitive producers that use labour and capital to produce final output,owned by the patient households.
- housing producers who transform final output into housing subject to housing investment adjustment costs, owned by the patient households.

2.1 Household Sector

There is a measure 1 of households, with θ_s patient savers and $\theta_{bo} = 1 - \theta_s$ impatient borrowers.

2.1.1 Patient Agents (savers)

Patient households have a relatively high discount factor, and they have access to complete financial markets without any financing constraints. They provide deposits to banks. These savers can costlessly diversify any repayment risk from an individual bank's deposits among themselves. In addition they own all firms in the economy

The representative saver picks sequences of consumption, working hours, housing and deposits at the bank $\{c_t^s, n_t^s, h_t^s, d_t\}$to maximise

$E_0 \Sigma_{t=0}^{\infty} \beta^t \left[\ln c_t^s + \xi_h \ln h_t^s + \xi_n \ln(1 - n_t^s)\right]$

subject to a sequence of constraints

$c_t^s + q_t[h_t^s - (1 - \delta_h)h_{t-1}^s] + d_t = R_t d_{t-1} + w_t n_t^s + \Pi_t^h + \Pi_t$.

where Π_t^h are profits from the housing producers and Π_t are profits from the final output producers.

The first order conditions for the saver are standard:

$$\begin{aligned} d_t &: \frac{1}{c_t^s} = \beta E_t \frac{1}{c_{t+1}^s} R_{t+1} \\ h_t^s &: q_t \frac{1}{c_t^s} = \frac{\xi_h}{h_t^s} + \beta E_t \frac{1}{c_{t+1}^s} q_{t+1}(1 - \delta_h) \\ n_t^s &: \frac{\xi_n}{1 - n_t^s} = \frac{1}{c_t^s} w_t. \end{aligned}$$

2.1.2 Impatient Agent (borrowers)

Impatient households have the same intra-period preferences over housing,consumption and leisure as patient households. They are risk averse, and have a lower discount factor than lenders(patient households): $\beta^{bo} < \beta$. The higher discount rate means that impatient households will be borrowers in a neighbourhood of the steady state. In fact, absent any frictions their borrowing would be unbounded in the steady state. Financing frictions make borrowing l_t bounded.

In addition to their wage income, their only other asset is housing valued at $(1-\delta_h)q_t h_{t-1}^{bo}$. Borrowers belong to one of a measure 1 continuum of population segments, each of measure $\theta^{bo} \equiv 1-\theta^s$. Each segment is served by a continuum of banks. Each bank is specialized and can only lend to one segment.

Borrowers' incomes and housing stock values are subject to segment specific shocks ε_t that are i.i.d across segments and across time. Clearly, financial intermediaries are not so specialized in the real world. However, the assumption used here is a tractable starting point for capturing the fact that bank loan portfolios are imperfectly diversified-an assumption that will be essential in motivating financial frictions on the funding side of banks and linking them to borrower-bank financing frictions[10].We assume that ε_t has a CDF $F(\varepsilon_t)$ with $F'(\varepsilon_t) = f(\varepsilon_t)$. Defining total assets A_t as the sum of the value of the borrower's house and his wage income, we have $A_t = \varepsilon_t[q_t(1-\delta_h)h_{t-1}^{bo} + n_t^{bo}w_t]$[11]. For future reference it is useful to define the expected value of assets conditional on the time t aggregate shocks as $\bar{A}_t = q_t(1-\delta_h)h_{t-1}^{bo} + n_t^{bo}w_t$, with $A_t = \varepsilon_t\bar{A}_t$. Lending in this economy is only possible through 1-period debt contracts that require a constant repayment $R_t^l l_{t-1}$ independent of ε_t.

The borrower can default and refuse to repay the debt. Savers cannot force borrowers to repay. Instead lending must be intermediated by banks that have an enforcement technology allowing them to seize collateral $\varepsilon_t[(1-s_h)q_t(1-\delta_h)h_{t-1}^{bo} + (1-s_w)n_t^{bo}w_t] = \varepsilon_t\tilde{A}_t$ at a cost $\mu\varepsilon_t\tilde{A}_t$ when the borrower defaults. $0 < \mu < 1$ determines the deadweight cost of default, $0 < s_w \leq 1$ and $0 < s_h \leq 1$ represent wage income and housing exemptions respectively. Realistic exemptions for housing are discontinuous and cannot be handled by standard perturbation methods, and it isn't clear yet how to set s_h to take them into account. Therefore, all the results that we report assume $s_h = 0$.In contrast we will vary s_w to reflect various wage garnishment rates. Conditional on enforcement, the law cannot prevent the bank from seizing all of $\varepsilon_t\tilde{A}_t$. Suppose first that the borrower does not have access to any insurance against the ε_t shock. Whenever $\varepsilon_t < \bar{\varepsilon}_t$ the borrower prefers to default and lose $\varepsilon_t\tilde{A}_t < R_t^l l_{t-1} = \bar{\varepsilon}_t\tilde{A}_t$ when the bank enforces the contract. On the other hand when

[10] To justify the use of banks in order to process loans to borrowers,we can assume that borrowers are also subject to idiosyncratic borrower specific shocks ω_t, but these shocks can be diversified across each segment, and banks have the ability to costlessly enforce a constant loan repayment regardless of the realisation of ω_t. Since borrowers inside the segment can in fact diversify away the differences in ω_t they will be able to make a fixed payment despite a low realisation of ω_t. The reduction in loan monitoring costs obtained by the diversification of this borrower specific shock can justify the use of banks instead of direct lending between savers and borrowers.

In contrast we assume that banks cannot force borrowers to make a constant repayment regardless of the value of the segment specific ε_t.

[11] The assumption that the shock is common to both the housing stock and and wage income simplifies the model substantially. See Jeske and Krueger(2005)[31] for evidence on regional shocks to the value of housing and another model where the stock of housing of borrowers is subject to shocks.

$\varepsilon_t \geq \bar{\varepsilon}_t$ the borrower prefers to pay $R^l_t l_t$ rather than lose $\varepsilon_t \tilde{A}_t \geq R^l_t l_t$. This implies that the net worth of the borrower after any loan repayment or default is $A_t - \min[\varepsilon_t, \bar{\varepsilon}_t]\tilde{A}_t$[12][13]. Note that we have allowed loan rates to depend on the aggregate state on the economy as in BGG[7]. This reduces the costs of default in the model. In reality loan rates are not perfectly indexed to the aggregate state of the economy, though it may be possible to partially renegotiate payments for some borrowers to avoid default. We view our assumption on loan rates as a useful benchmark that may be relaxed in future work[14].

To be able to use a representative agent framework while maintaining the intuition of the default rule above, we assume that borrowers belong to a large family that can costlessly pool their assets and diversify away the risk related to ε_t after loan repayments are made. As in Lucas (1990)[32] and Shi (1997)[43], the family maximises the expected lifetime utility of borrowers with an equal welfare weight for each borrower. The payments from the insurance scheme cannot be seized by the bank. As a result, despite the insurance the bank cannot force the borrower to repay $R^l_t l_{t-1}$ when $\varepsilon_t < \bar{\varepsilon}_t$. Like the individual borrowers, the insurer cannot commit to always repay the loan(or make up for any lack of payment by a borrower), even though from an ex-ante perspective it is optimal to do so. Ex-post, from the perspective of maximising the expected welfare of the borrowers, for any given R^l_t it is optimal to have borrowers with $\varepsilon_t < \bar{\varepsilon}_t$ default and borrowers with $\varepsilon_t \geq \bar{\varepsilon}_t$ repay $R^l_t l_{t-1}$. By pooling the borrowers' resources, the insurer can then guarantee every borrower a total wealth of $\bar{A}_t - [(1 - F(\bar{\varepsilon}_t))\bar{\varepsilon}_t + \int_0^{\bar{\varepsilon}_t} \varepsilon dF]\tilde{A}_t = \bar{A}_t + H(\bar{\varepsilon}_t)\tilde{A}_t$. To do this, it provides each borrower with a payout equal to $\bar{A}_t - A_t + (H(\bar{\varepsilon}_t) + \min[\varepsilon_t, \bar{\varepsilon}_t])\tilde{A}_t$ (an insurance premium when this expression is negative)[15].

Define the rate of return required by the bank on loans made at $t-1$ as $\bar{R}_t$. We assume that banks have access to an inter-bank insurance scheme that allows them to diversify the segment specific shock ε_t among themselves. Therefore, each bank only requires that the loan is profitable in expectation. In or-

[12] Here, we could have assumed that ε_t is the private information of the borrower but can be observed at a cost $\mu\varepsilon_t\tilde{A}_t$ by the bank. Assuming that the bank can commit to monitoring ex-post, we could then derive debt as the optimal contract. We chose not to take this route because it is not as plausible when ε_t is common to the bank. Instead, like other papers modeling equilibrium default(e.g Chaterjee et al.(07)[14], Livshits et al 06[36], Meh and Terajima 08[39]), we take the use of a debt contract for household lending as given and focus on exploring its general equilibrium implications

[13] As in BGG, we will assume that the derivative of $\frac{\bar{\varepsilon} f(\bar{\varepsilon})}{1-F(\bar{\varepsilon})}$ is positive. This will be true over the range that is relevant for the optimal $\bar{\varepsilon}$ when ε follows a lognormal distriubtion.

[14] With direct intermediation of loans, banks may have a strong incentive to renegotiate loans to avoid costly default. Even with indirect loan intermediation (e.g through mortgage backed securities) it may still be possible to renegotiate some loans to avoid default. Therefore allowing some dependence on loan rates on the aggregate state is not unreasonable. What is not so obvious is how to model this partial dependence of the loan rate on the aggregate state(as opposed to the extremes of full or no dependence).

[15] The insurer can enforce this default rule on borrowers by seizing any assets left to a deviating agent. This punishment scheme makes it optimal for borrowers' default decisions to follow the insurer's recommendation. In addition it clearly satisfies the the insurer's budget constraint that positve insurance payments not exceed insurance premia.

der to participate in the loan, the bank requires that $[1-F(\bar{\varepsilon}_t)]\,R_t^l l_{t-1} + (1-\mu)\int_0^{\bar{\varepsilon}_t} \tilde{A}_t \varepsilon dF = [1-F(\bar{\varepsilon}_t)]\,\bar{\varepsilon}_t \tilde{A}_t + (1-\mu)\int_0^{\bar{\varepsilon}_t} \tilde{A}_t \varepsilon dF \geq \bar{R}_t l_{t-1}$.[16] Competition among banks will make this constraint bind. The bank's break-even constraint is the borrowing constraint in this model, in contrast to the strict borrowing constraint assumed in models with no equilibrium default(such as Kiyotaki and Moore97)[33]. Defining $G(\bar{\varepsilon}_t) = [1-F(\bar{\varepsilon}_t)]\bar{\varepsilon}_t + (1-\mu)\int_0^{\bar{\varepsilon}_t} \varepsilon dF$, we can rewrite the bank participation constraint as $G(\bar{\varepsilon}_t)\tilde{A}_t = \bar{R}_t l_{t-1}$.

The representative borrower picks sequences of consumption,housing, loans, labour supply and default threshold functions $\left\{c_t^{bo}, h_t^{bo}, l_t, n_t^{bo}, \bar{\varepsilon}_t\right\}_{t=0}^{\infty}$

to maximise

$E_0 \Sigma_{t=0}^{\infty} \beta^{bo^t}\left[\ln c_t^{bo} + \xi_h \ln h_t^{bo} + \xi_n \ln(1-n_t^{bo})\right]$

subject to a sequence of budget constraints

$c_t^{bo} + q_t h_t^{bo} = q_t(1-\delta_h)h_{t-1}^{bo} + n_t^{bo} w_t + H(\bar{\varepsilon}_t)[(1-s_h)q_t(1-\delta_h)h_{t-1}^{bo} + (1-s_w)n_t^{bo} w_t] + l_t$

and the participation constraints of the bank $G(\bar{\varepsilon}_t)\ [(1-s_h)q_t(1-\delta_h)h_{t-1}^{bo} + (1-s_w)n_t^{bo} w_t] = \bar{R}_t l_{t-1}$

At an optimum $G'(\bar{\varepsilon}_t) > 0$. As a result, one can solve for a function $\bar{\varepsilon}_t(\frac{\bar{R}_t l_{t-1}}{\tilde{A}_t})$ with $\bar{\varepsilon}_t'(\frac{\bar{R}_t l_{t-1}}{\tilde{A}_t}) > 0$. Therefore, the default rate is increasing in the beginning of period household leverage ratio.

The optimality conditions for the borrower are:

$$
\begin{aligned}
l_t &: \quad \frac{1}{c_t^{bo}} = \beta^{bo} E_t \psi_{t+1} \bar{R}_{t+1} \\
h_t^{bo} &: \quad \frac{1}{c_t^{bo}} q_t = \frac{\xi_h}{h_t^{bo}} + \beta^{bo} E_t \left[\frac{1}{c_{t+1}^{bo}} + (1-s_h)[\psi_{t+1} G(\bar{\varepsilon}_{t+1}) + \frac{H(\bar{\varepsilon}_{t+1})}{c_{t+1}^{bo}}]\right] q_{t+1}(1-\delta_h) \\
n_t^{bo} &: \quad \frac{\xi_n}{1-n_t^{bo}} = \left[\frac{1}{c_t^{bo}} + (1-s_w)[\psi_t G(\bar{\varepsilon}_t) + \frac{H(\bar{\varepsilon}_t)}{c_t^{bo}}]\right] w_t \\
\bar{\varepsilon}_t &: \quad \psi_t = -\frac{H'(\bar{\varepsilon}_t)}{c_t^{bo} G'(\bar{\varepsilon}_t)}
\end{aligned}
$$

where ψ_t is the Lagrange multiplier on the bank's break-even constraint.

Note that using the first order condition for $\bar{\varepsilon}_t$, we can rewrite the first order conditions as:

[16] Note that with aggregate shocks, the borrower would prefer to get some insurance by having a lower $\bar{R}_t$ in a recession, in exchange for accepting a higher $\bar{R}_t$ in a boom. Computing the optimal risk sharing between risk averse depositors, bankers and borrowers is a difficult task. We follow the standard assumption in the litterature by ignoring these optimal risk sharing considerations and assuming that $\bar{R}_t$ is only a function of the risk free rate and the additional marginal cost of loans due to frictions between bankers and depositors.

$$\frac{1}{c_t^{bo}} = \beta^{bo} E_t \frac{1}{c_{t+1}^{bo}} \left(-\frac{H'(\bar{\varepsilon}_{t+1})}{G'(\bar{\varepsilon}_{t+1})}\right) \bar{R}_{t+1} ,$$

$$\frac{1}{c_t^{bo}} q_t = \frac{\xi_h}{h_t^{bo}} + \beta^{bo} E_t \frac{1}{c_{t+1}^{bo}} \left[1 + (1 - s_h)[H(\bar{\varepsilon}_{t+1}) - \frac{H'(\bar{\varepsilon}_{t+1})}{G'(\bar{\varepsilon}_{t+1})} G(\bar{\varepsilon}_{t+1})] \right] q_{t+1}(1 - \delta_h) \text{ and}$$

$$\frac{\xi_n}{1 - n_t^{bo}} = \left[1 + (1 - s_w)[H(\bar{\varepsilon}_t) - \frac{H'(\bar{\varepsilon}_t)}{G'(\bar{\varepsilon}_t)} G(\bar{\varepsilon}_t)] \right] \frac{w_t}{c_t^{bo}}.$$

There are several important observations that can be made from these equations. First, in a deterministic steady state the first equation is only a function of the steady state $\bar{\varepsilon}$. This makes computation of the steady state relatively easy as in BGG's[7] framework. Next, $EFP_t = -\frac{H'(\bar{\varepsilon}_t)}{G'(\bar{\varepsilon}_t)} > 1$ is the the external finance premium faced by borrowers on loans. $EFP_t'(\bar{\varepsilon}_t) > 0$, which makes it countercyclical as long as the default threshold $\bar{\varepsilon}_t$ is countercyclical. The response of the default threshold to a shock is governed by $\bar{\varepsilon}_t'(\frac{\bar{R}_t l_{t-1}}{\bar{A}_t}) > 0$. On impact, with l_{t-1} and h_{t-1}^{bo} predetermined, any positive shock which increases wages,labour supply and house prices will reduce the default rate and lower the external finance premium. The effect of the positive shock in the next periods depends on how borrowers adjust loan demand and housing in response to the shock. In a model with risk neutral households, loan demand would probably increase so much that a positive shock may ultimately lead to a higher default rate (see Covas and Den Haan (2007)[16] for a good discussion of this point in the case of financially constrained firms). But with a diminishing marginal utility of consumption, this does not have to be the case. In a neighbourhood of the steady state the existence of a soft borrowing constraint makes the impatient household behave more like the consumption smoothing patient household with a bias towards debt financed consumption instead of saving. For a fixed level of financial frictions and desired housing, a consumption smoothing borrower reacts to an increase in wealth by increasing savings(since savings are negative given his impatience, he reduces borrowing). At the same time an increase in the value of collateral encourages higher borrowing. For plausible calibrations the first effect dominates, and the loan to assets ratio $\frac{\bar{R}_t l_{t-1}}{\bar{A}_t} = \frac{\bar{R}_t l_{t-1}}{q_t h_{t-1} + n_t^{bo} w_t}$ is countercyclical. This makes the external finance premium countercyclical beyond the initial impact of a shock[17].

The Euler equation for housing shows how the value of investing in housing increases due to its collateral role while at the same time decreasing due to the monitoring costs attached to it in bad borrower states. The labour supply equation shows how the financial friction distorts the borrower's labour supply decision. For a given default rate, the financing friction affects labour supply indirectly by changing the sensitivity of labour supply to $\frac{w_t}{c_t^{bo}}$ and by affecting c_t^{bo}.

[17] With uncertainty, one also has to take into account precautionnary saving which generates movements in saving in the opposite direction to those motivated by consumption smoothing. But for the typical level of aggregate flucutations, the consumption smoothing motive should dominate(in fact the linear approximation of the model omits any precautionnary savings effect).

The level of financing frictions has a direct impact on labour supply through its effect on $H(\bar{\varepsilon}_t) - \frac{H'(\bar{\varepsilon}_t)}{G'(\bar{\varepsilon}_t)} G(\bar{\varepsilon}_t)$ for a given $\frac{w_t}{c_t^{bo}}$. Taking the derivative of this expression with respect to $\bar{\varepsilon}$ and using $\frac{d}{d\bar{\varepsilon}}(\frac{\bar{\varepsilon} f(\bar{\varepsilon})}{1-F(\bar{\varepsilon})}) > 0$, we see that $H(\bar{\varepsilon}_t) - \frac{H'(\bar{\varepsilon}_t)}{G'(\bar{\varepsilon}_t)} G(\bar{\varepsilon}_t)$ is increasing in $\bar{\varepsilon}_t$. Therefore, the direct impact of higher financing frictions is to increase the work effort of borrowers, essentially in order to maintain their living standards with higher financing costs. A reduction in financing frictions will therefore lower borrowers' labour supply, holding everything else constant. This effect disappears when labour income is fully exempt. In that case, labour supply is determined by the same equation as patient households' labour supply.

2.2 Banks

We introduce bankers separately from households, since one cannot really have financing frictions between identical depositors and banks if those very same depositors own the banks[18]. We restrict financial arrangements between banks and depositors to 1 period contracts. Our model of the financing friction between banks and depositors is similar to Townsend's (1979)[46] and Krasa and Villamil's (1992)[35] costly state verification framework. Without loss of generality, assume that there is a measure 1 of ex-ante identical banks at the beginning of period t. Bankers pick loan supply, deposit demand and consumption to maximise their lifetime expected utility.

Bankers take the expected rate of return on loans and the risk free rate earned on deposits as given and maximise expected life time utility by picking consumption(the dividend), loan supply and deposit demand in each period. We assume that deposits take the form of 1 period debt contracts with that guarantee depositors a repayment of $R_t \theta^s d_t$. Recall that in order be able to enforce loan contracts against borrowers, a bank must specialize in a specific segment of borrower, exposing it to a common shock to borrowers ε_t. Therefore, it cannot guarantee depositors a constant deposit repayment. The segment specific shock ε_t is the private information of banks serving the segment. Without any monitoring mechanism banks would have an incentive ex-post to claim that their revenues were too low and that they cannot repay deposits. However, banks belong to a deposit insurance scheme that can guarantee depositors the risk free repayment. The deposit insurer has access to a monitoring technology that allows it to verify a bank's assets A_t^b at a cost $\mu_b A_t^b$ and seize A_t^b. In addition we assume that banks belong to an inter-bank insurance arrangement that can diversify the shocks to their profits and guarantee each bank the same ex-post profit at no cost. Like the borrowers with respect to bank loan repayments, banks can hide any gains from this second insurance arrangement from the deposit insurer. The bank's revenue is $\theta^{bo} \bar{\varepsilon}_t \tilde{A}_t$ when $\varepsilon_t \geq \bar{\varepsilon}_t$ and $\theta^{bo} \varepsilon_t \tilde{A}_t$ when $\varepsilon_t < \bar{\varepsilon}_t$. Defining $s_t \equiv \bar{\varepsilon}_t$ when $\varepsilon_t \geq \bar{\varepsilon}_t$ and $s_t \equiv \varepsilon_t$ when $\varepsilon_t < \bar{\varepsilon}_t$, the bank's revenue is $s_t \tilde{A}_t$. In non audited states incentive compatibility requires a

[18] We abstract from agency problems between bank managers and shareholders. The 2008 financial crisis has shown that a model addressing such agency problems may be be quite valuable, but this is beyond the scope of the current paper.

fixed repayment $R_t^d \theta^s d_{t-1} \equiv \hat{s}_t \tilde{A}_{t-1}$. Our assumption that the benefits of the inter-bank insurance arrangement cannot be committed to repay depositors implies that as in the standard costly state verification framework of Townsend (1979)[46] it is optimal to minimize the expected monitoring costs. To achieve this, the contract establishes a default threshold $\hat{s}_t$, such that the bank makes the fixed deposit repayment if $s_t > \hat{s}_t$ and repays $s_t \tilde{A}_t$ otherwise. In order for banks to be willing to serve as intermediaries between savers and borrowers, $\hat{s}_t$ must be lower than $\bar{\varepsilon}_t$. Otherwise banks would lose money on the loans. As a result the contract can also be seen as specifying a threshold $\hat{\varepsilon}_t$ such that the bank defaults whenever $\varepsilon_t < \hat{\varepsilon}_t < \bar{\varepsilon}_t$.

With the insurance scheme, and using $G(\bar{\varepsilon}_t)\tilde{A}_t = \bar{R}_t l_{t-1}$ each bank gets profits from loans(net of deposit repayments) of

$$\theta^{bo}[G(\bar{\varepsilon}_t) + H(\hat{\varepsilon}_t)]\tilde{A}_t = \theta^{bo}\left[1 + \frac{H(\hat{\varepsilon}_t)}{G(\bar{\varepsilon}_t)}\right]\bar{R}_t l_{t-1} \equiv \theta^{bo} H^b(\hat{\varepsilon}_t)\bar{R}_t l_{t-1}$$

Note that the bank takes $\bar{\varepsilon}_t$ as given when allocating its funds, therefore for the purpose of deriving the optimality conditions we can suppress the dependence of $H^b(.)$ on $\bar{\varepsilon}_t$.

Finally, depositors expect to break even on deposits:

$$\theta^{bo}\frac{G(\hat{\varepsilon}_t)}{G(\bar{\varepsilon}_t)}\bar{R}_t l_{t-1} \equiv \theta^{bo} G^b(\hat{\varepsilon}_t)\bar{R}_t l_{t-1} \geq \theta^s R_t d_{t-1}$$

,which is binding at an optimum. Defining the bank's capital as $\theta^{bo} l_t - d_t$ this constraint is the model's version of a market determined bank capital adequacy requirement.

Each banker picks sequences of consumption c_t^b, loans l_t , deposits d_t and $\hat{\varepsilon}_t$ to maximise

$$E_0 \Sigma_{t=0}^{\infty} \beta^{b^t} \ln c_t^b$$

subject to a sequence of constraints

$$\begin{aligned} c_t^b + \theta^{bo} l_t &\leq \theta^{bo} H^b(\hat{\varepsilon}_t)\bar{R}_t l_{t-1} + \theta^s d_t \text{ and} \\ \theta^{bo} G^b(\hat{\varepsilon}_t)\bar{R}_t l_{t-1} &\geq \theta^s R_t d_{t-1} \end{aligned}$$

The first order conditions of the banker are:

$$\begin{aligned} d_t &: \frac{1}{c_t^b} = \beta^b R_{t+1} E \psi_{t+1}^b \\ l_t &: \frac{1}{c_t^b} = \beta^b \bar{R}_{t+1} E_t \left(\frac{1}{c_{t+1}^b} H^b(\hat{\varepsilon}_{t+1}) + \psi_{t+1}^b G^b(\hat{\varepsilon}_{t+1}) \right) \\ \hat{\varepsilon}_t &: \psi_t^b = \frac{1}{c_t^b}\left(-\frac{H^{b\prime}(\hat{\varepsilon}_t)}{G^{b\prime}(\hat{\varepsilon}_t)} \right) \end{aligned}$$

where ψ_t^b is the multiplier on the depositor break-even constraint.

Note that just like for the borrowers we can replace ψ_{t+1}^b in the Euler equations for loans and deposits and get an external finance premium on deposits $efp_t^b = \frac{-H'(\hat{\varepsilon}_t)}{G'(\hat{\varepsilon}_t)}$, which is increasing in $\hat{\varepsilon}_t$. $\bar{R}_{t+1} - R_{t+1}$ represents the spread between the expected rate of return on the loan and on the deposits due to the bank financing frictions. Absent the enforcement problems between the bank and depositors we would have $\bar{R}_{t+1} = R_{t+1}$. We can get more insight into what affects this spread close to the steady state by linearizing and combining the bank's Euler equations for loans and deposits. To a first order approximation we have the following relation in terms of percentage deviations from the steady state:

$\bar{R}_{t+1} - R_{t+1} = aE_t\hat{\varepsilon}_{t+1} + bE_t\bar{\varepsilon}_{t+1}$, where $efp_t^{b\prime}(\hat{\varepsilon}_t) > 0$ implies that $a > 0$, and $b > 0$ for most reasonable calibrations of the steady state. This clearly shows the feedback between the default rates of banks and borrowers. Higher expected bank default rates raise $\bar{R}_{t+1} - R_{t+1}$ which for any given expectations on future borrower collateral values and any given loan raise expected borrower default rates, which in turn raise $\bar{R}_{t+1} - R_{t+1}$. However, this does not imply that $\bar{R}_{t+1} - R_{t+1}$ is countercyclical in general equilibrium because consumption smoothing by borrowers and lenders will tend to raise $\frac{d_t}{l_t}$ in a boom. This increases the financing frictions between banks and depositors and raises $E_t\hat{\varepsilon}_{t+1}$. As a result $\bar{R}_{t+1} - R_{t+1}$ may be procyclical.

2.3 Production

Housing is produced by a representative firm owned by the savers. The firm purchases I_t^h units of the consumption good from savers and turns it into $I_t^h = h_t - (1-\delta)h_{t-1}$ units of housing while paying an adjustment cost of $\frac{\gamma^h}{2}(\frac{I_t^h}{h_{t-1}} - \delta))^2 h_{t-1}$. Note that the firm takes the aggregate housing stock h_{t-1} as given when choosing I_t^h. With these assumptions, the housing producer's problem reduces to picking I_t^h

each period to maximise profits $\theta^s \Pi_t^h = (q_t - 1)I_t^h - \frac{\gamma^h}{2}(\frac{I_t^h}{h_{t-1}} - \delta_h))^2 h_{t-1}$.

The first order condition for housing supply is:

$$q_t = 1 - \delta_h\gamma^h + \gamma^h\frac{I_t^h}{h_{t-1}} = 1 - \gamma_h + \gamma_h\frac{h_t}{h_{t-1}}.$$

Note that in the steady state $q = 1$ and the housing producer makes no profits.

Final output is produced by perfectly competitive financially unconstrained firms using capital and labour. The firms are owned by savers. The representative firm produces

$y_t = z_t k_t^\alpha n_t^{1-\alpha}$,

where $z_t = e^{a_t}$ is an aggregate productivity shock, equal to 1 in the steady state.

$a_t = \rho a_{t-1} + e_t^z$, e_t^z follows a normal with mean 0 and standard deviation σ_z.

Firms pick sequences of capital and labour $\{k_{t+1}, n_t\}$ to maximise their present value

$$E_0 \Sigma_{t=0}^{\infty} \beta^t \frac{1}{c_t^s} [z_t k_t^{\alpha} n_t^{1-\alpha} - w_t n_t - (k_{t+1} - (1-\delta) k_t)].$$

The first order conditions for this problem are:

$$\begin{aligned} 1 &= \beta E_t \frac{c_t^s}{c_{t+1}^s} \left[1 + \alpha \frac{y_{t+1}}{k_{t+1}} - \delta \right] \\ (1-\alpha) \frac{y_t}{n_t} &= w_t. \end{aligned}$$

Given the importance of the labour market for the model's dynamics, we also solve a version of the model with capital adjustment costs of the same form as the housing adjustment costs in order to examine the effect of a less elastic labour demand curve.

We assume that savers own the capital producing firm. Profit maximisation by capital producers yields the supply curve
$q_t^k = 1 - \delta\gamma + \gamma \frac{I_t}{k_t}$.

Finally we also examine extensions allowing for variable capital utilisation rates and labour adjustment costs. Our main interest in adding these features is to see how modifications in the factors shifting labour demand affect the impact of financing frictions on the transmission of shocks. Variable capital utilisation u_t modifies the production function $z_t (u_t k_t)^{\alpha} n_t^{1-\alpha}$. As in Burnside and Eichenbaum(1996)[9] increasing capacity utilisation raises the depreciation of capital and modifies the capital accumulation equation to $k_{t+1} = I_t + (1 - \delta_0 u_t^{\phi}) k_t$.

We model labour adjustment costs as a quadratic function $\gamma_n (\frac{n_t - n_{t-1}}{n_{t-1}})^2 n_{t-1}$ as in Cooper and Willis(2006)[15].

3 Results

3.1 Calibration

We solve the model at a quarterly frequency. Since our main focus is on the model's dynamics in response to stationary shocks we abstract from long run growth and set $z = 1$ in the steady state. Table 1 provides a summary of our calibration. We use standard values from the real business cycle literature for most parameters that are not related to the financing frictions. These include

β, δ, δ_h,α and ρ. We set ξ_n and ξ_h to match a steady state work share of around $\frac{1}{3}$ and an annualized housing stock to output ratio of around 1.35, in line with the estimates for the US in Iacoviello and Neri (2008)[28].

γ is set to $0.25/\delta$ as in Bernanke, Gertler and Gilchrist (1999)[7]. There is much less evidence on the adjustment cost parameter for housing supply. We set $\gamma_h = 1$ based on the estimates in Topel and Rosen (1988)[45] on the short run elasticity of housing prices in the US. For the model with variable capital utilisation rates, the curvature of the cost of varying utilisation rates ϕ can be found from the steady state first order condition for u_t after setting $u = 1$ and $\delta = 0.02$ in the steady state. For the model with labour adjustment costs we use $\gamma_n = 2$ based on estimates in Cooper and Willis (2006)[15].

We set the share of patient agents $\theta_s = 0.65$ in line with the estimates in Iacoviello (2005)[26]. The impatient households' discount factor of 0.97 is in the middle of the range of estimates for poorer households who are more likely to be heavily in debt as reported in Iacoviello (2005)[26] and Cagetti (2003)[10]. There is little evidence on the cost of loan enforcement parameter μ for household loans. We use $\mu = 0.25$ as in Carlstrom and Fuerst (1997)[12], which is in the upper range of estimates used in firm level financial accelerator models, since we suspect that the losses in home foreclosures are higher than the costs for business default [19]. Since we have not found any direct evidence on μ_b we assume as a benchmark that $\mu_b = \mu$ and do sensitivity analysis with respect to μ_b/μ. Given μ and β^{bo} we calibrate σ to try to match a steady state annual household bankruptcy rate in the US of around 1% as reported in Athreya (2001)[5]. $\sigma = 0.12$ produces a steady state annual default rate of 1.27%. Again, the results reported below are not very sensitive to moderate changes in σ[20].

We set β^b to match a financial sector loans to bank capital ratio (the model's leverage ratio) of around 6 as reported in Greenlaw, Hatzius, Kashyap and Stein (2008)[22]. This is lower than the leverage ratio of around 7.15 used in Meh and Moran (2008)[38] or the ratio of 10 used in Aikman and Paustian (2006)[2]. We end up using a lower leverage ratio because we net out the assets and liabilities owed among different financial intermediaries. This is consistent with the model's definition of leverage which only includes the assets and liabilities of the banking sector with respect to the non-financial sector.

Finally, we examine two scenarios for the wage garnishment rate. The benchmark scenario treats wages like housing and sets $s_w = 0$. The second scenario examines the other extreme and sets $s_w = 1$.

Table 1:

[19] We have only recently become aware of a paper by Krueger and Jeske(2005) which reports a deadweight loss in foreclosure estimate of 0.22, based on comparing resale values of foreclosed properties with an estimate of their market value without foreclosure. Based on sensitivity analysis, we suspect that using $\mu = 0.22$ wouldn't have a significant impact on the results.

[20] We also and report some results for $\beta^{bo} = 0.98$, in which case we recalibrate $\sigma = 0.2$.

Parameter	Description	Value
β	Patient households' discount factor	0.99
β^{bo}	Impatient households' discount factor	0.97
β^{b}	Bankers' discount factor	0.9899
α	capital share	0.34
δ	capital depreciation rate	0.02
δ_h	housing depreciation rate	0.005
$\gamma_h\delta_h$	elasticity of q_t^h to I_t^h/h_{t-1}	1
$\gamma\delta$	elasticity of q_t to I_t/k_t	0.25
γ_n	labour adjustment cost parameter	2
ρ	persistence of tfp shock	0.95
ϕ	curvature of capital depreciation function	1.5051
ξ_n	weight of leisure in utility function	1.8
ξ_h	housing weight in utility function	0.12
θ_s	proportion of patient households	0.65
μ	enforcement cost parameter for households	0.25
μ_b	enforcement cost parameter for banks	0.25
σ	standard deviation of borrower segment specific shock	0.12
s_w	exemption level for wage income	0 or 1

3.2 Impulse Response Function Analysis

We linearize the model's equations around the deterministic steady state and solve the approximate model using a standard linear rational expectations algorithm (Klein 2000)[34].

We compare impulse response functions for 3 models: a standard RBC model with housing but without any financing frictions, a model with borrower-lender frictions but without any banking related financing frictions, and finally the full model with a role for bank capital.

We first consider the effect of a 1% increase in total factor productivity relative to the steady state. The responses of the RBC model without financing frictions to a temporary but persistent increase in total factor productivity are by now well documented. The only twist to the standard story is the addition of housing to the model. Without housing adjustment costs households at first reduce investment in housing in order to allow the firms they own to invest more in capital and to increase more valuable non durable consumption. Afterwards, as TFP converges back to the steady state value and the returns to investing in capital decline households start increasing investment in housing relative to the steady state. With adjustment costs, it no longer makes sense to first reduce investment housing and increase it later. Instead households increase their investment in housing gradually with a peak around 15 quarters after the shock.

Adding financing frictions for households dampens the response of output to the shock in the short run. On impact the rise in output is about 0.11% smaller with household financing frictions. However, the increase in output is slightly more persistent in the model with borrowing constraints. In fact if we simulate the response to the shock for a longer horizon, the increase in output relative to the steady state is larger in the model with credit constraints than in the standard RBC model after 57 quarters, but by then the original tfp shock has almost completely died out and the difference is very small. The credit constraints create a difference in the composition of the response to the shock. Consumption relative to the steady state increases significantly more than in the RBC model initially, but is lower than in the RBC model after 11 quarters. In contrast both investment in housing and capital increase by less than in the RBC model. Together with the smaller rise in labour supply this explains why output does not respond as much as in the model without financing frictions.

To understand these differences in more detail, we now examine the IRF's of borrowers and savers separately. For borrowers, the increase in wages makes external financing for a given level of borrowing less expensive. Since borrowers are credit constrained , their steady state consumption and housing stock is significantly below that of savers. As a result, they take advantage of the reduction in borrowing costs to sharply increase their non durable consumption and their stock of housing. The increase in demand for housing raises house prices which further relaxes the borrowing constraint of borrowers for a given wage. However, as productivity converges back towards its steady state level, wages go down which increases the cost of financing for a given level of borrowing. As a result, the rise in non durable consumption and housing investment by borrowers is strongest on impact and declines slowly over time. Meanwhile, given the role of wage income as collateral, the relaxation of the borrowing constraint reduces the value of working for borrowers. In combination with the strong wealth effect generated by the rise in consumption, this encourages borrowers to reduce labour supply. It should be noted that the actual decline in the external finance premium relative to the steady state is due to the fact that borrowers don't increase their demand for loans as fast as the increase in the value of their collateral. On impact, this is simply due to loans being predetermined. Afterwards, borrowers can adjust their loans but their desire to smooth consumption limits their demand for loans at a time when their current income is high relative to their permanent income.

For savers, the key difference in comparison to the RBC model is the extra consumption smoothing opportunity given by the presence of borrowers. As a result their deposits increase at the expense of lower housing investment and consumption. The lower increase in saver consumption also reduces the income effect on savers' labour supply, and as a result they work more than in the RBC economy. The analysis so far highlights two difficulties in amplifying exogenous shocks using household level credit frictions. First, to the degree that borrowing ability is positively linked to labour income (either because it serves as collateral or more generally because there are limits on borrowing related to income) and to the degree that borrowers' consumption is more responsive to shocks than that of savers, there may be strong income effects on borrower labour supply that dampen the change in labour supply in response to shocks. Second, the greater increase in consumption and housing investment by borrowers must be financed in general equilibrium by more modest increases (or even declines)in the consumption, housing and capital investment of savers if production does not increase sufficiently.

Overall, the effects of adding financing frictions on dynamics is modest if one only looks at aggregate consumption or output or investment. The financing frictions do have a large impact on the distribution of consumption and housing investment, with consumption and housing investment being much more procyclical for borrowers than for savers .

The addition of bank-depositor frictions has virtually no impact on aggregate output, investment, consumption and labour supply. The only perceptible effect is on bank and lending related variables. There is a modest increase in the deposits to loans ratio accompanied by a rise in bank profits, in line with the empirical evidence of procyclical financial intermediary leverage(see Adrian and Shin 08, Meh and Moran 07). On one hand, consumption smoothing by bankers and increasing bank profits would tend to decrease the deposits to loans ratio as bankers attempt to increase savings. At the same time consumption smoothing by savers tends to raise deposits, and consumption smoothing by borrowers means that despite the relaxation of the borrowing constraint borrowers don't increase their demand for loans by as much as savers increase their supply of deposits. The second effect dominates in equilibrium, and the bank's leverage increases. The banks' increasing reliance on external funding through deposits raises their external finance premium and the spread between $\bar{R}_{t+1}$ and R_{t+1} by a small amount.

One could argue that perhaps the result that bank depositor frictions don't matter for the main aggregate macroeconomic quantities is due to our assumption that the enforcement cost parameter of the bank $\mu_b = \mu$ of the borrower. But this result is robust to making $\mu_b > \mu$ (e.g. $\mu = 3\mu$) or $\mu_b < \mu$ (e.g. $\mu_b = \mu/3$)[21]. Finally one may argue that the weak effects of bank-depositor frictions is due to our calibration of the bank's discount factor which produces a very low steady state external finance premium for banks. To test this, we reset the bankers' discount factor to $\beta^b = 0.985$, generating an annual external finance premium for banks of 2% at the steady state. Even with this unrealistically high steady state difference between risk free rates and bank lending rates, the impulse responses for the model with bank-depositor frictions were indistinguishable from those of the model with only borrower-lender financing frictions.

In an attempt to reverse the declining labour supply of the borrowers, we examine a version of the model in which labour income is fully exempt from seizure by the bank. In this version of the model, labour income is no longer part of the loans's collateral. Therefore, a reduction in the costs of borrowing no longer directly encourages workers to reduce their labour supply. Borrowers'

[21] We also did sensitivity analysis to changes in the cost of auditing μ, the idiosyncratic volatility σ, the adjustment cost parameters for housing and capital γ_h and γ . The main conclusions reached in this section were robust to these perturbations.

labour supply now increases for the first 3 periods . It then declines relative to the steady state due to the strong income effect generated by the boom in borrower consumption, but by less than in the case without an exemption. The response of output is a bit stronger than in the case without exemptions, but the IRF's are otherwise very similar. Once again, the impact of adding bank-depositor frictions is minimal. Another factor that could affect the labour supply of borrowers is the degree of borrower impatience. Lower impatience reduce the optimal amount of borrowing and lowers the steady state external finance premium of borrowers. As a result the increase in borrowers' work effort due to financing frictions is smaller. We raised β^{bo} to 0.98 and recalibrated σ to match an annual default rate of around 1%. Now borrower labour supply increases in response to a positive tfp shock, but the increase is still much smaller than for savers.

Next we analyse the effect of a demand shock in the model. We use shocks to agents' discount factors to examine the model economy's response to demand shocks. The discount factor is now βb_t. Justiniano et al. (2006)[42] have shown the importance of allowing for such shocks to the model's Euler equations. If taken literally as random changes in the level of impatience, it is hard to interpret these shocks as structural which may cast some doubt on analysing them as exogenous. A possibly more structural interpretation is suggested by Browning and Tobacman (2007)[8] who show that changes in the impatience level are isomorphic to changes in agents' expectation about future paths of income: in particular one cannot use observations on consumption or saving to disentangle higher impatience from more optimistic expectations on future income. Under this interpretation the demand shocks in the model can be seen as temporary deviations from rational expectations due for example to overoptimistic forecasts of future productivity levels or future asset prices. As such, they can provide insight into the impact of the financial frictions in the model on the response to news shocks as in Jaimovich and Rebelo (2008)[30] or to asset price bubbles as in Bernanke and Gertler(2000)[6]. Similar to the productivity shock, the discount factor shock b_t equals 1 in the steady state and its percentage deviation from the steady state follows $\hat{b}_t = \rho_b \hat{b}_{t-1} + \varepsilon_t^b$, where ε_t is i.i.d and $0 < \rho_b < 1$. Following the estimation results of Justiniano and Primicieri we set $\rho_b = 0.83$. We assume that the preference shock is the same for bankers, borrowers and savers.

Like the typical RBC model our model cannot generate demand driven booms. In the version without financing frictions, an increase in b_t encourages agents to increase non durable consumption. However due to the wealth effect on labour supply, households reduce labour supply. Labour demand does not move on impact since productivity has not changed and capital is predetermined. As a result output falls, and non durable consumption crowds out investment in housing and capital. Despite the fact that the preference shock also increases in the relative utility of current housing, households prefer to increase non durable consumption at the expense of lower housing investment due to the lower utility weight of the housing stock. The reduction in investment sustains the decline in output despite the decline in b_t over time. Adding financial frictions on the household side reduces the decline in output significantly. The fall in housing investment relative to the steady state leads to a decline in house prices. This increases the external finance premium faced by borrowers despite the increase in wages. Holding the wealth effect from increasing non durable consumption constant, the increase in the cost of borrowing pushes borrowers to increase labour supply in the model without any labour income exemption. In addition, due to the increase in financing costs the increase in borrower consumption is smaller than that of the saver. This reduces the strength of the wealth effect for the borrower. In the model where labour income is exempt labour supply is no longer directly affected by the role of labour income as collateral, but the smaller increase in borrower consumption still reduces the wealth effect's negative impact on borrower labour supply. In both cases overall labour supply declines by less and therefore the decline in output is lower. Adding capital adjustment costs naturally reduces the crowding out of investment by non durable consumption. But now housing investment declines even more. Non durable consumption increases by less, reducing the fall in labour supply due to the wealth effect. In addition to the smaller decline in investment this results in a much smaller decline in output. The effect of borrowing frictions on some households is to reduce the fall in labour supply. Due to the greater decline in house prices and the smaller increase in wages the increase in external financing costs is larger and the borrower's labour supply actually increases.

The effect of financial frictions between banks and depositors is, as for TFP shocks, virtually non existent for non-banking related macroeconomic aggregates. The banks' deposits to loans ratio declines, mostly because savers reduce deposits to increase their consumption by more than the fall in borrowers loan demand. The higher external finance premium leads to a reduction in loans, but by less than the decline in deposits, due to the countervailing effect of borrowers' desire to consume more. The external finance premium on deposits rises on impact since the banks' leverage ratio is predetermined and the borrower's external finance premium has increased. In subsequent periods the external finance premium on deposits falls due to the fall in bank leverage. This leads to a fall in $\bar{R}_{t+1} - R_{t+1}$ and in banks' profits.

Other interesting experiment for dynamics: uncertainty shock-treat σ_t of bank level shocks as state variable following e.g. AR(1) in logs. as in Bloom or Jaimovich and Bloom. Does bank capital matter for this shock?

3.2.1 Further Robustness Checks:

We examine the response to tfp shocks with several other real frictions to check if it is possible to reduce the fall or significantly smaller rise in the labour supply of borrowers, reverse the dampening effect of household financing frictions on output responses and make bank related financing frictions matter for aggregate output,consumption or investment. Capital adjustment costs make labour demand less elastic, which for a given cost of external financing reduces the impact of the borrower's lower labour supply on total labour hours. However, in general equilibrium the greater increase in wages with a less elastic labour demand curve translates into a greater relaxation of the borrowers' financing constraint and a larger increase in borrower and saver consumption. As a result the income effect on labour supply is stronger than before. Borrowers' labour supply falls even more in the presence of capital adjustment costs. Allowing a variable capacity

utilisation rates for capital does not change the qualitative differences between the frictionless RBC model and the models with financing constraints, though it accentuates them. In particular it strengthens the previously discussed differences in the responses of output, consumption and investment. Finally we add labour adjustment costs. When combining labour adjustment costs with capital adjustment costs, one can finally see some perceptible differences between the IRF's of the models with and without banking, but the differences are still small. In particular banking frictions dampen the response of output to a tfp shock.

For demand shocks, these extensions still cannot generate comovement of consumption and labour or output, and the impact of bank-depositor frictions remains minimal on non-bank quantities or prices[22].

3.3 Comparison of model 2nd moments to the data

-do this for tfp shocks for now since demand shocks don't produce realistic cycles in current model.

4 Conclusion

This paper has developed a model of the interaction between household credit frictions and bank capital based on imperfect diversification of bank loan portfolios and costly financial distress. The analysis so far has not found the bank capital channel for the transmission of shocks to be quantitatively important. Instead of amplifying shocks, bank financing frictions in the model dampen shocks due the effects of consumption smoothing by borrowers and savers on bank leverage.

We have also developed a highly tractable alternative model of household collateralised borrowing. In the current version of the model credit frictions have only a modest impact on aggregate output fluctuations though they have significant distributional consequences both in terms of the ratio of consumption to investment and in terms of the different responses of borrowers and lenders to shocks. In response to supply shocks, the credit frictions in the model dampen output fluctuations while increasing their persistence. This is due in large part to

[22] One obvious option to reduce the income effect on labour supply that is so critical in the inability to generate demand driven booms would be to use GHH preferences or their generalisation by Jaimovich and Rebelo (08)[30],though this modification may be seen as somewhat ad-hoc. Another interesting possibility that we intend to explore is to allow for nonseparability between non durable consumption, housing and leisure as in Davis and Heathcote(2005)[17] and Euseppi and Preston(2008)[19].

the strong income effect generated by changes in the costs of external financing on labour supply.

There are several key issues that we have ignored in the current model and that could give bank financing frictions a more important role. We have abstracted from issues related to maturity mismatch and lending among financial intermediaries. At the same time while allowing for costs related to defaults in bank loan portfolios we have omitted any asymmetric information related to the quality of the loans before default. For example we have assumed perfect information about the volatility of the bank specific shocks σ. It is possible that asymmetric information about the uncertainty of loan outcomes could generate a more important role for bank financing frictions frictions. In theory incorporating this feature should not be difficult if we start with the simple case in which σ can take two values. Finally, in the current model we have followed BGG (1999)[7] in assuming that loan rates could be made contingent on the aggregate state of the economy. This may have significantly weakened the strength of the bank capital channel in the model. A more realistic assumption is that loan rates are predetermined with respect to the aggregate state of the economy, and that they can only be partially renegotiated.

There are several other interesting extensions of the current model. First, we can use a similar framework to the one used for households to introduce financially constrained entrepreneurs with lending collateralised by capital and profits. This would allow us to study spillovers between financial frictions in the household and the firm sector as well as address reduced form evidence on the relative shares and behaviour of loans to firms versus loans to households across the business cycle. The impact of bank capital may also be quite different when the loans are used for production.

Second, the effects of banking could be different in a monetary model with either sticky prices or limited participation. In addition to permitting analysis of monetary policy, using a monetary model would also allow us to consider the inside money role of bank liabilities, instead of modeling deposits as simple loans. We leave these extensions of the model to future work.

Appendix:

Linearized equations:

n.b: all variables below are in either %deviations of in deviations from SS, whether they're hatted or not

Savers:

Budget Constraint-

$c^s\hat{c}^s_t + \delta h^s \hat{q}_t + h^s \hat{h}^s_t + d\hat{d}_t = (1-\delta_h)h^s\hat{h}^s_{t-1} + Rd(\hat{R}_t + \hat{d}_{t-1}) + wn^s(\hat{n}_t + \hat{w}_t) + \Pi^h_t + \Pi_t$

deposits Euler equation-

$\hat{c}^s_t = E_t\hat{c}^s_{t+1} - \hat{R}_{t+1}$

Housing Euler equation-

$(\hat{c}^s_t - \hat{q}_t) = \frac{\xi^h c^s}{h^s}\hat{h}^s_t + \beta(1-\delta_h)E_t(\hat{c}^s_{t+1} - q_{t+1})$

Labour supply-

$\frac{n^s}{1-n^s}\hat{n}^s_t = \hat{w}_t - \hat{c}^s_t.$

Borrowers:

The following equations are for $s_w = 0$. The equations for $s_w > 0$ are similar.

Budget constraint-

$c^{bo}\hat{c}_t^{bo} + h^{bo}\left[1-(1-\delta_h)(1+(1-s_h)H(\bar{\varepsilon}))\right]\hat{q}_t + h^{bo}h_t^{bo} = H'(\bar{\varepsilon})\bar{\varepsilon}\left[(1-\delta_h)h^{bo}(1-s_h) + n^{bo}w(1-s_w)\right]\bar{\varepsilon}_t + (1-\delta_h)h^{bo}[1+(1-s_h)H(\bar{\varepsilon})]\hat{h}_{t-1}^{bo} + [1+H(\bar{\varepsilon})(1-s_w)]n^{bo}w\left(\hat{w}_t + \hat{n}_t^{bo}\right) + l\hat{l}_t$.

Bank break-even constraint-

$G'(\bar{\varepsilon})\bar{\varepsilon}\left[(1-\delta_h)(1-s_h)h^{bo} + (1-s_w)wn^{bo}\right]\bar{\varepsilon}_t + G(\bar{\varepsilon})(1-\delta_h)(1-s_h)h^{bo}(\hat{q}_t + h_{t-1}^{bo}) + G(\bar{\varepsilon})(1-s_w)wn^{bo}(\hat{w}_t + \hat{n}_t^{bo}) = \bar{R}l(\bar{R}_t + \hat{l}_{t-1})$.

Loan Euler equation-

$\hat{c}_t^{bo} = -E_t\hat{\psi}_{t+1} - \bar{R}_{t+1}$

Housing Euler equation-

$\frac{1}{c^{bo}}(\hat{c}_t^{bo} - \hat{q}_t) = \frac{\xi_h}{h^{bo}}\hat{h}_t^{bo} + \beta^{bo}(1-\delta_h)\frac{1+(1-s_h)H(\bar{\varepsilon})}{c^{bo}}E_t\hat{c}_{t+1}^{bo} - \beta^{bo}(1-\delta_h)\left[\frac{1+(1-s_h)H(\bar{\varepsilon})}{c^{bo}} + \psi G(\bar{\varepsilon})(1-s_h)\right]E_t\hat{q}_{t+1} - \beta^{bo}(1-s_h)(1-\delta_h)\psi G(\bar{\varepsilon})E_t\hat{\psi}_{t+1}$

Labour supply-

$\frac{\xi_n}{(1-n^{bo})^2}n^{bo}\hat{n}_t^{bo} = \left(\psi G(\bar{\varepsilon})(1-s_w) + \frac{1+(1-s_w)H(\bar{\varepsilon})}{c^{bo}}\right)w\hat{w}_t - \frac{1+(1-s_w)H(\bar{\varepsilon})}{c^{bo}}w\hat{c}_t^{bo} + \psi G(\bar{\varepsilon})(1-s_w)w\hat{\psi}_t$

Optimal default threshold

$\psi\hat{\psi}_t = \frac{H'(\bar{\varepsilon})}{G'(\bar{\varepsilon})c^{bo}}\hat{c}_t^{bo} + \left(\frac{H'(\bar{\varepsilon})G''(\bar{\varepsilon}) - H''(\bar{\varepsilon})G'(\bar{\varepsilon})}{G'(\bar{\varepsilon})^2}\right)\frac{\bar{\varepsilon}}{c^{bo}}\bar{\varepsilon}_t$

Note that using this expression for $\hat{\psi}_t$ and the steady state condition $\psi c^{bo} = -\frac{H'(\bar{\varepsilon})}{G'(\bar{\varepsilon})}$, we can get a borrower's counterpart to the saver's linearized Euler equation of the form: $\hat{c}_t^{bo} = E_t\hat{c}_{t+1}^{bo} - A_{\bar{\varepsilon}}E_t\bar{\varepsilon}_{t+1} - \bar{R}_{t+1}$, where $A_{\bar{\varepsilon}} = \left(\frac{H'(\bar{\varepsilon})G''(\bar{\varepsilon}) - H''(\bar{\varepsilon})G'(\bar{\varepsilon})}{G'(\bar{\varepsilon})^2}\right)\frac{\bar{\varepsilon}}{\psi c^{bo}} > 0$. This highlights the key modification of the borrower's linearized Euler equation relative to the standard one: in addition to $\bar{R}_{t+1}$, the borrower faces a linearized external finance premium $A_{\bar{\varepsilon}}E_t\bar{\varepsilon}_{t+1}$ which depends on changes in the expected future default rate.

Banks:

Bank's balance sheet/budget constraint:

$c^b\hat{c}_t^b + \theta^{bo}l\hat{l}_t = \theta^{bo}H^b(\hat{\varepsilon})\bar{R}l\left(\bar{R}_t + l_{t-1}\right) + \theta^{bo}\bar{R}l\frac{H'(\hat{\varepsilon})}{G(\bar{\varepsilon})}\hat{\varepsilon}\hat{\varepsilon}_t - \theta^{bo}\bar{R}l\frac{H(\hat{\varepsilon})}{G(\bar{\varepsilon})^2}G'(\bar{\varepsilon})\bar{\varepsilon}\bar{\varepsilon}_t + \theta^s dd_t$

Depositor break-even constraint:

$\theta^{bo}G^b(\hat{\varepsilon})\bar{R}l\left(l_{t-1} + \bar{R}_t\right) + \theta^{bo}\frac{G'(\hat{\varepsilon})}{G(\bar{\varepsilon})}\bar{R}l\hat{\varepsilon}\hat{\varepsilon}_t - \theta^{bo}\frac{G(\hat{\varepsilon})}{G(\bar{\varepsilon})^2}\bar{R}lG'(\bar{\varepsilon})\bar{\varepsilon}\bar{\varepsilon}_t = \theta^s Rd\left(d_{t-1} + R_t\right)$

Deposit Euler equation:

$c_t^b = -E_t\psi_{t+1}^b - R_{t+1}$

Loan Euler equation:

$\frac{1}{c^b}c_t^b = \beta^b \bar{R}\frac{H^b(\hat{\varepsilon})}{c^b}E_t c_{t+1}^b - \frac{1}{c^b}\bar{R}_{t+1} - \beta^b \bar{R}\psi^b G^b(\hat{\varepsilon})E_t\psi_{t+1}^b + \beta^b \bar{R}\frac{G'(\bar{\varepsilon})}{G(\bar{\varepsilon})^2}\left(\frac{H(\hat{\varepsilon})}{c^b} + \psi^b G(\hat{\varepsilon})\right)\bar{\varepsilon}E_t\bar{\varepsilon}_{t+1}.$
$\hat{\varepsilon}_t$ foc:
$\psi_t^b = -c_t^b + \frac{1}{c^b\psi^b}\frac{d}{d\hat{\varepsilon}}\left(\frac{-H'(\hat{\varepsilon})}{G'(\hat{\varepsilon})}\right)\hat{\varepsilon}\hat{\varepsilon}_t$
Housing supply:
$\hat{q}_t = \gamma^h(\hat{h}_t - \hat{h}_{t-1})$
$\Pi_t^h \approx \frac{h\delta_h}{\theta^s}\hat{q}_t$
$h\hat{h}_t = \theta^s h^s \hat{h}_t^s + \theta^{bo}h^{bo}\hat{h}_t^{bo}$

final output profit:
$\pi_t = \theta^s \Pi_t = (y - wn)y_t - k\left[k_{t+1} - (1-\delta)k_t\right]$

Labour demand:
$y_t - n_t = w_t.$
Labour adjustment costs modify this to
$(1-\alpha)\frac{y}{n}\hat{y}_t - [(1-\alpha)\frac{y}{n} + \gamma_n(1+\beta)]\hat{n}_t + \gamma_n\hat{n}_{t-1} + \beta\gamma_n E_t\hat{n}_{t+1} = w\hat{w}_t$
capital:

$c_t^s = E_t c_{t+1}^s - \alpha\beta\frac{y}{k}\left(E_t y_{t+1} - k_{t+1}\right)$
With capital adjustment costs we have
$c_t^s = \hat{q}_t^k + E_t c_{t+1}^s - \alpha\beta\frac{y}{k}\left(E_t y_{t+1} - k_{t+1}\right) - \beta(1-\delta)E_t\hat{q}_{t+1}^k$,
$\hat{q}_t^k = \gamma(\hat{k}_{t+1} - \hat{k}_t)$,
$\hat{\pi}_t^k = \delta k\hat{q}_t^k$.
With variable capacity utilisation rates we have
$\hat{y}_t - \hat{k}_t = q_t^k + \phi\hat{u}_t$,
$c_t^s = \hat{q}_t^k + E_t c_{t+1}^s - \alpha\beta\frac{y}{k}\left(E_t y_{t+1} - k_{t+1}\right) - \beta(1-\delta)E_t\hat{q}_{t+1}^k + \beta\delta\phi E_t\hat{u}_{t+1}.$
production function

$y_t = z_t + \alpha k_t + (1-\alpha)n_t$
or
$y_t = z_t + \alpha(k_t + \hat{u}_t) + (1-\alpha)n_t$ with variable capacity utilisation.
tfp shock process: $\hat{z}_t = \rho\hat{z}_{t-1} + e_t^{\tilde{z}}$

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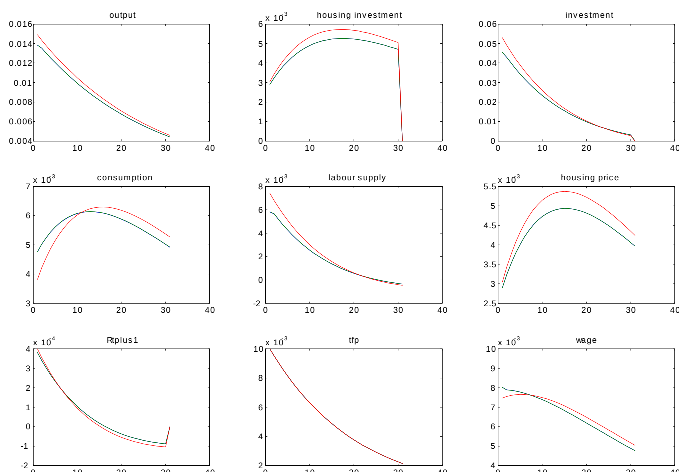
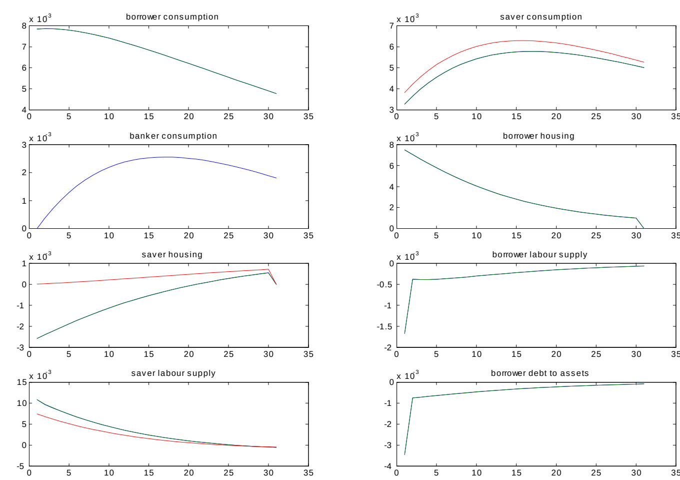


1% positive tfp shock, sw=0. Red is RBC model with no financial frictions, green is model with borrowing frictions but no banking frictions, blue is full model with banking frictions.


borrower consumption
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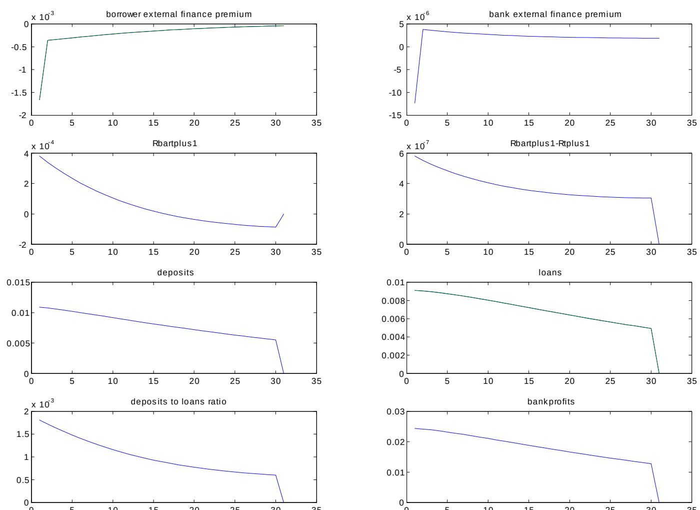
borrower housing
saver housing
borrower labour supply
saver labour supply
borrower debt to assets


borrower external finance premium
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Rbartplus1
Rbartplus1-Rtplus1
deposits
loans
deposits to loans ratio
bankprofits

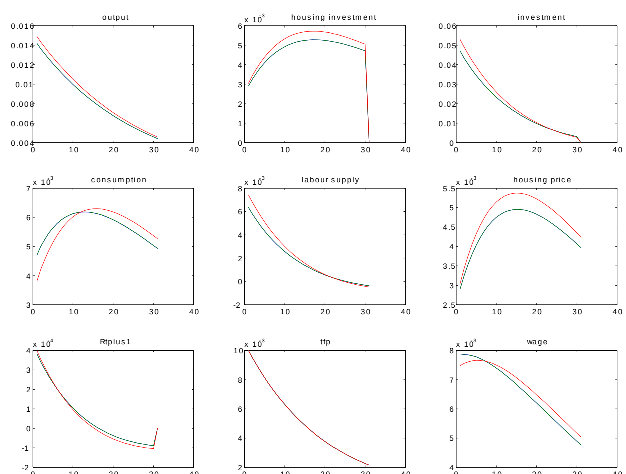
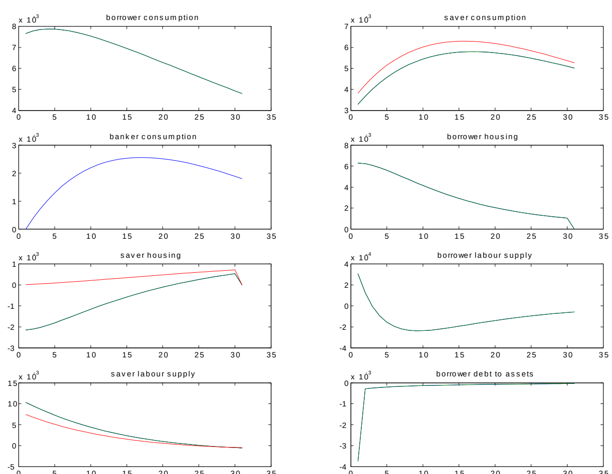


Figure 1: 1% positive tfp shock, sw=1. Red is RBC model with no financial frictions, green is model with borrowing frictions but no banking frictions, blue is full model with banking frictions.


borrower consumption
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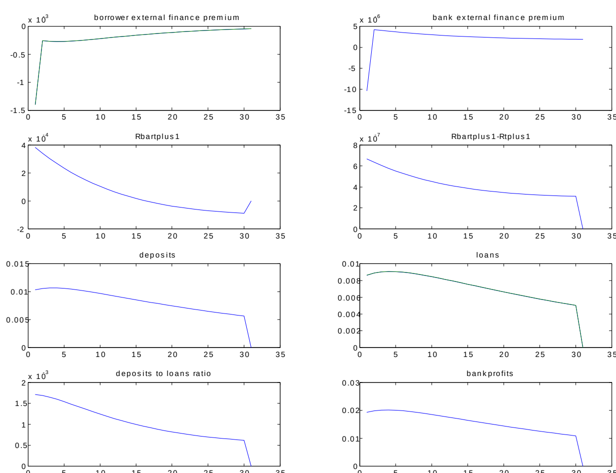
borrower housing
saver housing
borrower labour supply
saver labour supply
borrower debt to assets


borrower external finance premium
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deposits
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deposits to loans ratio
x 10-3
bankprofits

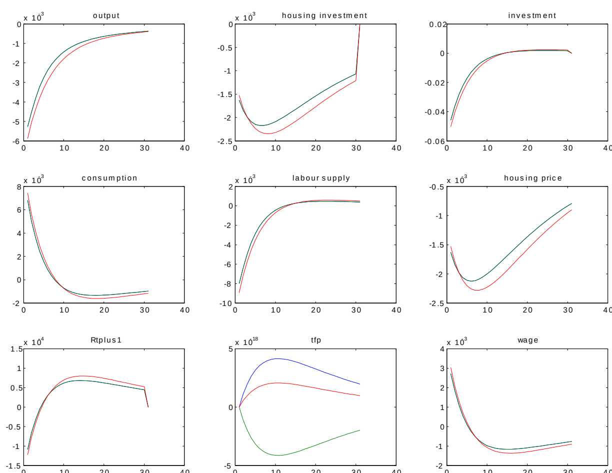
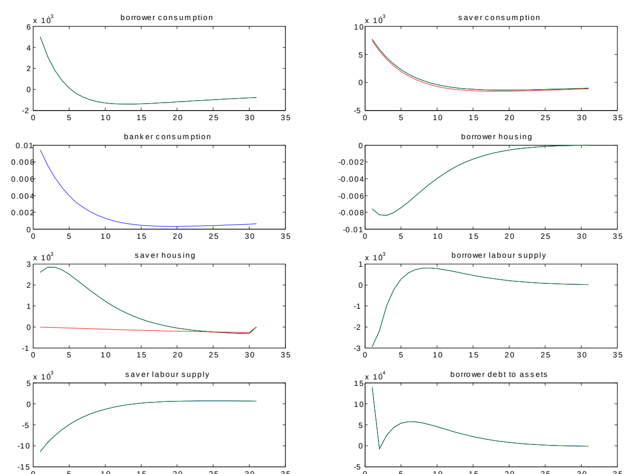


Figure 2: 1% positive preference shock, sw=0. Red is RBC model with no financial frictions, green is model with borrowing frictions but no banking frictions, blue is full model with banking frictions.


borrower consumption
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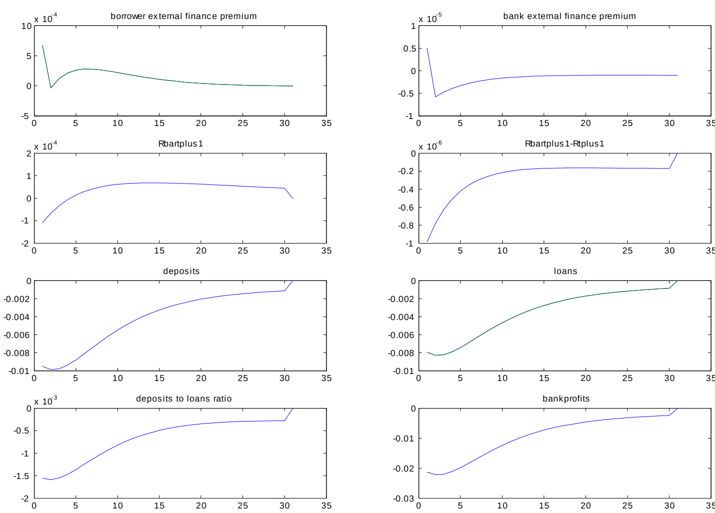
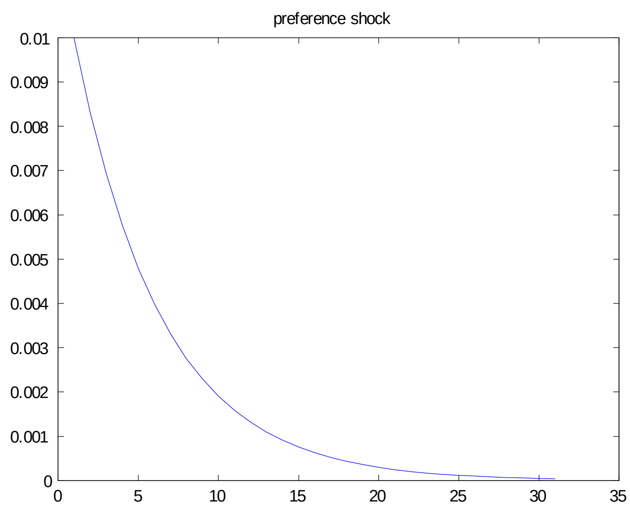
banker consumption
borrower housing
saver housing
borrower labour supply
saver labour supply
borrower debt to assets



borrower external finance premium
x 10^-4
bank external finance premium
x 10^-5
Rbartplus1
x 10^-4
Rbartplus1-Rplus1
x 10^-6
deposits
loans
deposits to loans ratio
x 10^-3
bankprofits


preference shock
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