A New Keynesian Model with Collateral Quantity Constraints

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Robert C. M. Beyer*

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Abstract

It is often argued that information insensitive debt is crucial for explaining the financial crisis and that it is fundamentally different from information sensitive debt (Hölmstrom, 2015). I introduce potentially information insensitive loans in a New Keynesian Model close to Iacoviello (2005), in order to analyze the macroeconomic effect of such debt. Key features of the model include heterogeneous collateral and costly information production about its value. Investors in this model may find it optimal to borrow without information production by lenders. The possibility of such debt results in different information regimes – information sensitive and information insensitive – and adds a new constraint on borrowing, which I name *collateral quantity constraint.* First, I show that opacity about collateral quality may enhance growth but increase volatility and that monetary policy is crucial in determining the equilibrium effects of regime switches. Second, I document that a model with collateral quantity constraints can explain the general patterns observed before, during, and after the financial crisis: large output expansions without substantial price movements, a large drop in output due to a small shock, and a slow recovery.

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*Goethe University Frankfurt and IMFS. Contact: House of Finance, Theodor-W.-Adorno-Platz 3, D-60323 Frankfurt am Main, Germany. Tel.: +49(0)69 798 33613. E-Mail: robert.beyer@hof.uni-frankfurt.de

1 Introduction

In the aftermath of the financial crisis important questions about the role of debt in causing the crisis arose. Holmström (2015) clarifies different logics of different credit markets. In particular, he emphasizes that some debt may be information insensitive, by which he means that some debt is over-collateralized so that price discovery is avoided. Such debt is, for example, created in money markets. Interestingly, the financial crisis erupted with a run on sale and repurchase agreements (Gorton 2010). Such transactions, in which money is typically lend for a short period of time, are frequently collateralized with securitized bonds. During the credit boom preceding the financial crisis, asset- and mortgage backed securities with high information production cost were increasingly used as collateral (Gorton and Metrick 2012a). Holmström (2015) and Gorton and Ordoñez (2014a) recognize debt in the repo market as information insensitive and argue that collateral has been accepted without knowledge of its actual value. Once the value of the bonds provided as collateral became questionable, banks were suddenly wondering about the collateral's. This means that information-insensitive debt turned into information-sensitive debt. After the banks corrected their perceptions about collateral values, they did not renew a lot of the existing short-run debt, which led to the financial crisis (Gorton and Metrick 2012b). The volume of collateral in the economy dropped strongly, as much of the privately created collateral during the preceding credit boom became nearly worthless. The crisis was hence the outcome of a small shock causing a switch of the information regime.

In order to better understand the financial crisis many different financial frictions were introduced into New Keynesian Models.[1] However, debt in these models always is and remains information sensitive. Acknowledging that information production plays an important role requires a different kind of friction, that I name *collateral quantity constraints*. Clearly, the term *quantity* highlights that not prices of assets used as collateral, but the amount available limits the loan size. Such constraints work fundamentally different. For example, switches of the information regime are necessarily non-linear.[2] The crisis has reminded us that depending on the circumstances, the same shock can cause diverse dynamics and affect the economy with varying degrees of strength. Even a small shock can lead to a financial crisis with a persistent output depression.

[1] There have been written far too many papers to list all of them. Important examples include Del Negro et al. (2011), Jermann and Quadrini (2012), and Christiano et al. (2013). While an up-to date survey of this literature is to my best knowledge not available, the different mechanisms of financial frictions are well surveyed by Brunnermeier et al. (2012). Despite all justified criticism of New Keynesian Models, they continue to be the work horse of contemporary macroeconomics and are widely used at central banks.

[2] The effects of shocks in linearized models are necessarily symmetric and linear and large shocks are required to explain large affects. However, the financial crisis did not result from a large shock (Gorton and Ordoñez, 2014a) and the recession following the financial crash differed from typical business cycles dynamics (Mendoza, 2010).

This paper builds on Iacoviello (2005) and adds collateral quantity constraints. The new constraints result from the presence of heterogeneous collateral and costly information production. The model features an additional group of producers, called investors, that own good or bad portfolios and need to borrow against the uncertain return of their collateral. Lenders decide endogenously whether they are producing information about the collateral or not. The mechanism used is closely related to Gorton and Ordoñez (2014a). If lenders produce information, the value of the collateral limits the loan. If, on the other hand, lenders do not produce information, the value of the collateral is unknown and the perception about its value limits the loan. There are hence two information regimes. Switches from the information sensitive to the information insensitive regime can lead to rational credit extensions, so called ignorance bubbles (Gorton and Ordoñez, 2014a). A switch from the information-insensitive to the information-sensitive regime causes a debt crisis and severe recession.

After developing a model with collateral quantity constraints in Section 2, I will study some interesting properties of the model in Section 3. First, switches of the information regime are shown to move the economy to another equilibrium. Ignorance about the value of the collateral increases growth with households and investors benefiting and entrepreneurs being damaged in the long-run. Second, an economy with information insensitive debt is more volatile and reacts stronger to changes of the fraction of investors with good portfolios. Section 4 deals with the equilibrium effects of different monetary policies. If the central bank is only concerned with inflation, spillovers from the investors to households and entrepreneurs are relatively small. When it also reacts to output deviations, however, effects can be huge. In Section 5 the model is solved using the piecewise linear methodology developed by Guerrieri and Iacoviello (2015). I will document that positive shocks to the fraction of good portfolios can explain the emergence of credit bubbles. Output expansions caused by credit growth due to more and more information insensitive debt can be sizable without moving prices much. Once an economy is long enough in an information insensitive regime, nearly identical shocks have very different effects depending on whether they are causing information production or not. After information is reproduced, the economy only recovers slowly.

2 Model

The model is based on the basic model in Iacoviello (2005), in which patient households lend to credit constraint entrepreneurs, who invest in risky projects. The latter borrow against the value of their housing stock, so that changes of the housing prices have effects in the real economy. I add a third group of agents, named investors, and employ a mechanism related to Gorton and Ordoñez (2014a, 2014b) to introduce collateral quality constraints. Investors have available risky projects and own portfolios that potentially deliver consumption goods at the end of the period and hence can serve as collateral. Lenders need to pay an information production cost in order to determine the quality of the collateral, but can choose between information sensitive and information insensitive loans, i.e. whether they produce information about the quality of the collateral or not.[3] In addition, there are retailers producing final goods and a central bank setting the interest rate. Households, entrepreneurs, retailer, and investors live infinitely and are all of measure one; as usual, time is discrete.

Households

Households derive utility from consumption and housing and disutility from working. They maximize a lifetime utility function given by

$$E_0 \sum_{t=0}^{\infty} \beta^t (\ln c'_t + j \ln h'_t - (L'_t)^\eta/\eta)),$$

where c'_t is their consumption, h'_t their housing stock, and L'_t the hours worked. Their flow of funds is

$$c'_t + q_t \Delta h'_t + \frac{R_{t-1}}{\pi_t}(b'^h_{t-1} + b'^l_{t-1}) = b'^\Psi_t + b'^l_t + w'_t L'_t + F_t, \tag{1}$$

where q_t is the price of housing, R_t is one plus the interest rate, π_t is the inflation rate, b'^Ψ_t is lending to entrepreneurs and b'^l_t is lending to investors, w'_t is the wage, F_t are profits received from retailers, and T'_t are lump-sum transfers. In contrast to Iacoviello (2005), households can lend both to entrepreneurs and investors. From their optimization problem I get the following first-order conditions

$$\frac{1}{c'_t} = \beta E_t (\frac{R_t}{\pi_{t+1} c'_{t+1}}) \tag{2}$$

$$w'_t = (L'_t)^{\eta-1}/c'_t \tag{3}$$

$$\frac{q_t}{c'_t} = \frac{j}{h'_t} + \beta E_t (\frac{q_{t+1}}{c'_{t+1}}) \tag{4}$$

[3] The micro foundations are provided by Gorton and Pennacchi (1990). In their setting bank liabilities and money market instruments provide transaction services because such information insensitive debt allows trade without the possibility of adverse selection.

Entrepreneurs and Retailers

Entrepreneurs and Retailers are standard and identical to Iacoviello (2005). Entrepreneurs use a Cobb-Douglas constant returns-to-scale technology and produce intermediate goods according to

$$Y_t = a(h_{t-1})^{v}(L_t)^{1-v}, \tag{5}$$

where Y_t are intermediate goods, h_t is their housing stock, and L_t is the labor employed in production. Their utility is given by

$$E_0 \sum_{t=0}^{\infty} \gamma^t \ln c_t,$$

where c_t is their consumption and $\gamma < \beta$ so that they discount the future more than households. The flow of funds of entrepreneurs is

$$Y_t/X_t + b_t^h = c_t + q_t \Delta h_t + R_{t-1} b_{t-1}^h/\pi_t + w_t' L_t, \tag{6}$$

where X_t is the mark-up and b_t^h is the lending to entrepreneurs. There is a limit on the obligations of the entrepreneurs[4] given by

$$b_t^h \leq m E_t(q_{t+1} h_t \pi_{t+1}/R_t).$$

From the optimization problem of entrepreneurs I get the following first-order conditions

$$\frac{1}{c_t} = E_t(\frac{\gamma R_t}{\pi_{t+1} c_{t+1}}) + \lambda_t R_t, \tag{7}$$

$$\frac{1}{c_t} q_t = E_t(\frac{\gamma}{c_{t+1}}(v \frac{Y_{t+1}}{X_{t+1}, h_t} + q_{t+1}) + \lambda_t m \pi_{t+1} q_{t+1}) \tag{8}$$

$$w_t' = (1-v) Y_t/(X_t L_t). \tag{9}$$

Since $\lambda = (\beta - \gamma)/c > 0$ we know that the inequality related to the borrowing limit will hold with equality, so that[5]

$$b_t^h = m E_t(q_{t+1} h_t \pi_{t+1}/R_t). \tag{10}$$

Retailers buy intermediate goods and transform them into final goods. The optimal price

[4]For details refer directly to Iacoviello (2005).

[5]As Iacoviello (2005) I need to assume that the degree of impatience is strong enough to relative to uncertainty so that entrepreneurs never borrow less than they can.

solves

$$\sum_{k=0}^{\infty} \theta^k E_t\{\Lambda_{t,k}(\frac{P_t^*(z)}{P_{t+k}} - \frac{X}{X_{t+k}})Y_{t+k}^*(z)\} = 0 \tag{11}$$

and the evolution of the aggregate price level is

$$P_t = (\theta P_{t-1}^{\epsilon} + (1-\theta)(P_t^*)^{1-\epsilon})^{1/(1-\epsilon)}. \tag{12}$$

Profits of retailers are transfered to the households and given by $F_t = (1 - \frac{1}{X_t} Y_t)$.

Investors

Investors have the following utility function

$$E_0 \sum_{t=0}^{\infty} \delta^t \ln c_t'',$$

where c_t'' is their consumption. They have available one-period investment projects and their production function is stochastic and given by

$$Y_t^I = \begin{cases} A \min\{b_{t-1}^{\Psi}, b_*^{\Psi}\} & \text{with} \quad s \\ 0 & \text{with} \quad (1-s) \end{cases} \tag{13}$$

where Y_t^I are final consumption goods, A is the productivity, b_*^{Ψ} is the maximum input[6], and s is the probability that projects are successful. Note that they do not employ any labor, which could be rationalized by locating these projects in another country or due to the small employment share of some sectors, for example the financial sector.

Each investors owns an unmarketable portfolio Ψ, which is either good or bad. Good portfolios deliver consumption goods an the end of the period, bad ones do not:

$$\text{at the end of period } t \quad \Psi \quad \text{delivers} \quad \begin{cases} c^{\Psi} & \text{if } \Psi \text{ is good} \\ 0 & \text{if } \Psi \text{ is bad,} \end{cases}$$

where c_t^{Ψ} stands for the consumption good it delivers. The fraction of good portfolios is given by p_t^i. Households can find out the quality of a portfolio by paying an information production cost of μ. The expected flow of funds of investors is

$$Y_t^I + b_t^{\Psi} + p_t^i c^{\Psi} = c_t'' + \frac{R_{t-1} b_{t-1}^l}{\pi_t}, \tag{14}$$

[6]For example due to limited management capabilities. While this specification is not needed, it simplifies the analysis.

where c_t'' is their consumption, b_t^l the amount they borrow. We assume that the return from the portfolio is directly observable, but project returns are not. Hence there is a limit to the amount investors can borrow. We get a first-order condition

$$\frac{1}{c_t''} = E_t(\frac{\delta R_t}{\pi_{t+1} c_{t+1}''}) + \lambda_t R_t,$$

showing again, as $\delta < \beta$ and $\lambda = \frac{\delta - \gamma}{c} > 0$ in steady state, that investors, as entrepreneurs, want to borrow as much as possible.[7]

Loans to investors are short-term and collateralized and can be information sensitive or insensitive. As in Gordon and Ordoñez (2014a) borrowers choose the loan size and can decide whether to trigger information or not. Triggering information is costly, because lenders need to be compensated for the information production cost. Not producing information may be costly as well, because less may be borrowed.

Information Sensitive Debt

Lenders are competitive and risk neutral and get a return of R_t on the loans. As mentioned, they can pay an information production cost μ to find out the value of the borrowers' portfolios.[8] They consider an information sensitive loan only if

$$p(s\Sigma_{t|S} + (1-s)\alpha_{t|S} c^{\Psi} - R_t b_{t|S}^l) = \mu,$$

where Σ_t is the face value of debt and α_t is the fraction promised as collateral. The expected benefit of checking the quality of the portfolio must compensate for the cost. Of course they only give out an information sensitive loan if the portfolio is good. Debt must be risk-free, so that there is no incentive to deviate[9]. We hence know that $R_{t|S} = \alpha_{t|S} c^{\Psi}$ and $\alpha_{t|S} = \frac{p_t R_t b_{t|S}^l + \mu}{p_t c^{\Psi}}$, which is the fraction of land that needs to be put up as collateral and by necessity is smaller than one. If $\frac{p_t R_t b_*^{\Psi} + \mu}{p_t c^{\Psi}} \leq 1$, investors with good land can borrow the optimal amount.[10] As Gordon and Ordoñez (2014a) I assume that this conditions holds so that good portfolios deliver enough return to sustain optimal lending b_*^{Ψ}. With information sensitive debt expected profits Π_t are given by

$$E_t \Pi_{t|S} = p_t b_*^{\Psi} (sA - R_t) - \mu$$

[7] As for the entrepreneurs, I need to assume that uncertainty relative to impatience is small. Even in a credit boom caused by shocks to p, the incentive to borrow more due to impatience needs to outweigh the incentive to borrow less than the maximum in order to buffer consumption against future shocks.

[8] As in Gordon and Ordoñez (2014a) borrowers here cannot find out the quality of their own portfolios. This simplifies the analysis but does not change the general results Gordon and Ordoñez (2014b).

[9] Otherwise firms would either always default and hand in the collateral or sell the collateral and pay the face-value of the debt.

[10] As long as $p_t c^{\Psi} \neq \mu$, the loan size would otherwise be given by $\frac{p_t c^{\Psi} - \mu}{p_t}$. If that condition did not hold, investors could not borrow at all.

and the loan size (net of information costs) is

$$b^l_{t|S} = p_t b^\Psi_* - \frac{\mu}{sA - R_t}.$$

Information Insensitive Debt

The other possibility is to borrow without triggering information production. Again the lenders need to earn the interest rate so that the participation constraint is given by

$$sR_{t|I} + (1-s)p_t\alpha_{t|I}c^\Psi = R_t b^l_{t|I}$$

In order to have no incentive to deviate, we need to have $R_{t|I} = \alpha_{t|I}pc^\Psi$ so that $\alpha_{t|I} = \frac{R_t b^\Psi_{t|I}}{pc^\Psi}$, which again needs to be smaller than one.

For such a loan contract lenders have an incentive to produce information, in order to only lend to investors with good portfolios. Hence, the contract also needs to fulfill the following incentive constraint

$$p_t(sR_{t|I} + (1-s)\alpha_{t|I}c^\Psi - R_t b^\Psi_{t|I}) < \gamma$$

which using again $R_{t|I} = \alpha_{t|I}pc^\Psi$ gives

$$(1-p_t)(1-s)R_t b^\Psi_{t|I} \leq \gamma$$

It is now obvious that investors, by reducing the size of the loan, can prevent the households from producing information. If the above condition is binding, investors will borrow as much as possible

$$b^\Psi_{t|I} = \frac{\gamma}{(1-p)(1-s)R_t}.$$

If is not binding, investors can borrow the optimal loan size b^Ψ_*. The value of p for which investors are no longer financially constraint is defined as p^*.

With information insensitive loan contracts investors with portfolios of unknown quality get the same loan whether the portfolio is good or bad. In fact, the loan size only depends on the (perceived) probability that the portfolio is good. As long as $p_t c^\Psi > \frac{\gamma}{(1-p)(1-s)R_t}$ we have two possible sizes of information insensitive loans:[11]

$$b^\Psi_{t|I} = \min\{b^\Psi_*, \frac{\gamma}{(1-p)(1-q)R_t}\}$$

[11] If the condition did not hold lenders would sell the collateral and the loan size would be given by $p_t c^\Psi$. This would be the case for very small values for p only.

Expected profits are then given by

$$E_t\Pi_{t|I} = \begin{cases} b_*^\Psi(sA - R_t) & \text{if} \quad b_*^\Psi \leq \frac{\gamma}{(1-p_t)(1-s)R_t} \\ \frac{\gamma}{(1-p)(1-q)R_t}(sA - R_t) & \text{if} \quad b_*^\Psi > \frac{\gamma}{(1-p_t)(1-s)R_t} \end{cases}$$

Actual Loan Size

Whether investors prefer to trigger information or not depends on the fraction of good portfolios. This fraction is, of course, equal to the expected probability that a portfolio is good. If we equalize the profit functions $\Pi_{t|S}$ and $\Pi_{t|I}$ we find two cut-offs p^{low} and p^{high} .[12] Investors prefer no information production for low and high probabilities and information production for intermediate values. If we assume that p_t is always higher than the lower cut-off p^{low}, we get the following loan sizes (net of information cost)

$$b_t^\Psi = \begin{cases} p_t b_*^\Psi - \frac{\gamma}{sA-R_t} & \text{if} \quad p_t < p^{\text{high}} & \text{information sensitive} \\ \frac{\gamma}{(1-p_t)(1-s)R_t} & \text{if} \quad p^{\text{high}} < p_t < p^* & \text{constraint information insensitive} \\ b_*^\Psi & \text{if} \quad p^* < p_t & \text{unconstraint information insensitive} \end{cases} \tag{15}$$

Central Bank

Finally, the central bank follows a Taylor-type rule. Deviations of inflation, entrepreneurial output, and total output from their steady state values are possible arguments; its reaction function is

$$R_t = (R_{t-1})^{r_R}(\pi_{t-1}^{1+r_\pi}(Y_{t-1}/Y)^{r_Y}(Y_{t-1}^T/Y^T)^{r_{Y^T}}\overline{rr})^{1-r_R}e_{R,t}, \tag{16}$$

where $e_{R,t}$ is a monetary policy shock, Y is the output produced by the entrepreneurs and Y^T is the sum of Y and the output produced by the investors, i.e. Y^I. The parameters r_π, r_Y, r_{Y^T}, and r_R determine the strength of the interest rate reaction to fluctuations of the respective variables and the strength of interest rate smoothing.

Equilibrium and Dynamics

Abstracting from shocks the model has a unique stationary equilibrium, which is an allocation of aggregates $\{h_t, h_t', L_t, L_t', Y_t^T, Y_t, Y_t^I, c_t, c_t', c_t'', b_t^h, b_t'^h\}_t^\infty$ together with a sequence of values $\{w_t', R_t, P_t, P_t^*, X_t, \lambda_t, q_t\}_t^\infty$ that satisfies equations (2) to (16) and the equilibrium conditions $b_t^h + b_t'^\Psi = 0$, $b_t^\Psi + b_t'^l = 0$, $b_t^h + b_t^\Psi = b_t$, and $Y_t^I + Y_t = Y_t^T$ given $\{h_{t-1}, R_{t-1}, b_{t-1}^h, b_{t-1}^l, P_{t-1}\}$ and the sequence of monetary and collateral shocks together

[12] The cut-offs solve the quadratic function $\mu = (p_t b_*^\Psi - \frac{\gamma}{(1-p)(1-s)R_t})(sA - R_t)$.

with the relevant transversality conditions. The equilibrium value of b_t^Ψ originates from a pair of debt face values and a pair of fractions of portfolio returns such that households are indifferent and a choice by investors that maximizes their profits.

The model can be reduced to a linearized system conditional on p. Let variables with a hat stand for percentage deviations from steady state and variables without subscript for the respective steady state values. The steady state of the economy conditional on p is described in Appendix A. The linearized model is given by:

$$c\hat{c}_t = b^h \hat{b}_t^h + Rb^h(\hat{\pi} - \hat{R}_{t-1} - \hat{b}_{t-1}^h) + \frac{vY}{X}(\hat{Y}_t - \hat{X}) - qh\Delta\hat{h}_t \tag{L01}$$

$$\hat{q}_t = \gamma_e \hat{q}_{t+1} + (1-\gamma_e)(\hat{Y}_{t+1} - \hat{h}_t - \hat{X}_{t+1}) - m\beta\hat{r}r_t - (1-m\beta)\Delta\hat{c}_{t+1} \tag{L02}$$

$$\hat{q}_t = \beta\hat{q}_{t+1} + \iota\hat{h}_t + \hat{c}_t' - \beta\hat{c}_{t+1}' \tag{L03}$$

$$\hat{b}_t = \hat{q}_{t+1} + \hat{h}_t + \hat{\pi}_{t+1} - \hat{R}_t = \hat{q}_{t+1} + \hat{h}_t + \hat{r}r_t \tag{L04}$$

$$\hat{Y}_t = \frac{v\eta}{\eta - (1-v)}\hat{h}_{t-1} - \frac{(1-v)}{\eta-(1-v)}(\hat{X}_t + \hat{c}_t') \tag{L05}$$

$$\hat{\pi}_t = \beta E_t \hat{\pi}_{t+1} - \kappa\hat{x}_t, \tag{L06}$$

$$\hat{R}_t = r_R\hat{R}_{t-1} + (1-r_R)((1+r_\pi)\hat{\pi}_{t-1} + r_{Y^T}\hat{Y}_{t+1}^T + r_Y\hat{Y}_{t+1}) + \hat{\epsilon}_{R,t} \tag{L07}$$

$$c''\hat{c}_t'' = (sA - \frac{1}{\beta})b^l\hat{b}_{t-1}^l + b^l\hat{b}_t^l + pc^\Psi\hat{p}_t - Rb^l(\hat{R}_{t-1} - \hat{\pi}_t) \tag{L08}$$

$$Y^T\hat{Y}_t^T = c\hat{c}_t + c'\hat{c}_t' + c''\hat{c}_t'' - pc^\Psi\hat{p}_t \tag{L09}$$

$$\hat{Y}_t^T = \frac{Y}{Y^T}\hat{Y}_t + \frac{Y^I}{Y^T}\hat{Y}_t^I, \tag{L10}$$

$$\hat{Y}_t^I = \hat{b}_{t-1}^l. \tag{L11}$$

$$\hat{b}_t^l = \begin{cases} p\hat{p}_t - \tau\hat{R}_t & \text{information sensitive} \\ \frac{p}{1-p}\hat{p}_t - \hat{R}_t & \text{constraint information insensitive} \\ 0 & \text{unconstraint information insensitive} \end{cases} \tag{L12}$$

where $\iota = (1-\beta)\frac{h}{h}'$, $\kappa = (1-\theta)(1-\beta\theta)/\theta$, and $\tau = \frac{\gamma R}{(sA-R)^2 b^{l,S}}$.

Calibration

The parameters for households, entrepreneurs, and retailers are the same as in Iacoviello (2005). The loan-to-value ratio of entrepreneurs is 0.89, the probability that retailers change the price is 0.25, and the discount factors are 0.99 for households and 0.95 for entrepreneurs. The elasticity of output with respect to housing is 0.03 and the weight of housing in the utility function of households is 0.1, which in steady state implies that around twenty percent of the housing stock is owned by entrepreneurs. The elasticity of labor supply is 1.01. The technology parameter A is set in a way to normalize entrepreneurial output to one. The parameters of the investors' sector are set in a way to make investors' output a third of the entrepreneurial sector and allow for information regime switches. The fraction of good portfolios is 0.82, the maximum capital for production is 0.5, the probability that projects are successful is only 0.25 but if it turns out successful investors get back sixfold the input. The return on good portfolios is 0.7 and information costs are 0.05. The thresholds p^{high} and p^{*} are then given by 0.76 and 0.87.

Figure 1: Loans to Investors for different p

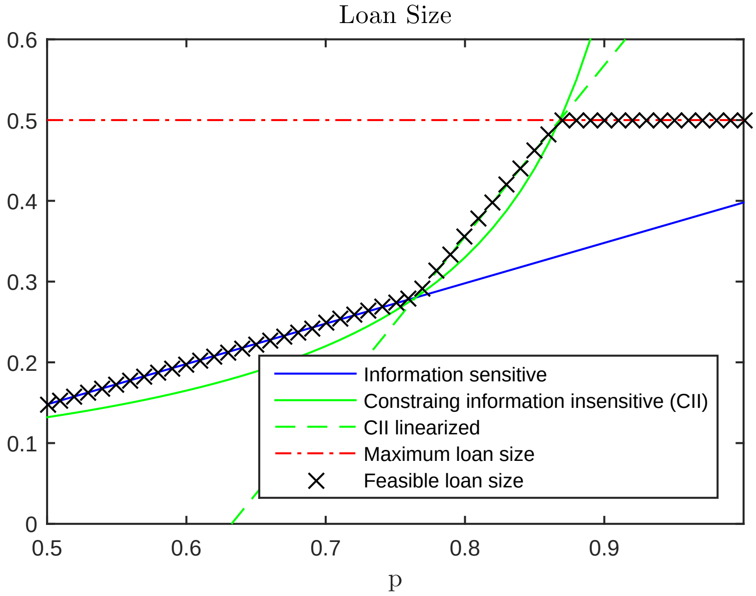


Figure 1 shows the loan sizes in different regimes depending on p_t. The blue line plots the loan size when debt is information sensitive; it increases only slightly and linearly with p. The green solid line shows information insensitive but financially constraint loans and the green dashed line a linearization thereof. The right line shows the maximum input and the black crosses the actual loan size.

3 Virtue and Vice of Information Insensitive Debt

In this Section I discuss two consequences of collateral quantity constraints. First, I will show how the economy – once information insensitive becomes possible – moves to a new equilibrium. Second, I will contrast the reactions to changes of the quality of the collateral in the two equilibria.

3.1 Transition from perfect information to bubble equilibrium

The probability that the investors' portfolios are good is 0.82 and thus higher then the threshold for which information insensitive debt becomes optimal. In this experiment I will, however, initially not allow lending without information production. There could be a regulation, for example, that requires lenders to prove that a portfolio is good before it can be used as collateral.[13] With such a regulation, loans will be information sensitive and only investors with good portfolios will able to borrow. If we now relax the regulation nothing changes initially, as the quality of portfolios has been produced before and hence is common knowledge. However, I am now introducing the following shock process to portfolios: one fifth of them is changing quality in every period, whereby neither the probability to change quality nor the quality after the shock, which remains the same, depends on the quality before the shock. In other words, portfolios change quality in a mean preserving manner. Since information here is not reproduced, this means that over time more and more portfolios have unknown quality, i.e. information in the economy depreciates over time. The economy then moves from an equilibrium with information sensitive loans to an equilibrium with information insensitive loans. In order to isolate the effect arising from the additional collateral available, I will initially restrict the reaction of the central bank to inflation and set $r_Y = r_{YT} = 0$. The central bank will follow the simple rule[14]

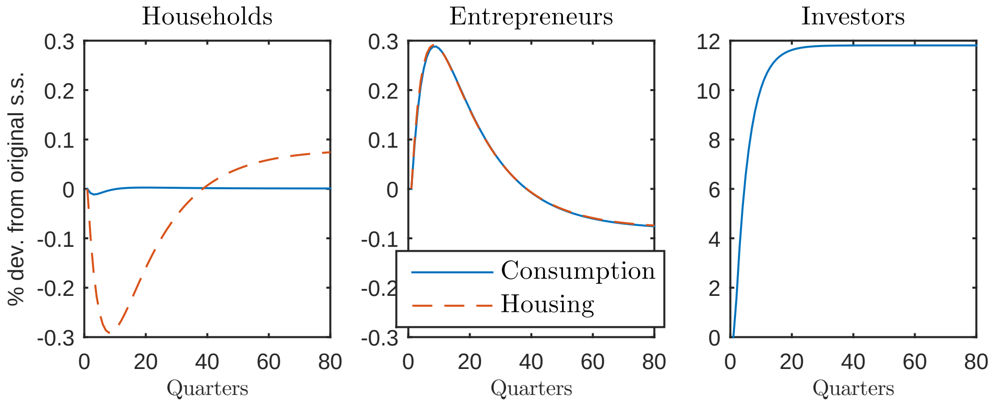
$$\hat{R}_t = 0.7 * \hat{R}_{t-1} + 0.3 * 1.5 * \hat{\pi}_{t-1}. \tag{CB1}$$

Figure 2 shows consumption and housing for all agents during the transition from the equilibrium with information sensitive debt to the economy with information insensitive debt. Households initially reduce their housing stock to increase their lending. After 5 years the housing stock goes back to the old value and then increases slowly the new steady state value that is somewhat higher then in the old equilibrium. Consumption does not react much, so that both together clearly make households better off. Entrepreneurs are the counterpart in the households' housing trades and so their housing stock moves in the opposite direction. Their consumption is closely related to the housing stock, as the housing stock determines their borrowing limit. While entrepreneurs benefit in the short-run, they are at a worse position in the long-run. The consumption of investors increases strongly. First and foremost, this regulatory change is hence to their advantage. Note, that the increase in their consumption results from the fact that now all investors can borrow

[13]A rationale for such a regulation could be that some households will loose by lending without information production (those whose investors run unsuccessful projects and have bad portfolios).

[14]The role of monetary policy and different central bank objectives will be the focus of the next section.

Figure 2: Consumption and Housing During Transition



and produce, whereas before only those with good portfolios could. The transition paths hence conceal a decreased heterogeneity between investors and an increased heterogeneity between households. A switch of the regime has indeed distributional consequences within the groups of agents: some households have bad luck and give loans to investors, that cannot repay; and instead of only the investors with good collateral, in an ignorance bubble also those with bad collateral get loans so that they can produce and consume as much as those with good collateral.

Ignorance is beneficial as long as investors have profitable projects and there are no shocks. In that case an ignorance bubble enhances growth. Note that in the absence of shocks an ignorance bubble can be permanent phenomena. Credit cycles can in fact be very long. Gorton and Ordoñez (2014b), for example, classify the US to have experienced a credit boom from the mid-80s until the financial crisis.

3.2 Effects of shocks to collateral quality

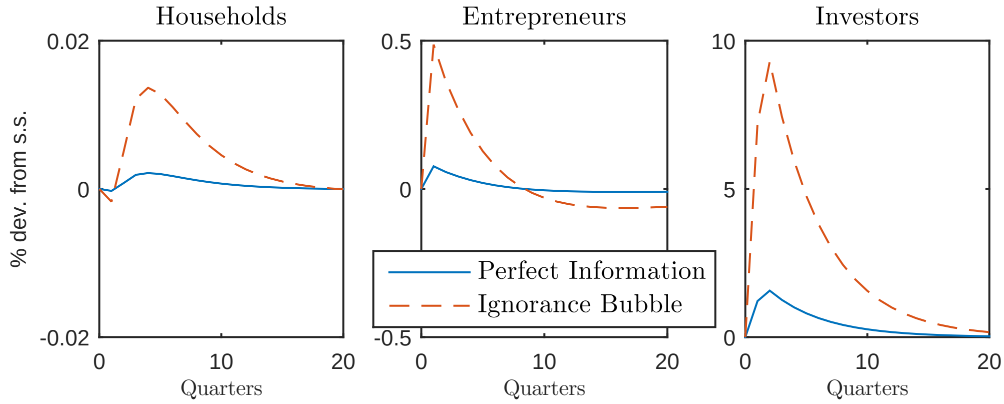
Here I want to show the effects of a change of the fraction of good portfolios and whether they differ in the two information regimes. As in the previous exercise 82% of the portfolios are good. Assume that p_t changes according to the AR(1) process

$$\hat{p}_t = 0.8 * \hat{p}_{t-1} + \epsilon_{p,t}.$$

I know investigate the effect of a one-time increase in p by five percent under the two regimes.

From (L12) we know that a shock to p of the same size will have a stronger effect in an economy with information insensitive than with information sensitive debt. The reason

Figure 3: Consumption after Shock to p



is, as in Gorton and Ordoñez (2014a), that in the information sensitive regime only the portfolios that before the shock had been bad and then became good support new loans, whereas with information insensitive loans all portfolios sustain more borrowing. The larger effects of the loan size result in larger effects also of all other variables. Figure 3 shows the different impulse responses for consumption of households, entrepreneurs and investors. The effect is strongly amplified.

Summarizing, information insensitive debt has one advantage and one disadvantage. If the information costs and the probability that portfolios are good make it optimal for households not to check the true quality, then such debt moves the economy to a new equilibrium with more production and a higher utility of households. On the other hand, the economy in the new equilibrium reacts much stronger to changes of the percentage of good portfolios.[15] So far, the changes seem mostly to effect the investors, whereas the consequences for the entrepreneurs and households are relatively weak. This changes once the central bank responds to either the output of entrepreneurs or total output, which is the topic of the next section.

4 Equilibrium Effects of Different Monetary Policies

In this model it is not clear to what the central bank should react to. Note that the output of investors is not inflationary and hence one could argue that the difference of actual total output from steady state total output should be ignored. However, the central could still dislike such movements or be unable to know whether output originates from

[15]The difference is even larger when we assume that only perceived quality changes. As long as debt is information sensitive, such changes have no effect at all. However, when loans are information insensitive, such changes have important implications.

entrepreneurs or investors. Questions of optimal policy are left for future work and instead the implications of different interest rate rules are analyzed. It first looks at the new equilibria the economy is converging to under different central bank rules and then how a shock to the amount of good portfolios effects the economy differently.

So far the only variable that the central bank was paying attention to was inflation. In order to better understand the role of monetary policy, I define four additional central bank rules with either the output of entrepreneurs or total output as only or additional input:

$$\hat{R}_t = 0.7 * \hat{R}_{t-1} + 0.3 * Y_{t-1} \tag{CB2}$$

$$\hat{R}_t = 0.7 * \hat{R}_{t-1} + 0.3 * (1.5 * \hat{\pi}_{t-1} + Y_{t-1}) \tag{CB3}$$

$$\hat{R}_t = 0.7 * \hat{R}_{t-1} + 0.3 * Y^T_{t-1} \tag{CB4}$$

$$\hat{R}_t = 0.7 * \hat{R}_{t-1} + 0.3 * (1.5 * \hat{\pi}_{t-1} + Y^T_{t-1}) \tag{CB5}$$

Table 1: Equilibrium Changes with Different Monetary Policies

Interest Rate Rule	1	2	3	4	5
Consumption					
Households	0.00	-0.01	0.02	0.78	-3.58
Entrepreneurs	-0.08	-0.10	-0.05	1.51	-7.43
Investors	11.81	11.85	11.75	8.81	25.61
Housing					
Households	0.08	0.09	0.06	-0.71	3.73
Entrepreneurs	-0.08	-0.09	-0.06	0.71	-3.73
Output					
Entrepreneurs	-0.08	-0.09	-0.07	0.73	-3.80
Investors	26.60	26.70	26.47	19.86	57.70
Total	8.31	8.34	8.28	6.75	15.55
Lending					
to Entrepreneurs	-0.08	-0.10	-0.05	1.51	-7.43
to Investors	26.60	26.70	26.47	19.86	57.70
Prices					
Inflation	0.00	-0.09	0.13	6.75	-31.09
Interest Rate	0.00	-0.09	0.13	6.75	-31.09
House Prices	0.00	-0.01	0.01	0.80	-3.70
Mark-up	0.00	0.01	-0.02	-0.79	3.62

Note: *Table 1 reports the percentage deviation of the new equilibrium with information insensitive debt from the old one with information sensitive debt.*

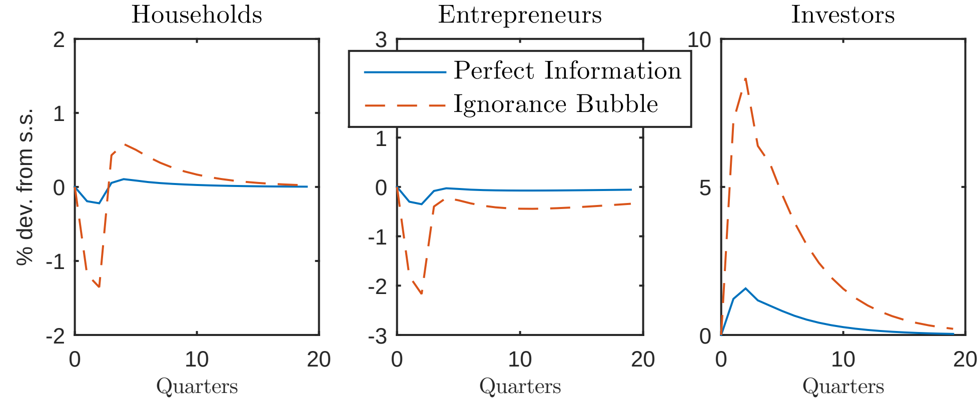
Table 1 shows the equilibrium effects, i.e. the permanent long-run effects, of the same experiment as above for different specifications of the central bank's policy rule. The left column refers to the case in which the central bank only cares about inflation and hence corresponds to the long-run responses of the impulse responses shown in Figure 2. In the new equilibrium households consume the same as before, but hold more housing. Entrepreneurs consequently reduce the housing stock and, as house prices are unchanged, can borrow less, which in turn reduces their output and consumption. Investors borrow more and hence produce and consume more. In this equilibrium prices are unchanged. If the central bank reacts only to the output of entrepreneurs, it decreases rates as output of entrepreneurs is below the old steady state value. In contrast to a monetary shock, a lower equilibrium interest rate does not increase their output. Due to the lower interest rate households have less incentive to save. As a consequence, households increase their housing stock, which reduces the borrowing capacity of entrepreneurs. If the central bank reacts both to inflation and entrepreneurial output, the equilibrium rate rises, with the opposite effect. Inflation is somewhat higher than before, but the decrease in entrepreneurial output is smaller. With the exception of the investors' sector, equilibrium changes have so far been relatively small. However, if the central bank reacts to total output, changes are huge. If it only cares about total output, it increases the rates, as total output moves up. The higher interest rate reduces lending to investors and increases lending to entrepreneurs. Interestingly, now all agents can consume more than in the old equilibrium. High interest rates here are beneficial, because they increase the housing stock of entrepreneurs and in turn their output. However, inflation is also much higher. If the central bank has a dual mandate and reacts to inflation and total output, it is in a dilemma. As total output is higher than in the old equilibrium, the central bank has a motive to increase its rates; but with higher rates the inflation rises. Instead, the economy moves to an equilibrium with much lower interest rates accompanied with an further increase of total output but very low inflation. Here lending to investors increases further and lending to entrepreneurs shrinks.

As we have seen, the kind of equilibrium the economy converges to when information insensitive debt becomes possible depends strongly on the central bank. Using the same shock size and process as before but again different specifications of the central bank reaction function, allows to compare the strength of the fluctuations depending on the information regime and the interest rate rule.

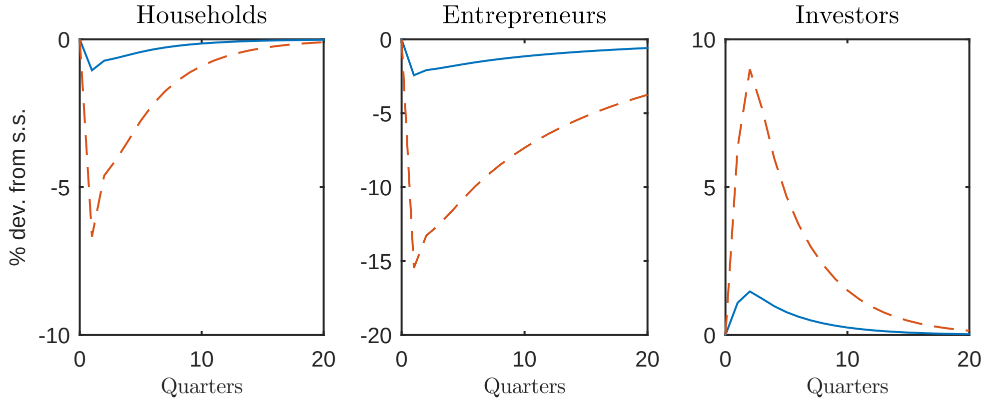
Figures 4 shows the impulse responses for consumption. As expected after having analyzed the new equilibria, the additional interest rate channel causes much larger fluctuations. While the new equilibrium was very similar whether the central bank reacted only to inflation or also to the output of entrepreneurs, the fluctuations are much larger for the latter. The impulse responses of the other variables are reported in Appendix B.

Figure 4: Consumption after Shock to p with Different Monetary Policies

(a) Central Bank Rule with Inflation and Entrepreneurial Output (CB3)



(b) Central Bank Rule with Inflation and Total Output (CB5)



Even if the introduction of investors alone had relatively small effects on entrepreneurs both regarding equilibrium changes and increased vulnerability to collateral quantity changes, in combination with a central bank that cares about output - in particular for total output - effects can be huge.

One could also ask how a monetary policy shock plays out differently in the two regimes. Figure A5 in the Appendix shows the effect of a surprising one percent increase of the interest rate. Since investors can still borrow the optimal amount if debt is information sensitive, the impact on the investors is smaller with such debt compared to insensitive debt, for which all investors are able to borrow less. For the other sectors the effect is the same and variables react as expected.

5 Emergence of Bubble and Slow Recovery after Bursting

An interesting feature of information insensitive debt is that it can explain the emergence of a credit bubble, which of course is the prerequisite for a financial crisis resulting from the bursting of such a bubble. I will, in isolation, discuss the emergence of a bubble and then the reason for a slow recovery after the bubble bursts.

Ignorance Bubble

Assume that the fraction of good land is too small to allow for information insensitive debt, say 0.7. Assume a shock that temporarily changes the fraction of good portfolios so that debt becomes information insensitive. Obviously a simple linear approximation of the model around the steady state is not able to capture the effects of the switch of information regimes. Instead, I follow the suggestion of Guerrieri and Iacoviello (2015)[16] and apply an adapted first-order perturbation method in a piecewise fashion in order to solve a dynamic model with occasionally binding constraints. The occasionally binding constraints are related to the two information regimes. In one regime banks produce information about the collateral value, in the other they do not. This solution allows for capturing effects of shocks depending on the information regime and the amount of information-insensitive debt in the economy. The method links the model's first-order approximation around the same point under the two regimes.

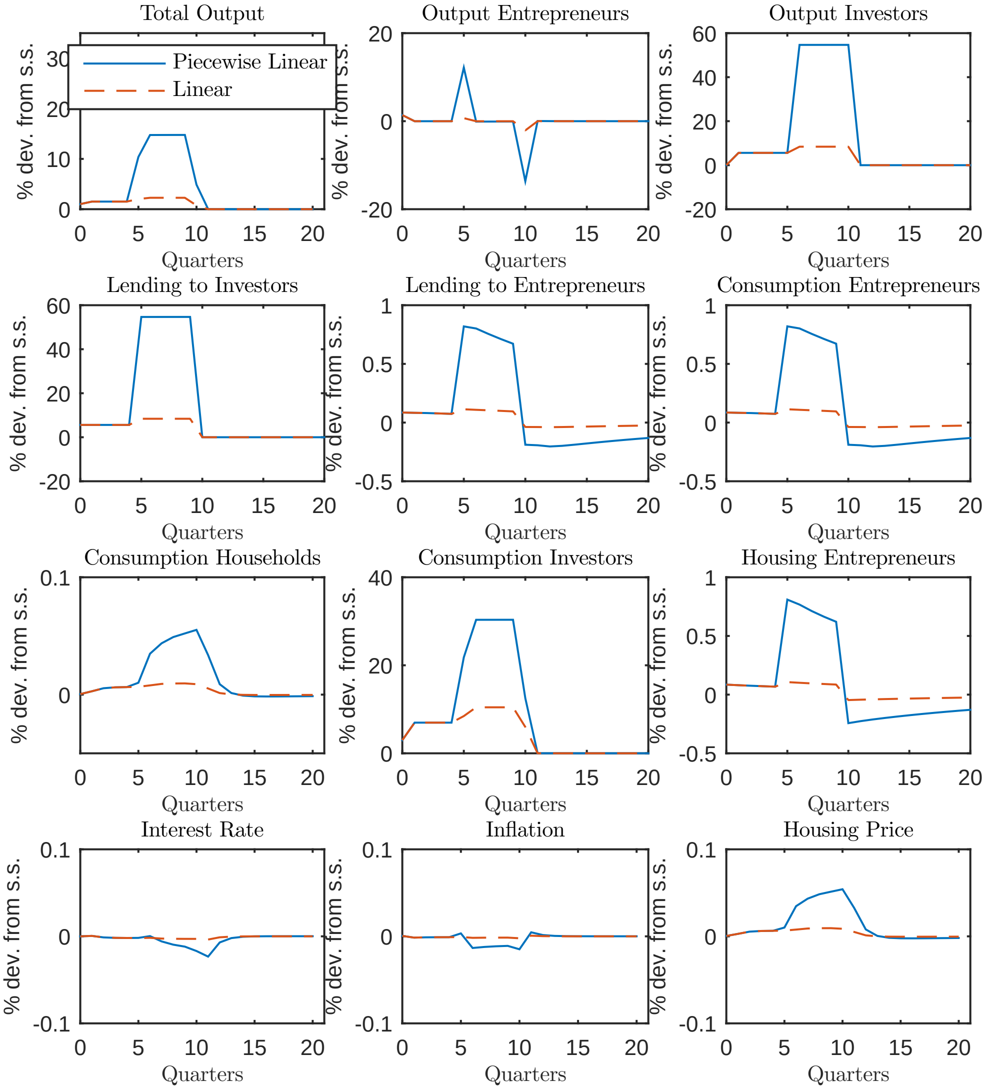
Assume the following: in every period all portfolios are shocked and with probability p they are good and with probability $1-p$ they are bad. Then all information produced in period t is lost in $t+1$. Let's now change p for five periods only slightly, say from 0.7 to 0.76, so that loans remain still information sensitive. For the following five quarters p is again increasing, say to 0.78, which is above the threshold for which debt becomes information insensitive. After these ten periods with more good portfolios, p jumps back to the steady state value.

Figure 5 plots all variables for the described shock process using a typical linear approximation and the piecewise linear approximation. The central bank is only concerned about inflation and follows (CB1), so that effects originating from an easing of the collateral quantity constraints are isolated.

During the first five periods both solutions are identical, as all debt remains information sensitive. In the following five periods, however, the impulse responses are very different. The linear model strongly underestimates the effects of the changes of the amount of

[16] Their methodology has been shown to deliver satisfactory results in many different models. In contrast to a nonlinear global solution - as all first-order perturbation solutions - it neglects future shocks so that precautionary behavior, due to constraints possibly binding in the future, is not taken into account. However, it preserves the advantages of such solutions. Above all, it can be applied to models with a large number of state variables and thus to models useful for quantitative policy analysis.

Figure 5: Temporary Ignorance Bubble



investors with good collateral. The consumption of entrepreneurs moves very little with the linear approximation, but increases by one percent when the non-linearity is considered. Note that total output now increases by nearly 15%. This sizable effect is accompanied by only minimal changes of the prices. In the presence of collateral quantity constraints the real economy can move considerably even without large movements in prices.

The drop in output and all other fluctuations are obviously much larger after a nearly identical shock when information insensitive debt has been created before. However, some variables, for example total output, returned to the original level already one period after p is back at the steady state. Remeber that here collateral is shocked every period, so that information needs to be reproduced every period. In the next section, persistence of information is reintroduced.

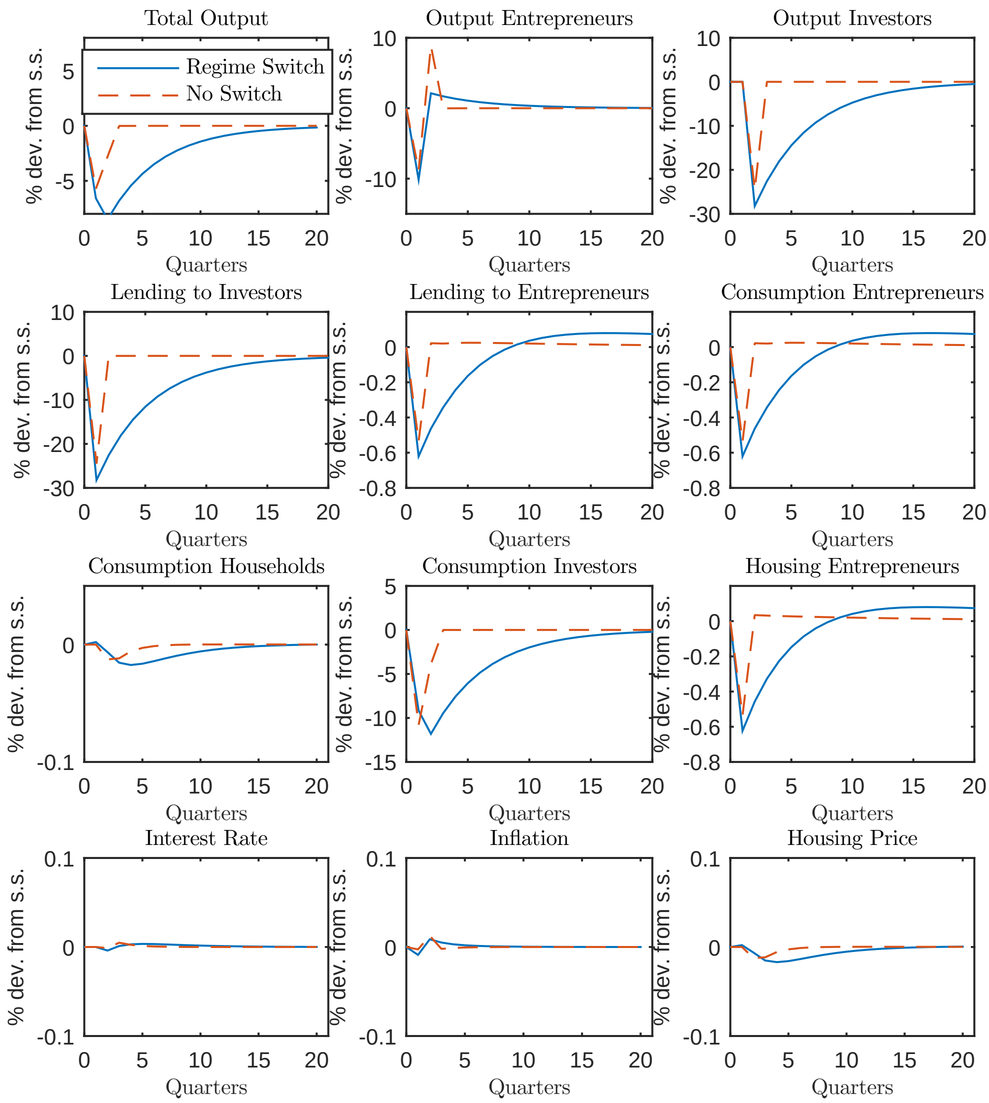
Figure A4 in the Appendix plots for the same shock process the impulse responses for positive and negative shocks using the piecewise linear method. Obviously, the responses are asymmetric, as the positive shock results in a switch of the information regimes, whereas the negative shock does not.

Slow Recovery after Bubble Bursts

Assume now that the economy has been in an ignorance bubble for some time so that all information has vanished. In fact, let's go back to the economy we started with, where $p = 0.82$. In addition, instead of all collateral again only one fifth of it is shocked in every period. In such a set-up, nearly identical shocks can have very different effects even when the amount of information insensitive debt is the same. Figure 6 compares the effect of a one period decrease of the fraction of good portfolios to 0.77 and to 0.76 respectively. The slightly larger shock results in information production, whereas the smaller one does not.

Figure 6 shows the very different reactions of the economy. In the first period reactions are similar. Lending to investors is reduced with all the related effects discussed before. Little surprising the effects are somewhat larger for the larger shock. The big difference arises in the periods thereafter. As the shock is not persistent, the economy returns immediately to the information insensitive equilibrium when information remains insensitive. Lenders simply adjust to the higher number of good portfolios and increase lending to investors again. When information is reproduced, however, the economy converges only slowly back to the pre-shock level. Note that the fraction of good portfolios is the same in the two scenarios from the second period onwards. The difference is that without information production lenders do not know which portfolios are good and which ones are bad, so that they lend to all investors. After information has been reproduces they do know which portfolios are good and which ones are bad. It then takes some time for information to diminish and hence for the economy to return to pre-shock levels. Switches of the information regime hence offer an explanation for slow recoveries.

Figure 6: Financial Crisis



6 Possible Policy Applications of the Model

The model immediately suggests some interesting policy applications. In this section I briefly discuss three of them, but the actual analyses are left for future work.

Macro-prudential Regulation and Growth

In a model with collateral quantity constraints a higher growth path is associated with higher fragility (as in Gordon and Ordoñez 2014a, 2014b, and in Ranciere, Tornell, and Westermann 2008), which induces a real trade-off for macro prudential regulation. Such a model can hence be used to analyze the cost of decreasing macroeconomic volatility and which factors determine the cost. In this respect an extension of Gorton and Ordoñez (2014b) is interesting. They show that when the project returns of entrepreneurs decrease with the amount of active entrepreneurs, endogenous credit cycles can emerge, i.e. even without a shock, ignorance bubbles burst after some time. Note that new credit before the financial crises went mostly to low TFP sectors (Brunnermeier and Reis 2014). A model like the one presented here can also be used to study how a decline in TFP interact with an ignorance bubble in a general equilibrium model.

Quantitative Easing and ABS Programs for SMEs

In this model the central bank (or government) may be interested in preventing information production after a negative shock in order to prevent a credit crunch. For example, they may find it optimal to use tax income to buy debt, when the regime switches to information sensitive debt. Beyond that, we observed during the crisis that the sectorally impaired monetary transmission mechanism favored debt of large corporations. In the model sectoral differences could be modeled by assuming different information production costs for different firms. This introduces heterogeneity among firms regarding the access to information insensitive funding. In this context it is interesting to discuss the ECB's consideration to buy securitized loans. In addition to the advantages outlined in Brunnermeier and Sannikov (2014b), the model here adds the rationale to prevent information production about the collateral quality. An interesting question could be whether the timing of such programs matters, in particular whether they are done before or after information is reproduced.

The Role of Quantities in Monetary Policy

In most New Keynesian Models financial frictions work through prices and quantities hardly play a role. But taking into account developments of quantitative aggregates may improve monetary policy. Brunnermeier and Sannikov (2014b) highlight that quantitative aggregates contain information that is absent in prices, which are prone to sudden and large corrections. Money aggregates, for example, could be used as an indicator for how close an economy is to move to a new equilibrium. Beck and Wieland (2008) suggest using the growth of monetary aggregates as a cross-check for monetary policy and show that with output gap misperceptions it improves policy outcomes. Adrian and Shin (2009) advise tracking balance sheet items because the aggregate size of the balance sheet contains information about the risk of a liquidity crisis. Also Borio and Drehmann (2009) and

Drehmann (2013) propose looking at aggregates, namely the debt to GDP ratios in order to detect the build-up of imbalances and Borio and Lowe (2004) recommended central banks to pay greater attention to credit aggregates already ten years ago. The ECB's monetary pillar attests the widespread belief in the usefulness of quantities when the ECB was created. In a model with collateral quantity constraints, quantitative quantities could be very useful for monetary policy.

7 Conclusions

In this paper I have introduced information insensitive debt in a New Keynesian Model. Such debt leads to a new friction that I named collateral quantity constraint. Opacity about collateral quality is found to enhance growth but also to increase volatility. Monetary policy proved crucial in determining the equilibrium effects of regime switches. The model offers an explanation for strong output growth without large price movements. Nearly identical shocks to the fraction of good collateral have been shown to potentially cause very different effects depending on the amount of information insensitive debt in the economy and whether information is reproduced or not. The model hence may react non-linearly and asymmetrically to collateral quantity changes.

Even though the model developed in this paper is probably much too simple to be already very valuable for actual policy applications, the introduction of collateral quantity constraints revealed interesting questions related to macroprudential regulation, monetary policy, and growth. For example, the model features a real trade-off between higher consumption and less volatility. The model may hence provide a good starting point for actual policy application. In addition, the model should be estimated in order to confirm that collateral quantity constraints are important and quantify their contribution to economic fluctuations.

Bibliography

Adrian, T., & Shin, H. S. (2009). Money, liquidity, and monetary policy. FRB of New York Staff Report, (360).

Beck, G. W., & Wieland, V. (2008). Central bank misperceptions and the role of money in interest-rate rules. Journal of Monetary Economics, 55, 1-17.

Bernanke, B. & Gertler M. (1989). Agency Costs, Net Worth and Business Fluctuations. American Economic Review, 79(1):14-34.

Bernanke, B. S. (1983). Nonmonetary Effects of the Financial Crisis in Propagation of the Great Depression. American Economic Review, 73(3):257-76.

Borio, C. E., & Lowe, P. W. (2004). Securing sustainable price stability: should credit come back from the wilderness?.

Borio, C., & Drehmann, M. (2009). Assessing the risk of banking crises?revisited. BIS Quarterly Review, 29, 46.

Brunnermeier, M. K, & Sannikov Y. (2014b). Monetary Analysis: Price and Financial Stability. ECB Forum on Central Banking. Sintra, Portugal

Brunnermeier, M. K. & Reis R. (2014). A Crash Course On The Euro Crisis. In preparation

Brunnermeier, M. K., & Sannikov, Y. (2012). The I Theory of Money. Working Paper, Princeton University.

Christiano, L. J., Roberto M., & Rostagno M. (2010). Financial Factors in Economic Fluctuations. ECB Working Paper 1192.

Christiano, L., Motto, R., & Rostagno, M. (2013). Risk shocks (No. w18682). National Bureau of Economic Research.

Negro, M., Eggertsson, G., Ferrero, A., & Kiyotaki, N. (2011). The great escape? A quantitative evaluation of the fed's liquidity facilities (No. 520). Staff Report, Federal Reserve Bank of New York.

Drehmann, M. (2013). Total credit as an early warning indicator for systemic banking crises. BIS Quarterly Review, June.

Gorton, G. B. (2010). Slapped by the invisible hand: The panic of 2007. Oxford University Press.

Gorton, G. B., & Metrick, A. (2012b). Who Ran on Repo? (No. w18455). National Bureau of Economic Research.

Gorton, G., & Metrick, A. (2012a). Securitized banking and the run on repo.Journal of Financial Economics, 104(3), 425-451.

Gorton, G., & Ordoñez G. (2014a). Collateral Crises. American Economic Review, 104(2): 343-78.

Gorton, G., & Ordoñez, G. (2014b). Crises and Productivity in Good Booms and in Bad Booms (No. 14-008). Penn Institute for Economic Research, Department of Economics, University of Pennsylvania.

Guerrieri, L., & Iacoviello, M. (2014). Collateral Constraints and Macroeconomic Asymmetries. Federal Reserve Board.

Guerrieri, L., and Iacoviello M. (2015). Occbin: A Toolkit to Solve Models with Occasionally Binding Constraints Easily. Journal of Monetary Economics, March, vol. 70, 22-38.

Holmström, B. (2015). Understanding the Role of Debt in the Financial System. BIS Working Paper 479.

Iacoviello, M. (2005). House prices, borrowing constraints, and monetary policy in the business cycle. American Economic Review, 739-764.

Jermann, U., & Quadrini, V. (2012). Macroeconomic effects of financial shocks. American Economic Review 102(1), 238-71.

Mendoza, E. G. (2010). Sudden stops, financial crises, and leverage. The American Economic Review, 100(5), 1941-1966.

Ranciere, R., Tornell A., & Westermann F. (2008). Systemic Crises and Growth. Quarterly Journal of Economics 123: 359-406.

A Steady State

A.1 Steady State

The steady state is given by the following equations:

$$\frac{qh}{Y} = \frac{\gamma v}{(1-\gamma^e)X} \tag{A.1}$$

$$\frac{b^h}{Y} = \frac{\gamma v m \beta}{(1-\gamma^e)X} \tag{A.2}$$

$$\frac{c}{Y} = v\frac{(1-\gamma)(1-\beta m)}{(1-\gamma^e)X} \tag{A.3}$$

$$\frac{c'}{Y} = \underbrace{(X - v + \frac{(1-\beta)m\gamma v}{(1-\gamma^e)})\frac{1}{X}}_{\Theta} + (1-\beta)\frac{b^\Psi}{\beta Y} \tag{A.4}$$

$$b^l = \begin{cases} pb_*^\Psi - \frac{\gamma}{sA-R} & \text{if} \quad p < p^{\text{high}} \\ \frac{\gamma}{(1-p)(1-s)R} & \text{if} \quad p^{\text{high}} < p < p^* \\ b_*^\Psi & \text{if} \quad p^* < p \end{cases} \tag{A.5}$$

$$c'' = (sA\beta - 1 + \beta)\frac{b^\Psi}{\beta} + pc^\Psi \tag{A.6}$$

$$\frac{H}{h} = 1 + \frac{j(1-\gamma^e)X}{(1-\beta)\gamma v}(\Theta + (1-\beta)\frac{b^l}{Y}\frac{1}{\beta}), \tag{A.7}$$

where $\gamma^e = m\beta + (1-m)\gamma$.

B Additional Figures

Figure A1: Impulse Responses with Interest Rate Rule 1

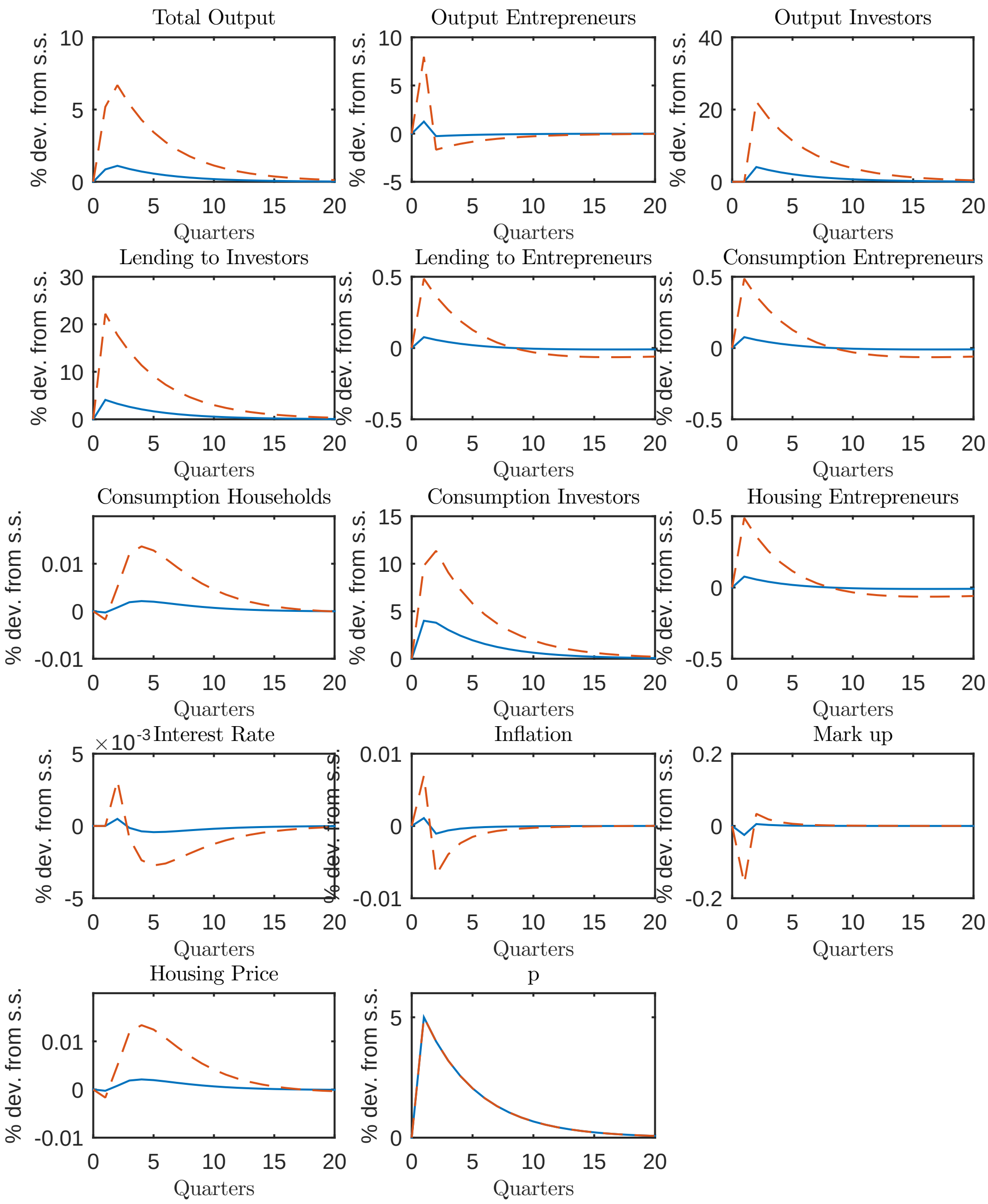


Figure A2: Impulse Responses with Interest Rate Rule 3

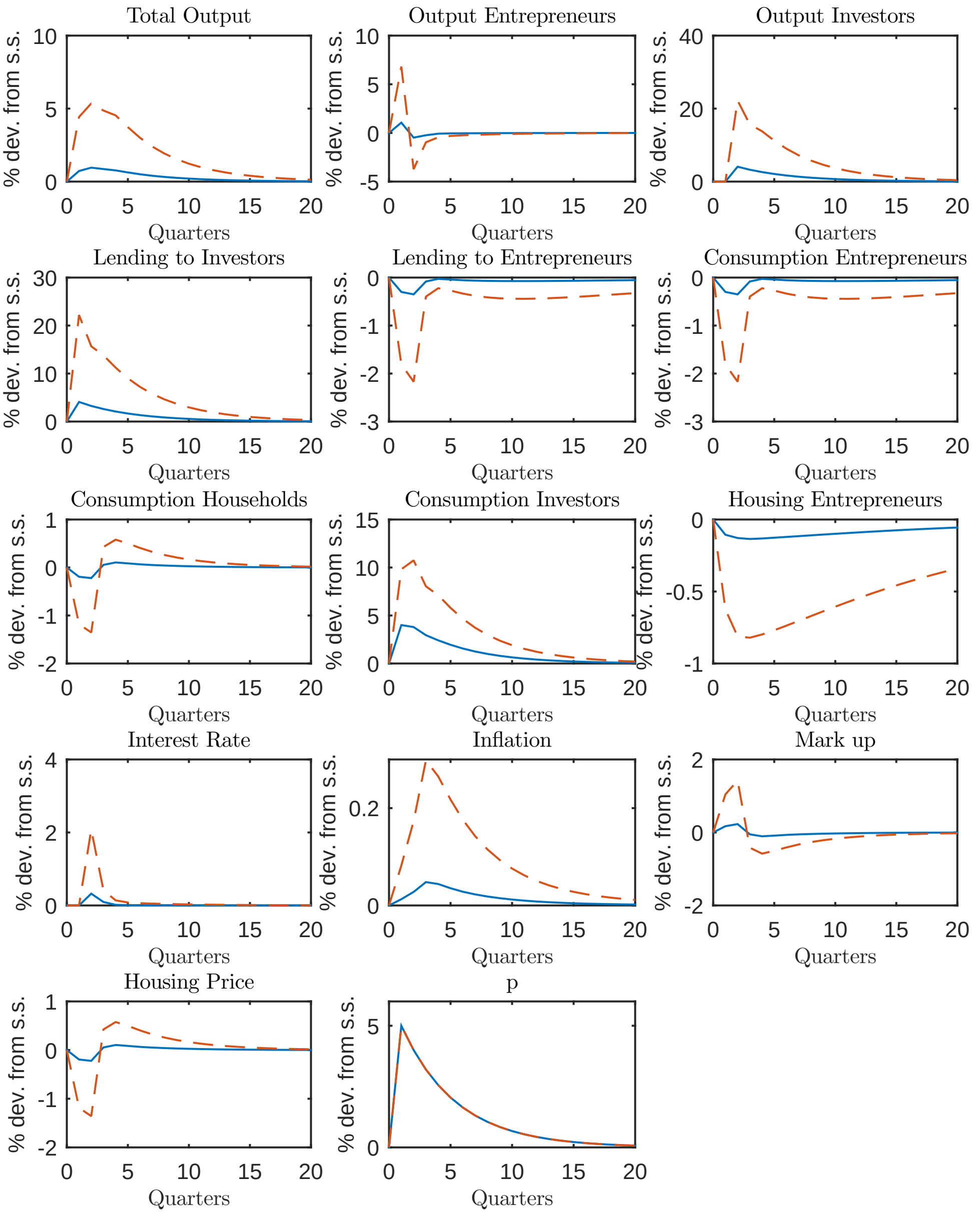


Figure A3: Impulse Responses with Interest Rate Rule 5

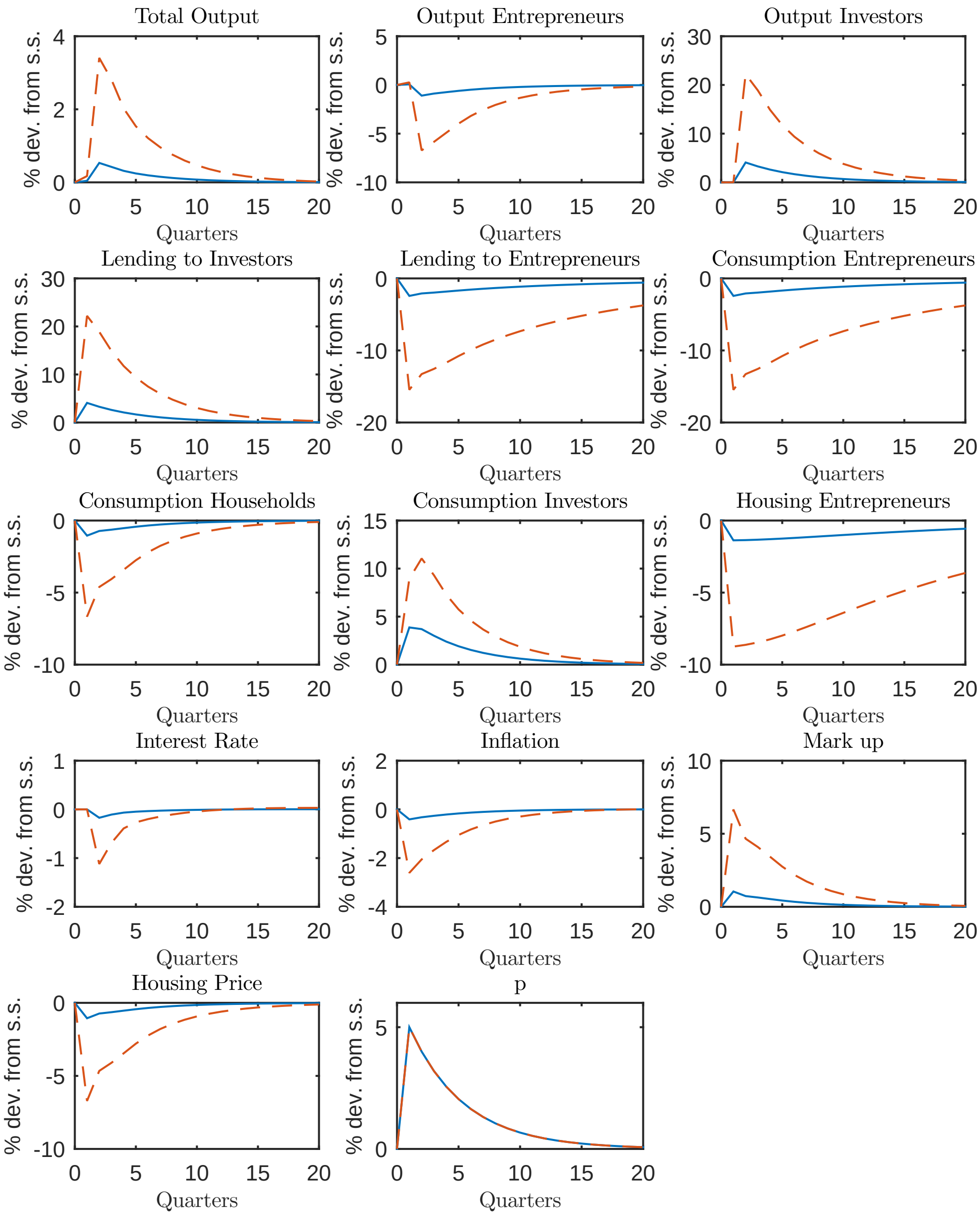


Figure A4: Non-liniar Responses with Piecewise Linear Solution

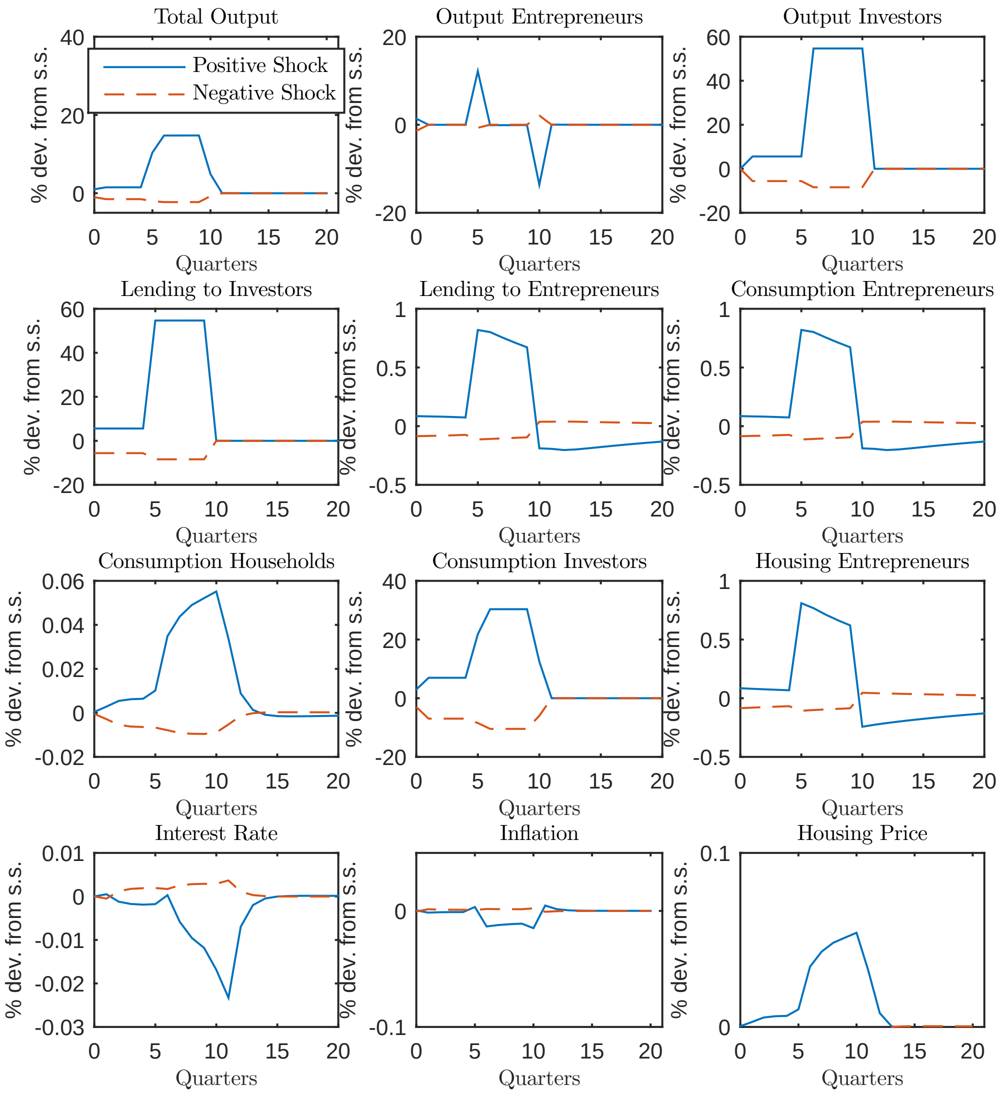


Figure A5: Impulse Response after Interest Rate Shock