No. 13 | 2010

Staff Memo

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NORGES BANK

ISSN 1504-2596 (online only)

ISBN 978-82-7553-576-2 (online only)

Credit, Asset Prices and Monetary Policy

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October 15, 2010

Abstract

Based on the established literature, we develop a structural model for the Norwegian economy that incorporates feed-backs from asset prices and credit to the real economy. We then use this framework for policy analysis, focusing on the role of asset prices and credit under optimal simple monetary policy rules.

1 Introduction

The recent financial crisis made clear that existing macro models in use at central banks were unsuitable to analyze the effects that disruptions in the financial market may have on prices and activity. Although there was a large literature on for example the credit channel of monetary policy available, including general equilibrium models (Kiyotaki & Moore (1997), Bernanke et al. (1999), Iacoviello (2005)), these mechanisms were largely absent from DSGE models used at central banks at the time of the financial crisis. The main short-coming of standard DSGE models in this respect is the lack of feed-back from financial variables to the rest of the economy. This originates from a number of simplifying assumptions. First, the Modigliani-Miller theorem holds, which implies that balance sheet positions do not affect real decisions. Second, financial markets are normally summarized by one interest rate only. Finally, there is no heterogeneity, for instance all agents have the same expected consumption paths, which means no borrowing and lending in equilibrium.

Without question, these are unrealistic assumptions. Still, they might be innocuous approximations in normal times. During most of the period termed 'the Great Moderation' in developed economies, there were few episodes where credit disruptions were a hindrance to economic growth. One example, however, is the banking crisis in the Scandinavian countries in the beginning of the 90s, where also Norwegian banks were hard hit. This led to a period of subdued growth and increasing unemployment in Norway. However, following the restructuring of the banking sector and new regulation, the period 1993-2008 was characterized by well-functioning credit markets. Norwegian banks also seem to have survived the recent financial crisis quite well.

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The effect of asset prices on activity and consumer prices can be expected to run mainly through two channels. First, there is the wealth effect on consumption, the fact that higher wealth potentially leads to increased levels of consumption. Second, asset prices can influence economic decisions more indirectly by affecting agents' access to credit. This latter mechanism can be classified as a balance sheet effect, originating from the existence of various types of frictions in the credit market. We shall argue that of the two channels, the balance sheet effects of asset prices are probably relatively more important.

In this report, we focus on two main theories why private sector balance sheets matter. One is due to Bernanke et al. (1999). In their model, asymmetric information and costly state verification lead lenders to charge a premium above the riskless rate, depending on the net worth of the borrower. A reduction in net worth implies an increase in premia and, hence, borrowing costs. To the extent that net worth is procyclical, the balance sheet effect will tend to amplify movements in activity and prices. This mechanism is also known as the financial accelerator.

A related theory, originating with Kiyotaki & Moore (1997), states that, due to limited enforceability of contracts, lenders will require borrowers to post collateral in order to obtain credit. Hence, the access to credit will depend on borrower's collateral value, which typically is related to asset prices. One interpretation of this theory is that the credit premium is zero as long as the borrowing constraint does not bind, and goes to infinity when demand for credit hits the constraint. Again, to the extent that the collateral value is procyclical, this mechanism will tend to stimulate business cycle movements.

Including financial frictions could potentially improve the empirical merits of our models. Furthermore, it will close the gap between the economic stories told by the model and the corresponding motivations underlying the actual policy actions. For example, we often refer to housing prices in our inflation reports, even though this variable is absent from most monetary policy models. Similarly, a more careful modeling of financial variables also allows for a richer set of economic disturbances to help understand the driving forces of the economy.

We therefore develop and estimate two models, focusing on the demand for credit by households and firms, respectively. Our point of departure, which also serves as a reference model, is a medium scale DSGE model for a small open economy. An alternative approach would have been to build one model incorporating both mechanisms. However, a goal of this paper is to shed some light on the empirical importance of credit frictions originating in the household sector versus the firm sector, respectively. Both models are estimated on Norwegian data.

An interesting question is to what extent the existence of financial frictions makes the conduct of monetary policy more demanding. That is, for a given set of exogenous disturbances to the economy, will the presence of financial frictions increase the volatility in the target variables? In this paper, we answer this question by comparing the expected loss in models with and without frictions, respectively.

Another issue, which has been raised in models with asset prices, is whether monetary policy should respond to movements in asset prices. The models developed in this paper lend themselves naturally to investigate this question. We approach it by analyzing optimal simple instrument rules, analogously to the influential studies by Bernanke & Gertler (1999) and Bernanke & Gertler (2001).

As a result of the crisis, there is now increasing interest in issues related to the link between monetary policy and financial stability. This stems from the recognition that there might exist a trade-off between stability in prices and real activity on the one hand, and financial stability on the other. A related issue that has been raised in the policy debate after the crisis, is the role played by financial regulation in stimulating or dampening macroeconomic fluctuations, and whether such regulation should be used as a macroeconomic stabilization tool (as discussed by, for instance Blanchard et al. (2010)). We use our estimated model to perform a stylized policy analysis on this subject. Our approach is to first consider optimal simple policy rules with an without private credit in the objective function of the policymaker. Our analysis indicates that if credit is a separate concern to the monetary authority, and the interest rate is the only policy instrument, then there are substantial gains from letting the interest rate react to credit movements. However, if credit is of no separate concern, over and above its role in affecting inflation and output dynamics, then the interest rate should not respond to credit. Finally, if policy is conducted with two instruments, both a rule for the loan-to-value ratio and an interest rate rule, then interest rates should react to inflation and output alone, whereas the credit related instrument deals with the concern for financial stability.

The literature on estimated DSGE models with financial frictions is rapidly expanding. However, there are two important aspects of the economy missing from most of these studies. First, even thought the first order conditions making up our macro models are inherently non-linear, most macro models are linearized around steady state as a first order approximation. This rules out the potential effects of uncertainty on economic decisions. Hence, there is no role for precautionary behavior or risk premia in asset prices, the latter being a central feature of asset markets. Second, agents are assumed to form rational, or model consistent, expectations, which makes the existence of asset bubbles highly unlikely. Hence, the rational expectations assumption makes it hard to analyze non-fundamental behavior, which appears to be an inherent feature of asset prices. As part of this project, we have therefore worked along these two dimensions, developing tools to address them. However, neither of these tools have yet reached the stage where they can be taken seriously as a quantitative representation of the data, and we therefore do not use them below.

The rest of this paper is organized as follows. First we give a brief background discussion on how asset prices may influence the economy through wealth effects and credit market imperfections. We thereafter proceed by describing the two models we use for our analysis, and shed some light on their properties by studying calibrated versions of them. In section 4 we present the results from estimating the models on Norwegian data. In section 5 we consider some policy experiments within the model found to be the most empirically relevant. In section 6 we give a discussion of further issues we have worked on, but that are not included in the model based analysis. We also give a brief review of part of the very recent literature on financial intermediation and unconventional monetary policy spurred by the financial crisis.

2 Background

The link between financial variables and the real economy is complex. Looking at asset prices, there are two channels that have received special attention in the literature. First, there is the wealth effect on consumption. The link between asset prices and consumption follows more or less directly from the budget restriction. All else equal, wealthy households will consume more than poorer households. The question is, however, by how much and when. Second, movements in asset prices will affect the real economy through so-called balance sheet effects. In the presence of credit market frictions, borrowers' access to credit will be determined by their net worth. Since asset prices determine net worth, asset prices will influence the real economy indirectly through the credit market.

2.1 Wealth effects on consumption

The study of wealth effects on consumption goes at least back to Ando & Modigliani (1953) and Friedman (1957). Assuming that households maximize lifetime utility given a budget constraint, we can arrive at the following simplified 'consumption function':

$$c_t = ra_{t-1} + y_t^P \tag{1}$$

where c_t denotes (the logarithm of) consumption, a_{t-1} is household wealth at the beginning of period t, and y_t^P represent permanent income, i.e. the annuity of human wealth. The aggregate return on assets is denoted by r. The simple representation given by (1) rests on a number of strong assumptions, like infinitely lived households, linear marginal utility, constant return on assets, and returns being equal to the inverse discount factor. A reasonable "guesstimate" of r would be in the neigborhood of 0.04, indicating that a 1 percent increase in wealth should make consumption increase by 0.04 percent.

In order to estimate the marginal propensity to consume out of wealth(MPC, hereafter), it is common to start with a generalization of (1), like e.g.:

$$c_t = \delta a_{t-1} + \beta y_t + errorterm \tag{2}$$

where we have linked permanent income, Y_t^P, to current disposal income, y_t, and δ and β denote the marginal propensity to consume out of wealth and income, respectively. For simplicity, we assume that the variables are measured in logs. There are a number of reasons to expect that the size of δ will depend on the composition of a, relating to riskiness and other factors. There is a significant theoretical difference between financial assets on the one hand and housing on the other. This stems from the fact that the housing stock has a dual role; housing is a wealth object that can be used as a means of saving, but for homeowners, the housing stock also provide housing services from which the household obtain utility. Thus, an increase in the price of housing has two effects. There is a direct effect on wealth proportional to the price increase. However, this effect is offset by the fact that the price of housing services increases at the same time, which is equivalent to a reduction in real disposal income. Hence, based on this argument, one would expect that the effect of housing prices on consumption would be smaller than the MPC of other asset prices. In most countries, housing wealth is the dominant form of wealth held by households.

There is a long list of empirical work on the effect of house prices on consumption. The estimated elasticities differs widely between studies and countries, with estimated elasticities ranging from slightly below zero up to around 20 percent. A recent study based on Norwegian data, Jansen (2010), suggests a long-run elasticity of 15 percent. However, it appears that the MPC out of housing wealth is higher in countries with more developed credit markets. This suggests that the effect of housing prices affects consumption indirectly through the credit market. This is confirmed by Muellbauer (2008), who shows that the effect of housing prices is insignificant once he controls for a "credit availability" index measuring households' access to credit. Since there is a close link between housing value and the amount households can borrow, house prices mainly affect consumption indirectly by determining their access to credit. When house prices increase, homeowners can withdraw some of their home equity in the form of increased borrowing. Some of this borrowing will be spent on consumption. An important premise for this channel to be operative is that credit markets are not perfect, but instead are characterized by frictions leading lenders to impose collateral requirements on their borrowers. We discuss the commonly known sources of financial frictions and their implications in the next section.

2.2 Financial frictions and balance sheet effects

In general, financial frictions refers to features that prevent funds from flowing between agents with different opportunities to make productive use of them. The best understood sources of financial frictions are asymmetric information between borrowers and lenders, costly state verification and limited enforcement of financial contracts. Asymmetric information may here both regard the effort borrowers induce to make productive use of their capital, and knowledge about central properties, such as profitability and riskiness, of the projects borrowers wish to finance. The former information asymmetry leads to the problem of *moral hazard*, whereas the second leads to *adverse selection*.

In order to overcome these agency problems, borrowers are typically required to post collateral in order to obtain funds. In broad terms, the link between collateral value and access to funds may take two forms. First, there may be a price mechanism, by which the interest rate on a loan is lower, the more collateral a borrower can post. This mechanism typically arises in environments where only the borrower knows the true state of his project, while the lender must pay a cost to observe it. Ex post, after a project has matured, the borrower has an incentive to underreport the value of his project so as to pay a low yield to the lender. Lenders on their side, are not happy to control if reports of low returns are truthful or not, as such verification is costly. To mitigate the problem, firms must partly rely on their own, internal, funds to finance projects. The higher is the share of internal funds, the weaker is the incentive to misreport that a bad state has occurred, and hence the lower are the expected state verification costs to the lender. Because lenders finance their verification costs by charging an interest rate premium, it follows that the larger is the share of internal financing in projects, the lower is the external finance premium. Optimal financial contracts with costly state verification were first analyzed by Townsend (1979), while the aggregate implications of this friction have later been studied by Bernanke & Gertler (1989), Bernanke et al. (1999), Christensen & Dib (2008), and, more recently, Christiano et al. (2009). In short, the common feature of the models used in these analyses is that external financing of projects is more expensive than internal financing, and that the gap between these two sources of funds ("the external finance premium") increases when borrowers must finance more of their projects externally. Hence, when borrowers' financial situation improve, credit becomes cheaper, and more investment projects become profitable.

The alternative mechanism linking financial asset values to credit access is a more direct collateral constraint, by which the amount of lending is constrained to a fraction of borrowers' collateral value. This type of constraint arises in environments where the value of capital requires effort by the borrower to yield returns. Because these agents cannot pre-commit to making productive use of their capital, they will not be able to borrow more than the collateral value that their creditors are able to replenish in case of default. Hence, in times with high asset prices, activity is stimulated as productive agents get better access to credit. The macroeconomic implications of this type of contractual arrangement are associated with Kiyotaki & Moore (1997), who focused on investments in capital used for production. Later studies are Iacoviello (2005) and Iacoviello & Neri (2010), who focus on residential investments by households.

These two approaches to consider financial market imperfections in macro models have in common that the financial conditions of borrowers affect the real economy. A broad term for this class of mechanisms is therefore *balance sheet effects*, capturing that movements in asset prices may influence agents' decisions by altering their balance sheets.

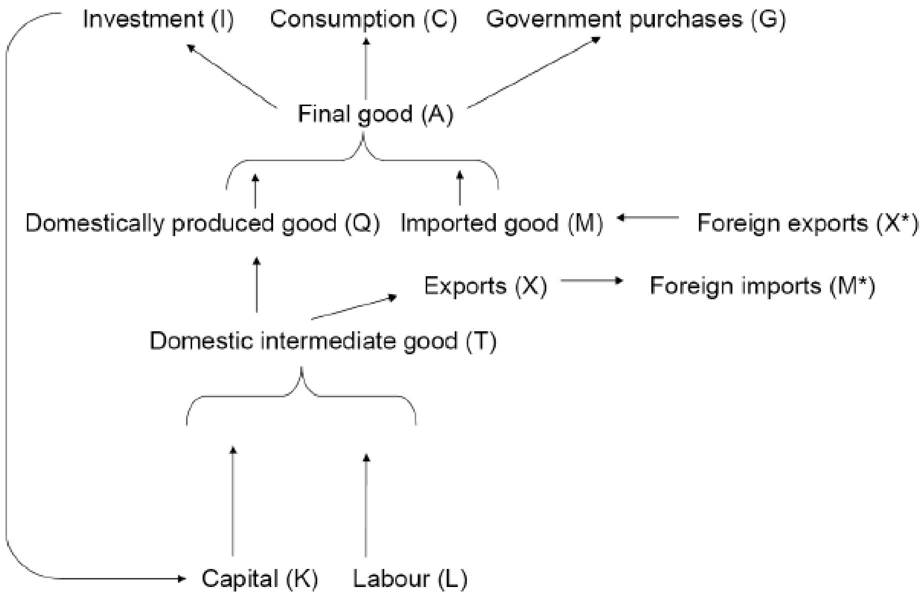
3 Two models with financial frictions

Our point of departure is the Norges Bank policy model NEMO, which is a small open economy DSGE model for the Norwegian economy. The theoretical framework builds on the New Open Economy Macroeconomics (NOEM) literature (see e.g., Lane (2001) for a survey) as well as the closed economy models in e.g., Christiano et al. (2005b) and Smets & Wouters (2003), and is similar in structure to existing open-economy models such as the Global Economy Model (GEM) model at the International Monetary Fund and the model developed in Adolfson et al. (2007).[1]

Figure 1 depicts the overall demand and supply structure of NEMO. The domestic economy has two production sectors, an intermediate goods sector and a final goods sector. Each intermediate good is produced by a single firm, using differentiated labour (L)

[1] We refer to Brubakk et al. (2006) for a more thorough discussion of the model and literature references.

Figure 1: The production structure of NEMO



and capital (K) services as inputs. The market for intermediate goods is characterized by monopolistic competition. The intermediate good (T) can be exported (M^*) or sold domestically (Q) to the final goods sector. The monopolistically competitive intermediate good firms set prices as a mark-up over marginal costs. Since we abstract from the possibility of arbitrage across countries, intermediate good firms can set different prices at home and abroad. Furthermore, we assume that it is costly for intermediate firms to change their prices. Prices are set in the currency of the buyer (local currency pricing). The specification of the price adjustment costs is consistent with Rotemberg (1982). This assumption implies a 'hybrid' Phillips curve that includes both expected future inflation and lagged inflation. Intermediate firms choose hours, capital[2], investment, the capital utilization rate and prices to maximize the present discounted value of cash-flows, taking into account the law of motion for capital, and demand both at home and abroad. Firms in the perfectly competitive final goods sector combine domestically produced (Q) and imported intermediate goods (M) into an aggregate good (A) that can be used for private consumption (C), investment (I), and government spending (G).[3]

There are two types of households in the economy 'spenders' (or liquidity constrained households) and 'savers'. The spenders simply consume their disposable income. The remaining households, the savers, have access to domestic and foreign capital markets, and base their consumption decisions on an intertemporal optimization problem. Each household is the monopolistic supplier of a differentiated labour input. The household sets

[2] Capital is firm-specific, but since all firms are identical and there is no price dispersion this assumption does not affect the linearised dynamics of the model.

[3] We model the mainland economy, that is, the total economy excluding the oil sector. However, although oil production is not modeled, we include (exogenously) oil investments on the demand side, affecting mainland industries.

the nominal wage subject to the labour demand of intermediate goods firms and subject to quadratic costs of nominal wage adjustment. This assumption implies a 'hybrid' Phillips curve for wages. The model is closed by assuming that domestic households pay a premium on the foreign interest rate when they borrow in foreign bonds. The premium is increasing in the aggregate level of foreign debt in the domestic economy. The model evolves around a balanced growth path, where the growth rate is determined by exogenous technological growth. For simplicity, the fiscal authority is assumed to run a balanced budget each period, financed by lump-sum taxes. The small open economy assumption implies that the foreign economy is fully exogenous from the domestic agents point of view. Hence, economic developments in Norway have no effects on its trading partners.

3.1 The reference model (NEMO)

The perfectly competitive final goods sector consists of a continuum of final good producers indexed by $x \in [0,1]$ that aggregate composite domestic intermediate goods, Q, and imports, M, using a constant elasticity of substitution (CES) technology:

$$A_t(x) = \left[\eta^{\frac{1}{\mu}} Q_t(x)^{1-\frac{1}{\mu}} + (1-\eta)^{\frac{1}{\mu}} M_t(x)^{1-\frac{1}{\mu}}\right]^{\frac{\mu}{\mu-1}}, \tag{3}$$

The degree of substitutability between the composite domestic and imported goods is determined by the parameter $\mu > 0$, whereas η $(0 \leq \eta \leq 1)$ measures the steady-state share of domestic intermediates in the final good for the case where relative prices are equal to 1.

The composite good $Q(x)$ is an index of differentiated domestic intermediate goods, produced by a continuum of firms $h \in [0,1]$:

$$Q_t(x) = \left[\int_0^1 Q_t\left(h,x\right)^{1-\frac{1}{\theta_t}} dh\right]^{\frac{\theta_t}{\theta_t-1}}, \tag{4}$$

where the time-varying elasticity of substitution between domestic intermediates is captured by θ_t and evolves according to an AR(1) process.

Similarly, the composite imported good is a CES aggregate of differentiated import goods indexed by $f \in [0,1]$:

$$M_t(x) = \left[\int_0^1 M_t\left(f,x\right)^{1-\frac{1}{\theta^f}} df\right]^{\frac{\theta^f}{\theta^f-1}}, \tag{5}$$

where $\theta^f > 1$ is the steady-state elasticity of substitution between imported goods.

Intermediate goods sector Each intermediate goods firm h is assumed to produce a differentiated good $T_t\left(h\right)$ for sale in domestic and foreign markets using the following CES production function:

$$T_t(h) = \left[(1-\alpha)^{\frac{1}{\xi}} \left(Z_t z_t^L l_t(h)\right)^{1-\frac{1}{\xi}} + \alpha^{\frac{1}{\xi}} \overline{K}_t(h)^{1-\frac{1}{\xi}}\right]^{\frac{\xi}{\xi-1}}, \tag{6}$$

where $\alpha \in [0,1]$ is the capital share and ξ denotes the elasticity of substitution between labour and capital. The variables $l_t(h)$ and $\overline{K}_t(h)$ denote, respectively, hours used and effective capital of firm h in period t. There are two exogenous shocks to productivity in the model: Z_t refers to an exogenous permanent (level) technology process, which grows at the gross rate π_t^z, whereas z_t^L denotes a temporary (stationary) shock to productivity (or labour utilization). The technology processes are modelled as

$$\ln(Z_t) = \ln(Z_{t-1}) + \ln(\pi^z) + \ln\left(\frac{\pi_t^z}{\pi^z}\right), \tag{7}$$

where

$$\ln\left(\frac{\pi_t^z}{\pi^z}\right) = \lambda_z \ln\left(\frac{\pi_{t-1}^z}{\pi^z}\right) + \varepsilon_t^z, \qquad 0 \le \lambda_z < 1, \quad \varepsilon_t^z \sim iid\left(0, \sigma_z^2\right), \tag{8}$$

and

$$\ln\left(\frac{z_t^L}{z^L}\right) = \lambda_L \ln\left(\frac{z_{t-1}^L}{z^L}\right) + \varepsilon_t^L, \qquad 0 \le \lambda_L < 1, \quad \varepsilon_t^L \sim iid\left(0, \sigma_L^2\right). \tag{9}$$

The variable $K_t(h)$ is defined as firm h's capital stock, which is chosen in period t and becomes productive in period $t+1$. Firm h's *effective* capital in period t is related to the capital stock that was chosen in period $t-1$ by

$$\overline{K}_t(h) = u_t(h) K_{t-1}(h), \tag{10}$$

where $u_t(h)$ is the endogenous rate of capital utilization. When adjusting the utilization rate the firm incurs a cost of $\gamma_t^u(h)$ units of final goods per unit of capital. The cost function is

$$\gamma_t^u(h) = \phi_1^u \left(e^{\phi_2^u(u_t(h)-1)} - 1\right), \tag{11}$$

where ϕ_1^u and ϕ_2^u are parameters determining the cost of deviating from the steady state utilization rate. The steady state utilization rate is normalized to one.[4]

Firm h's law of motion for physical capital reads:

$$K_t(h) = (1-\delta) K_{t-1}(h) + \kappa_t(h) K_{t-1}(h), \tag{12}$$

where $\delta \in [0,1]$ is the rate of depreciation and $\kappa_t(h)$ denotes capital adjustment costs. The adjustment costs take the following form:

[4] Note that ϕ_1^u is not a free parameter. It is set to ensure that the marginal cost of utilisation is equal to the rental rate of capital in steady-state.

$$
\begin{aligned}
\kappa_t(h) &= \frac{I_t(h)}{K_{t-1}(h)} - \frac{\phi_1^I}{2}\left[\left(\frac{I_t(h)}{K_{t-1}(h)} - \left(\frac{I}{K} + z_t^I\right)\right)\right]^2 \\
&\quad - \frac{\phi_2^I}{2}\left(\frac{I_t(h)}{K_{t-1}(h)} - \frac{I_{t-1}}{K_{t-2}}\right)^2, \qquad (13)
\end{aligned}
$$

where I_t denotes investment and z_t^I is an investment shock[5] that evolves according to an AR(1) process

The labour input is a CES aggregate of hours supplied by a continuum of infinitely-lived households indexed by $j \in [0,1]$:

$$
l_t(h) = \left[\int_0^1 l_t(h,j)^{1-\frac{1}{\psi_t}}\,dj\right]^{\frac{\psi_t}{\psi_t - 1}}, \qquad (14)
$$

where ψ_t denotes the elasticity of substitution between different types of labor, evolving as an AR(1) process.

Firms sell their goods in markets characterized by monopolistic competition. International goods markets are segmented and firms set prices in the local currency of the buyer. An individual firm h charges $P_t^Q(h)$ in the home market and $P_t^{Mf}(h)$ abroad, where the latter is denoted in foreign currency. Nominal price stickiness is modelled by assuming that firms face quadratic costs of adjusting prices,

$$
\gamma_t^{P^Q}(h) \equiv \frac{\phi_1^Q}{2}\left[\frac{P_t^Q(h)}{\pi P_{t-1}^Q(h)} - 1\right] + \frac{\phi_2^Q}{2}\left[\frac{P_t^Q(h)/P_{t-1}^Q(h)}{P_{t-1}^Q/P_{t-2}^Q} - 1\right]^2, \qquad (15)
$$

$$
\gamma_t^{P^{Mf}}(h) \equiv \frac{\phi_1^{Mf}}{2}\left[\frac{P_t^{Mf}(h)}{\pi P_{t-1}^{Mf}(h)} - 1\right] + \frac{\phi_2^{Mf}}{2}\left[\frac{P_t^{Mf}(h)/P_{t-1}^{Mf}(h)}{P_{t-1}^{Mf}/P_{t-2}^{Mf}} - 1\right]^2, \qquad (16)
$$

in the domestic and foreign market, respectively and where π denotes the steady-state inflation rate in the domestic economy. In every period cash-flows are paid out to the households as dividends.

Firms choose hours, capital[6], investment, the utilization rate and prices to maximize the present discounted value of cash-flows, adjusted for the cost of changing prices, taking into account the law of motion for capital, and demand both at home and abroad, $T_t^D(h)$. The latter is given by:

$$
T_t^D(h) = \int_0^1 Q_t(h,x)dx + \int_0^1 M_t^f(h,x^f)dx^f \qquad (17)
$$

[5] This shock could e.g., represent changes in the relative price of consumption and investment.

[6] Capital is firm-specific, but since all firms are identical and there is no price dispersion this assumption does not affect the linearised dynamics of the model.

Households There are two types of households in the economy: 'spenders' (or liquidity constrained households) and 'savers'. The spenders simply consume their disposable income. Total consumption is a weighted average of the consumption levels of the two types of households.[7]

The savers' utility function is additively separable in consumption and leisure. The lifetime expected utility of household j is:

$$U_t(j) = E_t \sum_{i=0}^{\infty} \beta^i \left[z_{t+i}^u u(C_{t+i}(j)) - v(l_{t+i}(j)) \right], \tag{18}$$

where C denotes consumption, l is hours worked and β is the discount factor $0 < \beta < 1$. The consumption preference shock, z_t^u, evolves according to an AR(1) process.

The current period utility functions for consumption and labour choices, $u(C_t(j))$ and $v(l_t(j))$, are

$$u(C_t(j)) = (1 - b^c/\pi^z) \ln \left[\frac{(C_t(j) - b^c C_{t-1})}{1 - b^c/\pi^z} \right], \tag{19}$$

and

$$v(l_t(j)) = \frac{1}{1+\zeta} l_t(j)^{1+\zeta}. \tag{20}$$

where the degree of external habit persistence in consumption is governed by the parameter b^c $(0 < b^c < 1)$ and the disutility of supplying labour is governed by the parameter $\zeta > 0$.

Each household is the monopolistic supplier of a differentiated labour input and sets the nominal wage subject to the labour demand of intermediate goods firms and subject to quadratic costs of adjustment, γ^W:

$$\gamma_t^W(j) \equiv \frac{\phi^W}{2} \left[\frac{W_t(j)/W_{t-1}(j)}{W_{t-1}/W_{t-2}} - 1 \right]^2 \tag{21}$$

where W_t is the nominal wage rate.

The flow budget constraint for household j is:

$$\begin{aligned} P_t C_t(j) + S_t B_{H,t}^f(j) + B_t(j) \leq{}& W_t(j) l_t(j) \left[1 - \gamma_t^W(j)\right] \\ &+ \left[1 - \gamma_{t-1}^{B^f}\right] \left(1 + r_{t-1}^f\right) S_t B_{H,t-1}^f(j) \\ &+ (1 + r_{t-1}) B_{t-1}(j) + DIV_t(j) - TAX_t(j), \end{aligned} \tag{22}$$

where S_t is the nominal exchange rate, $B_t(j)$ and $B_{H,t}^f(j)$ are household j's end of period t holdings of domestic and foreign bonds, respectively. Only the latter are traded internationally. The domestic short-term nominal interest rate is denoted by r_t, and the nominal return on foreign bonds is r_t^f. The variable DIV includes all profits from intermediate goods firms and nominal adjustment costs, which are rebated in a lump-sum fashion. Finally, home agents pay lump-sum (nondistortionary) net taxes, TAX_t, denominated in home currency.

[7] We assume that the spenders' wage rate is equal to the savers' (average) wage and that they supply whatever is demanded of their type of labour.

A financial intermediation cost, γ^{Bf}, is introduced to guarantee that aggregate net foreign assets follow a stationary process. This cost depends on the aggregate net foreign asset position of the domestic economy. Specifically, the intermediation cost takes the following form[8]

$$\gamma_t^{Bf} = \phi^{B1} \frac{\exp\left(\phi^{B2}\left(\frac{S_t B^f_{H,t}}{P_t Z_t}\right)\right) - 1}{\exp\left(\phi^{B2}\left(\frac{S_t B^f_{H,t}}{P_t Z_t}\right)\right) + 1} + z_t^B, \tag{23}$$

where $0 \leq \phi^{B1} \leq 1$ and $\phi^{B2} > 0$. The exogenous 'risk premium', z_t^B, evolves according to an AR(1) process.

Government The government purchases final goods financed through a lump-sum tax. Real government spending (adjusted for productivity), $g_t \equiv G_t/Z_t$, is modelled as an AR(1) process. The central bank sets a short-term nominal interest rate, r_t, according to the following simple rule (in log-linear form)

$$r_t = \lambda_r r_{t-1} + (1 - \lambda_r)\left[\lambda_\pi \pi_t + \lambda_y y_t\right] + \varepsilon_t^r, \tag{24}$$

where π_t is the inflation rate and y_t denotes the output gap. The monetary policy shock is represented by ε_t^r.The parameter $\lambda_r \in [0, 1\rangle$ determines the degree of interest rate smoothing.

Foreign variables The foreign variables that enter the model are the real marginal cost of foreign firms, mc_t^f, the output gap, y_t^f, the interest rate r_t^f and the inflation rate π_t^f. The foreign variables are assumed to follow AR(1) processes.

3.2 Adding financial frictions

3.2.1 Housing model

This model deviates from NEMO in that households in addition to (non-housing) consumption and leisure also obtain utility from housing services. There are two different types of households in the model economy, termed 'patient' and 'impatient', respectively. 'Impatient' households can only borrow up to a fraction, the loan-to-value ratio, of the market value of their housing stock. By assumption, they would always want to borrow more than implied by their collateral value. The stock of housing is supplied by an additional production sector, which simply takes the final good as input. Productivity growth in the production of housing is assumed to be lower than in the rest of the economy, which is consistent with the observed trend in the relative price of housing.

The utility function of a representative household of type $k = im, pa$ is given by:

$$U_t^k = E_t \sum_{i=0}^{\infty} \left(\beta^k\right)^i \left[z_{t+i}^u u\left(C_{t+i}^k\right) + z_{t+i}^h \omega(H_{t+i}^k) - v\left(l_{t+i}^k\right)\right], \tag{25}$$

[8] See e.g., Laxton & Pesenti (2003) for a discussion of this specification of the intermediation cost.

and the subutility of housing services, $\omega(H_t^k)$, is given by

$$\omega(H_t^k) = \left(1 - b_h^k \pi^h/\pi^z\right) \ln \left[\frac{\left(H_t^k - b_h^k H_{t-1}^k\right)}{1 - b_h^k \pi^h/\pi^z} \right]$$

where H_t^k denotes the housing stock (and housing services) of household type k, z_t^h is a housing preference shock, π^h denotes the steady state productivity growth rate in housing production and b_h^k is a housing habit parameter.

The budget constraint of patient households is similar to (22), but is also taking into account the fact that households now invest in housing capital. We assume that only patient households have access to the foreign bonds market. Hence, for impatient households we have the following budget constraint:

$$P_t C_t^{im} + \frac{B_{t-1}^{im}}{(1+r_{t-1})} + P_t^H H_t^{im} \leq W_t^{im} l_t^{im} \left[1 - \gamma_t^{W^{im}}\right] + B_t^{im} + P_t^H (1-\delta_H) H_{t-1}^{im} + DIV_t^{im} - TAX_t^{im},$$

where $B_t^{im} > 0$ is interpreted as *borrowing* by impatient households. Assuming that the domestic credit market is in zero net supply, we have that:

$$B_t^{im} + B_t^{pa} = 0$$

Hence, impatient households borrow from patient households, i.e. $B^{im} = -B^{pa} (> 0)$. However, impatient household borrowing is restricted by their housing value. This can be formulated as:

$$R_t B_t^{im} \leq \varkappa P_t^H H_t^{im} \tag{26}$$

where $\varkappa > 0$ is the loan-to-value ratio.

The description of the intermediate sector is similar to the benchmark model, except for the fact that the labor input now is an aggregate of hours worked by both impatient and patient households. We assume the following simple Cobb-Douglas technology:

$$l = \left(l_t^{im}\right)^{\sigma} \left(l_t^{pa}\right)^{1-\sigma}$$

where σ denotes the income share of impatient households.

Residential investment is supplied by a housing production sector using the following technology

$$IH_t = \kappa^H \left(\frac{I_t^H}{H_{t-1}} \right) H_{t-1} \tag{27}$$

where IH_t denotes investment in new housing, I_t^H is the input of the final good used to produce new housing and the function $\kappa^H(\cdot)$ is given by :

$$\begin{aligned} \kappa^H \left(\frac{I_t^H}{H_{t-1}} \right) &= \frac{I_t^H}{H_{t-1}} - \frac{\phi_1^H}{2} \left[\left(\frac{I_t^H}{H_{t-1}} - \frac{I^H}{H} \right) \right]^2 \\ &\quad - \frac{\phi_2^H}{2} \left(\frac{I_t^H}{H_{t-1}} - \frac{I_{t-1}^H}{H_{t-2}} \right)^2, \end{aligned} \tag{28}$$

where $\phi_1^H, \phi_2^H > 0$ are parameters. The housing stock evolves according to the following law of motion:

$$H_t = (1 - \delta_H) H_{t-1} + IH_t \tag{29}$$

and in equilibrium, it must be true that:

$$H_t = \sigma H_t^{im} + (1 - \sigma) H_t^{pa}, \tag{30}$$

i.e. the total supply of housing is divided between patient and impatient households, respectively.

Households choose consumption, housing services, wages and borrowing in order to maximize expected utility given the budget restriction and, in the case of the impatient households, the collateral constraint. Intermediate firms choose prices and factor inputs in order to maximize expected cash flow.

3.2.2 BGG model

In this model, there is a continuum of entrepreneurs who invest in capital. Investments are partly financed by internal funds, but in addition, the entrepreneurs depend on external funding from banks. To avoid that entrepreneurs reach a state where they can fully self-finance, it is assumed that each period entrepreneurs exit ("die") with a given probability. Entrepreneurs are identical up to an idiosyncratic productivity shock. However, banks cannot observe the productivity level without paying a cost proportional to entrepreneur's net worth, which gives rise to a optimal contracting problem. Under a set of assumptions, the solution to the contracting problem implies that the credit premium paid by entrepreneurs is an inverse function of net worth to total assets.

The entrepreneur finances investments by drawing on own resources, N, and borrowing from the financial intermediary, B.

$$B_{t+1} + N_{t+1} = P_t^K K_{t+1} \tag{31}$$

where P^K is the price of capital and K is the capital stock. By choosing the gross interest rate on borrowing, Z, the intermediary implicitly chooses a cut-off value of the idiosyncratic shock, $\overline{\omega}$, such that for $\omega < \overline{\omega}$ the entrepreneur will declare bankruptcy.

$$\overline{\omega}_{t+1} R_{t+1}^k P_t^K K_{t+1} = Z_{t+1} B_{t+1} \tag{32}$$

The zero-profit condition for the intermediary sector is given by:

$$[1 - F_t(\overline{\omega}_{t+1})] Z_{t+1} B_{t+1} + (1 - \mu) \int_0^{\overline{\omega}_{t+1}} \omega dF_t(\omega) R_{t+1}^k P_t^K K_{t+1} = R_t B_{t+1} \tag{33}$$

where F is the normal cumulative density function and R denotes the risk free rate. Making use of (32), we can rewrite (33) as:

$$\frac{K}{N} = \frac{1}{\left(1 - \frac{R^k}{R}\left[\Gamma_t(\omega) - \mu G_t(\omega)\right]\right)} \tag{34}$$

where:

$$G_t(\omega) \equiv \int_0^{\overline{\omega}_{t+1}} \omega dF_t(\omega)$$

and:

$$\Gamma_t(\omega) \equiv \left[1 - F_t(\overline{\omega}_{t+1})\right]\overline{\omega}_{t+1} + G_t(\omega)$$

The optimal contract maximizes entrepreneurs expected net earnings, subject to the zero profit condition (33). The first order conditions can be summarized by the following equation:

$$E_t\left[\frac{R^k_{t+1}}{R_t}\left(1 - \Gamma_t(\omega)\right) + \frac{\Gamma'_t(\omega)}{\left(\Gamma'_t(\omega) - \mu G'_t(\omega)\right)}\left(\frac{R^k_{t+1}}{R_t}\left[\Gamma_t(\omega) - \mu G_t(\omega)\right] - 1\right)\right] = 0$$

Net worth evolves according to:

$$N_{t+1} = \gamma_t V_t + W^e_t$$

where γ is the survival rate, W^e is entrepreneur wage and V is net earnings (or net equity), given by:

$$V_t = R^k_t Q_{t-1} K_t \left(1 - \Gamma_{t-1}(\omega)\right) \tag{35}$$

Using (35), this reduces to:

$$N = \frac{W^e}{1 - \gamma\left(\left[R^k - R - \mu G(\omega) R^k\right]\frac{K}{N} + R\right)}$$

In addition, the gross return to capital, R^k_t, is given by:

$$R^k_t = \left(u_t RK_t - \gamma^u_t + (1-\delta) P^K_t\right)/P^K_{t-1}$$

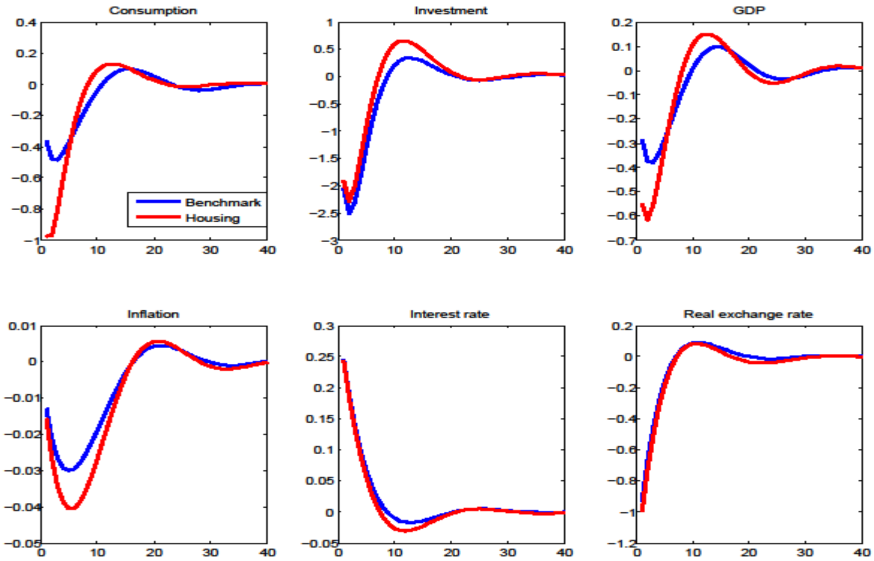
where RK_t is the rental rate of capital and Γ^u_t denotes capital utilization costs.

Summarizing, the above set-up adds three new equations to the benchmark model. In addition, the equation for the rate of return on capital substitutes for one of the equations in the benchmark model.

3.3 Some properties

In this section, we look at how financial frictions affect impulse responses from various shocks. We also consider some model specific shocks. As will be clear from what follows, the presence of financial frictions does not necessarily amplify the business cycle effects of a given shock. In some cases, the opposite is actually true. This goes against the intuition

Figure 2: The effects of a monetary policy shock



held by many, that financial frictions in general lead to accelerator effects, irrespective of the shock driving the economy. In fact, the only shock for which the financial accelerator effect is clearly visible, is the monetary policy shock.

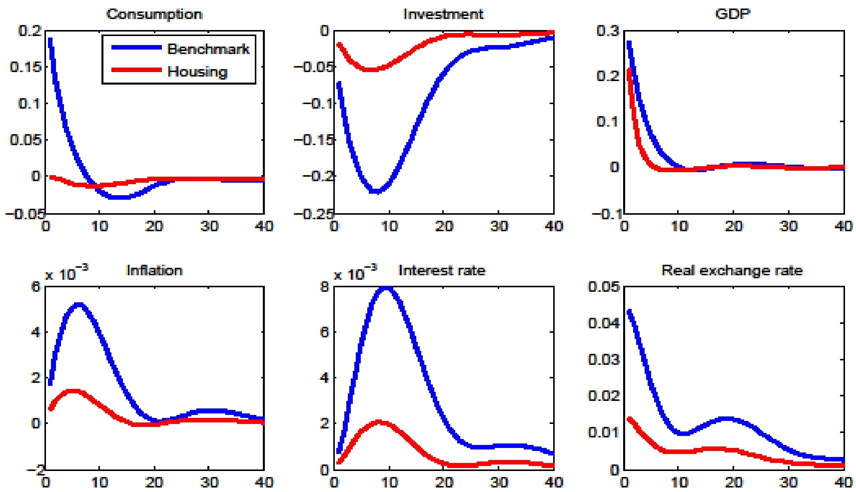
3.3.1 Housing model

In Figure 2, we display the effects of a monetary policy shock[9] in the housing model and in benchmark model. Higher interest rates lead to a drop in production and prices in both models. However, looking at the different demand components, we see that in the housing model the effect on consumption is particularily pronounced. Higher interest rates will dampen house prices and thereby reduce the housing value. For the impatient households this implies a fall in collateral value, which necessitates a further cut in borrowing. Hence there is an additional effect through the borrowing constraint. This is the financial accelerator at work. As a result consumption drops more in the housing model than the benchmark model. Lower consumption also spills over to production and prices.

In Figure 3, we depict the effect of 1 pct. increase public spending that gradually dies out. The presence of rule-of-thumb consumers in the Benchmark model (and equally constrained households in the housing model) induce an initial increase in consumption, contrary to the crowding-out effect typically found in standard models. The reason is that an increase in public spending leads to higher demand for factor inputs, an increase in wages and thus increased wage income. Since constrained households have a higher propensity to consume out of current income than patient households, consumption actually increases on impact. However, the increase in consumption in the Housing model is modest and temporary. This follows from the fact that house prices falls, driven by reduced demand for housing services by patient households due to higher interest rates. Lower house prices reduce impatient households access to credit in the Housing model and thereby dampens

[9] A temorary increase of 25 basis points

Figure 3: The effects of a public spending shock



the initial positive effect on consumption from higher wage income. Hence, the positive effect on consumption, and thereby on total demand, will be weaker in the Housing model than in the Benchmark model. The general message here is that the volatility in output and inflation is not mechanically increased just because we introduce a link between asset prices and credit. Rather, this link will stimulate the output (inflation) response to shocks that move asset prices and output (inflation) in the same direction, and dampen the response otherwise.

An interesting exercise is to look at the effect of increasing the loan-to-value ratio, which is illustrated in Figure 4 by an initial increase in the LTV ratio from 0.9 to 0.95, that slowly returns to its initial level. This will have the immediate effect of allowing impatient households to increase their borrowing for a given housing value. Consequently, demand for consumption and housing services increase. As does house prices, which gives an additional to demand impatient households' demand. Higher demand leads to an increase in production and prices start rising. As a result, interest rates will increase, leading to an initial reduction in patient household spending. Higher interest rates eventually lead to a drop in consumption and production.

We have also included a housing preference shock. Figure 5 shows the effect of a sudden increase in patient households' preferences for housing services. This will increase demand for housing, and, as a result, push up house prices. Although patient households substitute away from non-housing consumption, overall non-housing consumption actually increases due to the positive effect of higher house prices on consumption by impatient households. Hence, initially all demand components increase except for non-residential investment which falls due to higher interest rates.

3.3.2 BGG model

As can be seen from Figure 6, a monetary policy shock leads to an initial fall in demand and inflation in both models. However, looking at investment, it is clear that the negative effect is substantially stronger in the BGG model. A drop in demand reduces capital prices

Figure 4: The effects of a shock to the loan-to-value ratio

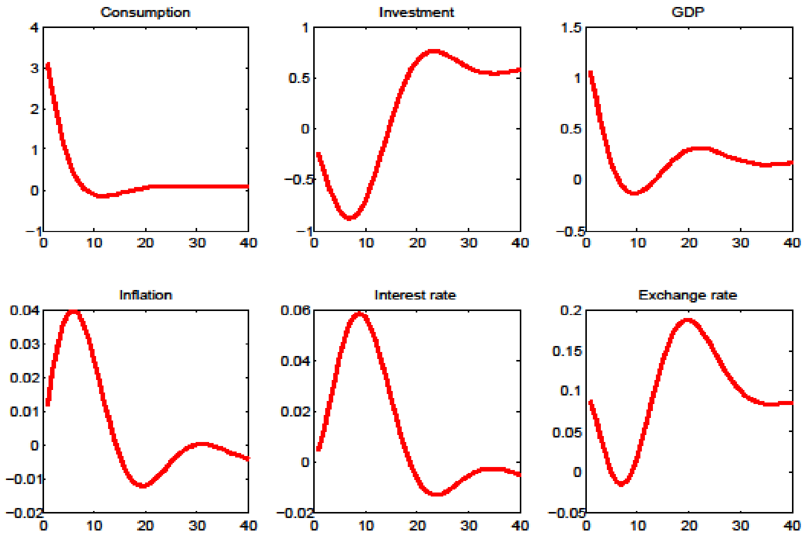


Figure 5: The effects of housing preference shock (savers)

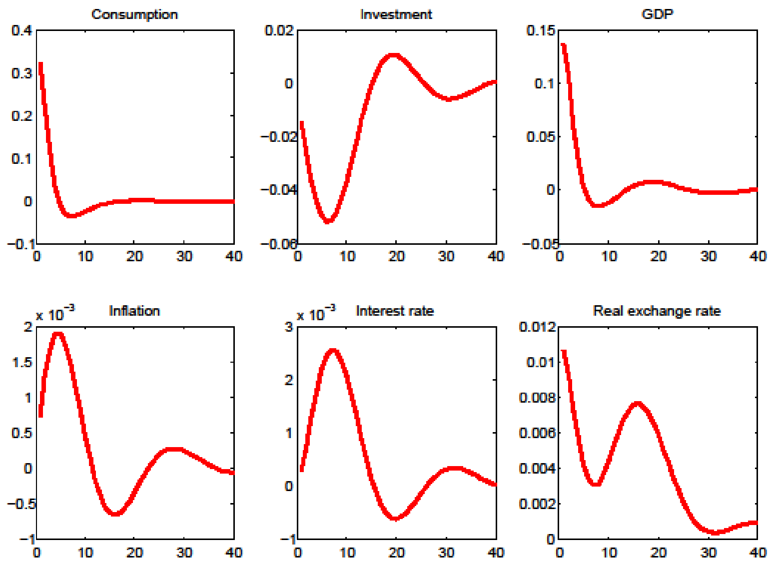
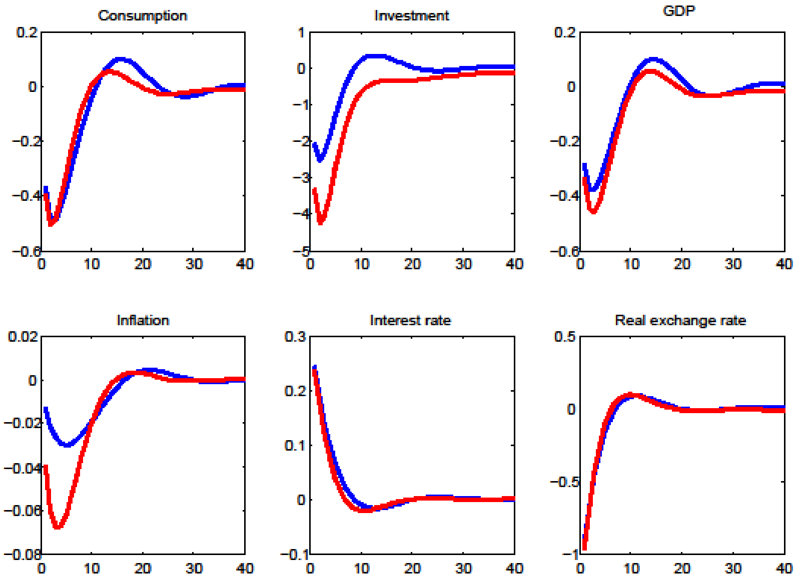


Figure 6: The effects of a monetary policy shock



and the return to capital. As a result, net worth decreases and there will be an additional negative effect on investment demand due to an increase in the credit premium. Lower investment demand relative to the benchmark model is also reflected in a more pronounced cut-back in production and lower prices compared to benchmark.

In Figure 7, we depict the effect of an increase in the variance of the idiosyncratic productivity shock. This can be interpreted as an increase in risk from the point of view of the banks. Higher productivity dispersion will increase the likelihood of entrepreneurs defaulting, all else equal. In response, banks will increase borrowing costs which will be passed on to goods producing firms. Consequently, consumer prices increase and production drops. The negative impact on production will be further strengthened by the financial accelerator effect.

We have also included an exogenous shock to net worth, depicted in Figure 9, which directly influences financing costs. This can for example be interpreted as an exogenous increase in the value of the assets held by the entrepreneur. The improvement in balance sheets will lead to a drop in the credit premium, and consequently reduce production costs. Hence, production increases and inflation falls.

4 Estimation results

In this section we show the estimation results for the two models incorporating financial frictions. Both models are contrasted to the benchmark model, which we also estimate.

4.1 Data and estimation method

The models are estimated on quarterly, seasonally adjusted data for the Norwegian economy covering the period from 1989Q4 to 2009Q3. The information set differs between models, but all models use the following 15 variables: GDP, private consumption, business invest-

Figure 7: The effects of increased idiosyncratic risk

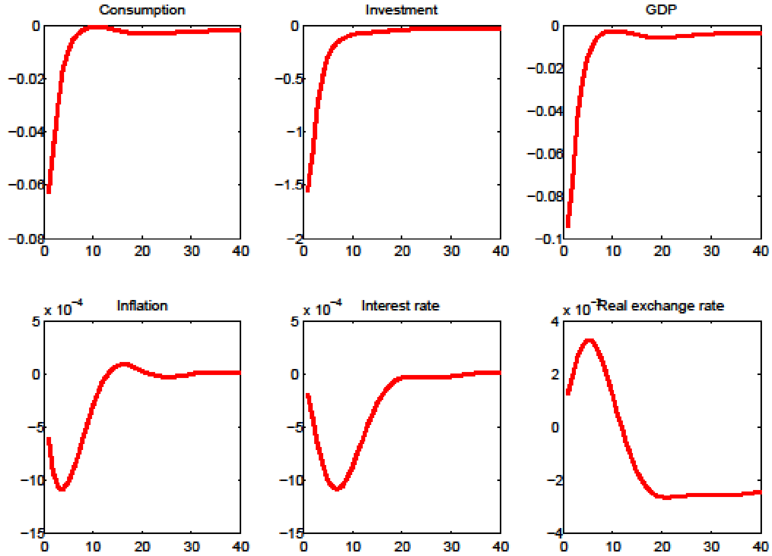


Figure 8: The effects of a net-worth shock

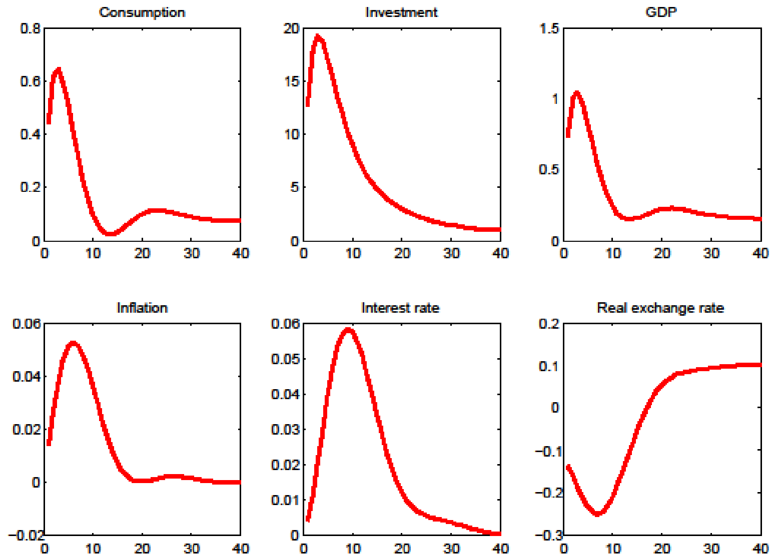


Figure 9:

ment, exports, government spending, hours worked, the real wage, overall inflation, imported inflation, the real exchange rate, the 3-month domestic and foreign nominal money market rates and foreign output gap. Since the model predicts that domestic GDP, consumption, investment, exports, government spending and the real wage are non-stationary, these variables are included in first differences. We take the log of the real exchange rate and hours worked. The BGG model in addition uses credit demand by private businesses, whereas the housing model adds data for housing prices, residential investment and credit demand by the household sector.

The data series relate to the mainland economy, that is, the total economy excluding the petroleum sector. The series for GDP, exports, consumption, business investment and hours worked are measured relative to the size of the working age population (16-74 years). The real wage is measured as total wage income per hour divided by the private consumption deflator. The quarterly series for growth in wage income per hour is obtained by taking a linear interpolation of the annual series from the national accounts. The nominal exchange rate is an effective import-weighted exchange rate based on the bilateral exchange rates of the Norwegian krone versus 44 countries. Consumer price inflation is measured as the total CPI adjusted for taxes and energy (CPI-ATE), and imported inflation is measured as the inflation rate for imported goods in the CPI-ATE. The money market rate is the 3 months effective nominal money market rate (NIBOR). All the series are demeaned prior to estimation. The choice of information set is based on data availability and on the perceived quality of the data series as well as a desire to obtain good estimates of the structural parameters in the DSGE model.[10] In general, the issue of parameter identification points to including a large number of variables in the information set.[11]

We estimate the DSGE models from a Bayesian perspective. The shape, the mean and the standard deviation of the prior distributions for the estimated parameters are partly taken directly from other studies and partly chosen in order to provide shock responses that are consistent with our prior beliefs on the transmission mechanism of the Norwegian economy. Note that we apply the same priors across models. This is meant to reflect the somewhat heroic assumption that these parameters are truly structural. Another way to choose the priors, would be to follow the approach of Del Negro & Schorfheide (2008).

4.2 Estimation results

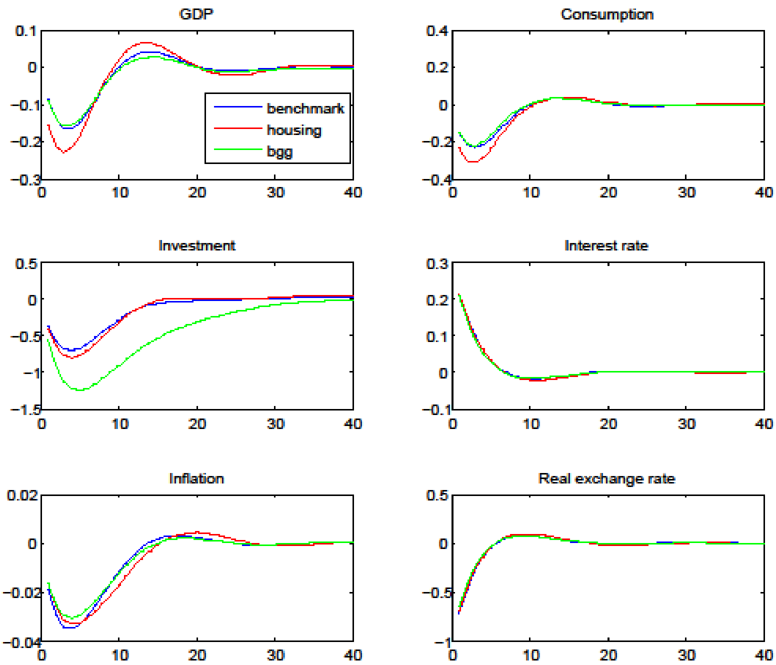
The estimated parameters[12], evaluated at the mode, do not differ substantially across models. Interestingly, the estimated share of impatient households is 0.35 in the housing model. In the benchmark model, the share of spenders is estimated to 0.25. In contrast to the impatient households in the housing model, the spenders do not have access to credit markets at all. This can be interpreted as a very strict form of credit rationing. We interpret the higher estimated share of constrained households in the housing model

[10] For instance, due to perceived poor quality of the national accounts data, imports are not used as an observable variable.

[11] See e.g., the discussion in Adolfson et al. (2007).

[12] A full technical description of the model, including the estimated parameters, can be obtained from the authors upon request.

Figure 10: Impulse responses from a monetary policy shock (mode)

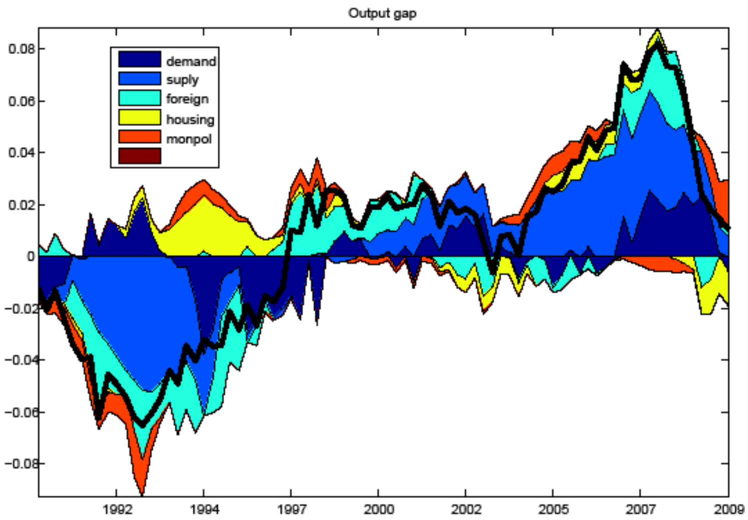


as a sign that the underlying description of credit behavior is more in agreement with the data. This is confirmed by the marginal data density, which is 25 log points higher for the housing model than the benchmark model (using the same information set), and hence gives relatively strong for the housing rather than the benchmark model.

Another way to gauge the estimation results is by looking at impulse responses based on estimated parameters. Again taking the monetary policy shock, we see that the accelerator effects are still present in the housing model. A temporary increase in interest rates will lead to a larger drop in consumption in the housing model than in the benchmark model. This again spills over to output. In the BGG model, as would be expected, investment drops significantly. However, this has no impact on aggregate production. As can be seen from Figure 10, the effect on the output gap in the BGG model is identical to the benchmark model. The reason is that the estimated steady state share of investment in the BGG model is more than halved relative to the prior, taken to be the sample average. Hence, even though investment drops almost twice as much as in the benchmark model, this has little effects on output, given that investment in the estimated BGG model is insignificant.

Based on the estimated shocks, we can calculate the historic variance decomposition of any variable of interest. Such a decomposition is given for the output gap, which is an unobservable variable, in Figure 11. In order to make the exposition transparent, we have grouped the various shocks together according to certain characteristics. The group labeled "housing" consists of a housing demand shock, a housing productivity shock and a shock to the loan-to-value ratio. As can be seen, shocks on the supply side of the economy account for the bulk of variation in the output gap over sample period. The contribution from the 'housing' shock are noticeable, but not very significant. Easier access to credit, through

Figure 11: Historical shock decomposition of the estimated output gap

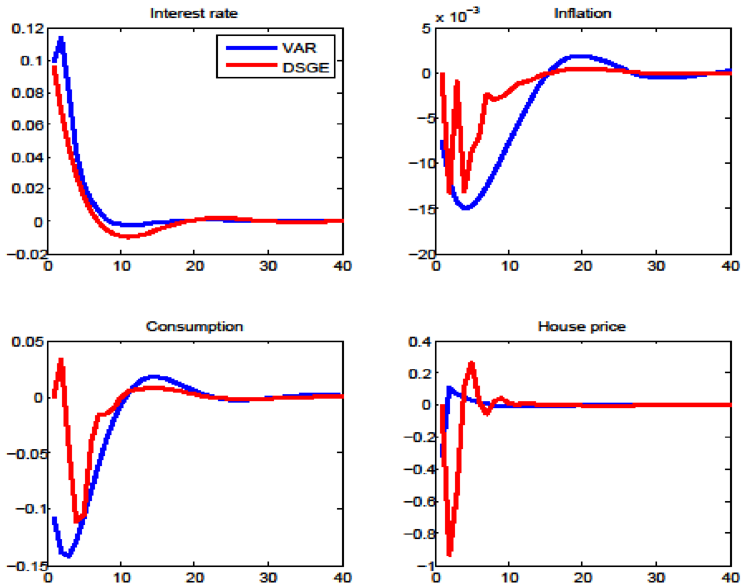


an increase in the loan-to-value ratio appears to have had a positive effect on production after the downturn ending in 1993. There is also evidence of a negative contribution after housing prices started falling in 2007/2008. Given the fact that most of the sample period is characterized by relatively easy access to credit, it is intuitively reasonable that the 'housing' shocks have not played a very prominent role over the business cycles the last 20 years.

We have also estimated a structural VAR model in order to contrast the findings from the housing model. The set-up is similar to Bjørnland (2008). More precisely we formulate a 5 variable VAR in consumption, inflation, house prices, interest rates and the exchange rate. In line with Bjørnland, our identification scheme is based on a mixture of short- and long-run restrictions. The assumptions are as follows: Consumption cannot respond contemporaneously to shocks. Inflation only responds to movements in consumption, house prices respond to inflation and consumption whereas the interest rate and exchange rate respond to all variables. The simultaneous response in the interest rate and exchange rate is identified by employing the restriction that the interest rate cannot affect the real exchange rate in the long run.

We concentrate on two estimated shocks, namely a monetary policy shock and a house price shock. The impulse responses from these identified shocks are compared to the impulse responses from similar shocks in the housing model. The impulse responses from a monetary policy shock is depicted in Figure 12. The immediate impression is that responses are quite similar, expect maybe for house prices, which exhibits a stronger initial response in the VAR model than in the DSGE model. A similar conclusion is reached when looking at the effects of a house price shock depicted in Figure 14, interpreted in the DSGE model as a housing preference shock. Both inflation and consumption move more or less in line with the corresponding variables in the VAR. However, there is a somewhat slower response in interest rates in the DSGE model. This probably has to do with the estimated reaction function in the DSGE model, which by assumption does not respond to house prices. In

Figure 12: Comparison of impulse responses from a monetary policy shock



the SVAR, the interest rate 'responds' to all variables, including house prices. All in all, we find that both the sign and amplitude of the responses are surprisingly close in the two models. Hence, the estimated housing model does not give fundamentally different implications from a SVAR, which is somewhat reassuring.

5 Monetary policy

5.1 Financial Frictions and Monetary Policy

In this section, we take a closer look at how the presence of financial frictions might affect monetary policy. Imperfections in the credit markets give rise to a credit channel for monetary policy. As noted by Bernanke & Gertler (1995), this is not really an independent channel, but rather a reinforcing mechanism that operates over and beyond the traditional monetary policy transmission mechanism.

There are two effects at work. For a given policy stance, the presence of financial frictions will in general reinforce the responses from some disturbances and dampen the effects of others. Typically, this depends on the correlation between balance sheets and the output gap for the disturbance in question, as emphasized before. If the correlation is positive, the presence of financial frictions will increase the effect on output. At the same time, as we have seen from the impulse responses of a monetary policy shock, interest rate movements affect the economy more strongly when financial frictions are present. Hence, output and to some extent inflation will respond more strongly to a given change in the interest rate. Thus, no general answer exist as to whether financial frictions will cause more or less volatility in inflation and output.

We have used the housing model in order to shed some light on this issue. Based on optimal simple rules, we compare losses in the benchmark model and the housing model,

Figure 13: Comparison of impulse responses from a shock to house prices

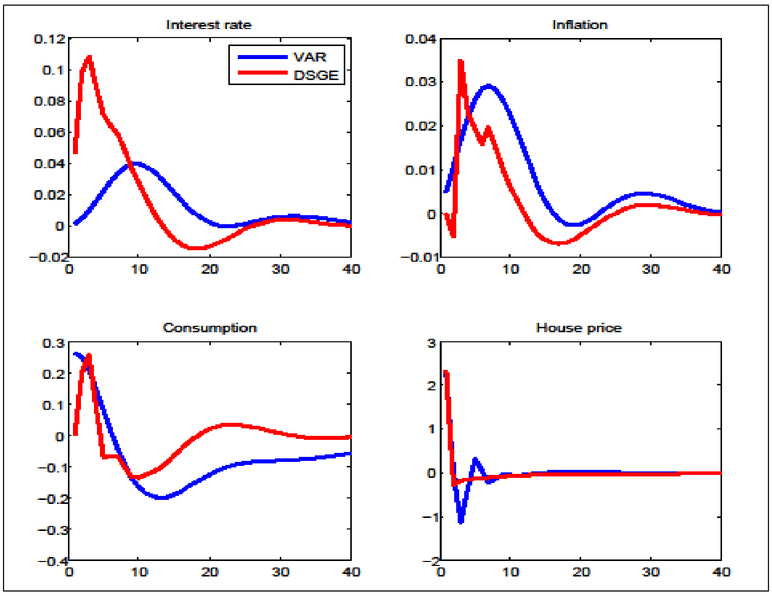


Figure 14:

Table 1: Optimal simple rule

	π	y	$GAIN$
Benchmark	5.78	2.38	
Housing model	2.49	0.76	40%

respectively. As can be seen from Table 1, the expected loss in the housing model is 40 percent. lower than in the benchmark model. Furthermore, the optimal parameters in the simple rule are smaller in the housing model than in the benchmark model. Hence, in the estimated housing model, it appears that the increased effects of interest rate movements dominates the potential increased instability originating from some of the shocks. However, it might also be that there is a negative correlation between house prices and output for a majority of the shocks.

To explore the robustness of this result, we perform the same exercise under a slight change in the model assumptions. Instead of assuming that the loan-to-value ratio is exogenous, we model it as a function of the output gap. The rationale for this is that lending policies might be laxer in good times, when the output gap is positive, and, conversely, that lending standards may be tighter during downturns. Making the loan-to-value ratio procyclical increases the likelihood of a positive correlation between the output gap and

Table 2: Optimal simple rule with procyclical loan-to-value ratio

	π	y	$GAIN$
Benchmark	5.78	2.38	
Housing model	2.49	0.76	40%
Housing model with procyclical loan-to-value ratio	3.34	1.11	-70%

the credit gap. For a given interest rate, this will tend to amplify the effect on the output gap and to some extent inflation. On the other hand, the interest rate will be an even more effective instrument. We compare the loss under the assumption of a procyclical loan-to-value ratio to a the model without procyclicality. As can be seen from Table 2, the presence of a procyclical lending policy implies a relative loss close to 70 percent. Hence, even if monetary policy has a stronger effect, the fluctuations in output and inflation will increase, based on the estimated shocks.

5.2 Should monetary policy respond to asset prices?

To what extent monetary policy should respond to asset prices has been a recurring topic of debate in the economic press and the academic literature over the last 20 years. Influential work here is Bernanke & Gertler (2001), Bernanke & Gertler (1999), and Cecchetti et al. (2000). According to the findings in Bernanke and Gertler, an inflation targeting central bank need not respond to asset prices, beyond their effect on the inflation forecast. Cecchetti et al., on the other hand, found that there are gains in responding to asset prices in the face of non-fundamental movements. An early and decisive response in interest rates can prevent the build-up of asset price bubbles and consequent instabilities in economic activity.

Bernanke and Gertler employ a simple rule with expected (one-step ahead) inflation as the only argument. Hence, in their set-up, the effect of asset prices on expected inflation is implicitly accounted for. However, expectations are highly model dependent. Since any theoretical model is likely to be misspecified, using an instrument rule with expected target variables as arguments might be less robust than using contemporaneous or lagged variables (see for instance Levin et al. (2003)).

Assets are claims to future (uncertain) cash-flows. Hence, asset prices incorporate expectations of future developments. Both in real life and in theoretical models, most asset prices are "jump variables", i.e. they react strongly and instantaneously to changes in expectations. On the other hand, evidence from the VAR literature indicates that both inflation and the output gap build up gradually in the response to various disturbances, before peaking several periods after the initial shock occurred.

This so-called "hump-shaped" behavior has been extensively documented, and is the reason why recent studies taking DSGE models to the data include various real and nominal rigidities (Smets & Wouters (2007), Christiano et al. (2005a)). In contrast, the aforementioned studies of monetary policy and asset prices are typically based on simple theoretical models where both inflation and output jump immediately after a shock. In this case, there will be little or no additional information to gain from asset prices. Hence, the simple theoretical models used in studies like Bernanke and Gertler (1999, 2001), may not be well-suited for discussing the information value of including asset prices in the reaction function. More or less by construction, asset prices do not add information value regarding future developments in the target variables in these models.

Again looking at optimal simple rules, we use the housing model to investigate whether the interest rate should respond to the house price in order to reduce inflation and output

Table 3: Gains from including house prices in optimal simple rules

Shock	*GAIN*
Permanent productivity	4%
Wage mark-up	$\boxed{10\%}$
Domestic price mark-up	0%
Investment	4%
Consumption preferences	4%
Temporary productivity	$\boxed{16\%}$
Public spending	1%
Exchange rate risk premium	$\boxed{17\%}$
Foreign	2%
Foreign demand	3%
Foreign interest rate	$\boxed{19\%}$
Foreign inflation	0%
Oil investment	4%
Permanent productivity in housing production	6%
Loan-to-value ratio	0%
Housing preferences	5%
All shocks	$\boxed{0\%}$

variability. Intuitively, this will depend on the nature of the disturbance hitting the economy. In line with the conventional view, we expect contemporaneous movements in house prices to be relevant if they add to the forecast accuracy for future inflation and output developments. Table 3 shows the results for each estimated shock in isolation, that is, assuming that this would be the only shock hitting the economy. The table highlights the shocks where there would be a significant gain from responding to the changes in the house price. Interestingly, for all the highlighted shocks, the house price responds instantaneously, whereas there is a slow and gradual build-up in output. When this happens, the house price increase (or decrease) serves as a signal of future developments in output. However, in real life there is a large set of disturbances hitting the economy. In this case, again given that monetary policy sticks to an optimal simple rule, Table 3 indicates that there is no gain from responding to asset prices. Hence, the gain from responding to housing prices for some of the shocks is more than outweighed by the loss that would occur in the face of other shocks.

5.3 Monetary policy and financial stability

In this section, we assume that the central bank explicitly cares about financial stability, in addition to its preferences over output and inflation stability. We operationalize this by adding a credit gap to the loss function. The credit gap measures the deviation of credit from its steady state level, adjusted for trend growth. This can be interpreted as a robustness device to guard against misspecification. To the extent that the model does not fully capture the effects of disruptions to the financial system, it might be sensible to monitor financial variables specifically.

Table 4: Gain from reacting to credit gap when only one instrument

Housing model	π	y	cr	$GAIN$
Interest rate rule without credit gap one instrument	1.6	0.1		
Interest rate rule without credit gap one instrument	10.6	≈ 0	1.4	69%

Table 5: Gain from reacting to credit when two instruments

Housing model	π	y	cr	$GAIN$
Interest rate rule with credit gap, one instrument	10.6	≈ 0	1.4	
Interest rate rule with credit gap, two instruments	7.4	2.9	≈ 0	90%

Table 4 shows the optimal parameters for the housing model under two alternative assumptions. The first row refers to the case where only inflation and output is included in the reaction function. In the second row we look at the case where the credit gap is included. Not surprisingly, with an explicit concern for credit, adding the credit gap to the reaction function leads to significantly reduced losses. More surprisingly, the weight on output now drops to zero.

We now extend the analysis by assuming the central bank also can control lending policies through the loan-to-value ratio. More specifically, the central bank is assumed to force banks to cut their loan-to-value ratio whenever the credit gap increases. In other words, in addition to an instrument rule for the interest rate, the central bank now also operates an instrument rule for the loan-to-value ratio. The results depicted in Table 5, indicate that with two instruments, the optimal policy is to use the interest rate to stabilize inflation and output, and to use the loan-to-value ratio to control the credit gap. The policymaker can achieve its three targets more efficiently with two instruments instead of one. Furthermore, the results indicate that the loan-to-value ratio should be used to stabilize the credit gap, whereas the interest rate is left to stabilize inflation and output. This of course reflects the fact that the loan-to-value ratio is a very effective (or, perfect) instrument to control the credit gap, whereas the interest rate is best suited to control inflation and output. In other words, the interest rate is not the most efficient instrument to achieve targets related to financial stability. Such concerns are better addressed by the policy instrument that is more directly targeted at these issues.

Without question, the assumption that the central bank can fully control banks' lending policies is inherently unrealistic. Our preferred interpretation of the above exercise is that it illustrates how in a richer model, incorporating the relevant effects and possible alternative instruments to the nominal interest rate, it is possible to approach questions related to the interaction between traditional monetary policy and macro-prudential policies. Clearly, this will be a subject of extensive research in the near future, as alluded to by Blanchard et al. (2010) and Bean et al. (2010).

6 Unresolved issues

In this report, the discussion has centered around the insights from two models with a financial accelerator. This approach is very much in line with the pre-existing literature on how to integrate financial market imperfections in theoretically based macro models. However, there are numerous limitations associated with this approach, and we discuss some of these unresolved issues here.

6.1 Asset prices

An obvious limitation of the models used above is that they have little ability to explain asset price movements reminiscent of what is seen in the data. This is a well-know fact, dating back to the seminal paper by Mehra & Prescott (1985) who showed how conventional theoretically based macro models struggled to explain empirical asset price regularities. Campbell (2003) surveys the extensive literature on the theme, and point at three puzzles that the researchers have struggled to understand. First, the historical returns to risky assets have been well above the risk-free rate, which cannot be reconciled with a conventional macro model unless households are extremely risk averse, well above what micro studies suggest (the "equity premium puzzle"). Second, it is difficult to explain why households have been willing to accept a risk-free interest rate as low as in the data, when their consumption growth has been high ("the risk-free rate puzzle"). Third, asset prices have tended to vary a great deal, far more than what the observed variation in expected dividends can justify ("the equity volatility puzzle").

A number of studies have tried to address the issues above. Cochrane (2008) provides an extensive survey of these, showing that considerable progress on these issues has been made, and that there now exists a host of plausible explanations of observed asset price movements. However, this literature is typically narrow in focus, focusing on asset prices rather than the rich set of variables which characterize macro models for monetary policy purposes. Embedding some of the mechanisms that explain asset price movements into business cycle models with financial frictions, seems like a fruitful direction for future research. After all, at the heart of the financial accelerator lies the idea that impulses to the economy gain a strengthend effect through their impact on asset prices. Having a good understanding of asset price movements is therefore important if one believes that credit market imperfections play an important role in the business cycle.

Related to this point, is the use of log-linearizations in solving the models above. Once this method is relied upon, one implicitly ignores any role of uncertainty in affecting agents' decisions, and the method is only valid when the economy is close to its steady state. Clearly, abstracting from uncertainty is particularly problematic when it comes to asset prices. Hence, we have explored the use of non-linear approximation tools, with the aim of building skills, and understanding the conditions under which non-linearities may be particularly important. A preliminary finding is that when the model economy is subject to small shocks and small risks, as measured by the standard deviations of the shocks, impulse responses are only marginally different under a second and first-order approximation, respectively. However, when the model is subjected to larger shocks and larger risk, the matters are different. In this case, the order of approximation matters significantly. This suggests that it is the presence of risk adverse agents that is the more important factor, and not the non-linearities *per se*.

6.1.1 Bubbles

All asset price movements in the models we have used above are driven by fundamentals, such as preferences and technology. For instance, in the housing model, there exist no shock to house prices per se, but to individuals' preferences for housing. In contrast, a broadly held view on the run-up to the recent crisis is that house prices were driven beyond their fundamentals in several countries (see for instance Brunnermeier (2009)). More generally, a recurrent question in the monetary policy debate is whether central banks should place weight on preventing asset price bubbles, in addition to inflation and output stabilization. Influential papers on this subject are Bernanke and Gertler (1999, 2001) mentioned above. Their approach is to impose an exogenous process by which asset prices are mispriced, within a model with a financial accelerator. This mispricing grows exponentially for some periods, before it bursts. The authors then study a set of simple interest rate rules, some of which entail a response to asset prices, and compare the variance of inflation and output under each rule. Their results indicate that for the sake of stabilizing output and inflation, little is gained from responding to asset prices. A later study by Tetlow (2005), considering optimal simple rules, confirms this finding.

An obvious weakness of the approach chosen in this analysis is that the existence and duration of an asset price bubble is entirely exogenous. Hence, monetary policy cannot affect the occurrence, nor the size of a bubble. The more informative approach would be to analyze policy in an environment where bubbles arise endogenously. This is, however, an extremely challenging task as current theoretical explanations of why bubbles occur are highly complex, and thus difficult to embed in an otherwise conventional macroeconomic model (for a survey on the literature explaining why bubbles occur, see Brunnermeier (2008)).

We have developed three alternative ways to consider large asset price movements within the otherwise conventional DSGE frameworks. First, we have followed the approach of Bernanke and Gertler, and constructed a purely exogenous bubble process. Second, we have considered a formulation based on imperfect information regarding the properties of technology shocks, as in Gilchrist & Saito (2006). This formulation assumes that agents observe a shock to aggregate technology, but are unaware of whether it is temporary or not. Gradually, agents learn the duration of the technology improvement, and as they do, asset prices adjust. The third approach we have considered builds on the work of Christiano et al. (2008), by considering the arrival of news regarding future technology innovations. At one point in time, agents are informed that aggregate productivity might improve in a given future period, but when that period arrives, the productivity increase need not materialize, in which case asset prices will drop dramatically. We plan to use these tools for policy analysis in the future.

6.2 Financial intermediation

The approach in the estimated model above builds a link between asset prices and the real economy, but does not explicitly consider the financial sector. Financial intermediaries are simply a veil. This seems problematic in the light of the financial crisis, where a key problem initiating the downturn was that financial institutions stopped lending to each other (see for instance Brunnermeier (2009) and Reis (2010)). This points to an important role for liquidity in financial markets, which are absent in the conventional financial accelerator models of the type we have used above.[13]

Of course, we are far from the first to notice this, and a growing number of studies try to address the issue and develop quantifiable business cycle models with an explicit financial sector and a role for liquidity. Gertler & Kiyotaki (2010) summarize this recent literature, and propose a framework where financial intermediaries interact. In their model, if the interbank market works perfectly funds flow smoothly from financial institutions with surplus funds to those in need of funds. Loan rates would then be equalized across intermediaries. However, when agency problems limit the intermediaries' ability to obtain funds from each other, loan rates will vary. Funds may then be inefficiently allocated both between firms within the financial sector, and between the financial and the non-financial sector. In a crisis these problems become more severe. Other prominent recent studies incorporating a financial sector are Reis (2010), Curdia & Woodford (2010), and Gertler & Karadi (2009). While still in the early stages, and too simplistic for a full quantitative analysis, these frameworks have the strength that they can be used to evaluate other monetary policy tools than the setting of interest rates.

6.3 Alternative policy instruments

6.3.1 Unconventional monetary policy

The monetary policy responses to the financial crisis have in many countries gone beyond conventional interest rate management. Reis (2010) refers to the terms quantitative policy and credit policy when describing the unconventional policy measures used in the U.S. after the crisis. Quantitative policy refers to changes in the size of the balance sheet of the Federal reserve and to changes in the composition of its liabilities. Credit policy refers to management of the asset side of the balance sheet, decisions regarding what type of assets to hold. These policy measures had not been studied much in the academic literature prior to the crisis. Closely related to the literature on financial intermediation, a growing number of studies have been exploring the role, and appropriate use, of these unconventional policy tools.

[13] A novel analysis of the role of liquidity in macroeconomic fluctuations, is that of Kiyotaki & Moore (2008), who focus on firms' need to liquidate existing equity in order to take advantage of new productive opportunities. Their approach captures the notion of "liquidity risk", as the possibility to resell equity is subject to shocks. Yet, as in most of the financial accelerator literature prior to the financial crisis, they do not consider financial intermediation explicitly, as there are no banks or other intermediaries in their model.

Curdia & Woodford (2010) use their framework with financial intermediation to explore the role of quantitative policy and asset purchases by the central bank (part of what Reiss refers to as credit policy). They argue that quantitative easing in the strict sense of variation in the supply of bank reserves is unlikely to affect the economy, over and above its effect on the nominal interest rate. Targeted asset purchases, on the other hand, will have effects if financial markets are sufficiently disrupted, in particular if the policy rate is at its zero lower bound.[14] Reis (2010) reaches a similar conclusion, and in addition discusses the merits of different types of credit policy.

Whereas the aforementioned studies are mainly qualitative in their discussion, Negro et al. (2010) perform a richer quantitative analysis of how the unconventional policy measures in the US affected the economy in the immediate wake of the 2008 US financial crisis. They consider a model economy characterized by nominally rigid prices and wages, and with financial imperfections of two forms. First, firms with fruitful investment opportunities cannot borrow more than a fraction of the net present value of the investment, similarly to the housing models we have used above. In addition, firms may only sell part of their existing assets to finance new investments. Hence, these assets which correspond to equity in other firms, are "illiquid". In contrast, government issued paper, money and bonds, is not subject to such a resaleability constraint. Government may therefore supply liquidity to the market. They then subject the model to a "liquidity shock" , in the sense that assets' resaleability suddenly drops, and assess how a policy of supplying more reserves stabilizes the economy. Their main conclusion is that such a policy will have large effects in the presence of nominal rigidities, and that the non-standard policy prevented the US economy from suffering a significantly larger downturn.

6.3.2 Macro-prudential policy

Related to this discussion is the use of "macro-prudential" policies. For instance, Blanchard et al. (2010) argue that lack of regulation and financial agents' behavior to evade and take advantage of it was a central factor behind the crisis.[15] They argue, as many others, that the crisis shows how monetary and regulatory policy must be seen together.

In our policy analysis above, we conducted a highly stylized and simplistic experiment, by considering policy using two tools: The interest rate and the loan-to-value ratio. Our results indicated that in such a scenario the interest rate should concentrate on output and inflation, while concerns for excessive credit developments in the private sector were best treated with the direct loan-to-value instrument. It seems important to develop understanding on this dimension further, taking into account realistic features such as policy coordination between different authorities and more limited possibilities to affect agents leverage ratio directly.

[14] The key assumptions in Curdia and Woodford's analysis are that reserves supply transaction services for private agents, and that not all agents, but only financial intermediaries, may trade the same set of financial instruments. The intermediation activity is subject to agency costs, financed by a spread between deposit and lending rates.

[15] For a deeper summary at this point, see Acharya et al (2009).

7 Conclusion/Summary

In this project we have built on the established academic literature to develop a quantitative structural model where asset prices and credit affect economic allocations, rather than being mere passive reflections of the state of the economy. We have used two specific models with financial frictions. One where firms' net worth affects how high an interest rate they must pay on loans, as in Bernanke et al. (1999), and another model where households must post housing as a collateral in order to borrow from each other, as in Iacoviello (2005).

When these two models are estimated on Norwegian data, our results indicate that the latter model is the more empirically relevant for Norway. Furthermore, the "housing model" has a better empirical "fit", as measured by its marginal data density, than a benchmark model of the Norwegian economy without financial frictions.

Based on this observation, we have used the housing model to perform a set of monetary policy exercises. These have in common that they focus on optimal simple instrument rules by which the interest rate responds to a limited set of variables in order to minimize a specified ad hoc loss function. One finding here is that the presence of financial frictions per se need not lead to greater output and inflation volatility, unless lending practices imply procylical loan-to-value ratios. Furthermore, we have revisited the classic question of whether monetary policy should respond to asset prices. Here we found that, within the confines of this specific model, for most economic disturbances there is little to gain from letting the interest rate respond to asset prices, in addition to output and inflation. However, for some specific shocks there may be non-negligible gains from responding to asset prices, and we attribute this to the fact that these shocks generate gradual "hump-shaped" responses in output, consistent with the idea that asset price may be used as an "early-warning" signal for monetary policy. In addition, we have used the model to explore the role of credit in monetary policy. We found that if the monetary authority cares for only inflation and output, there is little to gain from responding to credit. However, if the central bank has an explicit preference for stable credit growth in the private sector, there are gains from letting the interest rate react to it. Finally, we considered a stylized scenario where the monetary authority could control the loan-to-value ratio of the private sector, in addition to the nominal interest rate. The results from this exercise indicate that the best use of policy tools is to let the interest rates respond to output and inflation, while the regulation of lending standards takes care of any preference for credit stabilization.

In the final parts of this report we have discussed unresolved issues that remain open. In particular, we have emphasized the need to develop a richer analysis of asset price dynamics in general, and non-linearities in particular. We have also provided a brief summary of the recent literature on financial intermediation, and related policy instruments, which are absent from the frameworks analyzed in this report. Incorporating lessons from this literature is therefore high on the agenda for further model development.

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