The role of mortgages and consumer credit in the business cycle
Sterk, V.

Citation for published version (APA):
Sterk, V. (2011). The role of mortgages and consumer credit in the business cycle Amsterdam: Universiteit van Amsterdam

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Many households rely on mortgages and consumer credit to finance their expenditures. Lenders usually impose certain conditions on loans, such as limits on the amounts that can be borrowed. Conventional intuition suggests that such conditions are important for our understanding of the business cycle, for example because the effects of a negative macroeconomic shock could be exacerbated by a tightening of credit conditions.

This dissertation studies the role of mortgages and consumer credit in macroeconomic booms and recessions. The analysis provides surprising findings and insights. In particular, it is explained why in a standard model with durable and non-durable consumption goods, the macroeconomic effects of borrowing limits can be the exact opposite of what the conventional intuition suggests. Moreover, empirical results challenge the common view that innovations in markets for mortgages and consumer credit can help to explain why macroeconomic fluctuations stabilized in the 1980’s. However, the structure of mortgage contracts does help to explain how busts in housing markets lead to persistent increases in the unemployment rate, as falls in house prices obstruct geographical mobility among credit-constrained homeowners.

Vincent Sterk (1982) obtained his master’s degree in econometrics and operations research from Tilburg University in 2005. Subsequently, he worked as a policy advisor at the Dutch Ministry of Economic Affairs. In September 2007, he started a PhD in macroeconomics at De Nederlandsche Bank and the University of Amsterdam. Vincent will join the economics department of University College London in August 2011.

THE ROLE OF MORTGAGES AND CONSUMER CREDIT IN THE BUSINESS CYCLE
THE ROLE OF MORTGAGES AND CONSUMER CREDIT IN THE BUSINESS CYCLE

ACADEMISCH PROEFSCHRIFT

ter verkrijging van de graad van doctor
aan de Universiteit van Amsterdam
op gezag van de Rector Magnificus
prof. dr. D.C. van den Boom
ten overstaan van een door het college voor promoties
ingestelde commissie,
in het openbaar te verdedigen in de Agnietenkapel
op vrijdag 20 mei 2011, te 12:00 uur

door

Vincent Sterk

geboren te Gemeente Dordrecht
Promotiecommissie:

Promotor: Prof. dr. W.J. den Haan

Overige Leden: Prof. dr. L.H. Hoogduin

Prof. dr. N. Kiyotaki

Prof. dr. S.J.G. van Wijnbergen

R. Wouters

Faculteit Economie en Bedrijfskunde
Voor Rosanne
Acknowledgments

In 2007, De Nederlandsche Bank (DNB) and the University of Amsterdam (UvA) gave me the opportunity to start writing this PhD thesis. It has been a unique experience that allowed me to learn from economists in the worlds of academia and policy making. Swapping one world for the other required only a five minute bike ride.

I’ve learned that doing research can be a tough and absorbing job. But in the process, I have received invaluable guidance from my supervisor, Wouter den Haan. I am extremely grateful for the numerous times he gave me advice, for encouraging me to become a PhD student, for his patience, his impatience, and for making me see the beauty of macroeconomics.

At DNB, I have been given nearly complete freedom in choosing my research topics, as well as the generous opportunity to visit the Federal Reserve Bank of New York for four months. I have enjoyed the company of my colleagues at DNB and benefited from their advice, especially from Wilko Bolt, Peter van Els, Gabriele Galati, David-Jan Jansen, Pierre Lafourcade and John Lewis.

I also want to thank everybody in the “MInt” group at the UvA. In particular, I am grateful to Pontus Rendahl and Christian Stoltenberg, for their advice about life during and after the PhD. I had great fun drinking Friday night beers with them, Alex, Arturo, Joris, Markus, Matija, Naomi, Petr, Philip, Siert, Tim, Ward, Wouter and many others. Thanks guys!

I’m proud to continue my career at University College London, which would not have been possible without the support of Marco Del Negro, Jakob de Haan, Matteo Iacoviello and especially my advisor Wouter.

Finally, I want to thank the people who kept me grounded in the real world: my parents Wim en Nelleke, my sister Rosanne, her husband Kees, my friends, in particular Ilona, Jasper, Paul, Tom, and Wendy, and of course my love François.
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Chapter 1

Introduction and Overview

“That you have mortgaged the estate seems to me a matter of regret.” “No, not at all,” replied Pictukh. “In fact, they tell me that it is a good thing to do, and that every one else is doing it. Why should I act differently from my neighbours?”

N. Gogol, Dead Souls (1842)

Nikolai Gogol’s 1842 novel Dead Souls tells the story of an elaborate mortgage scam in Russia. At the time, slavery was still to be abandoned and serfs were considered legal property. The government held a census about once every ten years in order to be able to register serfs and impose a property tax. Moreover, serfs could even be used as collateral for mortgage loans.

The novel’s protagonist, a man named Chichikov, travels through the Russian countryside, trying to convince noblemen to cheaply sell him their deceased serfs (dead souls). His intention is to obtain an enormous mortgage loan, using as collateral a large number of serfs that are not actually alive anymore. Of course the collateral would be essentially worthless, but a lender would be able to find out only once the serfs are removed from property listings after the next census.

The story illustrates how relationships between borrowers and lenders are plagued by frictions. At a fundamental level, lenders have only imperfect information about the borrower’s ability to repay a loan. Moreover, borrowers have incentives to undertake actions that conflict with the interest of the lender. For example, a borrower could try
to divert the money and never repay the loan, which is probably Chichikov’s plan. In
order to prevent this type of behavior, borrowers are often required to provide collateral
for a loan, which can be seized in case the loan is not repaid. In Chichikov’s case, this
requirement would clearly not be effective, as his collateral is essentially worthless.

Nowadays, better screening technologies may enable banks to prevent scams like the
one planned by Chichikov. But despite these improvements, collateral requirements do
still not provide a perfect solution to the frictions between borrowers and lenders, because
the amount of borrowing is constrained. Moreover, collateral values fluctuate over time
and it is difficult for lenders to enforce any additional requirements after a loan has been
taken out. Therefore, declines in collateral values may be exploited by borrowers who
have previously obtained a loan.

This thesis explores the role that imperfections in household finance play in exacer-
bating macroeconomic booms and recessions. Many households rely on loans to finance
their expenditures. Thus, the conditions under which households can obtain credit are po-
tentially important factors in determining aggregate demand for consumption goods. At
the same time, limits on household borrowing depend on macroeconomic conditions, for
example because households use housing as collateral for loans and house prices respond
to macroeconomic shocks. Given the two-way interaction between markets for household
loans and the macroeconomic state, frictions in household finance can potentially help to
explain how small shocks can lead to large macroeconomic fluctuations, which remains a
major challenge in macroeconomics.

I analyze both empirically and theoretically how frictions in household borrowing can
shape macroeconomic dynamics. Below, I provide an overview of the remaining chapters
of this thesis.

Overview

How do frictions in household borrowing change the transmission of monetary shocks?
Chapter 2 considers a theoretical model of the macroeconomy in which households con-
sume both durable and non-durable goods. Empirical evidence and conventional intuition suggest that a sudden increase in the interest rate by the central bank leads to a decline in household purchases of both durables and non-durables. In sharp contrast, standard theoretical models without financial frictions predict that durable purchases increase after the increase in the interest rate. The economic literature has suggested that the properties of the theoretical model might be corrected by the introduction of financial frictions. In the proposed setting, households can borrow from other households within the economy, but borrowing is constrained by a collateral requirement. The intuition behind this proposal is that a monetary contraction leads to a tightening of constraints on household debt. As a consequence, the spending capacity of borrowers is reduced, forcing them to cut back on both durable and non-durable expenditures. The analysis in Chapter 2 shows that this is indeed the case when collateral constraints are introduced in the model.

Surprisingly, the introduction of the credit friction turns out to exacerbate the problem. In a model with collateral constraints, aggregate durable and non-durable purchases move even more in opposite directions following a monetary shock than in a standard model. The reason is that the decline in durable purchases by the borrowers is more than offset by an increase in durable purchases by the savers in the economy. When borrowers face a reduction in their borrowing capacity, then in equilibrium savers are forced to reduce their financial savings. But the savers can easily compensate for the decline in financial savings by purchasing more durable goods, which provides an alternative way of saving.

The analysis in Chapter 2 emphasizes the importance of general equilibrium effects when thinking about the role of frictions in household finance in the macro economy. In particular, it demonstrates how misleading it can be to focus exclusively on the role of the borrowers in determining aggregate demand, while ignoring the behavior of the savers. Chapter 2 has been published in the Journal of Monetary Economics as Sterk (2010).

Chapter 3 is joint work with Wouter den Haan and investigates whether innovations in the markets for mortgages and consumer credit have changed the nature of the business cycle. Since the early 1980’s, many countries have witnessed a period of relatively mild
macroeconomic fluctuations, which lasted at least up to the recent financial crisis. This period is usually referred to as the *great moderation*.

It has often been suggested that financial innovations reduced the severity of frictions in household finance and allowed consumers to keep on borrowing during recessions. This would avoid large reductions in aggregate demand during recessions, resulting in greater macroeconomic stability. A very striking empirical fact supporting this idea is that in the United States, the correlation between GDP and the volume of household debt fell dramatically since the 1980’s.

We employ empirical methods to study in what ways the behavior of the aggregate volumes of mortgage debt and consumer credit have changed, *conditional* on different types of macroeconomic shocks. We find that this conditional behavior has changed surprisingly little. Thus, our findings provide little evidence for the idea that innovations in household finance reduced the impact of macroeconomic shocks. The chapter will be published in the Economic Journal as Den Haan and Sterk (2011).

Chapter 4 studies how frictions in household finance can create interactions between the housing market and the labor market. A fall in house prices reduces households’ wealth levels and therefore obstructs geographical mobility among borrowing-constrained households. This is because moving requires one to take out a new mortgage loan and a certain amount of wealth is needed to provide the downpayment. By contrast, borrowers who do not move are not directly affected by a fall in house prices, since they can simply continue borrowing under their current mortgage contracts. The reduced incentives to move create inefficiencies in the labor market, because in some cases, unemployed households can only accept a job offer when they move. Empirical analysis shows that negative shocks arising in housing markets lead to adverse labor market outcomes. A theoretical model that is developed can qualitatively match this pattern, and thereby helps to explain the recent and persistent increase in the US unemployment rate. This increase has puzzled academics and policy makers, since historically there is a tight connection between the unemployment rate and the number of job vacancies. But during the recent
An important element of the model developed in Chapter 4 is the introduction of a new type of collateral constraint on mortgage debt. In standard business cycle models with frictions in household finance, mortgage loans are typically refinanced each month or quarter and each time, the borrower faces a renewed downpayment requirement. This is of course a very unrealistic assumption, since in reality mortgages are refinanced very infrequently, but it avoids the technically difficult task of modeling heterogeneity among borrowers. The setup in Chapter 4 also avoids this task, but the newly introduced constraint does capture the essential notion that mortgage debt is only infrequently refinanced, and that mobility decisions of households determine the fraction of aggregate mortgage debt that is refinanced in a given period.

Chapter 5 takes on the challenge of developing a model of heterogeneous borrowers, in which mortgage debt is refinanced infrequently at the individual level. Moreover, households adjust their house size only when they move. Solving for the optimal decision rules of the agents in this model is a computationally intensive exercise. I therefore simplify the model developed in Chapter 4 and assume prices and interest rates to be exogenous. I compare the dynamics of aggregate demand for consumption goods and mortgage loans in this model to those predicted by more convenient but less realistic models that avoid borrower heterogeneity, both with a standard collateral constraint and with the constraint introduced in Chapter 4. I find that replacing a standard collateral constraint by the constraint introduced in Chapter 4 brings the predictions of the model much closer to those of the "true" heterogeneous economy.
Chapter 2

Credit Frictions and the Comovement between Durable and Non-durable Consumption

Abstract

Frictions in lending between households have been proposed as a solution to the difficulties New-Keynesian models have in predicting a decline in both durable and non-durable consumption following a monetary tightening. By revisiting a standard New-Keynesian framework with collateral constraints, it is shown that the presence of such credit frictions in fact makes it more difficult to generate the joint decline. The intuitive reasons behind this result are provided, which should be helpful in developing models that are more successful in generating a positive comovement between durables and non-durables.

2.1 Introduction

An undesirable feature of standard New-Keynesian models is that they tend to generate counterfactual comovements between durable and non-durable consumption, as pointed out by Barsky, House, and Kimball (2003, 2007). For low levels of durable price stickiness, these models typically predict that during a monetary contraction, non-durable purchases will decrease, while durable purchases will, remarkably, increase. In the case of fully flexible durable prices, the predicted expansion in the durable goods producing sector is so large that the monetary tightening has almost no effect on total aggregate output.\(^1\) These

\(^1\)The literature typically focuses on completely flexible durable prices, for which case the comovement problem is most severe. According to Barsky, House, and Kimball (2007), prices of new homes are
predictions are in sharp contrast with the conventional wisdom and empirical evidence that especially durable consumption falls during a monetary tightening.\(^2\)

Barsky, House, and Kimball (2003, BHK henceforth) suggest that one reason why standard models have difficulties matching the empirical evidence could be that they assume frictionless financial markets. After a monetary tightening credit constraints may become tighter, and a reduced ability to borrow could then force credit-constrained households to decrease durable purchases. Monacelli (2009) formalizes this argument by extending the standard model to feature credit-constrained households, which in equilibrium borrow from households that are relatively patient. He shows that if one also allows for a moderate degree of price-stickiness in the durable goods producing sector, his model is able to generate a positive comovement between durables and non-durables.

This chapter revisits the framework of Monacelli (2009) and disentangles the contribution of the credit frictions from the effects that arise from the assumption that durable prices are somewhat sticky. By comparing the results of his model to a stripped-down version without frictions in financial markets, it is shown that without credit frictions it is easier to generate a positive comovement, that is, less stickiness of durable prices is needed. In the model of Monacelli (2009), credit-constrained households do, in fact, reduce their durable purchases after a monetary tightening. But the lending households increase their durable purchases so much that the response of aggregate durable purchases is more positive than in the version of the model without credit frictions. Also, in the case of fully flexible durable prices, the presence of credit frictions leads to a positive response of total aggregate output to a monetary tightening, whereas the model without credit frictions predicts a flat response.

To understand why the frictions in the market for household loans are unhelpful in solving the comovement problem, it is important to keep in mind that standard credit

\(^2\)For empirical evidence on the effects of monetary shocks on durable and non-durable consumption, see for example Bernanke and Gertler (1995), Barsky, House, and Kimball (2003), and Monacelli (2009).
frictions, including those considered by Monacelli (2009), do not eliminate equilibrium in the bond market. If borrowing by the credit-constrained households is reduced as a consequence of tighter credit constraints, then the bond market will only remain in equilibrium if lending by the other households decreases by the exact same amount. Since buying durables is an alternative way of saving, the lending households can avoid a large revision of their intertemporal plans by purchasing more durables instead of saving through bonds. Therefore, the forced reduction in borrowing can be expected to have a limited effect on aggregate consumption of durables and non-durables.\footnote{The importance of general equilibrium effects has been demonstrated in a different context by Thomas (2002). In her model, the effects of lumpy firm investment on aggregate quantities vanish because of the behavior of agents on the other side of the goods market, that is, the behavior of consumers.} In the model of Monacelli (2009), additional undesirable effects are generated by the fact that the borrowers’ incentives to buy durables depend positively on the tightness of the borrowing constraint, whereas the other households do not face a binding credit constraint. This chapter demonstrates analytically that it is precisely this feature, that causes Monacelli’s model to have more difficulties in generating a negative response of durable purchases to a monetary tightening, than a version of the model without credit frictions. Models with additional forms of heterogeneity between borrowers and lenders could offer better hopes of solving the comovement puzzle.

### 2.2 Two sticky-price models with consumer durables

Two New-Keynesian models with durable and non-durable consumption are analyzed. The first one replicates the credit friction model of Monacelli (2009), which describes a standard sticky-price economy augmented with collateral constraints and heterogeneous households that borrow and lend.\footnote{For a more detailed description of this model, the reader is referred to Monacelli (2009).} The second one is the same model, but with household heterogeneity eliminated so that it reduces to a standard New-Keynesian model in which credit frictions are not relevant.
2.2.1 The model with credit frictions

The credit friction model features two types of households with different rates of time preference, that is, one group of households is more patient than the other. Because in equilibrium the impatient households borrow from the patient households, they are referred to as borrowers and savers, respectively. Borrowing by the impatient households is restricted by a collateral constraint, which guarantees the existence of a well-defined steady state.\(^5\) The size of the total population is normalized to one and the fraction of borrowers is set equal to \(\pi\).

**Borrowers.** Impatient households maximize:

\[
E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, D_t, N_t) = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \log \left[ \left( 1 - \alpha \right)^{\frac{1}{\eta}} \left( C_t \right)^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} \left( D_t \right)^{\frac{\eta-1}{\eta}} \right] \left( n^t \right) - \frac{\mu N_{t+1}^{1+\varphi}}{1 + \varphi} \right\},
\]

where \(C_t\) is non-durable consumption, \(D_t\) is the stock of durable goods, \(N_t\) is labor supply, and \(\alpha, \eta, \nu, \) and \(\varphi\) are preference parameters. In every period, the borrowers face the following constraints:

\[
P_{c,t} C_t + P_{d,t} (D_t - (1 - \delta) D_{t-1}) + R_{t-1} B_{t-1} = B_t + W_t N_t,
\]

\[
R_t B_t \leq (1 - \chi) (1 - \delta) E_t \left\{ D_t P_{d,t+1} \right\},
\]

where \(P_{c,t}\) is the price of non-durables, \(P_{d,t}\) is the price of durables, \(R_t\) is the gross nominal interest rate, \(B_t\) is the nominal amount of debt, and \(W_t\) is the nominal wage. Equation (2.1) is the budget constraint. Equation (2.2) is a collateral constraint and states that the level of debt must be such that debt servicing in the next period cannot exceed a fraction \((1 - \chi)\) of the expected value of the depreciated current durable stock one period ahead. Therefore, \(\chi\) can be interpreted as a downpayment requirement. It is assumed

\(^5\)Similar constraints are considered in Kiyotaki and Moore (1997) and Iacoviello (2005).
that the collateral constraint always binds. Let $\psi_t$ be defined as the ratio of the Lagrange multiplier of the borrowing constraint to the Lagrange multiplier of the budget constraint.

The optimality conditions of the borrowers’ maximization problem are:

$$\frac{-U_{n,t}}{U_{c,t}} = w_t, \quad (2.3)$$

$$q_t U_{c,t} = U_{d,t} + \beta (1 - \delta) E_t \left\{ U_{c,t+1} \psi_{t+1} \right\} + (1 - \chi) (1 - \delta) U_{c,t} \psi_t E_t \{ \pi_{d,t+1} \}, \quad (2.4)$$

$$R_t \psi_t = 1 - \beta E_t \left\{ \frac{U_{c,t+1}}{U_{c,t}} \frac{R_t}{\pi_{c,t+1}} \right\}, \quad (2.5)$$

where $-U_{n,t}$, $U_{d,t}$ and $U_{c,t}$ are, respectively, the marginal utilities of leisure, durables and non-durables, $w_t \equiv W_t/P_{c,t}$ is the real wage in units of non-durables, $q_t \equiv P_{d,t}/P_{c,t}$ is the relative price of durables, and $\pi_{j,t}$ is gross inflation in sector $j$, with $j \in \{ \text{non-durables, durables} \}$.

Equation (2.3) is the standard optimality condition for labor, which equates the marginal utility of leisure to the product of the real wage and the marginal utility of non-durable consumption. The right-hand side of Equation (2.4) is the shadow value of durables to the borrowers, which is the sum of the immediate utility gain they derive from a marginal unit of durables, the discounted expected value of the undepreciated part of the durable next period, and a term reflecting their utility gain from the additional borrowing capacity. This last term is proportional to $\psi_t$, which measures the tightness of the borrowing constraint. At the optimum, the shadow value of durables must be equal to the marginal utility gain that is derived from buying $q_t$ non-durable goods. Equation (2.5) is the first-order condition for debt.

**Savers.** The patient households or savers have a discount factor $\gamma > \beta$ and their variables are characterized by a tilde. Savers receive all firm profits, so their budget

---

6It can be shown that the borrowing constraint is binding in the deterministic steady state. This paper checks the validity of the assumption that it also binds outside the steady state by performing an accuracy test. The test is described in the Appendix 2.A. The results show that the assumption is not problematic for the calibration considered in this paper.
reads:
\[ P_{c,t} \tilde{C}_t + P_{d,t} \tilde{I}_{d,t} + R_{t-1} \tilde{B}_{t-1} = \tilde{B}_t + W_t \tilde{N}_t + \frac{\Pi_t}{(1 - \omega)}, \tag{2.6} \]

where \( \Pi_t \) is total nominal firm profits. The optimality conditions of savers and borrowers are very similar, with the important difference that to the savers the collateral constraint is not relevant, since they are net lenders. This implies that \( \tilde{\psi}_t = 0 \) and consequently, the durable first-order condition for the savers can be written as:

\[ q_t \tilde{U}_{c,t} = \tilde{U}_{d,t} + \gamma (1 - \delta) E_t \left\{ \tilde{U}_{c,t+1} q_{t+1} \right\}. \tag{2.7} \]

Comparing the right hand sides of Equations (2.4) and (2.7) makes clear that the shadow value of durables is fundamentally different for borrowers and savers, as the latter are not restricted by a collateral constraint.

**Firms.** Final goods producers create bundles from intermediate goods according to the Dixit-Stiglitz aggregator. The final durable and non-durable goods are sold to the households. Intermediate goods firms face a quadratic cost of price adjustment, following Rotemberg (1982). The output of intermediate goods producer \( i \) in sector \( j \) is simply equal to labor input, that is, \( Y_{j,t} \) is simply equal to labor input. For a symmetric equilibrium, the optimality conditions of the intermediate non-durable and durable producers can be written, respectively, as:

\[ (1 - \varepsilon_c) + \varepsilon_c w_t = \vartheta_c (\pi_{c,t} - 1) \pi_c - \gamma \vartheta_c E_t \left[ \frac{U_{c,t+1}}{U_{c,t}} Y_{c,t+1} (\pi_{c,t+1} - 1) \pi_{c,t+1} \right], \tag{2.8} \]

\[ (1 - \varepsilon_D) + \varepsilon_D \frac{w_t}{q_t} = \vartheta_d (\pi_{d,t} - 1) \pi_d - \gamma \vartheta_d E_t \left[ \frac{U_{c,t+1}}{U_{c,t}} q_{t+1} Y_{d,t+1} (\pi_{d,t+1} - 1) \pi_{d,t+1} \right]. \tag{2.9} \]

where \( Y_{j,t} \) is output in sector \( j \), \( \varepsilon_j \) is the elasticity of substitution between intermediate goods and \( \vartheta_j \) is the price adjustment cost parameter.\(^7\) When price adjustment costs are

\(^7\)Firms discount future profits by the stochastic discount factor of the savers, i.e., the savers are their owners.
zero, prices are set according to a constant markup over nominal marginal costs, which is the nominal wage in this model. Thus, when durable prices are fully flexible, i.e., when $\vartheta_d = 0$, the real wage in units of durables $w_t/q_t$ is constant and from Equation (2.9) it can be seen to equal $(\varepsilon_d - 1)/\varepsilon_d$.

**Market clearing conditions and monetary policy.** Clearing of the markets for non-durables, durables, bonds and labor requires:

\[
Y_{c,t} - \frac{\vartheta_c}{2} (\pi_{c,t} - 1)^2 Y_{c,t} = \varpi C_t + (1 - \varpi) \tilde{C}_t, \tag{2.10}
\]

\[
Y_{d,t} - \frac{\vartheta_d}{2} (\pi_{d,t} - 1)^2 Y_{d,t} = \varpi (D_t - (1 - \delta) D_{t-1}) + (1 - \varpi) \left( \tilde{D}_t - (1 - \delta) \tilde{D}_{t-1} \right), \tag{2.11}
\]

\[
0 = \varpi B_t + (1 - \varpi) \tilde{B}_t, \tag{2.12}
\]

\[
Y_{c,t} + Y_{d,t} = \varpi N_t + (1 - \varpi) \tilde{N}_t. \tag{2.13}
\]

The model is closed by the following monetary policy rule:

\[
\frac{R_t}{R} = \left( \frac{\tilde{\pi}_t}{\tilde{\pi}} \right)^{\xi_s} \exp (\varepsilon_t), \tag{2.14}
\]

where $\tilde{\pi}_t = \pi_{c,t}^{1-\tau} \pi_{d,t}^\tau$ is a composite inflation index, $R$ and $\tilde{\pi}$ are the steady-state levels of the nominal interest rate and the inflation index, respectively, and $\varepsilon_t$ is an exogenous shock.\(^8\)

### 2.2.2 The model without credit frictions

The model with credit frictions can be modified to obtain a standard New-Keynesian model without credit frictions, by simply setting the fraction of borrowers, $\varpi$, equal to zero. So the model without credit frictions features a representative household, behaving like the savers in the model with credit frictions. With heterogeneity across households eliminated, debt equals zero in equilibrium and collateral constraints are irrelevant.

\(^8\)In order to enhance comparability with Monacelli (2009), I use the same monetary policy rule.
As explained by BHK (2007), the comovement problem is driven by a key property of standard representative household models, which is the quasi-constancy of the shadow value of durables. This means that the household cares little about the timing of durable purchases. Recall that the shadow value of durables is the right-hand side of the durable optimality condition (2.7) and note that this equation can be rewritten as follows:

\[ q_t \tilde{U}_{c,t} = E_t \sum_{k=0}^{\infty} \gamma^k (1 - \delta)^k \tilde{U}_{d,t+k} \approx \text{const}. \tag{2.15} \]

The reason the shadow value of durables for the representative agent is quasi-constant, is that the marginal utility of durables depends on the stock of durables, which is not much affected by variations in the flow of durables. Also, the shadow value of durables depends for an important part on the marginal utility of durables in the distant future, which is even less sensitive to temporary shocks. Because the shadow value of durables is near-constant, the relative price of durables \( q_t \) and the marginal utility of non-durable consumption \( \tilde{U}_{c,t} \) move in opposite directions. If prices of durables are flexible relative to prices of non-durables, the relative price of durables \( q_t \) falls during a monetary tightening, creating more incentives for households to purchase durables. At the same time, the decrease in \( q_t \) must be accompanied by an increase in the marginal utility of non-durables \( \tilde{U}_{c,t} \), which is associated with a lower level of non-durable consumption.

More insight in the comovement problem can be obtained by considering the special case of fully flexible durable prices. In the absence of durable price adjustment costs, the real wage in units of durables, \( w_t/q_t \), is constant. As a consequence, monetary policy shocks are neutral with respect to total real activity. This follows from the labor optimality condition, which can be expressed as a condition equating the marginal utility of leisure to the product of the real wage in units of durables \( w_t/q_t \) and the shadow value of durables, which equals \( q_t \tilde{U}_{c,t} \):

\[ -\tilde{U}_{n,t} = \frac{w_t}{q_t} q_t \tilde{U}_{c,t}. \]
Given that the real wage in units of durables is constant and the shadow value of durables is quasi-constant, the same holds for total employment (and total output). Also, the relative durable price $q_t$ decreases after a monetary tightening, and the quasi-constancy of $q_t\tilde{U}_{c,t}$ implies that non-durable consumption also decreases. Since total employment remains roughly constant, the production of durables must expand. Hence, durable purchases comove negatively with non-durable purchases.\(^9\)

### 2.3 Comparing the two models

A solution to the comovement problem requires a model that predicts a fall in both non-durable and durable purchases following a monetary tightening as well as a rise of the nominal interest rate.\(^{10}\) Monacelli (2009) shows that his credit friction model with moderate price-stickiness in the durable goods sector is able to generate these predictions. In this section, the results of Monacelli’s model are compared to those of a version of the model without credit frictions, under the same calibration and normalization of the steady state.\(^{11}\) The model is solved using a first-order perturbation method in logarithms, which allows one to exploit the observational equivalence between the log-linearized versions of the Rotemberg model with quadratic price adjustment costs and the Calvo-Yun model. The parameter values are displayed in Table 2.1.

Figure 2-1 plots, for both models, the Impulse Response Functions (IRFs) of the nominal interest rate, of aggregate durable and non-durable purchases, and of aggregate

---

\(^{9}\)This argument abstracts from resources lost because of price changes. In a log-linearized version of the model, these losses are equal to zero.

\(^{10}\)It is important to consider the nominal interest rate, because increasing price stickiness in the durable goods sector is helpful in solving the comovement problem, but it actually makes it more difficult to generate a realistic response of the nominal interest rate, as shown by BHK (2007) and Monacelli (2009).

\(^{11}\)To facilitate comparison to the numerical results in Monacelli (2009), the parameter $\tau$ reflecting the weight of durables in the composite inflation index in the monetary policy rule is set to zero. This means that monetary policy only responds to inflation in the non-durable goods sector. Appendix 2.B investigates the consequences of adopting the more realistic assumption that monetary policy also responds to prices of durables. This is shown to make it more difficult to obtain the desired comovements in the model without credit frictions, and even impossible in the model with credit frictions. Appendix 2.B also discusses results under a monetary policy rule that responds to both output and inflation.
Table 2.1: Parameter settings

<table>
<thead>
<tr>
<th>parameter</th>
<th>description</th>
<th>Model with credit frictions</th>
<th>Standard model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>discount factor borrowers</td>
<td>0.98</td>
<td>-</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>discount factor savers</td>
<td>0.99</td>
<td>0.99</td>
</tr>
<tr>
<td>$\delta$</td>
<td>depreciation rate durables</td>
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<td>0.01</td>
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<tr>
<td>$\varepsilon_c$</td>
<td>el. of subst. between nondurable varieties</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>$\varepsilon_d$</td>
<td>el. of subst. between durable varieties</td>
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<td>6</td>
</tr>
<tr>
<td>$\eta$</td>
<td>el. of subst. between durables and nondurables</td>
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<td>1</td>
</tr>
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<td>$\xi_{\pi}$</td>
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<td>1.5</td>
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<tr>
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<td>share of borrowers</td>
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<td>0</td>
</tr>
<tr>
<td>$\rho$</td>
<td>persistence parameter monetary policy shocks</td>
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</tr>
<tr>
<td>$\chi$</td>
<td>parameter in borrowing constraint</td>
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<td>-</td>
</tr>
<tr>
<td>$\varphi$</td>
<td>inverse elasticity of labor supply</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Notes: “Model with credit frictions” refers to the model of Monacelli (2009) that features patient households, who lend to impatient households who are at a credit-constraint. “Standard model” refers to the representative household model without credit frictions and with zero debt in equilibrium.

total output in reaction to a monetary tightening. Each row corresponds to a different level of durable price-stickiness.\(^{12}\)

First consider the model with credit frictions. The top row shows the results for the case of fully flexible durable prices. The responses of durable and non-durable purchases display the comovement problem as reported in the literature. But whereas BHK (2007) found that in their model with frictionless financial markets total output remains almost constant after a monetary tightening, the model with credit frictions even predicts an increase in total output, which is at odds with the typical decrease found in empirical studies. The IRFs in the bottom row correspond to four-quarter durable price-stickiness, in which case prices of durables and non-durables are equally sticky. For this calibration, both durable and non-durable purchases decrease, but the nominal interest rate moves in the wrong direction. The figure also replicates the finding of Monacelli (2009) that there exists a small range of intermediate levels of durable price-stickiness for which the model

\(^{12}\)In the context of the model, a monetary tightening is defined as an increase in the exogenous shock variable $\varepsilon_t$, even though the nominal interest rate actually goes down for some calibrations.
Figure 2.1: Responses to a monetary tightening in the model with and without credit frictions for the first eight quarters. The rows correspond to different degrees of durable price stickiness. Responses are plotted as percentage deviations from the steady state.

Notes: In the literature on models with durables, it is common to sum output components by their steady state prices, see for example BHK (2007) and Iacoviello and Neri (2009). Following this tradition, the output measure is constructed as $Y_{c,t} + qY_{d,t}$, where $q$ is the relative price of durables in the steady state, which equals one.
Figure 2.2: Responses to a monetary tightening of total durable purchases, as well as durable purchases by borrowers and by savers in the model with credit frictions.

Notes: Durable price stickiness is set to two quarters. Responses are plotted as percentage deviations from the steady state.

is successful in generating a positive comovement between durables and non-durables, as well as an increase in the nominal interest rate.

Now consider the model without credit frictions. The IRFs in the top row show that the version of the model without credit frictions also predicts a negative comovement between durable and non-durable purchases in the flexible durable price case. Without credit frictions, however, total output remains constant instead of displaying the counterfactual increase after a monetary tightening. The IRFs for the case where durable prices are as sticky as non-durable prices (the bottom row), show that the nominal interest rate also moves in the wrong direction in the model without credit frictions. But most importantly, the figure shows that, for any level of durable price-stickiness, removing the credit frictions leads to a less negative response of non-durable purchases and a less positive response of durable purchases. It is, thus, more difficult to generate the positive comovement in the model with credit frictions, as one needs to rely on a larger degree of durable price-stickiness.
To obtain more insight in this result, consider the responses for the borrowers and savers separately, as displayed in Figure 2-2 for two-quarter durable price-stickiness. The figure confirms the intuition that during a monetary contraction, constrained households reduce their amount of durable purchases. However, the figure also shows that this decline is accompanied by an increase in durable purchases by the savers. The results presented in Figure 2-1 make clear that this increase is so large that the response of aggregate durable purchases is more positive than in the model without credit frictions.\footnote{Figure 2-2 reveals another problem of the model with credit frictions, namely that it predicts extremely large volatilities for durable purchases by the borrowers and savers. While aggregate durable purchases falls by less than 0.75\%, the savers increase their durable purchase by more than 29\%, while durable purchases by the borrowers decrease by more than 57\%.}

### 2.4 Why do the credit frictions make the comovement problem more severe?

In Section 2.3 the model and calibration proposed by Monacelli (2009) were revisited, and it was shown that removing the credit frictions from the model makes it easier to generate a positive comovement between durables and non-durables. The purpose of the current section is to show that there is a simple reason for this undesirable result, and that one can expect this mechanism to be at play more generally in models with collateral constraints. At the center of the analysis is the fact that collateral constraints fundamentally affect the shadow value of durables for borrowers, but not for the other households. It is shown analytically that as a consequence the credit friction model generates (i) nearly the same responses of prices and wages as the model without credit frictions, (ii) a more positive response of aggregate employment, (iii) a more negative response of aggregate non-durable consumption. These results imply a more positive response of aggregate durable purchases to a monetary tightening.

For the savers, the shadow value of durables remains \textit{quasi-constant} following a monetary shock. Because the savers are not credit-constrained they face the same optimization
problem as the representative household in the model without credit-frictions. Hence, the reasoning in Section 2.2.2 explaining the quasi-constancy of the shadow value of durables in the model without credit frictions also applies to the savers in the credit friction model. As a consequence, the introduction of credit frictions leaves the responses of prices, wages and the nominal interest rate nearly unchanged. To see this, define \( \hat{V}_t \) as the shadow value of durables to the households that do not face a binding collateral constraint. Since their optimality condition for durables states that \( \hat{V}_t = q_t \hat{U}_{c,t} \), their Euler equation can be written as:

\[
1 = \gamma E_t \left\{ \frac{\hat{V}_{t+1}}{\hat{V}_t} \frac{R_t}{\pi_{d,t+1}} \right\}.
\] (2.16)

Note, also, that when the shadow value of durables is constant, the same holds for the real interest rate in units of durables. Also, the definition of the relative price of durables implies that \( q_t = \frac{\pi_{d,t}}{\pi_{c,t}} q_{t-1} \). Log-linearizing these two equations, as well both pricing equations for the intermediate goods firms and the monetary policy rule, gives

\[
\hat{R}_t = E_t \hat{\pi}_{d,t+1} + \hat{\pi}_c - \hat{\pi}_t, \quad (2.17)
\]
\[
\hat{q}_t = \frac{1}{\hat{\pi}_c} \hat{w}_t + \gamma E_t \hat{\pi}_{c,t+1}, \quad (2.18)
\]
\[
\hat{\pi}_c = \frac{\varepsilon_c - 1}{\hat{\pi}_c} \hat{w}_t + \gamma E_t \hat{\pi}_{c,t+1}, \quad (2.19)
\]
\[
\hat{\pi}_d = \frac{1}{\hat{\pi}_d} \left( \hat{w}_t - \hat{q}_t \right) + \gamma E_t \hat{\pi}_{d,t+1}, \quad (2.20)
\]
\[
\hat{R}_t = \xi \hat{\pi}_{c,t} + \varepsilon_t, \quad (2.21)
\]

where hatted variables denote log deviations from the steady state. The fact that the shadow value of durables for households who are not at a credit constraint is quasi-constant, implies that \( \hat{V}_t - \hat{V}_{t+1} \approx 0 \). Ignoring this term in Equation (2.17) leaves one with a subsystem that is the same for the model with and without credit frictions, and that consists of five equations in five unknowns \( (\hat{\pi}_{c,t}, \hat{\pi}_{d,t}, \hat{q}_t, \hat{R}_t, \hat{w}_t) \). It follows that the IRFs of the endogenous variables contained in this subsystem are nearly the same in the model with and without collateral constraints. The two variables that will play a
role in the analysis below are the relative price of durables \( q_t \) and the real wage in units of durables, \( w_t / q_t \). Figure 2-3 confirms that the IRFs for these two variables are indeed nearly equal for both models.

An important feature of the credit friction model is that for borrowers, the shadow value of durables rises during a monetary tightening. The reason is that the collateral constraint tightens and the possession of additional durables permits more borrowing, since durables serve as collateral for loans. To see this formally, rewrite the borrowers’ optimality condition for durables (2.4) as follows:

\[
V_t = q_t \bar{U}_{c,t} = \frac{U_{d,t} + \beta (1 - \delta) E_t \{ V_{t+1} \}}{1 - (1 - \chi) (1 - \delta) \psi_t \{ \pi_{d,t+1} \}^{\gamma}}. \tag{2.22}
\]

A tightening of the collateral constraint, reflected by an increase in \( \psi_t \), will, ceteris paribus, lead to an increase in the shadow value of durables for the borrowers \( V_t \).\(^{14}\)

The rise in \( V_t \) explains why in the case of completely flexible durable prices, aggregate output increases after a monetary tightening in the model with credit frictions. To understand this, it is useful to combine the labor optimality conditions for the savers and the borrowers with the labor market clearing condition (2.13), in order to express total aggregate employment \( N_{t}^{agg} \) as:

\[
N_{t}^{agg} \equiv \varpi N_t + (1 - \varpi) \bar{N}_t = \frac{w_t}{q_t} \left[ \frac{\varpi V_t}{\bar{\nu}} + \frac{1 - \varpi}{\bar{\nu}^2} \bar{V}_t \right]. \tag{2.23}
\]

When durable prices are fully flexible, the real wage in units of durables \( w_t / q_t \) is constant, because durable prices are set according to a constant markup over the nominal wage. Given that \( \bar{V}_t \) remains roughly constant, aggregate employment almost perfectly follows

\(^{14}\)A monetary tightening also increases \( U_{d,t} \), which pushes up \( V_t \) as well. However, this effect is relatively small, because variations in the stock of durables are small. Also, for sufficiently large levels of durable price stickiness, \( E_t \{ \pi_{d,t+1} \} \) decreases, which could offset the increase in \( \psi_t \). However, given that the real interest rate in units of durables is quasi-constant, calibrations for which \( E_t \{ \pi_{d,t+1} \} \) increases are those for which the nominal interest rate decreases. In the numerical results this effect never dominates as \( V_t \) always increases.
Figure 2.3: Responses to a monetary tightening of the real wage in units of durables \( w_t / q_t \) and the relative price of durables \( q_t \) in the model with and without credit frictions for the first eight quarters.

Notes: The rows correspond to different degrees of durable price stickiness. Responses are plotted as percentage deviations from the steady state.
the rise in the shadow value of durables for borrowers, $V_t$, when a sudden monetary contraction takes place. Because labor is the only production input, the response of aggregate total output also increases.

In the more general case with possibly sticky durable prices, Equation (2.23) still explains why aggregate employment responds more positively in the model with credit frictions than in the version without. Recall that in both models $\tilde{V}_t$ is quasi-constant and the response of $w_t/q_t$ is nearly the same, whereas the shadow value for the borrowers, $V_t$, is only present in the model with credit frictions. During a monetary tightening, $V_t$ increases, shifting up the borrowers’ labor supply curve. It follows from Equation (2.23) that this upward shift is behind the more positive response of aggregate employment (and output) in the credit friction model. The intuition is that during a monetary contraction the collateral constraint is particularly tight, which gives borrowers incentives to work more and use the additional wage income to dampen the decrease in durable purchases.

Similar logic can be applied to explain why the introduction of credit frictions lowers the response of aggregate non-durable consumption. Combine the durable optimality conditions for borrowers and savers with the non-durable market clearing condition (2.10) to express aggregate non-durable consumption, $C^{agg}_t$, as a function of the relative price $q_t$ and the two shadow values of durables:

$$C^{agg}_t \equiv \pi C_t + (1 - \pi) \tilde{C}_t = q_t (1 - \alpha) \left[ \frac{\pi}{V_t} + \frac{1 - \pi}{\tilde{V}_t} \right].$$ (2.24)

Given that in both models, with and without credit frictions, $\tilde{V}_t$ is roughly constant and the response of $q_t$ is the nearly the same, it is again the rise in $V_t$ that drives the more pronounced decline of non-durable purchases in the credit friction model. For households that are not at a credit constraint, the quasi-constancy of the shadow value of durables implies that they decrease their non-durable purchases in proportion to the fall in the

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15 Recall that the model without credit frictions is obtained by removing the borrowers from the model, that is, by setting $\pi = 0$. 
relative price of durables. For credit-constrained households, however, there are additional reasons to substitute away from non-durables, because dampening the decline in durable purchases alleviates the tightening of the collateral constraint. Equation (2.24) makes clear that this is the reason for the stronger decline of aggregate non-durable purchases in the model with credit frictions.

It now follows that the introduction of collateral constraints leads to a more positive response of aggregate durable purchases. If the response of aggregate employment is more positive after adding credit frictions, and aggregate non-durable consumption falls more, then the aggregate resource constraint can only remain satisfied if production in the durable goods producing sector responds more positively. Consequently, the collateral constraints considered by Monacelli (2009) push the responses of durables and non-durables further in opposite directions, i.e., they make the comovement problem more severe.

2.5 Concluding comments

In the model of Monacelli (2009), borrowers are different from lenders, because they face a binding collateral constraint, and precisely this feature reduces the model’s ability to solve the comovement puzzle. Introducing other forms of heterogeneity between borrowers and lenders could be a promising way forward in solving the comovement puzzle. For example, Carlstrom and Fuerst (2006) show that adding frictions in lending by firms to households helps to generate a positive comovement between durables and non-durables.\footnote{This may even be true in a model with collateral constraints, but the effects introduced by the additional form of heterogeneity would have to overturn the effects introduced by the collateral constraints.} They also show that the introduction of sticky wages helps to solve the comovement puzzle.
Appendix 2.A  Accuracy test

Monacelli (2009) shows that the borrowing constraint binds in the steady state. Following standard practice in the literature, he assumes that the borrowing constraint always binds, so that the model can be solved using perturbation methods. This chapter also follows this tradition. However, the question arises whether the assumption of an always-binding constraint is correct for a realistic calibration of the model, including the standard deviation of the shocks. To the best of my knowledge, this issue has not been addressed in the literature, except in Iacoviello (2005).\textsuperscript{18} This is surprising because the properties of the model are potentially very different if the constraint does not always bind.

The accuracy test is closely related to the standard test of Judd (1992) that checks Euler equation errors and it does not require the use of a global solution technique. The basic idea is to calculate how much debt the borrowers would choose under the assumption that the constraint does not bind and see how often the chosen amount is less than what is allowed by the constraint. That is, the accuracy test checks how often the constraint is not binding.\textsuperscript{19} The test is carried out by implementing the following steps:

1. Solve the model using a perturbation method (e.g. log-linearization).

2. Using the solution found in step 1, run a simulation of the state variables, and index simulated variables by $t = 1, \ldots, T$.

3. At each point in the simulation, shut off the borrowing constraint by setting $\psi_t$ equal to zero. In that case, the first order conditions of the borrowers can be rewritten to

\textsuperscript{18}Iacoviello (2005) investigates the non-linear solution of a simplified partial equilibrium version of his model.

\textsuperscript{19}The amount of debt chosen by the borrowers in the absence of a borrowing constraint can be calculated easily from the non-linear equilibrium conditions under the assumption that prices, wages, the nominal interest rate, the state variables and the conditional expectations are those predicted by the model with an always-binding constraint. That is, the assumption is that these variables are consistent with a binding constraint and the procedure checks whether the chosen debt level is consistent with a binding constraint as well.
find expressions for non-durables, durables and labor:

from Equation (5) : \[ C_t^* = \frac{1}{\beta R_t} E_t \{ \pi_{c,t+1} C_{t+1} \} \]  
(2.25)

from Equation (4) : \[ D_t^* = \frac{\alpha}{1 - \alpha} \left( \frac{q_t}{C_t^*} - \beta (1 - \delta) E_t \left\{ \frac{q_{t+1}}{C_{t+1}} \right\} \right)^{-1} \]  
(2.26)

from Equation (3) : \[ N_t^* = \left( \frac{w_t (1 - \alpha)}{\nu C_t^*} \right)^{1/\varphi} \]  
(2.27)

where the stars indicate that variables are calculated under the assumption that the constraint does not bind. The values of \( R_t, q_t, \) and \( w_t \) are calculated using the policy functions found in step 1. The policy functions from step 1 are also used to approximate the conditional expectations by Gauss-Hermite quadrature.

4. Calculate rel debt from the budget constraint, with real debt defined as \( b_t = B_t / P_{c,t} \):

\[ b_t^* = C_t^* + q_t (D_t^* - (1 - \delta) D_{t-1}) + R_{t-1} \frac{b_{t-1}}{\pi_t} - w_t N_t^* \]

and again use the policy functions found in step 1 to calculate \( q_t, D_{t-1}, R_{t-1}, b_{t-1}, \pi_t, \) and \( w_t \).

5. Compare the level of debt in the absence of a binding borrowing constraint \( b_t^* \) to \( b_t \), where \( b_t \) is the amount of debt chosen when the borrowing constraint always binds, which is calculated using the policy function found in step 1. If \( b_t^* \) is lower than \( b_t \) at some points in the simulation, then it can be concluded that the borrowing constraint is not always binding. I also investigate the consumption errors that arise from falsely assuming that the constraint binds, by comparing \( C_t^* \) to \( C_t \) and \( I_{d,t}^* \) to \( I_{d,t} \) at the points in the simulation where the constraint is found to be non-binding.

Running a simulation of the model requires further assumptions about the distribution of the innovations to the shocks. The assumption here is that they are normally distributed with mean zero and standard deviation \( \sigma_u \), which is to be calibrated. With larger shocks,
a non-binding constraint is a more likely outcome. The strategy followed here is to relate output volatility predicted by the model to output volatility in the data. Output volatility is estimated to be 0.0087 over the sample period 1988q1-2007q4. To remain agnostic about the importance of monetary shocks, several values for the standard deviation of the monetary shocks are considered. These values are chosen such that output volatility predicted by the model is a certain percentage of output volatility in the data, ranging from 10% to 100%.

Another factor that affects the likelihood of the borrowing constraint to be non-binding, is the difference between the discount factor of the savers $\gamma$ and the discount factor of the borrowers $\beta$. In the extreme case where the two types of households are equally patient, that is, when $\beta = \gamma$, the borrowing constraint will never be binding as debt equals zero in equilibrium. Thus, the closer the two discount factors are, the less likely it is that the borrowing constraint always binds. To investigate this issue quantitatively, I not only run the test with $\beta$ equal to its benchmark value 0.98, but I also repeat the test with $\beta$ equal to 0.985 and 0.989. These values are very close to the discount factor of the savers $\gamma$, which is equal to 0.99 in all calibrations.

To evaluate accuracy, criteria are needed. First define the variable $I_t$, indicating whether the constraint is non-binding:

\[
I_t = \begin{cases} 
1 & \text{if } b_t - b_t^* > 0, \\
0 & \text{otherwise}, 
\end{cases}
\]

\footnote{The data series used for output is real GDP at a quarterly frequency, taken from the website of the Bureau of Economic Analysis. The log of this series is detrended using the HP-filter with $\lambda = 1600$.}
and then define the following criteria:

\[
criterion 1 \equiv 100 \times \frac{\sum_{t=1}^{T} I_t}{T},
\]

\[
criterion 2 \equiv 100 \times \frac{\sum_{t=1}^{T} \frac{|\gamma_t - \beta_t|}{\beta_t} I_t}{\sum_{t=1}^{T} I_t},
\]

\[
criterion 3 \equiv 100 \times \frac{\sum_{t=1}^{T} \frac{|C_t - C_{t-1}|}{C_t} I_t}{\sum_{t=1}^{T} I_t},
\]

\[
criterion 4 \equiv 100 \times \frac{\sum_{t=1}^{T} \frac{|D_t^T - D_t|}{D_t - (1-\gamma)D_t-1} I_t}{\sum_{t=1}^{T} I_t}.
\]

The first criterion is the percentage of the cases where the constraint is found to be non-binding. The second, third, and fourth criteria are the average relative errors in the amount of debt, non-durable purchases, and durable purchases by the borrowers, respectively, conditional on the event of a non-binding borrowing constraint.

Table 2.2 reports the results. For the benchmark calibration with \(\beta = 0.98\), the solution under the assumption of an always-binding constraint turns out to be accurate in the sense that in none of the points in the simulation the constraint becomes non-binding, even if the standard deviation of monetary policy shocks is calibrated to be so large that monetary policy shocks explain all output volatility present in the data.\(^{21}\) Not surprisingly, the table also shows that as \(\beta\) approaches \(\gamma\), the constraint becomes binding more often, resulting in serious inaccuracies, especially regarding durable purchases by the borrowers, \(I_{d,t}\).

The procedure above is based on a standard accuracy test, in which the conditional expectations are calculated using a very accurate numerical integration procedure. The accuracy test executed here focuses on only one particular feature of the model, namely whether the constraint is binding or not. In this case, it is possible to use a much simpler procedure that avoids using numerical integration. In particular, instead of calculating

\(^{21}\)This possibly changes if one calibrates the model to feature other types of shocks as well. Because results would depend on the particular choice of shocks and their relative volatilities, I have limited the analysis to monetary policy shocks only.
Table 2.2: Accuracy test for the model with credit frictions.

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<th>criterion 2 (% error $b_t$)</th>
<th>criterion 3 (% error $C_t$)</th>
<th>criterion 4 (% error $I_{dt}$)</th>
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<tr>
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<tr>
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<tr>
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</tr>
<tr>
<td></td>
<td>100%</td>
<td>28.7</td>
<td>0.7</td>
<td>0.1</td>
<td>436.6</td>
</tr>
</tbody>
</table>

Note: The test is based on a simulation of length 51000, starting from the steady state and with the first 1000 observations discarded. Price stickiness of durables is set to 2 quarters. The percentages in the second column denote how much output volatility is predicted by the model with only monetary shocks, relative to output volatility observed in the data. Criterion 1 is the percentage of the cases in which the constraint is non-binding. Criterion 2, 3, and 4 are, respectively, the average of the absolute percentage errors in the amount of real debt, non-durable purchases and durable purchases by the borrowers, conditional on the event of a non-binding borrowing constraint. Conditional expectations are approximated using Gauss-Hermite quadrature with 10 nodes.
the conditional expectations in Equations (2.25) and (2.26) explicitly, one can use log-linear approximations. These can be obtained by simply adding the equations $x_{1,t} = E_t \{ \pi_{c,t+1} C_{t+1} \}$ and $x_{2,t} = E_t \{ \frac{q_{t+1}}{C_{t+1}} \}$ to the system solved in step 1.$^{22}$ Figure 2-4 plots the two conditional expectations calculated under both methods and suggests that differences are small. Table 2.3 compares criterion 1, calculated with both procedures, and shows that with the direct log-linear approximation of the conditional expectations, the constraint is non-binding somewhat more often, but the conclusions about accuracy would be the same in all cases.

**Figure 2-4:** Conditional expectations: Gauss-Hermite approximation versus direct log-linear approximation.

Notes: Model simulation with $\beta = 0.989$ and the standard deviation of the shocks calibrated such that output volatility in the model is 50\% of output volatility in the data.

$^{22}$I would like to thank Matteo Iacoviello for this idea.
Table 2.3: Accuracy test: comparing the Gauss-Hermite approximation of the conditional expectations to a direct log-linear approximation.

<table>
<thead>
<tr>
<th>( \beta )</th>
<th>output volatility model</th>
<th>criterion 1 (% non-binding)</th>
<th>Gauss-Hermite approximation</th>
<th>log-linear approximation</th>
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</thead>
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<tr>
<td>0.98</td>
<td>10%</td>
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<td>0.0</td>
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<tr>
<td>(benchmark)</td>
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<td></td>
<td>25%</td>
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<td></td>
<td>100%</td>
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<tr>
<td>0.985</td>
<td>10%</td>
<td>0.0</td>
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<td></td>
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<td></td>
<td>100%</td>
<td>1.1</td>
<td>1.5</td>
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<tr>
<td>0.989</td>
<td>10%</td>
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<td>4.3</td>
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<tr>
<td></td>
<td>50%</td>
<td>18.2</td>
<td>20.1</td>
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<tr>
<td></td>
<td>100%</td>
<td>28.7</td>
<td>33.3</td>
<td></td>
</tr>
</tbody>
</table>

Note: See Table 2.2.

Appendix 2.B Alternative monetary policy rules

Durable inflation in the monetary policy rule Following Monacelli (2009), the benchmark results are generated under the assumption that monetary policy attaches no weight to inflation in the durable goods sector. In this appendix, the more realistic assumption is adopted that monetary policy responds to a composite index of inflation in the durable and non-durable sectors. The weight attached to durable inflation is chosen to reflect the share of durable purchases in total expenditures in the steady state, that is, \( \tau \) is set to 0.2. Figure 2.5 plots the IRFs for both models with this monetary policy rule. The main difference with the benchmark rule is that the response of the nominal interest rate is more negative. With the more realistic monetary policy rule, the range of values for the durable price-stickiness parameter \( \vartheta_d \) for which durable purchases, non-durable purchases, and the nominal interest rate all move in the desired directions right after

\(^{23}\) The numerical results in Monacelli (2009) are generated by setting \( \tau \) equal to zero. In his model description, Monacelli (2009) proposes to set \( \tau \) equal to \( \alpha \) but provides no rationale for this choice. Recall that \( \alpha \) is the parameter that determines the relative importance of the stock of durables in the CES consumption basket. The parameter \( \alpha \) is, thus, not equal to the steady state expenditure share of durables.
Figure 2.5: Responses to a monetary tightening in the model with credit frictions and without credit frictions (standard model), both with a composite inflation index in the monetary policy rule ($\tau = 0.2$). The rows correspond to different degrees of durable price-stickiness. Responses are plotted as percentage deviations from the steady state.
the shock becomes very small for the standard model. The model with credit frictions performs even worse in the sense that there is no value for $\vartheta_d$ for which it generates positive comovement between durables and non-durables and a positive response of the nominal interest rate during the monetary tightening.

**Output gap in the monetary policy rule** I now consider a monetary policy rule that includes an output term. This does not change the result that the introduction of credit frictions makes the comovement problem more severe. I considered the following alternative monetary policy rule:

$$R_t = \left( \frac{\hat{\pi}_t}{\pi} \right)^{\xi_{\pi}} \left( \frac{Y_{t}^{agg}}{Y_{t}^{agg}} \right)^{\xi_{y}} \exp(\epsilon_t),$$

where $R_t$ is the nominal interest rate, $\hat{\pi}_t$ is the inflation index, $Y_{t}^{agg}$ is total aggregate output as defined in the main text of this chapter, $\epsilon_t$ is the shock, and variables without time index denote steady state values.\(^{24}\) I considered the following (standard) parameter values: $\xi_{\pi} = 1.5$ and $\xi_{y} = 0.5/4$. I left the remainder of the model, including the calibration, the same as in the main text of the chapter. The IRFs are shown in Figure 2-6. The IRFs show that, as under the benchmark rule without an output term, it is the case that in the model with credit frictions (i) the IRF of non-durables is more negative, (ii) the IRF of durable purchases is more positive, and (iii) total output responds more positively to a monetary tightening.

\(^{24}\)With only monetary policy shocks, the natural level of output is constant, and deviations of output from its steady state level equal the output gap in this model.
Figure 2.6: Responses to a monetary tightening in the model with credit frictions and without credit frictions under the alternative monetary policy rule with output gap.
Chapter 3

The Myth of Financial Innovation and the Great Moderation

Abstract

Financial innovation is widely believed to be at least partly responsible for the recent financial crisis. At the same time, there are empirical and theoretical arguments that support the view that changes in financial markets, in particular innovations in consumer credit and home mortgages, played a role in the "great moderation". This paper questions empirical evidence supporting this view. Especially the behavior of aggregate home mortgages changed less during the great moderation than is typically believed. A remarkable change we do find is that monetary tightenings became episodes during which financial institutions other than banks increased their mortgages holdings.\footnote{This chapter is joint work with Wouter den Haan.}

3.1 Introduction

There are both empirical and theoretical arguments that support the view that the changes that reshaped financial markets during the last couple of decades were partly responsible for the great moderation.\footnote{See, for example, Campbell and Hercowitz (2006), Cecchetti, Flores-Lagunes, and Krause (2006), Dynan, Elmendorf, and Sichel (2006), IMF (2006), Jermann and Quadrini (2006), Lacker (2006), Peek and Wilcox (2006), Wang (2006), Cecchetti (2008), Iacoviello and Pavan (2009), and de Blas-Pérez (2009), Guerlon-Quintana (2009), Blanchard and Simon (2001), In Appendix 3.A, we provide several citations from policy makers, policy institutions, and academics.} The great moderation is the period from roughly the mid eighties until the start of the recent financial crisis during which business cycle fluctuations were small relative to the ones observed in previous decades. The basic idea underlying
theories that predict that financial innovation dampened business cycles is that financial innovation reduced frictions in lending and that this made it possible for financial intermediaries to continue to fulfil their role efficiently during an economic downturn. One important piece of evidence presented in the literature—and confirmed in this paper—is the empirical finding that the comovement between real activity and the volumes of both mortgages and consumer credit has dropped enormously. This is a typical prediction of theories according to which financial innovation dampened business cycles.

Although it is now clear that the "innovated" financial sector could not protect the economy against a severe downturn and is—at least to some extent—responsible, it may still be the case that financial innovation is also behind the great moderation. Financial innovation can be responsible for both the great moderation and the financial crisis if, for example, financial innovation dampened the impact of the type of shocks observed during the great moderation, but magnified the type of shocks observed recently, like reductions in house prices that were unique in terms of how correlated they were across U.S. regions and even across borders.

The objectives of this paper are (i) to carefully document the changes in the time series properties of key financial and macro variables and (ii) to discuss whether these are or are not consistent with the predictions of theories according to which financial innovation dampens business cycles. In this paper, we focus on consumer loans, that is, home mortgages and consumer credit. This choice is motivated by the fact that innovations in consumer lending have been a key element in the debate on the role of financial innovations on dampening business cycles. It would definitely be interesting to also include firm financing, but firm financing is very complex and is better treated separately.\(^3\)

A proper evaluation of the changes in the time series properties requires a comprehensive set of statistics. We use the Impulse Response Functions (IRFs) of structural

\(^3\)Using a methodology like the one proposed here, Lozej (2010) analyses changes in the cyclical behaviour of firm lending and finds results that are consistent with financial innovation.
Vector Autoregressive models (VARs) to provide such a set. To see whether the time series properties have changed, we estimate the VAR over an early sample (from 1954Q3 to 1978Q4) as well as over a later sample (from 1984Q1 to 2008Q1) and compare the results. The estimated IRFs also make it possible to analyze the reasons behind the drop in the comovement between real activity and consumer loans, which—as was mentioned above—is used in support of the view that financial innovation dampened business cycles.

The evidence that financial innovation is behind the great moderation turns out to be extremely weak. In particular, we find that the responses of real activity and consumer loans to several shocks have remained remarkably stable over time. The drop in the comovement is due to changes in the IRFs of the monetary policy shock and the real activity shocks. The changes in the responses following a monetary tightening are substantial, but we argue that these changes are not consistent with theories according to which financial innovation dampened business cycles. The observed changes in the responses following a real activity shock also offer no support for these theories. Moreover, the changes in the responses following a real activity shock are quite minor. The responses of both the real activity and the loan variables switch sign following a real activity shock. In that case minor shifts in the responses can have substantial effects on the comovement statistics.

We also investigate what type of financial institution holds consumer loans and whether there have been changes in the behavior of who finances what when. A striking finding is that following a monetary tightening bank mortgages decline in both the earlier and the later subsample, but that mortgages held by other institutions actually increased in the later subsample. One wonders whether it is beneficial for the whole economy that those institutions that know the least about the quality of the borrowers end up holding more mortgages during an economic downturn, especially if—as we find to be the case—it does not affect the total amount of mortgages consumers obtain.

In Section 3.2, we explain our strategy to determine whether the data are consistent with the view that financial innovation moderated business cycles. In Section 3.3, we discuss the identification of the structural VAR and the data used to estimate it. In
Section 3.4, we discuss the trends in the variables considered and in Section 3.5 we discuss the cyclical behavior. In Section 3.6, we report and discuss the estimated IRFs and we also show how changes in the comovement can be related to the changes in the IRFs. Section 3.7 is our main section. In this section, we argue that the results are hard to reconcile with theories that predict that financial innovation dampened business cycles during the great moderation. The last section concludes.

3.2 What changes imply that financial innovation dampened business cycles?

The strong reduction in the unconditional correlation between the cyclical components of GDP and both consumer credit and mortgages is an argument in favour of the hypothesis that financial innovation played a role in the great moderation. For example, Campbell and Hercowitz (2006) develop a theory in which financial innovation generates a reduction in the volatility of real activity and in the comovement between consumer loans and real activity. But one can easily think of other reasons for the drop in the correlation. For example, the type of shocks that generates positive comovement could have become less important over time. Therefore, to properly assess whether financial innovation dampened business cycles during the great moderation one needs a much richer set of statistics than just unconditional correlation coefficients. At the core of our analysis are the IRFs of structural VARs estimated over different subsamples. Our analysis makes it possible (i) to answer the question which IRFs have changed and which have not and (ii) to answer the question whether the reduction in the comovement is simply due to some shocks becoming less important or due to fundamental changes in the IRFs.

Several of the responses are quite stable, which is in itself remarkable if financial innovation fundamentally changed business cycle properties. But some of the IRFs did change. The question is whether the observed changes are consistent with the view that financial innovation dampened business cycles during the great moderation. A set of observations
that would be easily explained by financial innovation consists of the following: (i) reductions in loans have negative effects on output, (ii) before financial innovation, consumer credit and home mortgages drop during an economic downturn, (iii) after financial innovation, loans decrease by less or even increase, and (iv) the reduction in output is larger before than after financial innovation has taken place. The idea would be that financial innovation makes it possible to dampen the reduction in lending during an economic downturn, which in turn dampens the reduction in real activity.

A particular set of empirical observations is unlikely to prove that financial innovation is behind the great moderation, because other theories may have the same set of implications. But a particular set of observations could be inconsistent with particular, or possibly even a broad range of, theories about financial innovation. For example, suppose that one would observe that the response of output following a monetary tightening becomes less negative and that the response of loans becomes more negative or possibly does not change much. Such an observation is inconsistent with standard models in which financial innovation dampens business cycles. In standard models, there is a financial friction which limits borrowing and typically this friction worsens during economic downturns. Financial innovation would alleviate this friction making it easier to keep on borrowing during an economic downturn. We suspect that in a large class of models the consequence of financial innovation is not the combination of a less negative output response and an unchanged or stronger reduction in loans.\footnote{The theory of Mertens (2008) seems to be an exception. In his model, the wage bill is constrained by the amount of available loans. Financial innovation is typically modelled as a relaxation of such constraints. In contrast, Mertens (2008) leaves this constraint untouched, but considers another type of financial innovation, namely the abolishment of Regulation Q. If the response of the real wage rate following a monetary tightening drops by more after the abolishment of Regulation Q, then this would lower the demand for loans making it possible to have a smaller reduction in output and a larger reduction in loans. The question arises whether it is plausible that there are such strong increases in the reduction of the real wage rate response when the reductions in real activity have become smaller.} According to the data, however, this seems to be the case.
3.3 Data and methodology

In this section, we describe the data and the methodology to construct IRFs and comovement statistics.\(^5\)

3.3.1 Data

U.S. data for home mortgages and consumer credit are from the Flow of Funds data set and cover the sample from 1954Q3 to 2008Q1.\(^6\) For the household sector, home mortgages and consumer credit are the two largest liabilities. For example, in 2005, home mortgages were 72% of total liabilities and consumer credit was 18%. Home mortgages not only include first and second mortgages, but also loans taken out under home equity lines of credit. Consumer credit consists of revolving credit (credit cards) and nonrevolving credit (e.g., automobile loans).\(^7\)

The fraction of loans owned by banks has become smaller over time. One reason is that it has become easy for banks to initiate a loan and then sell it so that the loan ends up on the balance sheet of another (financial) institution.\(^8\) Important for the increased incidence of ownership transition (both between different types of financial institutions and between banks) has been the emergence of "special-purpose vehicles".\(^9\) The securities issued to finance the purchase of these pools may be held by banks or other institutions.

Part of this project is to investigate whether the cyclical properties of the loans owned by different entities differ and whether this has played a role in the changing time series behavior of the aggregate loan series. For total mortgages, i.e., home plus non-home

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\(^5\)For more details see online Appendix B.

\(^6\)For some data series from the Flow of Funds, there is no seasonally adjusted version available. To take out any possible seasonality in these series, we include quarterly dummies when we use them in a VAR and we first filter them with X12-ARIMA when we calculate business cycle statistics.

\(^7\)Of the $2.3 trillion in consumer credit outstanding at the end of 2005, $830 billion was in the form of revolving credit and $1.5 trillion in the form of nonrevolving loans.

\(^8\)Throughout this paper, banks consist of U.S.-chartered commercial banks, savings institutions, and credit unions.

\(^9\)At the end of 2005, $609 billion of the $2.3 trillion in consumer credit was held in pools of securitized assets.
mortgages,\textsuperscript{10} we can determine the amount of mortgages held by banks, both directly (which we refer to as \textit{regular} bank mortgages) and indirectly through the ownership of asset-backed securities. For home mortgages, we can observe regular bank home mortgages, but not the amount of home mortgages indirectly held by banks. We are mainly interested in consumer loans and, thus, \textit{home} mortgages, but throughout this paper we will also report results on total mortgages, because it allows us to be more precise on the amount held by banks. Note that home mortgages are by far the largest component of total mortgages.\textsuperscript{11} There are many similarities between total and home mortgages, but also some differences. In online Appendix\textsuperscript{F}, we argue that none of the results depend on which series is used when both are available.

\textbf{Subsamples.} Our main focus is on comparing business cycle properties for the 1954Q3-1978Q4 subsample with those of the 1984Q1-2008Q1 subsample. Thus, our sample ends before the complete collapse of financial markets following the bankruptcy of Lehman Brothers in September 2008.

There is wide agreement in the literature that somewhere close to 1980 a trend break did occur. The literature often uses formal econometric tests to split a sample in two, but it is not always that easy to determine the exact break point.\textsuperscript{12} Our approach consists of excluding several years of data around the possible dates indicated as candidates for the break point in the literature. This makes it unlikely that the actual break point is not included. More importantly, we would think that the volatile transition period when Paul Volcker started the disinflation process is different from both the period before and after and so can better be excluded. Similarly, we exclude the most recent observations because the large fluctuations observed during the recent crisis are clearly not typical for

\footnotesize
\textsuperscript{10}Home mortgages are mortgages on 1-4 family properties, including mortgages on farm houses (but not on farms). Non-home mortgages consist of mortgages on multi-family homes, commercial mortgages, and farm mortgages.

\textsuperscript{11}Namely, 76\% in 2008Q1.

\textsuperscript{12}Boivin and Giannoni (2002) try to find the date at which the great moderation started and conclude that no robust breakpoint is found.
the last couple of decades.

The question arises whether the VAR specifications are constant in the subsamples. There are reasons to believe that they are not; using rolling windows, we find that the correlations between HP-filtered GDP and HP-filtered home mortgages as well as HP-filtered consumer credit have gradually declined since the early eighties. We suspect that these types of changes are likely to be the norm not the exception in macroeconomic time series analysis. The implication is that one should be careful in interpreting the results. One obviously cannot expect the IRFs to be equally valid at the beginning and the end of the sample used. The best way to interpret them would be to think of the estimated IRFs as average responses over the sample.

3.3.2 Identifying shocks

The standard procedure to study the impact of monetary policy on economic variables is to estimate a structural VAR using a limited set of variables. Consider the following VAR:

\[ Z_t = B_1 Z_{t-1} + \cdots + B_4 Z_{t-4} + u_t. \]  

(3.1)

The relationship between the reduced-form error terms, \( u_t \), and the structural shocks, \( \varepsilon_t \), is given by

\[ u_t = A \varepsilon_t, \]

(3.2)

where \( A \) is a \((7 \times 7)\) matrix of coefficients and \( E[\varepsilon_t \varepsilon_t'] \) is the identity matrix. We follow Bernanke and Blinder (1992) and many others by assuming that the federal funds rate is the relevant monetary instrument. In particular, we use the average of daily rates

---

13Given the size of the subsamples, we could not consider further splits.
14To simplify the notation, we do not display the constant, the linear trend term, and the quarterly dummies that are also included. The estimated trend is allowed to differ across samples. As a robustness check, we used data that are detrended using one trend specification for the complete sample. This leads to very similar results. The results are also robust to including no trend, as is shown in Appendix E.
15We use four lags since this is common practice when using quarterly data. Model selection criteria indicate that a shorter lag may be better, but as documented in online Appendix E the results are robust to using a smaller number of lags.
during the last month of the quarter. When using the federal funds rate at the end of the quarter,\textsuperscript{16} it makes sense to assume (i) that the Board of Governors of the Federal Reserve (FED) can respond to the contemporaneous realizations of the structural shocks and (ii) that the other variables in the system cannot respond to the monetary policy shock within the period.\textsuperscript{17}

The variable $Z_t$ consists of the federal funds rate, the log of real GDP, the log of the GDP deflator, the log of real durable expenditures, the log of real residential investment, the log of consumer credit deflated with the GDP deflator, and the log of home mortgages deflated with the GDP deflator. Thus, we could in principle identify six more shocks in addition to the monetary policy shock. To identify these, we use the Cholesky decomposition and order the remaining variables so that those variables that are likely to have the slowest response are ordered first.\textsuperscript{18}

It would be fair to question whether the identified shocks are truly structural. For our purpose, it is not strictly necessary that the shocks are structural. For example, we show that several aspects of the driving process, as represented by the IRFs of the VAR, have remained quite stable over time even though there also have been large changes in volatility and correlations. This is an interesting finding, independent of whether the shocks have a structural interpretation or not.

### 3.3.3 Comovement decomposition

As an alternative to measuring comovement with the correlation coefficients of HP-filtered time series, we use the comovement statistics of den Haan (2000) constructed using the estimated VAR. With these correlation coefficients we obtain results that closely resemble

\textsuperscript{16}We could have taken the last daily observation of the quarter, but daily observations of the federal funds rate are at times very volatile.

\textsuperscript{17}This implies that $\mathbf{A}$ has a block-triangular structure. Christiano, Eichenbaum, and Evans (1999) show that this is enough to identify the monetary policy shock. That is, one does not have to take a stand on the relationship between the remaining structural shocks and reduced-form error terms as is done when the Cholesky decomposition of the variance-covariance matrix of $u_t$ is used.

\textsuperscript{18}The ordering of the variables is as follows: price level, residential investment, durable expenditures, GDP, home mortgages, consumer credit, and federal funds rate.
those found using the standard correlation coefficients based on HP-filtered series.

The reason for including these alternative measures is not so much to document robustness. The main reason is that they allow us to determine the source(s) behind changes in comovement. More precisely, we can decompose the correlation between two variables into the contributions of the structural shocks of our empirical model. In particular, the covariance between the \(K\)-th-period ahead forecast errors of \(x_t\) and \(y_t\), \(\text{COV}(x_t, y_t; K)\), is equal to

\[
\text{COV}(x_t, y_t; K) = \sum_{m=1}^{M} \text{COV}(x_t, y_t; K, m) \quad \text{with} \quad \text{COV}(x_t, y_t; K, m) = \sum_{k=1}^{K} x_{k, m}^{\text{imp}} y_{k, m}^{\text{imp}},
\]

where \(x_{k, m}^{\text{imp}}\) and \(y_{k, m}^{\text{imp}}\) are the \(k\)-th-period responses of variables \(x\) and \(y\), respectively, to a one-standard-deviation innovation of the \(m\)-th structural shock. The total covariance is simply the sum of the accumulated cross products for all possible shocks and does \textit{not} depend on how the shocks are identified.

To decompose the correlation coefficient, we use

\[
\text{COR}(x_t, y_t; K) = \sum_{m=1}^{M} \text{COR}(x_t, y_t; K, m)
\]

with

\[
\text{COR}(x_t, y_t; K, m) = \frac{\sum_{k=1}^{K} x_{k, m}^{\text{imp}} y_{k, m}^{\text{imp}}}{\text{SD}(x_t; K) \text{SD}(y_t; K)},
\]

\[
\text{SD}(z_t; K) = \left(\sum_{m=1}^{M} \text{COV}(z_t, z_t; K, m)\right)^{1/2} \text{ for } z_t = x_t, y_t.
\]

In the denominator, we use the \textit{total} standard deviations of the \(K\)-th-period ahead forecast error (and not the standard deviations due to the \(m\)-th-shock) to ensure that the sum of all the scaled covariances is equal to the total correlation coefficient.
Figure 3.1: Consumer credit and mortgages; scaled by GDP or value underlying asset

A. Consumer credit as a percentage of GDP

B. Consumer credit as a percentage of value durables

C. Mortgages as a percentage of GDP

D. Mortgages as a percentage of value real estate

Notes: "Regular" bank mortgages are those directly held on the banks’ balance sheets and not in the form of asset-backed securities and "all" bank mortgages include both. Mortgages include home and commercial mortgages. In Panel B consumer credit is scaled with the replacement cost of the stock of durables and in Panel D mortgages are scaled with the market value of the total stock of real estate.
3.4 Trends

The panels on the left-hand side of Figure 3-1 document how consumer credit and mortgages have grown as a fraction of GDP. Both consumer credit and mortgages have increased substantially as a fraction of GDP, but mortgages have increased at a much sharper rate. From 1954Q3 to 2008Q1, consumer credit increased from 9.2% of GDP to 18.3% of GDP and mortgages from 28.8% to 104.2%.\textsuperscript{19} The panels on the right-hand side of Figure 3-1 plot the two liabilities scaled by the value of the associated asset. Scaled by the value of all real estate, total mortgages increased from 18.7% in 1954Q3 to 47.1% in 2008Q1.\textsuperscript{20} This is clearly less than the increase of mortgages relative to GDP, but still quite substantial. As a fraction of the replacement value of durables, consumer credit doubles, namely from 27.9% to 63.5%, just like it did as a fraction of GDP.

The increases in mortgages and consumer credit have not been uniform over the sample period. First consider consumer credit. As a fraction of GDP, consumer credit has displayed a steady increase. As a fraction of durables, a different picture emerges. A large part of the growth occurs in the beginning of the sample. Consumer credit increased to 41.9% of durables in 1970Q1 and then displayed no growth for over two decades. In the early nineties, the ratio started to increase again.

Now consider mortgages. As a fraction of GDP, mortgages have displayed quite an intriguing growth process. Throughout the sample, there are several periods during which the growth rate of mortgages as a fraction of GDP sharply increases, but the sustained increase in the growth rate of mortgages relative to GDP that started around the beginning of the new millennium is without precedent. As a fraction of the value of real estate, however, the growth pattern is a bit different. In particular, there is a sharp increase in the fifties and early sixties followed by a period of no growth, and starting in the early eighties a renewed steady increase. Interestingly, using real estate as the scaling’s

\textsuperscript{19}For home mortgages, these numbers are 18.9% and 79.4%.
\textsuperscript{20}For home mortgages relative to the value of household-owned real estate, these numbers are 19.5% and 50.9%.
factor, the sustained and sharp acceleration starting around 2000 is no longer present. The acceleration of mortgages relative to GDP can, thus, for a large part be attributed to a sharp increase in the value of the stock of housing relative to GDP. As a percentage of the value of real estate, mortgages display a substantial increase at the very end of the sample, which is not surprising given the recent drop in the value of real estate.

**Loans owned by different institutions.** Securitization has obviously changed financial markets enormously. It makes it possible for a financial institution to issue consumer credit and mortgages, but then sell them so that another institution ends up holding them. We do not know how much consumer credit banks indirectly hold on their balance sheets. Fortunately, for mortgages we do. Figure 3.1 displays the trends in the amount of consumer credit and mortgages that banks hold directly on their balance sheets, which we refer to as regular bank loans. For mortgages, it also plots the total amount of bank-owned mortgages (directly and indirectly held).

The amount of mortgages (home plus non-home) held directly on the banks’ balance sheets (which we refer to as regular bank mortgages) was equal to 51.7% of total mortgages in 1954Q3 and 34.1% in 2008Q1. Asset-Backed Securities (ABS) issuers started to become owners of mortgages at the end of the eighties and 19.6% of all mortgages is owned by them in 2008Q1. Mortgages are also held in "Agency and GSE-backed mortgage pools", which began buying mortgages in the late sixties and then gradually expanded; in 2008Q1 they held 31.3% of all mortgages. For total mortgages (home plus non-home), we can calculate the ownership of banks in the bonds issued by these two types of special purpose vehicles. Combining the direct ownership with the indirect ownership, we find that banks held 51.8% of all mortgages in 1954Q3 and 43.6% in 2008Q1. Banks participated in the precipitous increase in mortgages that started at the beginning of the millennium, but

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21 These are entities that hold pools of mortgages having similar features. These pools issue securities known as mortgage-pool securities, which are their liabilities. These pools are created by the government-sponsored enterprises (GSEs) Fannie Mae, Freddie Mac, and the Federal Agricultural Mortgage Corporation, by the government agency Ginnie Mae, and by the government agency formerly known as Farmers Home Administration (now part of the Farm Service Agency).
not as much as other financial institutions. That is, from 2000Q1 to 2008Q1 the share of mortgages held by banks (both directly and indirectly) declined from 46.8% to 43.6%.

The amount of consumer credit held directly on the banks’ balance sheets (which we refer to as regular bank consumer credit) was equal to 4.2% of GDP in 1954Q3 and equal to 7.9% in 2008Q1. Consequently, the increase in total consumer credit (from 9.2% to 18.3% of GDP) is not just due to an increase in regular bank consumer credit. For consumer credit, the most important new type of owner is the ABS issuer. Although these issuers are virtually nonexistent in the eighties, they hold roughly 26.9% of total consumer credit at the end of our sample.

3.5 Cyclical behavior

In this section, we document the changes that have occurred in the cyclical behavior of GDP, consumer credit, home mortgages, and the two components of consumer expenditures that often require financing: durable expenditures and residential investment. Regarding the consumer loan variables, we first consider the total series, i.e., bank and non-bank loans. Next we analyze whether the results are different for different owners.

Volatility. Table 3.1 reports the standard deviations of our key variables over the two subsamples.\footnote{Throughout this paper, we use the HP filter with a smoothing coefficient of 1,600 to calculate cyclical components.} Whereas the standard deviation of the cyclical component of GDP is equal to 1.75% during the 1954Q3-1978Q4 sample, it is equal to 0.89% during the 1984Q1-2008Q1 sample, a 49% decline.\footnote{When we extend the recent subsample up to 2009Q1, then the standard deviation in the second subsample is equal to 0.99% instead of 0.89%.} Similar declines are found for durable expenditures and residential investment.

The standard deviations of the cyclical components of consumer credit and mortgages have also declined. Comparing the two subsamples, we find that the drop in volatility is
### Table 3.1: Standard Deviations (in %)

<table>
<thead>
<tr>
<th></th>
<th>'54Q3-'78Q4</th>
<th>'84Q1-'08Q1</th>
<th>change</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Real activity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDP</td>
<td>1.75</td>
<td>0.89</td>
<td>-49%</td>
</tr>
<tr>
<td>Durable expenditures (DE)</td>
<td>5.21</td>
<td>2.83</td>
<td>-46%</td>
</tr>
<tr>
<td>Residential investment (RI)</td>
<td>10.73</td>
<td>6.33</td>
<td>-41%</td>
</tr>
<tr>
<td><strong>Consumer credit</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (T)</td>
<td>3.59</td>
<td>2.85</td>
<td>-21%</td>
</tr>
<tr>
<td>Regular bank consumer credit (RB)</td>
<td>3.75</td>
<td>3.73</td>
<td>-1%</td>
</tr>
<tr>
<td>(T) - (RB)</td>
<td>3.71</td>
<td>2.95</td>
<td>-21%</td>
</tr>
<tr>
<td><strong>Mortgages</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (T)</td>
<td>1.94</td>
<td>1.27</td>
<td>-35%</td>
</tr>
<tr>
<td>Regular bank mortgages (RB)</td>
<td>2.85</td>
<td>2.63</td>
<td>-8%</td>
</tr>
<tr>
<td>All bank-owned mortgages (B)</td>
<td>2.84</td>
<td>2.23</td>
<td>-22%</td>
</tr>
<tr>
<td>(T) - (RB)</td>
<td>1.32</td>
<td>1.58</td>
<td>20%</td>
</tr>
<tr>
<td>(T) - (B)</td>
<td>1.46</td>
<td>2.12</td>
<td>45%</td>
</tr>
<tr>
<td><strong>correlation with GDP</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real activity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Durable expenditures (DE)</td>
<td>0.87</td>
<td>0.63</td>
<td>-27%</td>
</tr>
<tr>
<td>Residential investment (RI)</td>
<td>0.59</td>
<td>0.48</td>
<td>-20%</td>
</tr>
<tr>
<td>Consumer credit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (T)</td>
<td>0.74</td>
<td>0.19</td>
<td>-75%</td>
</tr>
<tr>
<td>Regular bank consumer credit (RB)</td>
<td>0.76</td>
<td>0.29</td>
<td>-61%</td>
</tr>
<tr>
<td>(T) - (RB)</td>
<td>0.57</td>
<td>-0.10</td>
<td>-118%</td>
</tr>
<tr>
<td>Mortgages</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (T)</td>
<td>0.76</td>
<td>0.32</td>
<td>-58%</td>
</tr>
<tr>
<td>Regular bank mortgages (RB)</td>
<td>0.78</td>
<td>0.51</td>
<td>-34%</td>
</tr>
<tr>
<td>All bank-owned mortgages (B)</td>
<td>0.79</td>
<td>0.42</td>
<td>-46%</td>
</tr>
<tr>
<td>(T) - (RB)</td>
<td>0.26</td>
<td>-0.22</td>
<td>-184%</td>
</tr>
<tr>
<td>(T) - (B)</td>
<td>0.19</td>
<td>-0.14</td>
<td>-175%</td>
</tr>
</tbody>
</table>

Notes: The table reports statistics for the cyclical component of the indicated variable. In each sample, the trend used to construct the cyclical component is obtained by applying the HP filter over the whole sample. "regular" bank loans are those directly held on the banks’ balance sheets and not in the form of asset-backed securities. For mortgages the latter could be calculated and are included in "all" bank mortgages.
larger for mortgages than for consumer credit, namely 35% versus 21%. Both reductions are less than the 49% drop in volatility observed for GDP.\textsuperscript{24}

**Comovement.** Table 3.1 also documents the correlation between the cyclical component of GDP and the cyclical components of the other variables. The sharp reductions in the correlation between GDP and the loan variables are at least as striking as the reduction in volatilities. The correlation between consumer credit and GDP fell from 0.74 to 0.19 and the correlation between the cyclical components of mortgages and GDP fell from 0.76 to 0.32, not quite as large as the drop in the correlation of consumer credit and GDP, but still quite substantial. For home mortgages, the correlation dropped by more, namely from 0.80 to 0.13.

There are two aspects to the decline in the comovement between consumer loans and GDP. First, there is a reduction in the correlation between consumer lending and the associated spending component. The other part of the story seems to be that the correlation between GDP and the spending components has become smaller. For example, the correlation between consumer credit and durable expenditures falls from 0.65 to 0.31. This reduction is clearly not as spectacular as the drop in the correlation with GDP. The correlation between durable expenditures and GDP fell from 0.87 to 0.63. The results for mortgages and residential investment are similar.

The decline in the positive correlation between consumer loans and GDP is—as argued by Campbell and Hercowitz (2006)—consistent with the hypothesis that financial innovation makes it easier for consumers to keep on borrowing during an economic downturn. It is intriguing that the correlation between consumer credit and durables dropped by so much less than the correlation between consumer credit and GDP. But changes in unconditional correlation coefficients are open to several interpretations; the IRFs discussed below are better suited to understand how comovement patterns have changed.\textsuperscript{25}

\textsuperscript{24}For home mortgages the drop in volatility equals 30% and for non-home mortgages it equals 4%.
\textsuperscript{25}For example, unconditional correlation coefficients change when the relative importance of different shocks changes, even if all IRFs remain unchanged.
**Graphical presentation.** To understand better what is behind the unconditional volatility and comovement statistics, we plot in Figure 3.2 the cyclical component of GDP together with the cyclical components of the two loan variables. The figure clearly illustrates the change in the pattern of comovement. In the beginning of the sample, there is a very close connection between the movements of the cyclical components of GDP and both loan components.

For mortgages, this link is much weaker in the second half of the sample. But there are still substantial "business-cycle" type fluctuations and one full cycle during the nineties with large swings. There are three minor booms in the mortgage series, namely before the 1990-91, before the 2001 and before the most recent recession, but neither the 1990-91 nor the 2001 recessions were accompanied by substantial negative cyclical components, whereas residential investment did display substantial drops during these two recessions, especially during the 1990-91 recession.\(^\text{26}\)

To understand the post 1983 sample period better, it is insightful to look at Panel C of Figure 3.1 that plots the (unfiltered) ratio of mortgages to GDP. This picture makes clear that there is a sharp increase in the growth rate of mortgages in the mid eighties. During the 1990-91 recession there is a clear reversal, but the run-up before the 1990-91 recession had been so substantial that the cyclical component is still positive during the downturn. If a larger part of the increase in the second half of the eighties would have been allocated to the trend, then the cyclical component during this period would have been smaller. Thus, the observed positive cyclical component during the 1990-91 recession may be misleading.

Now consider the 2001 recession. Figure 3.1 shows that there is an acceleration of the growth rate around this recession. Since the HP filter is a two sided filter, this will show up as a negative cyclical component, but neither the ratio of mortgages to GDP nor the unscaled data seem to indicate that this was a period in which mortgages were low.

\(^{26}\)The graph for cyclical residential investment is given in Den Haan and Sterk (2009).
Figure 3.2: Cyclical components consumer loans

A. Mortgages (black) and GDP (grey)

B. Consumer credit (black) and GDP (grey)

Notes: The panels plot the HP-filtered residual of the indicated loan series and the HP-filtered residual of GDP. The vertical lines above (below) the x-axis correspond to NBER peaks (troughs).
Thus, the large positive cyclical component during the 1990-91 recession may overestimate the true cyclical component, but the small negative cyclical component during the 2001 recession may underestimate the true cyclical component.

The bottom panel of Figure 3-2 documents that the changes in the cyclical behavior are even more pronounced for consumer credit. Since the mid-nineties, consumer credit even seems to move in the opposite direction to both GDP and durable expenditures. In contrast to the results for mortgages, the changes in consumer credit do not seem an artefact of the filtering procedure. For example, Panel A of Figure 3-1 makes clear that during the 2001 recession the unfiltered ratio of consumer credit to GDP is also increasing.

Cyclical behavior of bank versus non-bank loans. Table 3.1 documents that the reductions in the standard deviations of both consumer credit and mortgages for the different types of owners do not add up to the reduction in the standard deviation for the total. For example, the drop for all mortgages is equal to 35%, but the drop is only 22% for bank mortgages and we find an increase in the volatility for non-bank mortgages equal to 45%. The reason is that there is a strong reduction in the correlation of the loans held by different institutions. For example, the correlation between bank mortgages and non-bank mortgages drops from 0.23 to -0.29. Similarly, the correlation between regular bank consumer credit and consumer credit not directly held on banks’ balance sheets drops from 0.75 to 0.32.\(^{27}\) The rapid emergence of the "originate and distribute" practice, which allows loans to be financed by a much wider group of investors is likely to be responsible for the lower and in some cases even negative correlation between the consumer loans held by different types of institutions.

Next we address the question whether the observed drop in the correlation between consumer loans and GDP depends on ownership. For example, the correlation between GDP and all mortgages dropped from 0.76 to 0.32, but the correlation between GDP and

\(^{27}\)These numbers and more detailed information on the correlation for series by ownership can be found in Den Haan and Sterk (2009).
regular bank mortgages dropped from 0.78 to only 0.51. Interestingly, the correlation between GDP and mortgages not held directly on the banks’ balance sheets even turned negative.

Figure 3-3 plots the cyclical components of the loan component by owner. It also illustrates that the observed changes in the cyclical components of the total are not uniformly observed for the components. Consider for example Panels A and B that plot the cyclical components of bank mortgages and non-bank mortgages, respectively. Recall from the discussion above that during the 1990-91 recession the cyclical component of mortgages aggregated across all institutions remained positive and during the 2001 recession it was negative, but much less negative than the values taken on during the earlier downturns. In contrast, the cyclical component of bank mortgages is negative in both recessions and in fact as negative as the cyclical component in the last observation of our sample, 2008Q1. For non-bank mortgages, we find in both recessions a large positive cyclical component; the cyclical component during the 1990-91 recession takes on its second largest positive value.

For consumer credit the graph also makes clear that it is important to consider ownership. The 2001 recession is a good example. In Figure 3-2 it was shown that the cyclical component of total consumer credit was positive during this downturn. Now consider Panel C of Figure 3-3 that plots the cyclical components of regular bank consumer credit and consumer credit held by ABS issuers. During the 2001 recession, the cyclical component of regular bank consumer credit is negative, just as it was in other post-war recessions although not as negative. In contrast, the cyclical component of consumer credit held by ABS issuers is positive during this period; it turns negative as the economy recovers and the cyclical component of regular bank consumer credit turns positive. Thus, if one wants to argue that changes in financial markets made it possible to have easy access to consumer credit during the 2001 downturn, then one should focus on ABS issuers.
**Figure 3.3:** Cyclical components consumer loans (bank versus nonbank)

Notes: The panels plot the HP-filtered residual of the indicated loan series and the HP-filtered residual of GDP. The vertical lines above (below) the x-axis correspond to NBER peaks (troughs). To be able to distinguish between "bank" and "non-bank" mortgages we use "all" instead of "home" mortgages for this graph.
3.6 Impulse response functions

In this section, we discuss the important IRFs, their changes, and relate these changes to the observed drop in the comovement.\footnote{As pointed out by a referee, our analysis is based on a linear framework. Consequently, there are no nonlinearities and no interactions between the shocks.}

Which structural shocks to consider? There are seven structural shocks in our empirical model. The IRFs of the three real activity shocks turn out to be quite similar so we can condense the discussion by focusing on the IRF that corresponds to the total responses when the innovation of each of the three variables is equal to one standard deviation. Online Appendix C discusses the IRFs for the individual shocks and documents that the main conclusions of this paper do not depend on looking at a joint shock.

We focus on this real activity shock and the monetary policy shock for two reasons. First, the changes in these two IRFs are responsible for the drop in the comovement between real activity variables and consumer loan variables, a drop that has played an important role in the debate on whether financial innovation dampened business cycles. Second, a cursory evaluation of the changes in the IRFs of a monetary policy and a real activity shock does seem to provide support for the hypothesis that financial innovation dampened business cycles. This view is misleading, however, and we will present evidence that there are aspects of the data that are problematic for this hypothesis, but this does require a bit of work. In contrast, the results for the other shocks are even more problematic for the theories that predict that financial innovation dampened business cycles, because the changes in the IRFs are not impressive and several of the changes that do occur are even the opposite of what such theories would predict. The responses to the other shocks are given and discussed in online Appendix D.

Monetary tightening. Figure 3-4 plots the IRFs following an unexpected monetary tightening. In the early subsample, all three real activity measures considered (GDP, res-
Figure 3.4: IRFs following a monetary tightening

Notes: Responses to a one-standard-deviation shock in the federal funds rate.
idential investment, and durable expenditures) display sizeable and significant decreases. Results are quite different in the later subsample. There is no longer a reduction in GDP and durable expenditures, which is consistent with the results reported in Boivin and Giannoni (2002, 2006). The response of residential investment has become smaller, but is still significantly negative.\footnote{For this specification of the VAR, we actually find a small marginally significant increase in GDP. This increase is, however, not robust. As documented in online Appendix E, it is possible to get a significant decline of GDP in the second subsample. Boivin and Giannoni (2006) also report IRFs with positive and negative responses for GDP over a similar sample. In contrast, the negative response in residential investment for the second subsample is quite robust.} Also, this response has become much more delayed and more persistent. This pattern for the response of residential investment is also found by McCarthy and Peach (2002). The maximum drop in residential investment (during the first five years) is equal to 2.7% in the early subsample and only 1.1% in the later subsample. But the maximum increase in the federal funds rate has also dropped, namely from 77 to 32 basis points.

The responses of home mortgages are still negative in the second subsample and several are significant. The maximum decrease in home mortgages (during the first five years) did become smaller, it namely dropped from 0.71% to 0.29%, but relative to the size of the federal funds rate response this is only a minor reduction. For all VAR specifications considered, we find a sizeable reduction in home mortgages. As discussed in online Appendix E, there are even VARs for which the responses of home mortgages are larger in the second subsample when the responses are rescaled for the size of the shock in the federal funds rate. Moreover, since home mortgages have increased sharply relative to GDP, the same percentage decrease in home mortgages implies a much larger change in the amount of home mortgages relative to GDP.

We find that the negative responses of consumer credit, like the negative responses for durable expenditures, have disappeared. Although we find this for several alternative VAR specifications, it is not a robust result. In online Appendix E, we document that some VARs generate reductions in consumer credit and that it is even possible to obtain
a reduction that, scaled for the size of the shock, exceeds the reduction observed in the first subsample.

**Price responses during a monetary tightening.** The only response not yet discussed is the price level response. In the early sample, the IRF of the price level suffers from the price puzzle in that there is a significant increase during the first two years. In the second subsample, there is a small and quite rapid reduction in the price level. The occurrence of the price puzzle is a common feature of VARs. An initial increase in the price level may happen if the innovation in the federal funds rate is not fully unexpected, but in part a response to higher inflation expectations. Motivated by the analysis of Castelnuovo and Surico (2009), we included a measure of inflation expectations, namely the Greenbook forecast. This reduced the price puzzle in the first subsample somewhat, but clearly did not eliminate it as is documented in online Appendix E.3. The appendix also shows that the other results are not affected when this expectations measure is included.

We could search for the magic variable that eliminates the price puzzle for our analysis. We do not think that our interpretation of the results is hampered much, however, by the fact that the increase in the federal funds rate is in part a response to inflationary pressure. It is possible that the initial inflationary pressure observed in our first subsample was caused by events that would have continued to push up real activity and lending if the monetary tightening would not have taken place. In this case, we underestimate the real activity and lending responses in the first subsample. But given that all three real activity variables and both lending variables decrease almost immediately, it is not clear that there was much upward pressure left.

**Bank versus non-bank lending during a monetary tightening.** Given that securitization has been one of the important changes in the market for consumer loans, the question arises whether the upward shifts in the responses of consumer credit and home
mortgages are found for bank as well as non-bank lending.

In Figure 3-5, we plot therefore the responses of bank and non-bank mortgages and the responses for regular bank consumer credit and other types of consumer credit. In the first subsample, the IRF of bank mortgages initially declines sharply and remains negative for up to three years, that is, it basically has the same shape as the IRF for home mortgages held by all institutions. In contrast, the IRF for non-bank mortgages only displays a very small decline. In the second subsample, the responses of bank mortgages are still negative, but the decline is much smaller than the decline observed in the first subsample and insignificant. In the second subsample, the responses of non-bank mortgages hover initially around zero, but after roughly a year take on quite large positive values. So the responses of both bank and non-bank mortgages shift up, consistent with the upward shift observed for total mortgages. But the finding that following a monetary downturn non-bank mortgages actually increase is the most intriguing.

For consumer credit, we find the IRF of regular bank consumer credit and the IRF for other consumer credit to be very similar in the first subsample and to resemble the IRF of total consumer credit. As for mortgages, both IRFs shift up. Figure 3-5 documents that the responses for regular bank consumer credit have shifted up much less. In fact, the responses for regular bank consumer credit are still negative and several responses are significant. In contrast, the responses for total consumer credit minus regular bank credit are almost all positive and they are significantly positive after roughly two and a half years.

Thus, if the changes in the IRFs for consumer credit and mortgages related to a monetary tightening are due to financial innovation, then the main cause does not seem to lie in a change in the behavior of consumer bank loans.

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30 Recall that bank mortgages include mortgages held directly and indirectly by banks, but that regular bank consumer credit only includes consumer credit held directly on the banks’ balance sheets.
**Figure 3.5**: IRFs following a monetary tightening; bank versus non-bank

Notes: Responses to a one-standard-deviation shock in the federal funds rate. "regular" bank loans are those directly held on the banks’ balance sheets and not in the form of asset-backed securities.
Figure 3.6: IRFs following a real activity shock

Notes: Responses to a simulatenous one-standard-deviation shock in residential investment, durable expenditures and GDP.
**Real activity shock.** Figure 3-6 plots the IRFs following a real activity shock. GDP, residential investment, and durable expenditures all decline for some time after which all increase. That is, the initial losses are later on partly recovered. This is true in both subsamples. In fact, the shapes of the IRFs are remarkably similar across subsamples. However, there are some changes in the magnitudes of the responses and the locations of the turning points. Although these gradual shifts do not seem very important, they turn out to matter quite a bit for the correlation between real activity and consumer loans.

The IRFs of home mortgages and consumer credit follow the same pattern as those of the real activity variables. For mortgages, however, we find that the initial decrease is smaller than the subsequent upturn. This is true in both subsamples, but the initial decrease has become very small in the second subsample and the IRF changes sign quicker. In contrast, for consumer credit the sign switch occurs at a later date in the second subsample. Except for this shift in the location of the sign switch, the pattern is similar across the two subsamples.

**IRFs and changes in comovement.** Using standard business cycle statistics, we found a strong drop in the comovement between real activity and both consumer credit and mortgages. In this section, we will show that the same result is found using the correlation of forecast errors as implied by the VAR. Moreover, we will relate the observed drop in the comovement to the observed changes in the IRFs. This is a straightforward exercise when the comovement is measured using the correlation of VAR forecast errors.\(^{31}\)

Figure 3-7 plots the correlation coefficients for the forecast errors of mortgages and GDP as well as the correlation coefficients for the forecast errors of consumer credit and GDP as implied by the VAR. It also plots the parts of the correlation coefficients that are due to the monetary policy and the real activity shock. It turns out that these two shocks are responsible for a very large part of the observed correlation coefficients and for why the correlation coefficients dropped so sharply.

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\(^{31}\)See Equation 3.4.
Figure 3.7: Decomposition of comovement between consumer loans and real activity

A. Correlation home mortgages and GDP

B. Correlation consumer credit and GDP

Notes: Correlation of forecast errors according to the benchmark VAR. The graph also indicates which part of the correlation is due to monetary policy and real activity shocks.
The two panels in the top row of the figure plot the results for mortgages and they show that the drop in this measure of comovement is at least as dramatic as the drop observed using standard business cycle statistics. The figure also shows that the monetary policy shock and the real activity shock imply a positive correlation in the first subsample, together being basically responsible for all of the observed comovement. In the second subsample, these two shocks do no longer generate a positive comovement. In fact, they generate a slight negative comovement. Since none of the other shocks generate a substantial comovement (either positive or negative), total comovement is slightly negative as well.

The results for the comovement between consumer credit and GDP are very similar to those for mortgages, except that real activity shocks still generate a modest positive comovement in the second subsample. These are displayed in the bottom two panels of the figure.

Recall that the sharp drop in the unconditional correlation between loan variables and GDP has been used to support theories that financial innovation played a role in the great moderation. The results in Figure 3-7 make clear that the drop in the comovement is due to changes in the IRFs of a monetary policy shock and the IRFs of a real activity shock. The advantage of the IRFs is that they provide more information than the unconditional correlation coefficients. In the next section, we will address the question whether the particular changes in the IRFs are indeed consistent with the hypothesis that financial innovation dampened the magnitudes of business cycles.

3.7 Financial innovation and the great moderation

In this section, we address the question whether the empirical evidence is consistent with the hypothesis that financial innovation reduced the magnitudes of cyclical fluctuations in variables like GDP, durable expenditures, and residential investment.
3.7.1 Preliminary evaluation

At first glance, the results presented in the previous two sections seem favorable to the hypothesis that financial innovation played a role in moderating business cycles. Consider the responses for consumer credit and home mortgages following a monetary tightening and a negative real activity shock, two not unimportant shocks. We find that the reductions in both types of consumer loans are smaller in the second than in the first subsample. These findings are consistent with the view that financial innovation has made it easier for financial intermediation to fulfill its role in the presence of adverse aggregate shocks, resulting in smaller drops in consumer lending, which in turn dampen the downturn. The sharp reductions in the observed comovement between real activity and consumer loans is also consistent with the view that financial innovation dampened business cycles.

In the next subsection, we express a series of arguments that cast doubt on this way of thinking about what the data tell us.

3.7.2 Doubts about financial innovation having dampened business cycles

In this section, we give reasons that made us doubt the validity of the hypothesis that financial innovation dampened business cycles during the great moderation. The organization of our arguments is the following. In Sections 3.7.2 and 3.7.2, we look more closely at the IRFs of a monetary policy and a real activity shock, respectively and argue (i) that the IRFs actually have not changed that much and (ii) that a close look at the changes reveals that they do not fit the standard story about financial innovation moderating business cycles that well. In Section 3.7.2, we take a closer look at the drop in the comovement between consumer loans and real activity. Our structural VAR makes it possible to link changes in the unconditional correlation coefficient to changes in the IRFs. We will show that the types of changes in the IRFs responsible for the drop in the correlation coefficient are not convincing evidence for the view that financial innovation dampened business cycles. In Section 3.7.2, we will show that the data do not
reveal much support for the hypothesis that the amount of loans issued actually has an important impact on real activity, an important ingredient for theories that predict that financial innovation dampens business cycles. Finally, we argue in Section 3.7.2 that there is a very simple alternative explanation for the observed changes in the IRFs.

**Financial innovation and changes in monetary IRFs**

Figure 3.4 displayed substantial differences between the IRFs in the first and second subsample. We want to argue, however, that the changes are not as large as they look. Moreover, we will argue that there are reasons to believe that mortgages dropped by *more* in the second subsample, not by less.

**Using the right scaling.** It is not clear whether the *percentage* change in home mortgages is the right measure, given that home mortgages have increased sharply relative to GDP and relative to the level of residential investment. That is, in the second subsample the same percentage reduction in home mortgages corresponds to a much larger drop in the amount of home mortgages relative to GDP. In particular, following a monetary tightening, the maximum reduction in home mortgages relative to GDP is equal to 0.19% in the first subsample and is actually somewhat larger, namely 0.22%, in the second subsample. If we calculate the drop in mortgages relative to the level of residential investment, then we find that the maximum reduction in home mortgages is equal to 3.95% in the first subsample and equal to a substantially larger reduction, namely 4.77% in the second subsample.

Measured relative to GDP or residential investment the drop in mortgages has become bigger in the second subsample *even though* the drop in the federal funds rate has become much smaller. We now turn to this issue.

**Comparing similar changes in the federal funds rate.** The IRFs corresponding to a monetary policy shock have an important advantage that the other IRFs do not
have and that is that the instantaneous response of the federal funds rate can be taken as a reasonable measure of the size of the shock. That is, a larger unexpected change in the federal funds rate is likely to correspond with a larger underlying structural shock. For the other shocks this is not so clear-cut, because the first-period responses provide not only a measure of the magnitude of the underlying structural shock, but also of the magnitude of the instantaneous response.

The magnitude of a monetary policy shock used to construct the subsample IRFs in Figure 3-4 is equal to the standard deviation of the shock in the subsample. The reduction in the standard deviation of the shock is at least partly responsible for the smaller responses. To facilitate the comparison of the responses in the face of the different time paths of the federal funds rate, we plot in Figure 3-8 the IRFs of home mortgages and residential investment for the VAR of the second subsample when we feed the VAR a series of monetary policy shocks that results in a time path for the federal funds rate that is identical to the one observed in the first subsample. The figure also plots the IRFs of home mortgages and residential investment for the first subsample. The figure documents that the responses of residential investment are not smaller in the later subsample, only more delayed. The responses of home mortgages have become smaller. Note, however that the response of home mortgages is initially actually larger in the second subsample.

If financial innovation—through an eventually smaller reduction in home mortgages—is behind the smaller negative responses of GDP and possibly even the smaller negative responses in durable expenditures, then it is somewhat surprising that the drop in residential investment did not become smaller. It is not impossible of course. For example, financial innovation may have made it possible for households to face a smaller decrease in

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32 This is not necessarily the case. Mertens (2008) develops a model in which monetary policy becomes more effective after the removal of Regulation Q in the early eighties. His model predicts that a smaller increase in the interest rate is needed to obtain the same drop in inflation after the removal of Regulation Q. See footnote 4 for a related discussion on the model of Mertens (2008).

33 The home mortgage response is also initially larger when the federal funds rate responses in the second subperiod are not rescaled to match those of the first subsample. But this initial decrease is much more pronounced when we do rescale the federal funds rate.
**Figure 3-8**: IRFs following a monetary tightening (with same interest rate response as in early sample)

A. Home mortgages

B. Residential investment

Notes: This figure plots the IRF of the indicated variable in the first sample following a monetary tightening and the IRF of the indicated variable mortgages in the second sample when the economy faces a sequence of monetary policy shocks such that the time path of the federal funds rate is identical to the one observed during a monetary tightening in the first subsample.
their home equity loans during a monetary tightening and this may have made it possible to have a lower reduction in durable expenditures, while at the same time their ability to use home mortgages to finance residential investment was still suppressed during this type of downturn.

The rescaling of monetary policy shocks does not affect the interpretation of the changes in the IRFs of consumer credit. The reason is that the responses of consumer credit are so close to zero in the second subsample that with or without rescaling one would conclude that the drop in consumer credit following a monetary tightening has disappeared in the second subsample, at least for the IRFs of the benchmark VAR.

Robustness. In online Appendix E.2, we show that there are other sensible VAR specifications in which the responses of home mortgages and consumer credit are much more similar in the two subsamples. In fact, we report two VAR specifications in which the maximum reduction in the second subsample is close to the one for the first subsample even for the much smaller increase in the federal funds rate used to generate the IRFs for the second subsample and even when we look at the percentage change in the loan series, not to the change relative to GDP.

Financial innovation and changes in non-monetary IRFs

The general shapes of the IRFs following a real activity shock are quite similar across the two subsamples, except that the magnitudes are smaller in the second subsample. Even if we take a close look, then there are only some minor noticeable changes in the shapes.

In the first subsample, the three real activity variables as well as consumer credit and home mortgages display an initial decrease followed by a quite substantial recovery. During this economic downturn, the federal funds rate drops by 50 basis points, which could be the reason for the subsequent expansion. In the second subsample, the observed pattern is very similar, except that GDP turns positive somewhat later, the reduction in consumer credit has become more persistent, durable expenditures turn positive earlier,
and home mortgages and residential investment turn positive earlier as well.

An increase in the persistence of GDP and consumer credit is not consistent with the standard story that financial innovation has dampened the effect of shocks. The shortening of the downturn for durable expenditures is, but it seems strange that financial innovation would cause consumer credit to remain suppressed for a longer time period and at the same time would shorten the period during which durable expenditures remain suppressed. The shortening of the downturn in residential investment is consistent with the observed shortening in the downturn of home mortgages. But these shifts in turning points are way too small to be used as support for a theory that argues that the great moderation came about by changes in the responses to shocks.

In online Appendix D, we report the IRFs for the other shocks. The striking result is that the changes in these other IRFs are quite small. It is not unusual that the IRFs of VARs are not robust at all in the sense that minor changes in, for example, the specification or the sample period lead to different outcomes. If financial innovation really did affect the business cycle behavior of the variables we consider, then one would have expected much larger changes in the IRFs of these other shocks.

**Financial innovation and the drop in comovement**

In Section 3.6, it was shown that the positive correlation coefficients between the two consumer loan series and real activity in the first subsample were due to the responses following monetary policy and real activity shocks. The reason the correlation coefficients dropped was that the responses following those two shocks changed.

As discussed in Section 3.7.2, the changes in the responses following a monetary policy shock are not trivial, but are not the type of changes that are convincing evidence for the view that financial innovation dampened business cycles.

As shown in Figure 3-6 and discussed above, the changes in the responses following a real activity shock are minor. The changes consist of small shifts. Although these IRFs do not change that much, these changes turn out to be quantitatively important for the
correlation coefficient. The reason is that the IRFs change sign. In the first subsample, the points at which the responses of home mortgages and GDP switch from negative to positive are not that far apart. This leads to a strong positive correlation. In the second subsample, home mortgages turn positive earlier and GDP turns positive later. Although the shifts are not that spectacular, they still imply that there is now a period in which the loan and the real activity responses have the opposite sign. This offsets the positive correlation at short and long forecast horizons.

The evidence presented here is not only interesting in terms of what it reveals about financial innovation, it is also informative about the usefulness of using changes in business cycle statistics like covariances as evidence. The comovement between consumer loans and real activity generated by real activity shocks displays a substantial drop that could easily be interpreted as a sign of an important change in the economy. But the observed changes in the IRFs make clear that this drop in comovement is caused by minor shifts.

**Financial innovation and effect of loans**

If business cycle fluctuations became smaller, because it became easier for financial intermediaries to continue lending during economic downturns, then consumer loans should of course have an impact on real activity. That is, we would like to know whether real activity would have dropped by less in the first subsample if loans would have dropped by less. To shed some light on this question, we recalculate the IRFs keeping the loan responses equal to zero. Figure 3-9 plots the original and the recalculated responses. The two panels on the left report the results when the home mortgage responses are kept equal to zero and the two on the right when the consumer credit responses are kept equal to zero. The top panels report the results for GDP and the bottom panels for the spending component most associated with the loan variable.

For consumer credit, we find that loans have virtually no effect on real activity. Lending activity in the mortgage market does seem to affect real activity. The impact of a monetary tightening on GDP is less than half as large if the mortgage response is set equal
Figure 3.9: Responses of real activity variables following a monetary tightening (consumer loans remain constant)

A. IRF of GDP

B. IRF of GDP

C. IRF of residential investment

D. IRF of durable expenditures

Notes: IRFs in the right (left) column are constructed by setting the response of home mortgages (consumer credit) equal to zero each period.
to zero. The evidence is mixed, however, because the impact on residential investment is actually somewhat larger if the mortgage response is set equal to zero.

**Simple alternative explanation**

In this paper, we have focused on the hypothesis that financial innovation dampened business cycles during the period of the great moderation. To limit the scope of the paper, we do not address the question whether our empirical results are consistent with alternative hypotheses about the great moderation including those hypotheses according to which financial innovation magnified business cycle fluctuations, for example, because leverage was increased.\(^{34}\)

Nevertheless, we would like to offer one alternative explanation for the observed changes in the responses following a monetary downturn which is so simple and obvious that it cannot be ignored. The alternative hypothesis is that loan responses are smaller because real activity responses are smaller and not the other way around.

To evaluate this hypothesis, we plot in Figure 3-10 the responses according to the VAR estimated using data from the second subsample when the economy faces a series of monetary policy and real activity shocks such that the time paths for the federal funds rate and the three real activity variables are identical to the responses following a monetary tightening in the first subsample. The graph shows that correcting for the magnitude of the economic downturn the loan responses are not smaller in the second sample at all. In fact, after some period they take on substantially larger values. That is, whereas in Section 3.7.2 we found that there is mixed evidence on whether consumer loans affect real activity, we find here that real activity does clearly have an effect on consumer loans.

\(^{34}\)This can still be consistent with the great moderation if other factors are at play such as better fiscal and/or monetary policy.
**Figure 3.10:** Loan responses following a monetary tightening (with same interest rate and real activity responses as in early sample)

**A. Home mortgages**

- 1984Q1-2008Q1 (same interest rate and real activity responses as in early sample)
- 1954Q3-1978Q4 (original)

**B. Consumer credit**

- 1984Q1-2008Q1 (same interest rate and real activity responses as in early sample)
- 1954Q3-1978Q4 (original)

Notes: This figure plots the loan responses following a monetary tightening in the first subsample and what the responses according to the VAR of the second subsample would be when the economy faces a sequence of monetary policy and real activity shocks such that the time paths of the federal funds rate and the three real activity variables are identical to the ones observed during a monetary tightening in the first subsample.
3.8 Concluding comments

There are limitations to a discussion like the one given in this paper that does not focus on a specific model about financial innovation, but tries to refute a whole class of theories. Nevertheless, we believe that the empirical evidence presented provides little support for the view that innovation in the markets for consumer loans dampened business cycles during the great moderation.

This does not mean that financial innovation did not have an effect. In the first place, we showed that there were important changes in what type of financial institution finances consumer loans when. In particular, in the second subsample other financial institutions than banks seem to take over the role of financing consumer loans during downturns, where financing means holding the loans (or the underlying securities) on your balance sheet not originating the loan. One can expect the quality of consumer loans to deteriorate during economic downturns and the recent financial crisis suggests that the financial institutions that took these loans on their balance sheets were probably not fully aware of the quality of these loans.

There are other reasons why financial innovation could still have had an effect on the economy even though it did not dampen business cycles. By increasing leverage, financial innovation could have magnified business cycles. This is still consistent with the great moderation as long as there is a more powerful factor dampening business cycles like better monetary policy. Finally, we would like to point out that our analysis only considers aggregate series. It may still be the case that financial innovation affected the cross-sectional distribution. For example, financial innovation may have made it possible to spread the losses more equally during economic downturns.
Appendix 3.A  The literature on financial innovation and the great moderation

In this section, we give citations to document widespread support for the view that financial innovation dampened business cycles during the great moderation among policy makers, policy institutions, and academics.\textsuperscript{35} Recent events may have changed the views of some of these authors. But a Google search on "financial innovation" and "bath water" generates many commentaries on the benefits of financial innovation and that in designing future policies one should be careful not to throw the baby away with the bath water. A striking quote is from the president of the Federal Reserve Bank of Richmond:

Financial innovation could contribute to growth, therefore, by reducing the volatility of consumption relative to income and expense shocks. While the intuition for this is straightforward at the level of an individual household, the effect of improved consumption-smoothing opportunities on aggregate volatility is not unambiguous. ... Nonetheless, a causal link between the great moderation and the simultaneous wave of financial innovation would seem to be a plausible conjecture.

\textsuperscript{(Lacker, 2006, p.3)}

The following two quotes are from the president of the European Central Bank:

..., the reason why the latest episode of stock market adjustments did not cause systemic problems could be attributed to the contribution of financial innovation to the more even distribution of risk.

\textsuperscript{(Trichet, 2003, p.3)}

\textsuperscript{35} A more complete set of references is given in footnote 2.
To be clear, I do not deny that financial liberalisation and financial innovation over the past two decades have made important contributions to the overall productivity of our economies. For example, the securitisation of assets—the transformation of bilateral loans into tradable credit instruments—had tremendous potential for the diversification and efficient management of economic risk.

(Trichet, 2009, p.2)

Policy institutions like the IMF also stressed the beneficial effects of financial innovation on stabilising the economic system. The April 2006 Global Financial Stability Report said the following:

There is growing recognition that the dispersion of credit risk by banks to a broader and more diverse group of investors, rather than warehousing such risk on their balance sheets, has helped to make the banking and overall financial system more resilient.

(IMF, 2006, p.51)

The remaining quotes in this section are from academics.

Our findings also suggest a role for improvements in financial markets in reducing consumption and investment volatility. ... The decrease in output volatility appears sufficiently steady and broad based that a major reversal appears unlikely. This implies a much smaller likelihood of recessions.

(Blanchard and Simon, 2001, p.163 and p.164)

..., the results are most consistent with a decline in shock variances which was reinforced by a decrease in financial frictions, making the economy less vulnerable to shocks.
When moving toward a more flexible portfolio, the model can account for almost one-third of the observed decline in the volatilities of output, consumption, and investment.

(Guerron-Quintana, 2009, p.255)
There are a variety of possible explanations for this unprecedented stability. ... , the one that I put most weight behind is that financial innovation has allowed companies and individuals to smooth consumption and investment in the face of fluctuations in income and revenue.

(Cecchetti, 2008, p.1)

The result of the last 20 years of financial innovation is that we can insure virtually anything and engage in activities we would not have undertaken in the past. As a result growth has been more stable and business cycles have been less frequent and severe.

(Cecchetti, 2008, p.2)

We employ a variety of simple empirical techniques to identify links between the observed moderation in economic activity and the influence of financial innovation on consumer spending, housing investment, and business fixed investment. Our results suggest that financial innovation should be added to the list of likely contributors to the mid-1980s stabilization.

(Dynan, Elmendorf, and Sichel, 2006, p.123)

..., we find that the volatility of output falls as a country’s financial system becomes more developed and its central bank becomes more independent. Volatility fell by more in countries where credit became more readily available.

(Cecchetti, Flores-Lagunes, and Krause, 2006, p.2)

Our results provide some evidence that the larger and more fully developed and integrated SMM [secondary mortgage market] tempers the responses of residential investment to income and to interest rates, and thereby lowers the volatility of residential investment.

(Peek and Wilcox, 2006, p.139)
Appendix 3.B  Constructing time series for bank mortgages

In the Flow of Funds data set, there is an item for bank mortgages, but this item only includes the mortgages banks hold directly on their balance sheets. Therefore, it only provides limited information, because banks hold a lot more mortgages on their balance sheets in the form of asset-backed securities. In this section, we explain how we calculate the amount of mortgages banks hold indirectly on their balance sheets.

To decide what should be included, we checked schedules RC-B & RC-D of the Call reports on which this part of the Flow of Funds is based and the Guide to the Flow of Funds Accounts published by the Board of Governors of the Federal Reserve System.36

Schedule RC-B, item 4, mortgage-backed securities:

4.a. Pass-through securities

1. guaranteed by GNMA
2. issued by FNMA & FHLMC
3. other pass-through securities

4.b. Other mortgage-backed securities (CMOs, REMICs, & Stripped MBSs)

1. issued or guaranteed by FNMA, FHLMC, or GNMA
2. collateralized by MBSs issued or guaranteed by FNMA & FHLMC
3. other MBSs

Schedule RC-D, item 4, mortgage-backed securities:

4.a. Pass-through securities issued or guaranteed by FNMA, FHLMC, or GNMA

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36Schedule RC-D provides information of assets held for trading, which are excluded in schedule RC-B.
4.b. Other mortgage-backed securities issued or guaranteed by FNMA, FHLMC, or GNMA

4.c. All other mortgage-backed securities

For U.S.-chartered commercial banks, the Flow of Funds lists the following potentially relevant series in L.110:\textsuperscript{37}

row 7 Agency- and GSE-backed securities: Mortgage and GSE-backed securities; this item consists of items 4.a.1 and 4.a.2 of schedule RC-B and item 4.a of schedule RC-D

row 8 Agency- and GSE-backed securities: CMOs and other structured MBS; this item consists of item 4.b.1 of Schedule RC-B and item 4.b of schedule RC-D.

row 9 Agency- and GSE-backed securities: Other; these include U.S. government agency obligations and MBSs are explicitly excluded.

row 12 Corporate and foreign bonds: Private mortgage pass-through securities; this item consists of item 4.a.3 of schedule RC-B and item 4.c of schedule RC-D.

row 13 Corporate and foreign bonds: Private CMOs and other structured MBS; this item consists of item 4.b.2 of schedule RC-B.

row 14 Corporate and foreign bonds: Other; this item consists of item 4.b.3 of schedule RC-B, but also of other items.

row 16 Mortgages

Obviously, we have to exclude row 9. Row 14 includes some MBSs, namely those that are not pass-through securities \textit{and} not related to GNMA, FNMA, or FHLMC,\textsuperscript{38} but

\textsuperscript{37}There are occasional changes in row numbers; our row numbers correspond to those of the March 2009 issue of the flow of funds.

\textsuperscript{38}Namely Call Report series RCON 1733 and RCON 1735.
it also includes securities that are not related to mortgages. Row 14 is not trivial in magnitude. In 2006, it was equal to 6% of the sum of rows 7, 8, 12, 13, and 16 and 22.6% of the sum when row 16 is excluded. The largest part of row 14, however, is not related to mortgages. We obtained individual bank data from the Call Reports and aggregated them to obtain the six items that are part of row 14. At the end of our sample, roughly 40% of row 14 is related to mortgages. This means that the mortgage part of row 14 is roughly 1.5% of all U.S.-chartered mortgages and 9% of these banks MBSs. Therefore, our total mortgage measure for U.S.-chartered commercial banks consists of rows 7, 8, 12, 13, and 16.

For savings institutions, the listed series in L.114 of the Flow of Funds are identical to those of U.S.-chartered banks and we construct our total mortgage measure for savings institutions in the same way.

For credit unions, the Flow of Funds lists in L.115 only the total amount of pass-through securities and the total for other mortgage-backed securities. For credit unions we, therefore, only use home mortgages (row 10) and agency-and GSE-backed securities (row 8). We would miss the MBSs in corporate and foreign bonds (row 9), but this balance sheet item is very small relative to both the quantities in row 8 and row 10.

Appendix 3.C Real activity shocks

Our VAR contains three real activity variables: residential investment, durable expenditures and GDP. For each of these variables, our Cholesky decomposition gives rise to an associated shock. In the main part of this paper, we analyze the IRFs when each of the three innovations is equal to one standard deviation. In this appendix, we discuss the responses to the three individual shocks. The corresponding IRFs are shown in Figures

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39 In particular, it includes other debt securities, RCON 1737 & RCON 1739, and foreign debt securities, RCON 1742 & RCON 1744.

40 It is not difficult to do such an exercise for one period, but it is to do it for a whole time series. The problem with the Call Reports is that it is not trivial to construct consistent time series because the definitions often change.
3-11, 3-12 and 3-13.

**Residential investment shock.** There are several similarities in the shapes of IRFs across the two subsamples. The main change seems to be that the magnitudes of the responses have declined, which resembles the results for a joint real activity shock.

In the first subsample, the three real activity variables as well as the two loan components display an initial decrease followed by a quite substantial increase. Similar to the change observed for the responses to a joint real activity shock, the responses of home mortgages to a residential investment shock seem to have shifted upward and turn positive earlier. In itself this is consistent with financial innovation, but comparing the IRFs for residential investment and GDP across the two samples indicates that there is not a substantial reduction in the economic downturn and that the drop in GDP even has become a lot more persistent. Relative to the IRFs reported in the main text for a real activity shock, these results provide less evidence in favor of the hypothesis that financial innovation is behind the reduction in the volatility of real activity.

**Durable expenditures shock.** When we compare the changes in the IRFs of durable expenditures and GDP to a durable expenditures shock with the changes in the IRFs to a real activity shock, then we find that the reduction of the negative responses are stronger for the first set. This would strengthen the case for financial innovation having had a favorable impact on business cycle behavior. When we compare the responses of consumer credit to a durable expenditures shock with the responses of consumer credit to a real activity shock, however, then we find that the responses to a durable expenditures shock are very similar across the two subsamples. With an almost equal reduction in consumer credit, it seems unlikely that financial innovation is behind the smaller reductions in real activity.

**GDP shock.** At first sight, the changes in the IRFs following a GDP shock do seem to support the view that financial innovation had a favorable impact on the transmission of
Figure 3.11: IRFs following a residential investment shock

Notes: Responses to a one-standard-deviation shock in residential investment.
Figure 3.12: IRFs following a durable expenditures shock

Notes: Responses to a one-standard-deviation shock in durable expenditures.
Figure 3.13: IRFs following a GDP shock

Notes: Responses to a one-standard-deviation shock in GDP.
this shock on the economy. That is, in response to a negative GDP shock home mortgages increase faster in the second subsample and so does the IRF of residential investment; GDP and durable expenditures drop by less in the second subsample. In the second subsample, however, the negative drop in GDP leads to a more persistent drop in the federal funds rate and this could also be behind the observed changes in home mortgages and residential investment.

Appendix 3.D Other shocks

In the main text, we discussed the responses to a monetary tightening and a joint real activity shock. In this section, we discuss the responses to the other shocks. The IRFs are plotted in Figures 3-14, 3-15, and 3-16.

3.D.1 IRFs of Other Shocks

Price shock.

Most of the responses are insignificant in the subsamples. Interestingly, the responses are often significant over the complete sample, which also includes the period from 1979Q1 to 1983Q4 during which inflation was sharply reduced. None of the two subsamples include this period. One interesting observation is that in the second subsample there is a significant monetary tightening in response to a positive price shock, whereas in the first subsample, there is an insignificant decline of the federal funds rate. This observation is consistent with the hypothesis that keeping inflation low has become more important for policy makers. Although we found that in the second subsample an unexpected monetary tightening does not have a significant downward effect on durable expenditures, the increase in prices combined with a monetary tightening does still lead to a substantial reduction in durable expenditures.
Notes: Responses to a one-standard-deviation shock in the price level.
Figure 3.15: IRFs following a consumer credit shock

Notes: Responses to a one-standard deviation shock in consumer credit.
Figure 3.16: IRFs following a home mortgage shock

Notes: Responses to a one-standard-deviation shock in home mortgages.
Consumer credit shock.

Except for the responses of consumer credit itself, almost none of the responses are significant, which is consistent with the result discussed in the main text that consumer credit does not seem to have a strong effect on the real economy.

Home mortgage shock.

The responses to a home mortgage shock are also not significant that often (except for the responses of home mortgages itself), but there are still somewhat more significant responses for a home mortgage shock than for a consumer credit shock. One striking observation is that in the second subsample both the negative response of home mortgages itself and the negative response of residential investment have become more persistent. This is, of course, not very supportive of the view that financial innovation dampened economic fluctuations. It is interesting to note that a negative disturbance in home mortgages did correspond with a (short-lived) reduction in durable expenditures and GDP in the first subsample, but that the responses of these two variables are basically flat in the second subsample. A possibly related observation is that in the first subsample consumer credit decreases together with home mortgages, although the reduction is not significant. In contrast, in the second subsample there is a sharp and significant increase in consumer credit. One possible interpretation is that in the first subsample disturbances in the market for home mortgages spread across markets, but that in the second subsample reductions in home mortgages gave rise to positive opportunities in other financial markets.

3.D.2 IRFs of Other Shocks and Financial Innovation

Price shock.

The changes in the IRFs after a price shock are close to the opposite of what one would expect if financial innovation had affected business cycle properties. In particular, the con-
sumer credit response has become more negative and the GDP response has become less negative (although possibly more persistent). Moreover, the response of durable expenditures is small and insignificant in the first subsample, but more negative and significant in the second subsample. A much more straightforward explanation for this change is that the FED has become more responsive to inflationary pressure, which explains the upward shift of the response of the federal funds rate, which in turn explains the downward shift of the responses of consumer credit and durable expenditures. Although the responses are not significant, a similar set of results is found for mortgages and residential investment.

Consumer credit shock.

The drop in consumer credit has only become larger and more persistent, whereas the IRFs of the three real activity variables have become more muted, which does not fit the standard story that better access to loans has dampened economic fluctuations. Given that the responses are typically not significant, however, there is little point in taking the changes seriously.

Home mortgage shock.

The most interesting change is that in the second subsample there is a negative comovement between home mortgages and consumer credit. This substitution between different types of loans could be a sign of financial innovation. For example, financial institutions may have better substitution possibilities and channel funds towards consumer credit when there are disruptions in the market for home mortgages. This substitution could then very well amplify the downturn in home mortgages and the downturn in residential investment, which is consistent with the IRFs. Better possibilities for financial institutions to adjust their loan portfolios could be beneficial for financial institutions. It is not clear, however, how such substitutions between one type of consumer loan for another benefit consumers and this pattern does not correspond with the view expressed in the literature that financial innovation made it easier for consumers to keep on borrowing
during bad times.

Appendix 3.E  Robustness

Alternative Filter to Calculate Business Cycle Statistics

Table 3.2 reports some key business cycle statistics when a band-pass filter instead of the HP filter is used. Our band-pass filter lets pass through that part of the time series associated with cycles with a period between 6 and 32 quarters. The HP filter is an approximate band-pass filter that focuses on cycles with a period less than 32 quarters. Since short-term cycles may be quite noisy and for example be affected by measurement error, it is important to document that the results are robust to this alternative procedure to construct cyclical components.

The table documents that our results do not depend on which filter is used.

Lack of Robustness of Second Subsample GDP Responses

In the second subsample, the response of GDP following a monetary tightening is slightly positive and significant. This is not a robust result. Alternative VAR specifications can give significantly negative responses. The results in Figure 3.17 are from a VAR identical to the one used in the main text, but without a deterministic trend. Excluding the deterministic time trend makes the responses across the two samples more similar, especially if we would equalize the size of the shock in the federal funds rate. GDP now starts to decrease in the first two quarters and the responses are significant after two years. The responses of durable expenditures as well as those for consumer credit are also significantly negative for this VAR specification. The negative response for home mortgages is stronger. The results generated by this VAR are even less in favor of financial

\[^{41}\text{The ideal band-pass filter is an infinite-order two-sided filter. To be able to implement the filter we truncate it at 8 quarters and then rescale the coefficients so that they still add up to zero. We experimented with alternative truncation choices and found the results to be similar.}\]
### Table 3.2: Standard Deviations (in %) according to the band-pass filter

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<tr>
<th></th>
<th>'54Q3-'78Q4</th>
<th>'84Q1-'08Q1</th>
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<td><strong>Real activity</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>GDP</td>
<td>1.38</td>
<td>0.63</td>
<td>-54%</td>
</tr>
<tr>
<td>Durable expenditures (DE)</td>
<td>3.75</td>
<td>1.71</td>
<td>-55%</td>
</tr>
<tr>
<td>Residential investment (RI)</td>
<td>7.68</td>
<td>3.94</td>
<td>-49%</td>
</tr>
<tr>
<td><strong>Consumer credit</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (T)</td>
<td>2.41</td>
<td>1.57</td>
<td>-35%</td>
</tr>
<tr>
<td>Regular bank consumer credit (RB)</td>
<td>2.59</td>
<td>2.04</td>
<td>-22%</td>
</tr>
<tr>
<td>(T) - (RB)</td>
<td>3.71</td>
<td>2.95</td>
<td>-21%</td>
</tr>
<tr>
<td><strong>Mortgages</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (T)</td>
<td>1.21</td>
<td>0.68</td>
<td>-35%</td>
</tr>
<tr>
<td>Regular bank mortgages (RB)</td>
<td>1.83</td>
<td>1.52</td>
<td>-17%</td>
</tr>
<tr>
<td>All bank-owned mortgages (B)</td>
<td>1.84</td>
<td>1.30</td>
<td>-30%</td>
</tr>
<tr>
<td>(T) - (RB)</td>
<td>0.79</td>
<td>1.10</td>
<td>40%</td>
</tr>
<tr>
<td>(T) - (B)</td>
<td>0.88</td>
<td>1.43</td>
<td>63%</td>
</tr>
<tr>
<td><strong>correlation with GDP</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Real activity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Durable expenditures (DE)</td>
<td>0.90</td>
<td>0.66</td>
<td>-26%</td>
</tr>
<tr>
<td>Residential investment (RI)</td>
<td>0.66</td>
<td>0.54</td>
<td>-18%</td>
</tr>
<tr>
<td><strong>Consumer credit</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (T)</td>
<td>0.67</td>
<td>0.08</td>
<td>-88%</td>
</tr>
<tr>
<td>Regular bank consumer credit (RB)</td>
<td>0.68</td>
<td>0.32</td>
<td>-53%</td>
</tr>
<tr>
<td>(T) - (RB)</td>
<td>0.43</td>
<td>-0.26</td>
<td>-161%</td>
</tr>
<tr>
<td>(T) - (B)</td>
<td>0.09</td>
<td>-0.29</td>
<td>-427%</td>
</tr>
<tr>
<td><strong>Mortgages</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (T)</td>
<td>0.75</td>
<td>0.16</td>
<td>-78%</td>
</tr>
<tr>
<td>Regular bank mortgages (RB)</td>
<td>0.76</td>
<td>0.51</td>
<td>-34%</td>
</tr>
<tr>
<td>All bank-owned mortgages (B)</td>
<td>0.78</td>
<td>0.39</td>
<td>-50%</td>
</tr>
<tr>
<td>(T) - (RB)</td>
<td>0.21</td>
<td>-0.37</td>
<td>-278%</td>
</tr>
<tr>
<td>(T) - (B)</td>
<td>0.09</td>
<td>-0.29</td>
<td>-427%</td>
</tr>
</tbody>
</table>

Notes: The table reports statistics for the cyclical component of the indicated variable. The cyclical component is calculated using a band-pass filter that let pass through the part of the series associated with cycles with a period in between 6 and 32 quarters. To implement the filter, which is an infinite-order two-sided filter, we truncate after 8 quarters and rescale the coefficients so that they still add up to zero. "regular" bank loans are those directly held on the banks’ balance sheets and not in the form of asset-backed securities. For mortgages the latter could be calculated and are included in "all" bank mortgages.
Figure 3.17: IRFs following a monetary tightening; no deterministic time trend

Notes: Responses to a one-standard-deviation shock in the federal funds rate. The IRFs are generated by a VAR with the same specification as the one used in the main text, except that no deterministic time trend is included.
innovation affecting business cycles. The results in Figure 3-18 are based on the same VAR except that the deflator is excluded. Now the negative responses of both the real activity and the consumer loan variables are even stronger. Scaled for the size of the federal funds rate shock, the drop in home mortgages would be much larger in the second than in the first subsample.

The finding that there are simple VAR specifications in which there are still sizeable drops in both real activity and consumer loans following a monetary tightening question the validity of the hypothesis that it has become easier for consumers to keep on borrowing during a monetary tightening and that in turn this reduced the magnitude of the economic downturn. Our interpretation of the empirical evidence is the following. In the second subsample, there is no robust evidence that real activity (except residential investment) declines following a monetary tightening. The conditional comovement between real activity and consumer loans does not seem to have changed, however. That is, whenever a VAR generates a sizeable drop in real activity, it also generates a sizeable drop in the two consumer loans. If a VAR does not generate a sizeable drop in all real activity variables, it may also not generate a sizeable drop in both types of consumer loans.

If consumer credit, durable expenditures, and GDP, all drop following a monetary tightening, as documented in Figure 3-18, then the question arises whether the correlation of the forecast errors still drops. The covariances according to the VAR underlying this figure are reported in Figure 3-19 together with the role of the monetary policy and the real activity shock. The covariance of consumer credit with both durable expenditures and GDP still drops, but clearly not as much as for the VAR used in the main text. That is, there are covariance measures between consumer credit and real activity that do not even drop, further weakening the evidence for the hypothesis that financial innovation played a role in the great moderation. Interestingly, the smaller drop in the correlation coefficients according to this VAR is not due to the IRFs of consumer credit and the real activity variables all dropping during a monetary tightening. The lesser importance of the monetary policy shock and the delayed drop in consumer credit keeps the covariance due
Figure 3.18: IRFs following a monetary tightening; no deterministic time trend and deflator

Notes: Responses to a one-standard-deviation shock in the federal funds rate. The IRFs are generated by a VAR with the same specification as the one used in the main text, except that neither the determinisitic time trend nor the deflator is included.
**Figure 3-19:** Decomposition of comovement between consumer credit and real activity; no deterministic time trend and deflator

A. Correlation consumer credit and GDP

B. Correlation consumer credit and durable expenditures

Notes: Correlation of forecast errors according to the VAR that is identical to the benchmark VAR, except that neither the deterministic time trend nor the deflator is included. The graph also indicates which part of the correlation is due to monetary policy and real activity shocks.
to monetary policy shocks low. Figure 3-19 shows that this comovement measure does not drop by this much because according to this VAR the comovement driven by real activity shocks does not drop by much and at higher forecast horizons even increases. This is not that surprising. In the main text, we documented that small changes in these IRFs could have large effects on the correlation between the forecast errors, because the IRFs switched sign and that the turning point moved over time, but differently for different variables. Then one can expect that the changes in the correlation coefficients are not that robust, which we show here is indeed the case.

**Alternative VAR Specifications**

We found that our main results are robust to several changes in the specifications of the VAR. In particular, across specifications we find that there is a sizeable drop in home mortgages and residential investment following a monetary tightening in both the first and the second subsample and that real activity variables have a strong effect on loan variables, but not vice versa. In Section 3.E, we already discussed the results when no deterministic trend was included and when the price deflator was not included. In this section, we document the results for some of the alternative specifications considered.

**Including house prices.**

One obvious alternative to consider is a VAR that includes an index for house prices. Figure 3-20 reports the IRFs for the real house price, residential investment, and home mortgages when the OFHEO house price index, deflated by the GDP deflator, is added to the VAR. The panels for residential investment and home mortgages also plot the IRFs when the VAR does not include the house price index, that is, the IRFs from Figure 3-4. Because of data limitations, we can only obtain these IRFs for the second subsample. The graph documents that a monetary tightening leads to a significant but small drop in house prices. Moreover, the IRFs of residential investment and home mortgages are not
Figure 3.20: IRFs following a monetary tightening; VAR with house price

Notes: Responses to a one-standard-deviation shock in the federal funds rate for the second subsample. The IRFs are generated by a VAR with the same specification as the one used in the main text, except that an index for house prices is included.
affected very much.\footnote{The results for the other variables are quite similar to those reported in Figure 4.}

**Different number of lags.**

Our benchmark VAR specification follows common practice and includes four lags of each variable. A smaller number of lags is preferred in several of the equations according to both AIC and BIC. To make sure that our results are robust to the number of lags, we report in Figure 3-21 the results for a monetary tightening when only two lags are included. The results are very similar except that with two lags the upward shift in the responses of residential investment is smaller. Since such an upward shift could be interpreted as evidence in favor of the hypothesis that financial innovation dampened business cycles, the smaller upward shift only strengthens our case.

**Different ordering.**

Our identification procedure relies on the assumption that variables do not respond to a monetary policy shock within the quarter is correct. To increase the plausibility of this hypothesis, we use the average daily federal funds rate during the last month of the quarter as our monetary policy instrument. To be on the safe side, we also consider an alternative identification assumption under which the two loan variables are able to respond within the quarter. The responses following a monetary tightening are shown in Figure 3-22. The figure documents that the results are very similar, except that the responses for consumer credit are now slightly positive instead of hovering around zero. These responses are insignificant, under both identification assumptions.

**Appendix 3.F Home versus total mortgages**

For the exercises in the main text related to bank and non-bank mortgages we used total mortgages, because we could not distinguish between home and other mortgages. In this
Figure 3.21: IRFs following a monetary tightening; two instead of four lags

Notes: Responses to a one-standard-deviation shock in the federal funds rate. The IRFs are generated by a VAR with the same specification as the one used in the main text, except that two instead of four lags are used as explanatory variables.
Figure 3.22: IRFs following a monetary tightening; different orderings

Notes: Responses to a one-standard-deviation shock in the federal funds rate. The IRFs are generated by a VAR with the same specification as the one used in the main text, except that consumer loans can respond to our end-of-quarter policy shock within the quarter.
section, we discuss the similarities and differences between the different mortgage series at the aggregate level.

**Trends.** Figure 3-23 is the equivalent of Figure 3-1, but uses home and non-home mortgages instead of total mortgages.\(^{43}\) The figure shows that most the long-term increase in total mortgages is clearly due to the increase in *home* mortgages. Similar to the results found for total mortgages, this increase in home mortgages is mainly due to an increase in mortgages that are not directly owned by banks.

**Cyclical behavior.** Figure 3-25 plots the cyclical components of home mortgages and GDP (in panel A) and the cyclical components of non-home mortgages and GDP (in panel B). A comparison with Figure 3-2 makes clear that the cyclical behavior of home mortgages is very similar to that of total mortgages throughout the sample. In particular, the correlation of the cyclical components of home and total mortgages is equal to 0.97 in the first subsample and 0.92 in the second subsample. The correlation between home and non-home mortgages for the second subsample is clearly smaller than the correlation for the first subsample. This does not lead to a strong decrease in the correlation between home and total mortgages, because the share of home mortgages in total mortgages is substantially higher in the second subsample.

Figure 3-25 documents that the cyclical behavior of home mortgages often resembles that of non-home mortgages, but there are some important differences. In particular, the run-ups in mortgages before the 1990-91 and the 2001 recession are not as large for home mortgages as for non-home mortgages, whereas the run-up before the recent turmoil is substantially larger for home mortgages.

\(^{43}\)For these series we cannot determine all bank-owned mortgages. The series that are indicated as "regular bank mortgages" in the graphs only include mortgages banks hold directly on their balance sheets.
Figure 3.23: Home and Non-Home mortgages; scaled by GDP or value underlying asset

Notes: "Regular" bank mortgages are those directly held on the banks' balance sheets and not in the form of asset-backed securities and "total" bank mortgages include both. In the two panels on the right, the mortgage series is scaled with the market value of the associated real estate variable.
Impulse response functions. In the first subsample, the IRFs of home, non-home, and total mortgages are all significantly negative.

Panel A of Figure 3-24 plots the IRFs for these three series for the second subsample. As discussed above, the IRF for home mortgages following a monetary tightening is still significantly negative in the second subsample. The IRF for total mortgages, however, is basically flat and the IRF for non-home mortgages even displays a substantial increase. This is likely to be due to the boom and bust in commercial mortgages in the early nineties. As documented in Figure 3-25, the cyclical component of non-home mortgages increases at the end of the eighties and remains high for an unusually long time. In fact, it remains high even when the economy is going through a downturn. Note that there is a boom in home mortgages too, but of much smaller magnitude and this one ends much earlier. The boom in non-home mortgages is followed by a bust, also of an unusually long time. That is, non-home mortgage lending was buoyant following the increases in the federal funds rate in the second half of the eighties and suppressed following the reductions in the federal funds rate in the early nineties.
Figure 3.24: IRFs for home, non-home, and total mortgages

Notes: IRFs for the indicated shocks.
Figure 3.25: Cyclical components of home and non-home mortgages

A. Home mortgages (black) and GDP (grey)

B. Non-home mortgages (black) and GDP (grey)

Notes: These two panels plot the HP-filtered residual of the indicated component and the HP-filtered residual of GDP. The vertical lines above (below) the x-axis correspond to NBER peaks (troughs).
Chapter 4

Home Equity, Mobility, and Macroeconomic Fluctuations

Abstract

How does a fall in house prices affect real activity? This chapter presents a business cycle model in which a decline in house prices reduces geographical mobility, creating distortions in the labor market. This happens because homeowners face declines in their home equity levels, after which it becomes more difficult to provide the downpayment required for a new mortgage loan. Unemployed homeowners therefore turn down job offers that would require them to move. The model explains joint cyclical patterns in housing and labor market aggregates, as well as the puzzling breakdown of the U.S. Beveridge curve that occurred during 2009.

4.1 Introduction

The recent "Great Recession" is characterized by unusual disruptions in both housing and labor markets. In housing markets, there was a sharp fall in both prices and the number of transactions. In labor markets, there was an increase in the unemployment rate that was not only exceptional in terms of its magnitude, but also surprising given that the number of vacancies did not fall as much (Elsby, Hobijn, and Sahin (2010)). Figure 4-1 plots vacancies versus the unemployment rate. The figure shows that the historically strong and negative correlation between the unemployment rate and vacancies, known as the Beveridge Curve, broke down during 2009. An interpretation of this finding is that frictions in the labor market had become more severe, causing unemployed workers and
Figure 4.1: Beveridge curve.

Notes: Log deviations from trend. Data are monthly and cover the period from January 1970 until December 2009. Variables were logged and HP-detrended with smoothing parameter value $81 \times 10^5$. This value corresponds to the one used by Shimer (2005) for quarterly data, but is adjusted for the frequency using the factor recommended by Ravn and Uhlig (2002). Source unemployment rate: U.S. Department of Labor. Source vacancy index: Barnichon (2010).

This chapter develops a Dynamic and Stochastic General Equilibrium (DSGE) model in which house prices affect real activity through a geographical mobility channel. When house prices decline, homeowners face difficulties in moving to a new house, reducing their incentives to accept job offers that are not within commutable distances from their current homes. As a consequence, a decline in house prices causes unemployment to rise and output to fall, which in turn feeds back into house prices. The calibrated model can explain joint cyclical fluctuations in housing and labor market variables. Moreover, based on only house price and output data, the model generates for 2009 a flattening of the
Beveridge Curve that is remarkably similar to the one observed in reality.

Joint movements in house prices and mobility arise due to the presence of a refinancing constraint that is new to DSGE models. Standard constraints tie the amount of debt to the value of the underlying housing collateral and in each period mortgagees have to refinance their loans (see e.g. Iacoviello (2005)). The unrealistic implication is that fluctuations in house prices affect the borrowing limits of all homeowners during each period. In contrast, my constraint only requires those who move to a new house to refinance their loans. In this environment, households can shield their borrowing capacity from a fall in house prices by staying at their current locations, avoiding the need to take out a new mortgage loan. After a fall in housing wealth, it becomes harder to provide the downpayment for a new loan, reducing incentives to move.

Fluctuations in mobility affect real activity through their effects on the process that matches unemployed workers and firms. This process is modeled following a standard version of the Diamond-Mortensen-Pissarides model, but with the addition that some job offers can only be accepted if the worker moves to a new location. When there are barriers to mobility due to a fall in house prices, more job offers are turned down. Thus, the economy enters a period during which, for a given level of vacancies, the unemployment rate is higher than during normal times. An interesting prediction of the model is that the mobility effects persist beyond the fall in house prices. Moreover, as the amount of leverage among households increases due to structural changes in mortgage markets, real activity becomes more sensitive to shocks, especially to those that arise in housing markets.

The model developed in this chapter is the first that allows one to study the dynamic effects of house prices on mobility, as well as the spillovers to the labor market and real activity. Because outcomes in all markets are endogenous, one can also analyze feedback

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1Stein (1995) considers a somewhat similar constraint and shows that it can generate positive comovement between house prices and transaction volumes in a deterministic partial equilibrium model with only three periods. The advantage of my constraint is that it is easily embedded in a DSGE framework that can be solved using standard techniques.
effects on house prices. Head and Lloyd-Ellis (2008) and Rupert and Wasmer (2011) have developed models with mobility effects to study the role of housing markets in determining long-run unemployment rates. However, their models are much less suited to study fluctuations in housing and labor markets, because solving stochastic versions of their models would be very challenging. In contrast, my model can be easily solved using standard methods.\(^2\)

The proposed geographical mobility channel is consistent with joint cyclical properties of aggregate housing and labor market data. This is shown in Section 4.2. Section 4.3 describes the theoretical model. The predictions of the calibrated model are presented, compared to the data, and explained in Section 4.4. Section 4.5 concludes.

4.2 Fluctuations in housing and labor markets: empirical evidence

The idea that house price declines deter geographical mobility is supported by micro-econometric studies, including Henley (1998), Chan (2001), Engelhardt (2003). At the aggregate level there is evidence that falls in house prices are associated with falls in housing transaction volumes. Stein (1995) finds that housing transaction volumes are positively correlated with past house price growth. Ngai and Tenreyro (2009) document that there is a common seasonal factor in house prices and transaction volumes. Given that a housing transaction is typically associated with a homeowner moving out, these findings are consistent with the idea that a fall in house prices reduces geographical mobility at the aggregate level.

The focus of this chapter is on the joint behavior of housing and labor market variables at business cycle frequencies. I consider measures of volatility and comovement

\(^2\)Business cycle models that are related to my model include those of Iacoviello and Pavan (2009), who model borrowing constraints and infrequent housing adjustments, but not matching frictions in the labor market, and of Andres, Bosca, and Ferri (2010), who analyze a model with frictions in labor and credit markets, but without mobility effects.
that are standard in the business cycle literature, permitting a relatively straightforward confrontation of my business cycle model with the data. At the center of the analysis are house prices, the number of home sales, and the rate at which workers flow out of unemployment. A link between these three variables is crucial for the proposed mobility channel to be at play at the aggregate level. But of course, unconditional business cycle statistics provide only limited information. I therefore also estimate a structural Vector AutoRegressive model (VAR), which allows me to condition on shocks that arise in housing markets.

4.2.1 Data and methodology

The data analysis focuses on quarterly observations of two housing market variables and three labor market variables. The sample runs from the first quarter of 1970 until the last quarter of 2009. The housing market variables are the real house price and home sales. These data were provided by the National Association of Realtors. The house price is the median sales price on existing single-family homes, deflated by the consumer price index.\(^3\) Home sales are measured by the number of existing single-family homes sold in a particular month.\(^4\) The reason for analyzing home sales is that this series can be expected to be a good proxy for overall mobility among homeowners.\(^5\)

The labor market variables are unemployment, vacancies, and the unemployment outflow hazard. Unemployment is measured by the civilian unemployment rate as released by the U.S. Department of Labor. Vacancies are measured by the Help Wanted Index, released by the Conference Board. To account for the rise in internet vacancies, I use the

\(^3\)The conclusions are not affected by using the OFHEO house price index (all transactions) instead. A disadvantage of this series is that data are only available from 1975 onwards.

\(^4\)Monthly series on house prices and the number of home sales were converted into quarterly series by taking simple averages.

\(^5\)The main alternative to the home sales index would be the mobility measures constructed from the Current Population Survey (CPS), that distinguish between owners and renters, but are released on a yearly frequency only. This severely limits the information content of these data, especially when constructing business cycle statistics. However, according to CPS data the mobility rate among homeowners fell thirty percent during the period 2005-2009, which is very similar to drop in the home sales during the same period.
corrected series as constructed by Barnichon (2010) for the post 1995 period. Following Shimer (2007), the quarterly unemployment outflow hazard, $F_t$, is constructed as

$$F_t = 1 - \frac{n_{u,t+1} - \hat{n}_{u,t+1}}{n_{u,t}},$$

where $n_{u,t}$ is the size of the pool of the unemployed, and $\hat{n}_{u,t}$ denotes the pool of those who have been unemployed for zero to four weeks.6

The first part of the empirical analysis consists of a detailed graphical investigation of the data. I consider raw data and construct their cyclical components using the Hodrick-Prescott (HP) filter. Finally, I estimate a structural VAR using nine variables. The VAR has the following form:

$$A(L)Z_t = u_t, \quad A(0) = I, \quad E(u_t'u_t') = \Sigma,$$

where $A(L)$ is a lag polynomial, $u_t$ is a vector of residuals of length 9, and $\Sigma$ is the variance-covariance matrix of the residuals.7 $Z_t$ is a vector a vector of the variables contained in the VAR, and can be divided into three parts:

$$Z_t = \begin{pmatrix} Z_{1,t} \\ Z_{2,t} \\ Z_{3,t} \end{pmatrix}.$$

$Z_{1,t}$ is a $(5 \times 1)$ vector that contains the consumer price index, industrial production, the unemployment rate, vacancies, and the unemployment outflow rate. $Z_{2,t}$ is a $(2 \times 1)$ vector contains the two variables that are directly associated with housing market shocks: the real house price and home sales. $Z_{3,t}$ is a $(2 \times 1)$ vector that contains the S&P 500

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6 The series used to construct $F_t$ is based on data from the CPS. Due to a change in CPS methodology, there is a structural break in January 1994. To account for this, the adjustment of Shimer (2007) is applied. I would like to thank Aysegul Sahin for sharing the adjusted series.

7 The VAR also contains a constant, a linear time trend, and quarterly dummies. For notational convenience, I do not display the corresponding terms.
index, and the federal funds rate. The VAR has four lags and is estimated in log levels.8

My goal is to identify shocks that arise in housing markets. One can assume that the reduced-form shocks in the VAR are related to a vector of uncorrelated structural shocks $\varepsilon_t$ by:

$$u_t = \overrightarrow{Q}\varepsilon_t.$$  

In order to identify structural shocks, restrictions on $\overrightarrow{Q}$ need to be imposed. Instead of using the standard Cholesky decomposition, I adopt a weaker assumption, as discussed in Christiano, Eichenbaum, and Evans (1999), by imposing a block-diagonal structure on $\overrightarrow{Q}$:

$$\overrightarrow{Q} = \begin{pmatrix} \overrightarrow{q}_{11} & 0 & 0 \\ \overrightarrow{q}_{21} & \overrightarrow{q}_{22} & 0 \\ \overrightarrow{q}_{31} & \overrightarrow{q}_{32} & \overrightarrow{q}_{33} \end{pmatrix}.$$  

This identifying assumption implies that the variables contained in $Z_{1,t}$ can only respond with a lag to housing market shocks. The motivation is that I am interested in shocks that arise in housing markets and subsequently spill over to real activity. My identifying assumptions also imply that the variables in $Z_{3,t}$ can respond to housing market shocks contemporaneously. The reason for allowing stock prices and the monetary policy rate to respond to housing market shocks within the quarter is that these two variables can be argued to be relatively forward looking.9 Given that both the real house price and home sales are contained in $Z_{2,t}$, one can identify two orthogonal housing market shocks by imposing restrictions on $\overrightarrow{q}_{22}$. My identification assumes $\overrightarrow{q}_{22}$ to be lower-diagonal, and orders the real house price above home sales. The idea behind this assumption is that

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8Although imposing unit roots or cointegration relationships on the variables contained in the VAR could improve the efficiency of the estimation, it would introduce a greater risk of misspecification.

9I use end-of-quarter values of stock prices and the federal funds rate. The federal funds rate is included as it is a potentially important driver of house price fluctuations. The main reason for including stock prices in the VAR is to avoid that housing market variables are the most forward-looking ones in the system. Then, housing market shocks might primarily capture news about future economic conditions. However, results are not qualitatively affected by leaving out stock prices.
house prices are more sluggish in nature than transaction volumes.

The VAR is used for two purposes. First, the VAR allows me to construct an alternative measure of comovement, namely the correlations between forecast errors of the variables in the VAR, as described by den Haan (2000). Second, I use the VAR to condition on housing shocks and recalculate the correlations between the forecast errors. I also study the underlying Impulse Response Functions (IRFs).

4.2.2  **Is the geographical mobility channel present in aggregate data?**

This subsection discusses the extent to which there is support in the aggregate data for the proposed geographical mobility channel. I analyze raw data and transformed data, using the methods that were discussed in the previous subsection.

If the geographical mobility channel is relevant, what cyclical patterns would one expect to see? First, one would expect that during periods when house prices are low, fewer homes are sold. At the same time, one would expect to see a fall in unemployment outflow rates during those periods. Moreover, the geographical mobility channel relies crucially on variations in the efficiency of labor market matching. Thus, one would expect measures of labor market efficiency to decline when house prices fall. Finally, one could expect comovements between housing and labor market variables to be particularly strong when conditioning on shocks that arise in housing markets.

**Raw data.**  Panels A and B of Figure 4.2 display the real house price and the number of home sales, respectively, for the period since 1970. Both variables are upward trending and display cyclical fluctuations. Two major boom-bust episodes in home sales stand out. The first boom began around 1975 and was associated with a run-up in house prices. The subsequent bust in the number of home sales started around the time Paul Volcker initiated his disinflationary monetary policy, and was accompanied by a moderate decline in house prices. The second boom seems to have started around the year 2000, and resulted in a bust that started around 2005.
Figure 4.2: Raw data series.

A. real house price index

B. number of home sales

C. unemployment outflow hazard

D. unemployment rate

E. vacancy index

Notes: Quarterly observations. Monthly series for house prices, home sales, the unemployment rate and the vacancy index were converted into quarterly series by simple averaging. Sources: see main text.
At the very end of the sample, there is a brief spike in home sales, which seems related to the Home Buyer Tax Credit program, that applied to homes purchased between January 1, 2009 and May 1, 2010.

The unemployment outflow hazard, the unemployment rate and the vacancy index are plotted in panels C, D, and E of Figure 4-2. The cyclical fluctuations in these variables seem much related to those in home sales during several episodes. An exception is the period from 2001 until 2004, when home sales increased but the outflow hazard fell. The unemployment rate reached its highest level during the two housing busts discussed above, and the increase in the unemployment rate during recent years was particularly sharp. Note that during the run-up in unemployment in the last year of the sample, vacancies no longer declined. The unemployment outflow hazard, however, declined to a level that is by far the lowest in the sample.

Cyclical components. The cyclical components of the real house price and the number of home sales are plotted in Panel A of Figure 4-3. Home sales are more volatile than the real house price and there is a positive comovement between the two variables. During the most recent boom-bust episode, the comovement between house prices and home sales seems to have been particularly strong, except for the final spike in home sales. Panel B of Figure 4-3 displays the cyclical components of home sales and the unemployment outflow hazard and shows that the two variables are positively correlated.

The cyclical properties of the series are characterized more systematically in Table 4.1, which reports the volatilities of GDP, home sales, the unemployment rate, vacancies, and the unemployment outflow hazard, relative to the volatility of the real house price. Home sales are more volatile than the real house price. The real house price, in turn, is more volatile than GDP. The unemployment rate, vacancies and the unemployment outflow hazard are somewhat more volatile than home sales.

Table 4.1 also displays the correlations between the above mentioned variables. Home sales are positively correlated with the real house price. Moreover, both house prices
Figure 4.3: Cyclical components.

Notes: Log deviations from trend. Following Shimer (2005), variables are HP-detrended with smoothing parameter value $10^5$. The vertical lines above (below) the x-axes denote business cycle peaks (troughs) as dated by the NBER.
Table 4.1: Standard deviations and correlations: data.

<table>
<thead>
<tr>
<th></th>
<th>house pr.</th>
<th>GDP</th>
<th>home sales</th>
<th>unemp. rate</th>
<th>vacancies</th>
<th>outfl. haz.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard deviations relative to house price</td>
<td>1</td>
<td>0.368</td>
<td>2.445</td>
<td>2.675</td>
<td>3.008</td>
<td>2.524</td>
</tr>
<tr>
<td>Correlations</td>
<td>house pr.</td>
<td>GDP</td>
<td>home sales</td>
<td>unemp. rate</td>
<td>vacancies</td>
<td>outfl. haz.</td>
</tr>
<tr>
<td>gdp</td>
<td>0.554</td>
<td>1</td>
<td>0.552</td>
<td>0.608</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>home sales</td>
<td>0.552</td>
<td>1</td>
<td>0.608</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>unemployment rate</td>
<td>−0.437</td>
<td>−0.858</td>
<td>−0.331</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>vacancies</td>
<td>0.400</td>
<td>0.819</td>
<td>0.472</td>
<td>−0.895</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>unemp. outflow hazard</td>
<td>0.464</td>
<td>0.861</td>
<td>0.360</td>
<td>−0.966</td>
<td>0.888</td>
<td>1</td>
</tr>
</tbody>
</table>

Notes: Data are quarterly. Following Shimer (2005), variables are logged and HP-detrended with smoothing parameter value $10^5$.

and home sales are positively correlated with output, vacancies and the outflow hazard, and negatively with the unemployment rate. These patterns are consistent with the geographical mobility channel. The estimated reduced-form VAR allows one to construct alternative comovement measures that do not rely on the HP filter. Table 4.2 displays the correlations of the forecast errors for the real house price, home sales and the outflow hazard, as implied by the VAR and at different forecast horizons. This comovement measure does not depend on the identification of the shocks.\(^\text{10}\) There is a positive correlation between all three variables, as for the cyclical components constructed using the HP filter.

**Conditioning on housing market shocks.** An advantage of the VAR-based comovement measures is that they can be recalculated conditional on housing market shocks.\(^\text{11}\) The conditional correlations are displayed in the bottom half of Table 4.2. The positive correlation between house prices and home sales is slightly weaker than unconditionally, but the correlations between home sales and the outflow hazard, and between the real house price and the outflow hazard, are substantially higher. For example, the correlation

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\(^{10}\) As described by den Haan (2000), the comovement measure is constructed as the cumulative product of Impulse Response Functions, summed over all shocks.

\(^{11}\) It can be shown that given the identification strategy outlined above, these measures does not depend on the whether home sales or the real house price is ordered first.
Table 4.2: Correlations of forecast errors implied by the VAR.

<table>
<thead>
<tr>
<th></th>
<th>1 year ahead</th>
<th>3 years ahead</th>
<th>5 years ahead</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RHP</td>
<td>HS</td>
<td>RHP</td>
</tr>
<tr>
<td>A. Unconditional</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>real house price (RHP)</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>home sales (HS)</td>
<td>0.619</td>
<td>1</td>
<td>0.510</td>
</tr>
<tr>
<td>unemployment outflow hazard</td>
<td>0.308</td>
<td>0.404</td>
<td>0.584</td>
</tr>
<tr>
<td>B. Conditional on housing shocks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>real house price (RHP)</td>
<td>1</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>home sales (HS)</td>
<td>0.596</td>
<td>1</td>
<td>0.467</td>
</tr>
<tr>
<td>unemployment outflow hazard</td>
<td>0.633</td>
<td>0.719</td>
<td>0.895</td>
</tr>
</tbody>
</table>

Notes: Following den Haan (2000), the unconditional measure of comovement between two variables is constructed as the products of their IRFs, summed over all nine shocks. The conditional comovement measure is constructed by summing only over the two housing market shocks.

between home sales and the outflow hazard is 0.72 at a one year forecast horizon, while unconditionally it is only 0.40.

Figure 4.4 shows the dynamic responses to a joint shock in house prices and home sales of one standard deviation. A negative shock leads to significant declines in house prices, home sales and the unemployment outflow hazard. Consumer prices, stock prices, industrial production and the federal funds rate also fall, while the unemployment rate increases.

More insight in the effects of housing market disturbances on the labor market matching process can be obtained by imposing a minimal degree of additional structure. Suppose that unemployed workers and firms are matched according to a function that has a (standard) Cobb-Douglas form:

\[ f(n_{u,t}, v_t) = \mu n_{u,t}^{\eta} v_t^{1-\eta}, \]

where \( f(n_{u,t}, v_t) \) is the number of matches, \( n_{u,t} \) is the unemployment rate, \( v_t \) is the number

\[ ^{12} I consider a joint shock for the sake of a parsimonious presentation. In Appendix 4.A it is documented that the individual responses to a house price and a home sales shock are very similar. \]
Figure 4.4: Structural VAR: housing market shock.

Notes: Responses to a joint and negative one standard deviation shock in real house prices and homesales. Grey areas are 90% confidence intervals, which are obtained by a bootstrap procedure.
**Figure 4.5:** Structural VAR: housing market shock. Unemployment outflow hazard implied by the matching function versus the actual outflow hazard.

Notes: Responses to a joint and negative one standard deviation shock in real house prices and homesales. VAR responses are plotted for the unemployment outflow hazard and the job finding probability implied by a matching function of the form 

\[ f(n_{u,t}, v_t) = \mu n_{u,t}^\eta v_t^{1-\eta}, \]

for various values of \( \eta \).

of vacancies, \( \eta \) is the elasticity of matches with respect to the unemployment rate and \( \mu \) is a scale parameter. For any given value of \( \eta \), one can evaluate the response of \( f(n_{u,t}, v_t) \) to a housing market shock, given the responses for the unemployment rate and vacancies. Petrongolo and Pissarides (2001) conclude that plausible values for \( \eta \) are between 0.5 and 0.7.$^{13}$

Figure 4.5 plots the response of the job finding probability implied by the matching function, \( f(n_{u,t}, v_t) / n_{u,t} \), for the two extremes of the range for \( \eta \), and also plots the actual unemployment outflow hazard. For \( \eta = 0.7 \), the overall decline outflow hazard predicted by the matching function is much smaller than the decline in the actual unemployment

$^{13}$Running a simple OLS regression of the log outflow hazard on a constant and the log of the vacancy-unemployment ration results in an estimate for \( \eta \) of 0.57. The value of the scale parameter \( \mu \) is irrelevant for this exercise.
outflow hazard. For \( \eta = 0.5 \), the initial declines in the two variables are similar, but the outflow rate declines more persistently than the decline predicted by the responses of unemployment and vacancies. These results provide evidence for a reduction in matching efficiency after negative housing shocks, although the evidence is particularly convincing for high values of \( \eta \).

### 4.3 The geographical mobility channel in general equilibrium

In this section, I describe the theoretical business cycle model.

#### 4.3.1 Main features of the model

Three main ingredients allow the model to capture the geographical mobility channel. First, agents are geographically mobile. Mobility decisions are integrated into their intertemporal optimization problems and are affected by both aggregate and individual conditions.

The second ingredient is a financial friction on the side of households, in the spirit of Kiyotaki and Moore (1997) and Iacoviello (2005). In their models, borrowing is limited by the value of the underlying collateral and debt contracts are renewed in each period. A consequence of this modeling choice is that a decline in the price of collateral affects the debt limits of all borrowers in the economy. But in reality, borrowers who do not refinance their loans are typically not affected when house prices fall.

A key innovation of my model is that collateral requirements apply only to new mortgages, which are taken out at the moment that an agent moves. For existing mortgages, debt is simply limited not to exceed the amount of the previous period.\(^{14}\) Precisely this feature generates a decline in mobility when house prices fall. Consider for example a fall

\(^{14}\)As a consequence, my constraint does not allow non-movers to increase debt after house prices increase. Allowing for home equity loans would introduce a nonlinearity that creates severe difficulties when solving the model. Note, however, that the key aspect of the proposed geographical mobility channel is that agents can protect their debt limits from declines in house prices by not moving.
in house prices that is so large that borrowers’ home equity levels shrink to zero. Without any wealth left, it becomes nearly impossible for agents to provide the downpayment required for a new mortgage loan, even a small one. However, when the agent decides not to move there is no renewed downpayment requirement, so the agent can sustain her current level of debt without problems. Consequently, moving is very unattractive in this situation.\footnote{My model abstracts from mortgage default. But note that homeowners who default are likely to have difficulties in getting a new mortgage for an even longer period of time.}

The final main ingredient of the model is a friction in the labor market. As in Pissarides (2000), unemployed agents search for vacancies and occasionally receive a job offer. But a fraction of those job offers can only be accepted if the agent moves, as commuting would be infeasible. When moving is sufficiently unattractive, e.g. because of difficulties in obtaining a new mortgage loan, the job offer is rejected and the agent continues searching for job offers.

\subsection*{4.3.2 Model description}

The model economy is populated by a continuum of households of unit mass. There are two types of households: impatient and patient households. In equilibrium, the impatient households borrow from the patient ones, but borrowing is restricted by a refinancing constraint. Each of the two representative households consists of a continuum of members, who are either employed or unemployed.\footnote{This construct was introduced by Merz (1995) and was followed by others, including Gertler and Trigari (2009). According to this setup, agents are fully insured against fluctuations in consumption that arise from idiosyncratic shocks. What follows is a framework with a representative saver and a representative borrower.} In each period, a certain fraction of the members moves and the household pays a fixed moving cost for each of those members. The desire to move depends on the degrees of satisfaction of members with their current locations, which are idiosyncratic and stochastic. So moving costs are only worth paying for those members who are sufficiently dissatisfied with their current locations.

Employment relationships are destroyed at an exogenous rate, after production has
taken place during the period. A member whose job gets destroyed in period $t$, can search for a job in the same period and may have a new job in period $t+1$ without becoming unproductive. If not, the member becomes unemployed in period $t+1$ and continues searching. The total number of meetings between workers and firms is determined by a standard matching function, depending on the aggregate number of job searchers and the number of vacancies. However, a fixed fraction of all meetings can only result in a productive relationship if the member moves. This captures the job offers from regions other than in which the worker resides.\footnote{For reasons of simplicity, geographic locations are not explicitly modeled, although one could think of the model as one with a continuum of locations that are a priori identical to agents. But note that the proposed framework is consistent with two essential aspects of the geographical mobility channel, namely that (i) moving necessitates refinancing a mortgage and (ii) in some cases moving is required to accept a job offer.} When moving is sufficiently unattractive, the job offer is turned down and the member remains unemployed.

To impatient households, there is one additional factor affecting mobility decisions, namely the effect of mobility on the borrowing capacity of the household. The fraction of debt that the household has to refinance is equal to the fraction of its members moving to a new location. After a fall in house prices, refinancing is hard to accomplish, which creates a barrier to geographical mobility.

\textbf{Impatient households}

The impatient households maximize the following objective function:

$$E_0 \sum_{t=0}^{\infty} \beta^t \left\{ \ln c_t + \alpha z_{h,t} \ln h_t + \kappa n_{u,t} + u_{lo,t} \right\},$$

where $\beta$ is their discount factor, $c_t$ is non-durable consumption, $h_t$ is the stock of housing, $\alpha$ is a housing preference parameter, $z_{h,t}$ is a housing preference shock, $n_{u,t}$ is the fraction of unemployed members, each generating a utility flow $\kappa$ arising from time spent at home. Finally, $u_{lo,t}$ is a utility flow term that stems from the degree of satisfaction of the household members with their locations of residence, which will be specified below.
**Consumption and borrowing decisions.** Each period, households decide on the amount of non-durable consumption, housing and borrowing. In doing so, they are restricted by the following budget constraint:

\[ c_t + p_{h,t} (h_t - h_{t-1}) + \zeta n_{m,t} + R_{t-1} d_{t-1} = (1 - n_{u,t}) y_t + d_t, \]

(4.2)

where \( p_{h,t} \) is the house prices in units of non-durables, \( \zeta \) is the fixed cost of moving a member, \( n_{m,t} \) is the fraction of members that moves, \( R_t \) is the gross interest rate on debt to be repaid in period \( t+1 \), \( y_t \) is wage income per employed member, and \( d_t \) is the amount of debt.\(^{18}\) So income consists of wage income, new debt and the sales value of the housing stock of the previous period, and income is spent on non-durable consumption, housing, moving costs, and servicing of old debt.

Debt is limited by the following refinancing constraint:

\[ d_t \leq n_{m,t} \chi p_{h,t} h_t + (1 - n_{m,t}) d_{t-1}. \]

(4.3)

The important feature of this constraint is that the fraction of debt that is refinanced depends on the mobility rate, \( n_{m,t} \). If all members move, that is when \( n_{m,t} = 1 \), all debt is refinanced and the constraint reduces to a standard collateral constraint. In that case, the household can borrow up to \( \chi p_{h,t} h_t \), that is, up to a fraction \( \chi \) of the value of the housing stock. If none of the members moves, that is when \( n_{m,t} = 0 \), the household can borrow up the amount of the previous period, that is up to \( d_{t-1} \).\(^{19}\) For a given housing stock, \( h_t \), a decline in the house price \( p_{h,t} \) lowers \( \chi p_{h,t} h_t \) relative to \( d_{t-1} \). This makes moving less attractive. Note that in the steady state, the borrowing constraint reduces to a standard collateral constraint. Given the presence of patient households with a higher

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\(^{18}\)I limit the attention to loans with variable interest rates, so refinancing only involves the enforcement of a renewed collateral constraint.

\(^{19}\)Campbell and Hercowitz (2009) consider a model in which debt also evolves in a recursive way. In their model, however, the weight of old debt in the constraint depends on a fixed amortization rate. In my model, it depends on the mobility rate, which is a choice variable.
discount factor, this constraint binds in the steady state. In order to be able to solve the model using a perturbation method, I following the literature by limiting the attention to shocks that are small enough for the constraint not to become unbinding.  

The first-order conditions for the amount of housing and debt are given by:

\[
\frac{p_{h,t}}{c_t} = \frac{\alpha z_{h,t}}{h_t} + \beta E_t \frac{p_{h,t+1}}{c_{t+1}} + \lambda_{cc,t} n_{m,t} \chi p_{h,t},
\]

\[
\frac{1}{c_t} = \beta E_t \left( \frac{R_t}{c_{t+1}} - \lambda_{cc,t+1} (1 - n_{m,t+1}) \right) + \lambda_{cc,t}.
\]

Equation (4.4) is the first-order condition for the amount of housing consumed by the household. The right hand side is the shadow value of housing, which consists of three terms. The first term captures the direct utility gain derived from a marginal unit of housing. The second term is the utility derived from the discounted resale value of the house in the next period. The third term is proportional to the Lagrange multiplier of the borrowing constraint, \(\lambda_{cc,t}\), the real house price \(p_{h,t}\), and the mobility rate \(n_{m,t}\). It captures the additional borrowing capacity that an extra unit of housing generates. If the borrowing constraint is not binding or if no member moves, this term reduces to zero. Equation (4.4) states that at the optimum, the shadow value of housing must be equal to the utility derived from \(p_{h,t}\) marginal units of non-durables. Equation (4.5) is the Euler equation for debt. A binding borrowing constraint introduces a wedge in this equation. The second term within the conditional expectation represents the fact that of the new debt taken on in period \(t\), only a fraction \(n_{m,t+1}\) will be refinanced in period \(t + 1\). The remaining debt is rolled over to period \(t + 2\).

**Location preferences.** Geographical mobility is an essential feature of the model. Naturally, mobility decisions are affected by a number of factors. The focus of this chapter is on considerations regarding employment and borrowing. However, mobility decisions also

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\(^{20}\)For a discussion on this issue, see Iacoviello (2005).

\(^{21}\)The optimality conditions for the impatient households are derived in Appendix 4.B.
depend on more private factors, such as changes in family composition or changes in the degree satisfaction with the neighborhood. In order for the model to generate realistic overall mobility rates, these considerations need to be taken into account as well.

The setup is as follows. For each individual member $j$, an idiosyncratic location satisfaction shock $\varepsilon_{j,t}$ is observed during period $t$.\textsuperscript{22} This shock represents the private factors that affect how willing somebody is to move.\textsuperscript{23} For members that do not move, the realization of $\varepsilon_{j,t}$ is received as a utility flow, while each mover generates a fixed utility flow $\psi$ instead.\textsuperscript{24} So for members with a low realization of $\varepsilon_{j,t}$, moving is relatively attractive. For those members that receive a "long-distance job offer", moving has an additional benefit, namely that it enables them to get out of unemployment.

The optimal mobility decision implies a cutoff level for the location satisfaction shock. If the realization of this idiosyncratic shock is below the cutoff level, the member moves, while the member does not move if the realization is above the cutoff level. So the cutoff level represents the location satisfaction of the marginal mover, being exactly indifferent between moving and not moving. Although there may in principle be different cutoff levels for different agents, depending on individual characteristics such as wealth and labor income, the advantage of the complete markets framework adopted here is that there will be only two such values: one for members with a long-distance job offer, denoted by $\varepsilon_{do,t}$, and one for those without such an offer, denoted by $\varepsilon_t$. Let $F(\cdot)$ be the cumulative distribution function of the shock. Thus, $F(\varepsilon_{do,t})$ is the mobility rate among members with a long-distance job offer and $F(\varepsilon_t)$ is mobility rate among the members without such a job offer. It follows from this setup that the total location satisfaction utility term

\textsuperscript{22} For simplicity, I assume that this location satisfaction shock is i.i.d. across time and members.

\textsuperscript{23} Stein (1995) and Ngai and Tenreyro (2009) consider similar shocks.

\textsuperscript{24} Alternatively, one could consider a model in which $\psi$ is stochastic and $\varepsilon$ is fixed, or a model in which both variables are stochastic. However, this would result in an observationally equivalent models under the distributional assumptions made in this paper. The reason is that what truly matters is the distribution of the difference between $\varepsilon_j$ and $\psi$. 
in equation (4.1) is given by

\[ u_{lo,t} = n_{do,t} \left[ \psi F(\varepsilon_{do,t}) + \int_{\varepsilon_{do,t}}^{\infty} \varepsilon dF(\varepsilon) \right] + (1 - n_{do,t}) \left[ \psi F(\varepsilon_t) + \int_{\varepsilon_t}^{\infty} \varepsilon dF(\varepsilon) \right], \]

where \( n_{do,t} \) is the fraction of members with a long-distance job offer.

**Mobility decisions.** The two cutoff levels that determine the mobility rate are chosen optimally by the household. This decision is taken at the beginning of the period, jointly with consumption and borrowing decisions.\(^{25}\) The corresponding first-order conditions are:

\[ \psi = \frac{\zeta}{c_t} + \varepsilon_t - \lambda_{ct} (\chi p_{h,t} h_t - d_{t-1}), \quad (4.6) \]

\[ \bar{\varepsilon}_{do,t} - \varepsilon_t = \frac{y_h}{c_t} - \kappa + (1 - \rho_u) G_t, \quad (4.7) \]

Equation (4.6) is the first-order condition for \( \varepsilon_t \), the moving cutoff for members without a long-distance job offer. The left- and the right-hand side of this equation are, respectively, the benefits and costs of moving, for a member who is exactly indifferent between moving and staying. On the left-hand side, \( \psi \) is the utility flow that is received for being at a new location. On the right-hand side, the first term is the utility loss arising from paying the moving cost \( \zeta \). The second term, \( \varepsilon_t \), is the utility flow received when staying at the current location, which is foregone when moving. The third term arises from the effect of mobility on the borrowing capacity of the household and can be either positive or negative. If the borrowing limit on old loans exceeds the borrowing limit on new loans, that is when \( \chi p_{h,t} h_t < d_{t-1} \), there is an additional cost to mobility.

Equation (4.7) determines the cutoff level for members with a long-distance job offer, \( \bar{\varepsilon}_{do,t} \), relative to the cutoff for members without a long-distance offer. The difference between \( \bar{\varepsilon}_{do,t} \) and \( \varepsilon_t \) is determined by two factors. The first factor is the difference in

\(^{25}\)When mobility decisions are taken, it is known what members have what type of job offers, because offers were received at the end of the previous period.
utility gains from the wage income of an employed member, $y_t/c_t$, and the utility flow from unemployment, $\kappa$. The second factor stems from a dynamic composition effect. If more members with a long-distance job offer move, more members flow into employment, and this positively affects the fraction of members that is employed in future periods. This effect is captured by $G_t$, which is defined in the appendix.

Equations (4.6) and (4.7) are essential in understanding the direct mechanism through which fluctuations in house prices affect real activity. Equation (4.6) reveals a direct and inverse relation between house prices and mobility among members without a long-distance job offer. Ceteris paribus, a decline in the house price, $p_{h,t}$, must be offset by a decline in the cutoff, $\bar{\epsilon}_t$. Recall that members move when their individual location satisfaction is below the cutoff. Thus, with a lower cutoff, mobility declines. Equation (4.7) shows that, ceteris paribus, a decline in $\bar{\epsilon}_t$ also leads to a decline in the cutoff for members with a long-distance job offer, $\bar{\epsilon}_{do,t}$. When mobility of members with long-distance job offers declines, a larger fraction of job offers is turned down, pushing up unemployment.

**Flow equations.** The mobility rate among household members, $n_{m,t}$, follows from the mobility cutoffs, and is given by

$$n_{m,t} = n_{do,t} F(\bar{\epsilon}_{do,t}) + (1 - n_{do,t}) F(\bar{\epsilon}_t). \quad (4.8)$$

The fraction of members with a long-distance job offer, $n_{do,t}$, is determined by

$$n_{do,t} = \omega \hat{g}_{t-1} n_{s,t}. \quad (4.9)$$

Here, $\hat{g}_t$ is the probability that an unemployed member meets a firm and gets a job offer, $\omega$ is the fraction of all meetings in which a member is required to move to accept the offer,
and $n_{s,t}$ is the fraction of members that is searching for a job, which is:

$$n_{s,t} = n_{u,t} + \rho_u \left(1 - n_{u,t}\right), \quad (4.10)$$

where $\rho_u$ is the exogenous job destruction rate. So the group of job searchers consists of the members that are unemployed and the employed members who just became obsolete at their current job. The fraction of unemployed members is equal to the fraction of job searchers of the previous period that did not receive a job offer, or that did receive a job offer but rejects it because moving is too unattractive:

$$n_{u,t} = n_{s,t-1} \left(1 - \hat{g}_{t-1} + \omega \hat{g}_{t-1} \left(1 - F (\bar{z}_{do,t})\right)\right). \quad (4.11)$$

**Patient households**

Patient households are the same as impatient households, except that their discount factor, $\gamma$, is higher than the discount factor of the impatient households, $\beta$. In equilibrium, patient households therefore lend to the impatient households and as a consequence the borrowing constraint is not relevant to the patient households. Also, patient households own the firms and receive their profits.

The first-order conditions for the patient households are the same as those for the impatient households, with the important difference that for the patient households, the Lagrange multiplier on the borrowing constraint is zero at all times. Let the variables of the patient households be denoted by a tilde. The first-order condition for the moving cutoff for members of the patient household without a distant job offer, $\tilde{z}_t$, is:

$$\psi = \frac{\zeta}{c_t} + \tilde{z}_t. \quad (4.12)$$

So for patient households, house prices are not directly relevant for mobility decisions. All fluctuations in this cutoff arise from fluctuations in the willingness of patient households...
to pay the moving cost \( \zeta \).

**Labor market**

Let aggregate variables be denoted by a hat, and let \( \nu \) be the share of impatient households in the total population. The aggregate unemployment rate, and the aggregate number of job searchers are, respectively, given by

\[
\hat{n}_{u,t} = \nu n_{u,t} + (1 - \nu) \tilde{n}_{u,t},
\]

and

\[
\hat{n}_{s,t} = \nu n_{s,t} + (1 - \nu) \tilde{n}_{s,t}.
\]

The labor market is characterized by a matching friction. The aggregate number of meetings between firms and job candidates \( \hat{m}_t \) is a Cobb-Douglas function of the total number of job searchers and the aggregate number of vacancies, \( \hat{v}_t \):

\[
\hat{m}_t = \mu \hat{n}_{s,t}^{\eta} \hat{v}_t^{1-\eta},
\]

where \( \eta \) is again the elasticity parameter, and \( \mu \) the scale parameter. The probability that a job searcher meets with a firm is:

\[
\hat{g}_t = \frac{\hat{m}_t}{\hat{n}_{s,t}}.
\]

The probability for a firm with a vacancy of meeting with a worker is:

\[
\hat{g}_{f,t} = \frac{\hat{m}_t}{\hat{v}_t}.
\]
Firms

Firms that are matched to a worker produce $z_{a,t}$ per period, where $z_{a,t}$ is an exogenous productivity process with a steady-state level equal to one. The wage is simply a share $\xi$ of total revenues, that is $y_t = \xi z_{a,t}$. The firm receives the remaining share $1 - \xi$.\footnote{I deviate from the more standard assumption that firms and workers bargain over the surplus that is created by an employment relationship. Instead, I assume that firms post wage contracts in which the worker gets a fixed fraction of the revenues. This setup makes the model tractable but also seems reasonable, given that in this model the total surplus of the match is affected by the utility derived from mobility. It seems implausible that firms would be able to observe the entire surplus and engage in bargaining over it.} Since firms are owned by the patient households, they discount future profits using the stochastic discount factor of those households. To firms, the asset value of a match, $V_t$, is:

$$V_t = (1 - \xi) z_{a,t} + (1 - \rho_u) E_t \tilde{\Lambda}_{t,t+1} V_{t+1}, \quad (4.18)$$

where $\tilde{\Lambda}_{t,t+1}$ is the stochastic factor of the patient households, that is,

$$\tilde{\Lambda}_{t,t+1} = \gamma \frac{\tilde{c}_t}{c_{t+1}}. \quad (4.19)$$

Firms that search for employees pay a vacancy cost $\vartheta$ per period. Free entry of firms in the goods market implies that the vacancy cost equals the expected benefit to the firm of posting a vacancy:

$$\vartheta = \tilde{g}_{f,t} \left( 1 - \omega + \omega \frac{\nu n_{s,t}}{\bar{n}_{s,t}} F \left( \bar{z}_{do,t+1} \right) + \omega \frac{1 - \nu}{\bar{n}_{s,t}} F \left( \bar{z}_{do,t+1} \right) \right) \tilde{\Lambda}_{t,t+1} V_{t+1}. \quad (4.20)$$

The term between large brackets in the free-entry condition is the fraction of meetings that is unsuccessful because the worker is unwilling to move. Aggregate firm profits are given by:

$$\tilde{\Pi}_t = (1 - \tilde{n}_{u,t}) (1 - \xi) z_{a,t} - \vartheta \tilde{c}_t. \quad (4.21)$$
Exogenous processes

The housing preference shock and the productivity shock are common to all agents and evolve according to the following laws of motion:

\[
\ln z_{h,t} = \rho_h \ln z_{h,t-1} + \varepsilon_{h,t},
\]
\[
\ln z_{a,t} = \rho_z \ln z_{a,t-1} + \varepsilon_{a,t},
\]

where \(\varepsilon_{h,t}\) and \(\varepsilon_{a,t}\) are i.i.d. innovations that are normally distributed, with mean zero and standard deviations \(\sigma_h\) and \(\sigma_a\), respectively.

Equilibrium

The supply of the total stock of housing is fixed and normalized to one. The housing market clearing condition is:

\[
\nu h_t + (1 - \nu) \tilde{h}_t = 1. \tag{4.22}
\]

Financial market clearing requires that aggregate debt is zero:

\[
\nu d_t + (1 - \nu) \tilde{d}_t = 0. \tag{4.23}
\]

Let \(\Xi_t\) denote the vector of variables that summarizes the economic state, which is given by \(\Xi_t = [g_{t-1} n_{s,t-1}, g_{t-1} \tilde{n}_{s,t-1}, d_{t-1} R_{t-1}, h_t, z_{h,t}, z_{a,t}]'\). A competitive equilibrium is defined by a set of functions for:

- non-durable consumption, housing and borrowing: \(c(\Xi_t), \tilde{c}(\Xi_t), h(\Xi_t), \tilde{h}(\Xi_t), d(\Xi_t), \tilde{d}(\Xi_t), \lambda_{cc}(\Xi_t)\),
- cutoff values for mobility: \(\tilde{\tau}(\Xi_t), \tilde{\tau}_{do}(\Xi_t), \tilde{\tau}_{do}(\Xi_t)\),
- rates of mobility, unemployment, job searchers, and members with long-distance job offers: \(n_{m}(\Xi_t), \tilde{n}_{m}(\Xi_t), n_u(\Xi_t), \tilde{n}_u(\Xi_t), \tilde{n}_u(\Xi_t), n_s(\Xi_t), \tilde{n}_s(\Xi_t), \tilde{n}_d(\Xi_t), \tilde{n}_{do}(\Xi_t), \tilde{n}_{do}(\Xi_t)\),
\[ \hat{n}_s(\Xi_t) , \]

- labor market matching variables: \( \hat{m}(\Xi_t) , \hat{g}(\Xi_t) , \hat{g}_f(\Xi_t) , \hat{v}(\Xi_t) , \)

- firm variables: \( \hat{V}(\Xi_t) , \hat{\Pi}(\Xi_t) , \hat{\Lambda}_{+1}(\Xi_t) , \)

- and market-clearing prices: \( p_h(\Xi_t) \) and \( R(\Xi_t) \).

These functions must satisfy the optimality conditions for the impatient households (4.2)-(4.11), the equivalent conditions for the patient households (9 equations), labor market equations (4.13)-(4.17), equations for the firms (4.18)-(4.21), and the housing and bond market clearing conditions (4.22)-(4.23). This gives a system of 30 equations in 30 endogenous variables.

### 4.3.3 Calibration

The model is calibrated to U.S. data. The frequency is monthly. Several parameters are calibrated to pin down essential steady-state properties of the model and one parameter is calibrated to match the volatility of home sales.

### Steady-state targets

The calibration procedure targets six steady-state properties of the model. First, the aggregate unemployment rate in the steady state is five percent. Second, the steady-state aggregate mobility rate is 0.65 percent per month. This corresponds to an annual mobility rate of 7.5 percent, as measured for US homeowners using data from the Current Population Survey (CPS) for the period 2000-2005. Third, the steady-state mobility rate due to members with long-distance job offers is 0.10 percent per month. This choice is based data from the CPS for the period 2000-2005 as well. On average, about 15 percent of the owners who had moved, indicated that the move was primarily for employment reasons. Fourth, the steady-state value of housing wealth is 140 percent of annual out-
Table 4.3: Parameter theoretical model (benchmark calibration).

<table>
<thead>
<tr>
<th>parameter</th>
<th>description</th>
<th>value</th>
<th>source/target</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta$</td>
<td>discount factor impatient h.h.</td>
<td>0.9899</td>
<td>Iacoviello and Neri (2009)</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>discount factor patient h.h.</td>
<td>0.9975</td>
<td>Iacoviello and Neri (2009)</td>
</tr>
<tr>
<td>$\alpha^{imp}$</td>
<td>housing pref. impatient h.h.</td>
<td>0.139</td>
<td>steady state</td>
</tr>
<tr>
<td>$\alpha^{pat}$</td>
<td>housing pref. patient h.h.</td>
<td>0.043</td>
<td>steady state</td>
</tr>
<tr>
<td>$\psi$</td>
<td>utility from new location</td>
<td>-7.905</td>
<td>steady state</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>stddev. location preference shock</td>
<td>3.5</td>
<td>volatility mobility</td>
</tr>
<tr>
<td>$\zeta$</td>
<td>moving cost</td>
<td>1.6</td>
<td>Stokey (2009)</td>
</tr>
<tr>
<td>$\rho_u$</td>
<td>rate of job destruction</td>
<td>0.035</td>
<td>Gertler and Trigari (2009)</td>
</tr>
<tr>
<td>$\eta$</td>
<td>elasticity parameter matching function</td>
<td>0.5</td>
<td>Gertler and Trigari (2009)</td>
</tr>
<tr>
<td>$\mu$</td>
<td>level parameter matching function</td>
<td>0.536</td>
<td>steady state</td>
</tr>
<tr>
<td>$\vartheta$</td>
<td>vacancy cost</td>
<td>0.181</td>
<td>steady state</td>
</tr>
<tr>
<td>$\omega$</td>
<td>fraction of long-distance job offers</td>
<td>1/3</td>
<td>no source, check for robustness</td>
</tr>
<tr>
<td>$\xi$</td>
<td>wage rule parameter</td>
<td>0.98</td>
<td>2% accounting profits</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>utility from unemployment</td>
<td>-4.898</td>
<td>steady state</td>
</tr>
<tr>
<td>$\nu$</td>
<td>share impatient h.h.</td>
<td>0.2</td>
<td>AHS / SCF data</td>
</tr>
<tr>
<td>$\chi$</td>
<td>collateral requirement</td>
<td>0.8</td>
<td>Campbell and Hercowitz (2009)</td>
</tr>
<tr>
<td>$\rho_h$</td>
<td>autocorr. housing pref. process</td>
<td>0.983</td>
<td>same as tech. process</td>
</tr>
<tr>
<td>$\rho_a$</td>
<td>autocorr. technology process</td>
<td>0.983</td>
<td>Kydland and Prescott (1982)</td>
</tr>
</tbody>
</table>

Fifth, the credit-constrained households consume the same amount of housing in the steady state as the patient households. Sixth, the probability that a vacancy is filled is 0.34 in the steady state. This implies a quarterly probability of 0.71, as in den Haan, Ramey, and Watson (2000).

Parameter values

The parameter values are presented in Table 4.3 and are discussed below.

---

27This choice follows Iacoviello (2005) and is based on data from the Flow of Funds.
28This choice is supported by data from the According to the American Household Survey 2007. For households with the very lowest downpayment ratios (up to five percent), the median home value is below the median home value for the total sample of homeowners. However, the median home value for households with a downpayment ratio between six and twenty percent is higher than the median for the total sample.
29Note that when the steady-state value of the housing stock owned by patient households is pinned down, the borrowing constraint determines the steady-state level of mortgage debt. The steady-state level of aggregate debt relative to aggregate income is 22.4 percent.
Preferences and moving technology. The calibration of the discount factors for patient and impatient households follows Iacoviello and Neri (2009). The discount factor of the patient households, $\gamma$, is set to 0.9975, which implies a steady-state real interest rate of about three percent per annum. The discount factor of the impatient households, $\beta$, is set to 0.9899.

The weight of housing in the utility function, $\alpha$, is set differently for patient and impatient households. The values follow from the steady-state targeting procedure described above. The value for the patient and impatient households are 0.043 and 0.139, respectively. The relatively high value for the impatient households is a direct consequence of the requirement that both types of households consume the same amount of housing in the steady state.\footnote{Note that impatient households discount the future resale benefits from housing more heavily than patient households. This would lead them to consume much less housing in the steady state than the patient households. As a consequence, the steady state level of debt of the impatient households would be unrealistically low.}

The idiosyncratic location satisfaction shock is calibrated to be normally distributed with mean zero and standard deviation $\sigma$. The standard deviation is important for the volatility of geographical mobility. A lower value of $\sigma$ means that preferences for household members’ current locations are less spread out. I choose the value of $\sigma$ to be such that in a version of the model with only technology shocks, mobility is about 2.4 times as volatile as the real house price, corresponding to the relative volatility found in the data for home sales. This requires setting $\sigma = 3.8$.

The roles of the moving cost parameter, $\zeta$, and the utility flow from moving, $\psi$, are similar to each other. This can be seen from Equation (4.6), the first-order condition for the mobility cutoff $\pi_t$. The parameter $\zeta$ is meant to capture physical costs of moving, such as transaction costs and fees for real estate agents. Unlike the utility flow $\psi$, the effect of the physical cost depends on the marginal utility of consumption, which varies in response to shocks. Following Stokey (2009), $\zeta$ is set to eight percent of the steady-state value of a unit of housing. The parameter $\psi$ is used in the steady-state targeting procedure and
its value is -7.905.

**Labor market.** The elasticity of matches with respect to the number of job searchers, $\eta_i$, is set equal to 0.5. The job destruction probability, $\rho_u$, is set to 0.035. These values are within the range of standard values considered in the literature and follow Gertler and Trigari (2009). The values of the scale parameter in the matching function, $\mu$, and the vacancy cost, $\vartheta$, follow from the steady-state targeting procedure, and are 0.536 and 0.181, respectively. The calibration implies that in the steady state 1.86 percent of output is devoted to vacancy costs.

The fraction of long-distance job offers, $\omega$, is difficult to calibrate as there is no direct equivalent in the data. My strategy is to set $\omega$ to one third and check for robustness. Alternative values for $\omega$ turn out to generate very similar results.\(^{31}\)

The parameter $\xi$ controls the fraction of the revenues that flows to workers in the form of wages. I assume that accounting profits of the firms are two percent, that is, $\xi = 0.98$. This choice is in line with typical calibrations of matching models, see Hornstein, Krusell, and Violante (2005).\(^{32}\)

The parameter $\kappa$ measures the utility flow received per unemployed worker, and is one of the parameters that are used to match the steady-state targets. Its value is -4.898. Thus, $\kappa$ can be thought of as an unemployment stigma. The negative value for $\kappa$ contrasts with standard models with Nash bargaining, in which the parameter is typically positive-valued. However, in those models, the main role of $\kappa$ is to determine the surplus from a match, affecting the incentives for firms to post vacancies. In my model, $\kappa$ is only relevant in that it affects the incentives for unemployed workers to accept long-distance

---

\(^{31}\)The reason is that the steady-state fraction of the workers accepting long-distance job offers is a direct target of the calibration procedure.

\(^{32}\)Unlike standard models, my results are not very sensitive to this aspect of the calibration. In my model, fluctuations in profits are proportional to fluctuations in productivity. Standard models typically assume Nash bargaining. In these models, profits are proportional to the surplus of a match. How much this surplus responds to shocks depends heavily on the calibration. This, in turn, has large consequences for the volatility of vacancies and unemployment (Hagedorn and Manovskii (2008)).
Therefore, a low value of \( \kappa \) ensures that in the steady state a realistic fraction of workers moves for employment reasons.\(^{34}\)

Credit frictions. The fraction of credit-constrained households, \( \nu \), and the collateral requirement parameter, \( \chi \), are potentially very important for the dynamics of the model. In my benchmark calibration, I set \( \nu \) and \( \chi \) such as to represent average values over the period since 1970. In order to study the effects of structural changes in mortgage markets, I consider two alternative calibrations, denoted by "low-leverage economy" and "high-leverage economy".

Using data from the Survey of Consumer Finances (SCF), Campbell and Hercowitz (2009) document that during the period 1983-2001, the average equity stake in newly purchased homes declined from 22.6 percent to 16.4 percent.\(^{35}\) In the model, \( 1 - \chi \) is the equity stake in the steady state. In my benchmark calibration, I set \( \chi \) equal 0.8. For the low- and high-leverage economy, \( \chi \) is set equal to 0.75 and 0.85, respectively.

The fraction \( \nu \) is meant to capture the real-world fraction of borrowing-constrained households in the total population (including renters). Data from the SCF show that during the period 1989-2007, the fraction of households with a mortgage or home equity loan increased from 39 percent to 46 percent. But of course, not all of these households are actually constrained by a borrowing limit. In my benchmark calibration, \( \nu \) is set equal to 0.2.\(^{36}\) In the low- and high-leverage economies, I set \( \nu = 0.15 \) and \( \nu = 0.25 \), respectively, capturing an increase in the number of households that is eligible for a mortgage.

---

\(^{33}\) Note that \( \kappa \) only enters the first-order condition for the mobility cutoff for workers with a long-distance offer. Thus, in a version of the model in which unemployed workers would be able to accept all job offers without moving, the value of \( \kappa \) would be irrelevant, provided that it is low enough to ensure that unemployed workers always accept a job offer.

\(^{34}\) An important reason why the value of \( \kappa \) has to be so low, is that in the model there are complete insurance markets, and therefore unemployed agents do not suffer from lower levels of consumption than employed agents.

\(^{35}\) The average is over home purchases with an equity stake of at most fifty percent.

\(^{36}\) Data from the American Housing Survey (AHS) show that in 2007, 62 percent of all mortgagors had put in a downpayment of 15 percent or less at the time they purchased their home. Earlier observations are not available.
Exogenous shock processes. The calibration of the persistence parameter of the productivity process, $\rho_a$, follows Kydland and Prescott (1982), who set the autocorrelation coefficient of their technology process equal to 0.95 at a quarterly frequency. For my model, this implies setting $\rho_a = 0.983$, as the frequency is monthly.

The persistence parameter of the housing preference process, $\rho_h$, is difficult to measure directly in the data. But since there are few a priori reasons to expect that the housing preference process is either more or less persistent than the productivity process, I set $\rho_h$ equal to $\rho_a$.\footnote{Iacoviello and Neri (2009) estimate a model with both housing preference shocks and productivity shocks using Bayesian methods. For the autocorrelation coefficients of both shock processes, their posterior mean estimates are around 0.95 at a quarterly frequency.}

4.4 Model results

The model is solved using a first-order perturbation method and then simulated. Three types of simulations are analyzed. First, I simulate the model with random sequences of productivity shocks and calculate standard business cycle statistics, which are compared to those found in the data. Second, I discuss the dynamic responses to one-time shocks in productivity and housing preferences. Finally, I consider a series of productivity and housing preference shocks that is chosen such that the model replicates data series for output and real house prices, over the period 1970 - 2010. The main purpose of this experiment is to investigate to what extent the model can explain the puzzling dynamics of unemployment and vacancies during the aftermath of the Great Recession.

4.4.1 Business cycle statistics

The model of this chapter is very stylized in many respects. For example, the model does not feature capital investment or nominal rigidities. Although the simplicity of the model helps to highlight its essential mechanisms, it reduces the extent to which the business cycle properties of the model can be expected to match the data. Moreover, the most
Table 4.4: Standard deviations and correlations. Model with only productivity shocks.

<table>
<thead>
<tr>
<th></th>
<th>house pr.</th>
<th>output</th>
<th>mob.rate</th>
<th>unemp.rate</th>
<th>vacancies</th>
<th>outfl.haz.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard deviations</td>
<td>1</td>
<td>0.926</td>
<td>2.408</td>
<td>1.566</td>
<td>1.125</td>
<td>1.208</td>
</tr>
<tr>
<td>relative to house price</td>
<td>(0)</td>
<td>(0.006)</td>
<td>(0.136)</td>
<td>(0.024)</td>
<td>(0.041)</td>
<td>(0.007)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>house pr.</th>
<th>output</th>
<th>mob.rate</th>
<th>unemp.rate</th>
<th>vacancies</th>
<th>outfl.haz.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correlations</td>
<td>0.999</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>output</td>
<td>(0.001)</td>
<td>(0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mobility rate</td>
<td>0.966</td>
<td>0.969</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>unemploment rate</td>
<td>(0.014)</td>
<td>(0.012)</td>
<td>(0)</td>
<td>(0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>vacancies</td>
<td>0.961</td>
<td>0.962</td>
<td>0.914</td>
<td>-0.798</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>(0.008)</td>
<td>(0.008)</td>
<td>(0.016)</td>
<td>(0.050)</td>
<td>(0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>outflow hazard</td>
<td>0.960</td>
<td>0.961</td>
<td>0.948</td>
<td>-0.979</td>
<td>0.860</td>
<td>1</td>
</tr>
<tr>
<td>(0.012)</td>
<td>(0.012)</td>
<td>(0.014)</td>
<td>(0.006)</td>
<td>(0.034)</td>
<td>(0)</td>
<td></td>
</tr>
</tbody>
</table>

Notes: The business cycle statistics are averages across 10000 simulations. Standard deviations over these simulations are displayed between brackets. Each simulation has a monthly frequency, has length 1480 and starts from the steady state. For each simulation, the first 1000 timer periods were discarded so that 40 years of data remained. Variables were logged and HP-detrended with smoothing parameter value \(81 \times 10^5\). This value corresponds to the one used by Shimer (2005) for quarterly data, but is adjusted for the frequency using the factor recommended by Ravn and Uhlig (2002).

An interesting application of the model seems to be to simulate episodes of large falls in house prices, which do not occur very frequently. Nonetheless, it seems important to know how well this simple model can explain "regular" business cycles. I therefore analyze the business cycle properties of a version of the model with only productivity shocks.

Volatilities implied by the model are displayed in Table 4.4. These numbers can be compared to the volatilities found in the data (Table 4.1). The model correctly predicts that the unemployment rate, vacancies, and the outflow hazard are more volatile than house prices, and output is less volatile than house prices. Quantitatively, however, the predicted volatilities of unemployment, vacancies and the outflow hazard are very low compared to the volatility of output. This is a general problem of labor market matching...
models, as emphasized by Shimer (2005).

Table 4.4 also displays the correlations of the above mentioned variables. For all correlations, the model predicts the correct sign. Also, the correlation between vacancies and the outflow hazard, and between the unemployment rate and the outflow hazard, are comparable to their data equivalents. However, there are also quantitative discrepancies between the model and the data. The correlation between the unemployment rate and vacancies is -0.80, which is less negative than the correlation coefficient of -0.90 found in the data.\textsuperscript{38} Most other correlations are much stronger than in the data. For example, the correlation between house prices and the unemployment rate is -0.93 in the model, whereas the correlation found in the data is -0.44.

### 4.4.2 Dynamic responses

This subsection discusses the dynamic responses to two types of shocks: housing preference shocks and productivity shocks. Although shocks to housing preferences are less common in the literature than shocks to productivity, this is not the first paper to consider housing preference shocks. For example, Iacoviello and Neri (2009) report that in their model with collateral constraints, housing preference shocks can have substantial effects on output. However, this holds even in version of their model without credit frictions, in which housing wealth effects are absent.\textsuperscript{39} In contrast, the structure of my model is such that a housing preference shock has no effect on output when credit frictions are removed from the model, as will be shown below. This permits a clear view on the causal role of house prices in driving fluctuations in real activity.

\textsuperscript{38} Thus, the model seems to predict a flatter Beveridge curve than is present in the data. This result, however, depends on the calibration of the autocorrelation parameter of productivity shock process. For higher values, the model predicts a steeper Beveridge Curve. In Subsection 4.4.3 it will be shown that the model is much better able to reproduce the Beveridge Curve than the analysis in this subsection may suggest.

\textsuperscript{39} Their model does not feature frictions in the labor market, but they do include a variety of other frictions, including nominal rigidities. Also, the housing stock is not fixed in their model.
**Figure 4-6:** Responses to a productivity shock in the theoretical model.

Notes: Responses to a 1% decline in productivity for the high-leverage economy \((\nu = 0.25, \chi = 0.85)\), the benchmark economy \((\nu = 0.2, \chi = 0.8)\), the low-leverage economy \((\nu = 0.15, \chi = 0.75)\), and the economy without borrowers \((\nu = 0)\).
**Productivity shock.** Responses to a sudden one-percent decline in productivity are displayed in Figure 4-6, for several calibrations. First consider the benchmark calibration. After a fall in productivity, output and house prices fall. As in standard business cycle models with search and matching frictions in the labor market, there is a decline in vacancies and in the (average) unemployment outflow hazard, and an increase in the unemployment rate. The mobility rate falls after the decline in productivity.

To understand the effects of refinancing constraints, consider the responses for an economy in which there are no impatient households (no borrowers). In such an economy, all households have the same discount factor and there is no debt in equilibrium. Thus, refinancing constraints are irrelevant. The responses for this economy are plotted in Figure 4-6 as well. Without credit-constrained households, the decline in vacancies is very similar to the decline in vacancies in the benchmark model. The unemployment rate, however, does not increase as much as in the benchmark model. Thus, the presence of credit-constrained households implies a somewhat flatter Beveridge curve. This is directly related to the fact that the drop in the mobility rate is also much less pronounced than in the benchmark economy. The declines in output and house prices, however, are quite similar across the two versions of the model. This indicates that these declines are mainly driven by the direct effects of the fall in productivity.

What are the consequences of structural changes in mortgage markets for the sensitivity of the economy to productivity shocks? Figure 4-6 plots the responses for the "low-leverage" and the "high-leverage" economies. Financial development clearly causes the mobility rate to be more sensitive to productivity shocks. For the other variables, the responses are more similar across the two economies.

**Housing preference shock.** How do shocks that originate in housing markets affect the real economy? Figure 4-7 displays the responses to a negative housing preference shock, generating a house price decline of about one percent on impact. First consider the benchmark calibration. Consistent with the VAR evidence, the model predicts a joint
Figure 4.7: Responses to a housing preference shock in the theoretical model.

Notes: Responses to a housing preference shock for the high-leverage economy \((\nu = 0.25, \chi = 0.85)\), the benchmark economy \((\nu = 0.2, \chi = 0.8)\), the low leverage-economy \((\nu = 0.15, \chi = 0.75)\), and the economy without borrowers \((\nu = 0)\).
decline in house prices, mobility, output, vacancies and the unemployment outflow hazard, and an increase in the unemployment rate.

Interestingly, the increase in the unemployment rate is larger and much more persistent than the decline in vacancies. For example, fifteen quarters after the shock, vacancies are only about 0.05 percent below their steady-state level, but the unemployment rate is still about 0.18 percent above its steady-state level.\(^{40}\)

Persistence is also observed in the decline of the mobility rate, which is much more prolonged than the fall in house prices. Six years after the shock, house prices have almost fully recovered, but the mobility rate is still one percent below its steady-state level.

What are the effects of collateral constraints? Figure 4.7 shows that in the economy without credit-constrained households, the decline in house prices is smaller than in the benchmark economy. But more importantly, real activity variables do not respond at all to the shock. To see why, note that the first-order condition for housing of the patient households is given by:

\[
\frac{p_{h,t}}{c_t} = \frac{\alpha z_{h,t}}{h_t} + \gamma E_t \frac{p_{h,t+1}}{c_{t+1}}.
\]

(4.24)

In the absence of credit-constrained households, this is the only model equation in which the house price enters.\(^{41}\) This implies that house prices and housing preferences are irrelevant for equilibrium allocations.\(^{42}\)

Now consider the low-leverage and the high-leverage economies. Figure 4.7 makes clear that structural innovations in mortgage markets substantially increase volatilities. In particular, the maximum responses of the unemployment and mobility rates in the high-leverage economy are about double the size of those in the low-leverage economy.

\(^{40}\)In a quantitative sense, the effects on real activity are very modest for a one percent fall in house prices. For example, the maximum increase in the unemployment rate is 0.012 percentage points. Thus, the model does not only generate little volatility in the unemployment rate conditional on productivity shocks, but also conditional on housing preference shocks. However, in the next subsection it will be shown that for large swings in house prices, the effects are substantial.

\(^{41}\)Since the aggregate supply of housing is fixed, the house price drops out of the budget constraint.

\(^{42}\)Note that one could simply remove Equation (4.24) from the system of equilibrium conditions, since one would lose one equation and one endogenous variable.
In contrast, the differences in the response of the real house price are small. Thus, real activity has become more sensitive to fluctuations in house prices as the amount of leverage in the economy increases, but the feedback on house prices seems limited.

### 4.4.3 Great Recession experiment

This subsection discusses how well the model can explain observed dynamics of unemployment and vacancies, and in particular the recent flattening of the Beveridge curve, as highlighted in Figure 4-1. For this purpose, the following experiment is conducted. Using data series on the real house price and GDP for the period 1970 - 2010, I back out realizations of the innovations to the productivity and housing preference shock processes.\(^{43}\) This is simply done by inverting the equilibrium laws of motions for output and the real house price.\(^{44}\)

The model is then simulated, using the shocks obtained from the inversion procedure. Column A of Figure 4-8 plots the simulated values of the real house price and output for the high-leverage economy for the period 2000 - 2010. By construction, the simulated data for house prices and output coincide with the real-world data. I also run a second, counterfactual simulation, in which housing preference shocks are shut off from 2005 onwards. In this simulation, house prices drop much less than in the benchmark simulation, and output slightly less. Column B plots both model simulations again, but now for the low-leverage economy. These simulations are very similar to those for the high-leverage economy.\(^{45}\)

Simulated values for unemployment and vacancies, as well as their data counterparts are plotted in Figure 4-9, for the period 1970 - 2010. The model does a very reasonable

\(^{43}\)Data were logged and linearly detrended. Quarterly GDP data were converted into monthly data by linear interpolation.

\(^{44}\)I assume that at the beginning of the sample, just prior to 1970, the economy was at the steady state. The results are not very sensitive with respect to this assumption, especially given that my focus is on the realizations in recent years.

\(^{45}\)For the sake of comparability, I do not back out a separate series of shock innovations for the low-leverage economy. Instead, I use the same shock innovations as for the high-leverage economy.
Figure 4.8: Great recession experiment: model simulations.

Notes: Model simulations for the high-leverage economy ($\nu = 0.25, \chi = 0.85$) and the low-leverage economy ($\nu = 0.15, \chi = 0.75$). "Counterfactual" denotes simulations with housing preference shock innovations set to zero from 2005 onwards. Numbers on the y-axes are log deviations from the steady state.
Figure 4.9: Great recession experiment: simulations and real-world data.

A. high-leverage economy

B. low-leverage economy

C. real-world data

Notes: Data and model simulations for the high-leverage economy ($\nu = 0.25, \chi = 0.85$) and the low-leverage economy ($\nu = 0.15, \chi = 0.75$). The real-world data series are in logs and are linearly detrended. Numbers on the y-axes are log deviations from the steady state / trend.
job in tracing the ups and downs of unemployment and vacancies over time. But as expected from the analysis in the previous subsections, the magnitudes of fluctuations in unemployment and vacancies are much smaller than in the data.

How well can the model account for the flattening of the Beveridge curve observed in 2009? Panel A of Figure 4.10 plots the unemployment rate versus vacancies for the high-leverage economy. For the period 1970-2008, there is a strong negative comovement between unemployment and vacancies, although not as strong as in the data. For 2009, the model predicts that the Beveridge curve is essentially flat, or even somewhat upward sloping, precisely as observed in reality (see Figure 4.1). The predicted increase in the unemployment rate is 7.4 percent. This is thirty percent of the increase observed in the data. But recall that the model fails to generate sufficient volatility in unemployment. Scaled by the volatility of the unemployment rate, the model actually predicts a larger increase in the unemployment rate than observed in the data: the model generates an increase of 1.8 standard deviations, versus an increase of only 1.2 standard deviations in the data.

What has been the role of the bust in house prices in recent years? Panel A of 4.10 plots the values of unemployment and vacancies in the counterfactual simulation. With housing preference shocks shut off from 2005 onwards, the behavior of unemployment and vacancies is much less extreme. In particular, the unemployment rate only increases to ten percent above its trend level, versus sixteen percent including housing preference shocks. Thus, the effects of shocks arising in housing markets are substantial.

The simulation results for the low-leverage economy are plotted in Panel B of Figure 4.10. Precisely as in the data, the model generates a correlation between the unemployment rate and vacancies of -0.9. Thus, for the overall sample, this version of the model

\[ \text{The correlation between the unemployment rate and vacancies is } -0.85, \text{ whereas it is } -0.9 \text{ in the data. This seems related to the fact that there are some outliers with negative values for the unemployment rate. These are predictions for the late 1980's. Also, note that for this simulation, the comovement is much closer to the data than in the simulations in Subsection (4.4.1).} \]

\[ \text{Unlike the high-leverage economy, there are no large negative outliers for the unemployment rate.} \]
Figure 4.10: Great recession experiment: Beveridge curves predicted by the model.

Notes: Log deviations from the steady state. Model simulations for the high-leverage economy ($\nu = 0.25, \chi = 0.85$) and the low-leverage economy ($\nu = 0.15, \chi = 0.75$). "Counterfactual" denotes simulations with housing preference shock innovations set to zero from 2005 onwards. For the sake of comparability, simulated data are HP-detrended as in Figure 4.1. The smoothing parameter value is $81 \cdot 10^5$. 
may be more appropriate than its high-leverage counterpart. At the same time, the low-leverage version is less successful in explaining the sharp increase in the unemployment rate during the Great Recession. Moreover, the flattening of the Beveridge curve during 2009 is not as pronounced as in the high-leverage economy.

4.4.4 Understanding the interactions between housing and labor markets

In the presence of refinancing constraints, outcomes in housing markets are not just passively determined by economic conditions, but have an active role in shaping real economic outcomes. The purpose of this subsection is to better understand this interaction. I focus on housing preference shocks, because this allows me to study the roles of credit frictions and mobility in isolation.

I will answer three main questions that arise naturally from the analysis of dynamic responses in Subsection 4.4.2. First, why are the mobility effects propagated over time? Second, why do vacancies fall following a negative housing preference shock? And finally, what determines feedback effects of fluctuations in real activity on house prices?

Sources of propagation

An interesting model prediction is that the responses of mobility and unemployment to a housing preference shock are more persistent than the response of house prices (Figure 4.7). But what drives this propagation?

Recall that Equation (4.6), the first-order condition for the moving cutoff for impatient households, is essential in determining fluctuations in the mobility rate. This equation relates the cutoff, $\tau_t$, directly to the real house price, $p_{h,t}$, but also to the stock of housing owned by impatient households, $h_t$, and their debt level, $d_{t-1}$. Panel A of Figure 4-11 plots the responses of $h_t$ and $d_{t-1}$ to a negative housing preference shock, and shows that

---

48Equation (Equation (4.6) also relates the cutoff to the marginal utility of consumption, $\frac{1}{c_t}$, and the Lagrange multiplier on the borrowing constraint, $\lambda_{cc,t}$. But fluctuations in these variables are of secondary importance in terms of understanding the main sources of propagation, as will be discussed below.
Figure 4.11: Responses to a housing preference shock in the benchmark model: impatient households.

A. original IRFs for the housing stock and debt

B. original and reconstructed IRFs for the mobility cutoff

Notes: Responses of housing stock and debt of the impatient household (Panel A), and of the mobility cutoff (Panel B) to a negative housing preference shock. The reconstructed responses in Panel B are obtained using Equation (4.6), but with the indicated variables kept at their steady-state levels.
the reduction in $h_t$ is larger than the fall in $d_{t-1}$. More importantly, the gap widens during the first four years, indicating that impatient households gradually become poorer, and thus less capable of providing downpayments.

To obtain a clearer view on the roles of $p_{h,t}$, $h_t$ and $d_{t-1}$ in driving propagation effects, consider the response of the moving cutoff $\zeta_t$, which is plotted in Panel B of Figure 4-11.\textsuperscript{49} Note that this response can be reconstructed from the responses of the other variables in Equation (4.6). As a mechanical exercise, I reconstruct the response of $\zeta_t$, but consider two variations. First, I keep all other variables in Equation (4.6) except for $p_{h,t}$ at their steady-state levels. This reconstructed response is also plotted in Panel B of Figure 4-11. Initially, the fall in the cutoff is about as large as observed in the original response. However, the reconstructed response is much less persistent than the original one and it is also not hump-shaped. So clearly, propagation effects are not driven by the real house price itself. Second, I repeat the exercise, but no keep all variables except for $p_{h,t}$, $h_t$ and $d_{t-1}$ at their steady-state levels. This reconstructed IRF is quite similar to the original one and in particular, it shows a persistent and hump-shaped decline of the cutoff. Thus, the fall in housing assets owned by the impatient households is essential in driving the propagation effects.

Why do impatient households sell housing stock in equilibrium, following a negative preference shock?\textsuperscript{50} Note that Equation (4.4), the first-order condition for housing of the impatient households, can be rewritten as:

$$\frac{p_{h,t}}{c_t} = E_t \sum_{k=0}^{\infty} \beta^k \frac{\alpha z_{h,t+k}}{h_{t+k}} + E_t \sum_{k=0}^{\infty} \beta^k \lambda_{cc,t+k} n_{m,t+k} \chi_{p_{h,t+k}}, \quad (4.25)$$

and recall that the right-hand side of this equation is the shadow value of housing. The first term on the right-hand side is the present value of all future marginal utility delivered by a unit of housing in the future. The second present value arises from the fact that

\textsuperscript{49}The shape of this response is very similar to one of the overall mobility rate.

\textsuperscript{50}Recall that the aggregate stock of housing is fixed, so any reduction in housing stock owned by the impatient households must be absorbed by the patient households.
**Figure 4.12:** Responses to a housing preference shock in the benchmark model.

![Graph of responses to housing preference shock](graph.png)

Notes: Responses of the shadow value of housing for the patient and impatient households to a negative housing preference shock. The figure also shows the IRF for the shadow value of the impatient households when collateral effects are shut off. This IRF is constructed from equation (4.25), but with the second present value term kept equal to its steady state level.

Housing serves as collateral for loans. Figure 4-12 plots the response of the shadow value of housing for both types of households and shows that there is a larger fall for impatient households.

To understand why incentives to buy housing decrease more for those who are credit-constrained, note the following. For the patient households, the second present value in the first-order condition for housing always equals zero, because for them the borrowing constraint never binds (i.e., $\lambda_{cc,t} = 0$ in each period $t$). For impatient households, however,
there is a decline in the second present value following a negative housing preference shock, because the house prices, \( p_{h,t} \), and the mobility rate, \( n_{m,t} \), both decline.\(^{51}\) Figure 4-12 also plots the response of the shadow value for impatient households, reconstructed from Equation (4.25), but with the second present value is kept at its steady-state level.

Without the effects of the refinancing constraint, the decline in the shadow value is much more similar for patient and impatient households.

The intuition behind the propagation effects is that as house prices decline, a unit of housing provides fewer collateral services, creating disincentives for credit-constrained households to hold housing stock. Moreover, these households expect to move less, and thus rely more on old debt. For those reasons, they gradually decumulate housing assets. But this means that by the time house prices have recovered, they are poorer than before the shock. The patient households, who purchased additional housing stock, have become richer.\(^{52}\)

**The role of vacancies**

Why is there a fall in vacancies following a negative housing preference shock? This decline is related to the fact that the patient households purchase housing stock from the impatient households. In order to finance these purchases, the patient households cut back on non-durable consumption expenditures, implying a decrease in their stochastic discount factor, \( e_{t,t+1} \). Since the firms are owned by the patient households, a decrease in \( \tilde{\Lambda}_{t,t+1} \) implies that the benefits from posting a vacancy are more heavily discounted. Therefore, vacancy posting decreases. This effect becomes clear when observing the free-entry condition, Equation (4.20). The intuition is that in order to take advantage of the

---

\(^{51}\)The Lagrange multiplier on the refinancing constraint, \( \lambda_{cc,t} \), increases following the shock, but this effect does not dominate.

\(^{52}\)In the model, low mobility does not deter trade in housing stock. In reality, it is difficult for non-movers to decrease their housing stock beyond cutting back on maintenance. But in reality there do exist other assets in which non-movers can trade much more flexibly. For example, households can take on credit card debt or decumulate savings that were initially intended for the downpayment needed for a future home purchase.
increase in returns on housing, impatient households reduce their investments in vacancies.

**Feedback on house prices**

An advantage of the DSGE framework adopted in this chapter is that one cannot only study the effects of house prices on real activity, but also feedback effects. However, it turns out that the response of the house price is quite similar across simulations with small and large mobility effects (Figure 4.7). To understand why feedback effects are quantitatively limited, note that the first-order condition for the patient households, Equation (4.24), needs to be satisfied in any of the model versions. This equation makes clear that all possible feedback effects of real activity on house prices must operate through the marginal utility of non-durable consumption of the patient households. Whereas impatient households suffer income losses when job offer rejection increases, patient households are not directly affected.\(^{53}\)

### 4.5 Concluding remarks

Both the empirical and the theoretical evidence presented in this chapter support the idea that geographical mobility can be an important channel through which changes in house prices spill over to the real economy. The model that was developed captures the essence of the mobility channel, but has been kept relatively simple in order to retain transparency and tractability. But it would be worthwhile to enrich the way in which housing and labor markets are modeled.

One obvious simplification of the current model is that it does not feature an endogenous choice between renting and owning. This would endow unemployed homeowners with the opportunity to accept a job offer and move into a rental home. In reality, however, homeowners and renters, as well as their homes, have different characteristics. Also, due

\(^{53}\)An increase in job offer rejection affects patient households via a decline in firm profitability, but this effect is small.
to information asymmetries between landlords and tenants, renters typically have limited discretion over their homes. So the extent to which effects might be dampened depends on how willing homeowners are to move into rental homes. Moreover, an increase in the relative demand for rental homes can be expected to push up prices in rental markets, relative to prices in markets for owner-occupied housing.

Another interesting extension would be to introduce search frictions in the housing market. In the current model, the housing stock is essentially traded on a spot market. Ngai and Tenreyro (2009) show that a model with search frictions in the housing market can generate joint (seasonal) movements in house prices and transaction volumes. One could expect that in the presence of such frictions, a decline in mobility among credit-constrained households creates a fall in mobility among the other households.

A final simplification of my model is that it avoids wealth heterogeneity. This has the benefit of simplicity. However, since housing wealth and financial wealth have been shown to be important drivers of fluctuations in mobility, dynamics are potentially even richer in a model with wealth heterogeneity.

Appendix 4.A Individual versus joint housing shocks

In section 2.2, a joint shock to house prices and home sales in the VAR was discussed. Figures 4.13 and 4.14 display the responses to a house price shock and a home sales shock individually. The IRFs are qualitatively very similar. In particular, house prices, home sales and the unemployment outflow hazard fall significantly. An interesting difference is that following a home sales shock, the real house price declines more persistently. Also, the decline in the outflow hazard declines is more prolonged following a home sales shock, while this is hardly the case for vacancies.
Figure 4.13: House price shock.

Notes: Responses to a negative one standard deviation shock in real house prices. Grey areas are 90% confidence intervals, which are obtained by a bootstrap procedure.
Figure 4.14: Home sales shock.

Notes: Responses to a negative one standard deviation shock in home sales. Grey areas are 90% confidence intervals, which are obtained by a bootstrap procedure.
Appendix 4.B Optimization problem of the impatient households

The optimization problem reads:

$$\max \ E_0 \sum_{t=0}^{\infty} \beta^t \{ \ln c_t + \alpha z_{h,t} \ln h_t + \kappa n_{u,t} + u_{lo,t} \},$$

s.t.  
$$c_t + p_{h,t}(h_t - h_{t-1}) + n_{m,t} \zeta + R_{t-1}d_{t-1} = (1 - n_{u,t}) z_{o,t} \theta \xi + d_t,$$

$$d_t = n_{m,t} \chi p_{h,t} h_t + (1 - n_{m,t}) d_{t-1},$$

$$n_{s,t} = n_{u,t} + \rho_u (1 - n_{u,t}),$$

$$n_{u,t} = n_{s,t-1} (1 - \gamma_t - \omega \gamma_{t-1} (1 - F(\tau_{do,t}))),$$

$$n_{m,t} = \omega \gamma_{t-1} n_{s,t-1} F(\tau_{do,t}) + (1 - \omega \gamma_{t-1} n_{s,t-1}) F(\tau_{s}),$$

where

$$u_{lo,t} = \omega \gamma_{t-1} n_{s,t-1} \left[ \psi F(\tau_{do,t}) + \int_{\tau_{do,t}}^{\infty} \varepsilon dF(\varepsilon) \right] + (1 - \omega \gamma_{t-1} n_{s,t-1}) \left[ \psi F(\tau_{s}) + \int_{\tau_{s}}^{\infty} \varepsilon dF(\varepsilon) \right].$$
The first-order conditions are:

\[
\begin{aligned}
\frac{\alpha z_{h,t}}{h_t} - \frac{p_{h,t}}{c_t} + \beta E_t \frac{p_{h,t+1}}{c_{t+1}} + \lambda_{cc,t} n_{m,t} \lambda_{Ph,t} &= 0, \\
\frac{1}{c_t} - \lambda_{cc,t} + \beta E_t \left( \lambda_{cc,t+1} (1 - n_{m,t+1}) - \frac{R_t}{c_{t+1}} \right) &= 0, \\
\beta E_t \left( +\omega \hat{g}_t \left[ \psi F (\tau_{do,t+1}) + \int_{\tau_{do,t+1}}^{\infty} \varepsilon dF (\varepsilon) \right] - \omega \hat{g}_t \left[ \psi F (\tau_{t+1}) + \int_{\tau_{t+1}}^{\infty} \varepsilon dF (\varepsilon) \right] \right) &= \lambda_{ns,t}, \\
\beta E_t \left( -\lambda_{mu,t+1} (1 - \hat{g}_t + \omega \hat{g}_t (1 - F (\tau_{do,t+1}))) + \lambda_{nm,t+1} \omega \hat{g}_t (F (\tau_{do,t+1}) - F (\tau_{t+1})) \right) \\
-\frac{\zeta}{c_t} - \lambda_{cc,t} (\chi p_{h,t} h_t - d_{t-1}) - \lambda_{nm,t} &= 0, \\
\psi - \tau_{t+1} - \lambda_{nm,t} &= 0, \\
\psi - \tau_{do,t} + \lambda_{nu,t} - \lambda_{nm,t} &= 0, \\
\kappa - \frac{z_{\theta,t} \theta \xi}{c_t} + \lambda_{ns,t} (1 - \rho_a) + \lambda_{nu,t} &= 0,
\end{aligned}
\]

where \(\lambda_{cc,t}, \lambda_{ns,t}, \lambda_{nm,t},\) and \(\lambda_{nu,t}\) are the Lagrange multipliers of the constraints for borrowing, job searchers, mobility and unemployment, respectively. These conditions can be combined to obtain:

\[
\begin{aligned}
\frac{\alpha z_{h,t}}{h_t} - \frac{p_{h,t}}{c_t} + \beta E_t \frac{p_{h,t+1}}{c_{t+1}} + \lambda_{cc,t} n_{m,t} \lambda_{Ph,t} &= 0, \\
\frac{1}{c_t} - \lambda_{cc,t} + \beta E_t \left( \lambda_{cc,t+1} (1 - n_{m,t+1}) - \frac{R_t}{c_{t+1}} \right) &= 0, \\
\frac{\zeta}{c_t} - \lambda_{cc,t} (\chi p_{h,t} h_t - d_{t-1}) + \tau_{t+1} - \psi &= 0, \\
\kappa - \frac{z_{\theta,t} \theta \xi}{c_t} + \tau_{do,t} - \tau_{t+1} + (1 - \rho_a) G_t &= 0,
\end{aligned}
\]

where

\[
G_t = \beta E_t \left( -\omega \hat{g}_t \int_{\tau_{t+1}}^{\tau_{do,t+1}} \varepsilon dF (\varepsilon) + (\tau_{do,t+1} - \tau_{t+1}) (1 - \hat{g}_t + \omega \hat{g}_t (1 - F (\tau_{do,t+1}))) \right. \\
+ \tau_{t+1} \omega \hat{g}_t (F (\tau_{do,t+1}) - F (\tau_{t+1})),
\]

are functions of the current and expected future values of economic variables.
The location satisfaction shock follows a normal distribution with mean zero and standard deviation $\sigma^2$. It can be shown that:

$$
\bar{\pi}_{do,t+1} \int_{\pi_{t+1}} \varepsilon dF(\varepsilon) = \frac{\sigma}{\sqrt{2\pi}} \left( \exp \left( -\frac{1}{2} \frac{\bar{\pi}_{t+1}^2}{\sigma^2} \right) - \exp \left( -\frac{1}{2} \frac{\bar{\pi}_{do,t+1}^2}{\sigma^2} \right) \right).
$$
Chapter 5

Demand Dynamics in a Model with Heterogeneous Borrowers and Collateral Constraints

Abstract

What are the costs of abstracting from borrower heterogeneity in a business cycle model with frictions in household finance? I study the behavior of aggregate demand for housing and mortgage loans in a partial equilibrium model with heterogeneous borrowers who move infrequently. Mortgage debt is limited by a collateral requirement that is renewed only when the agent moves. A key prediction of the model is that transitions in aggregate demand for housing and mortgage debt occur very gradually. I then investigate how closely these predictions are matched by two alternative models that make the more convenient but less realistic assumption of a representative borrower. The first alternative model features a standard borrowing constraint that implies a full renewal of the collateral requirement in every period. This model does not match the sluggish transitions in aggregate housing demand and mortgage debt. The second representative borrower model features a collateral constraint like in Chapter 4, that implies only a partial renewal of the borrowing limit in a given period. With this constraint, the representative borrower model does generate gradual transitions in aggregate debt, as observed in the heterogeneous agent model. However, the constraint is less helpful in reducing the excess sensitivity of aggregate housing demand. Price effects that would be obtained in a general equilibrium model seem much more important in reducing this sensitivity.

5.1 Introduction

There exists a vast literature that incorporates frictions in firm finance into business cycle models. Famous examples include Bernanke, Gertler, and Gilchrist (1999) and
Kiyotaki and Moore (1997). Fewer authors have paid attention to frictions in household finance, but it has been argued that such frictions deserve much greater emphasis (den Haan, Sumner, and Yamashiro (2007) and Mian and Sufi (2010)). The literature that does analyze the role of household finance in the business cycle usually follows Iacoviello (2005). He considers a model with a representative borrower and a representative saver. Debt is restricted by a collateral constraint that is assumed to be always binding and to be renewed in each period. Chapters 2 and 4 in this thesis also follow this setup, which has the great benefit of simplicity. In particular, the model can be solved using standard perturbation methods and with representative households it is easy to characterize the wealth distribution.

It has been observed that in some key aspects, economic aggregates behave similarly in heterogeneous agent models and representative agent models (Krusell and Smith (1998)). Moreover, the setup of Iacoviello (2005) may be viewed as less restrictive than standard models in the sense that with savers and borrowers there is some degree of wealth heterogeneity among households. Thus, one may be inclined to believe that if the representative agent assumption is innocuous in standard models, then this will certainly be the case in saver-borrower models.

However, there are two factors that may limit the degree to which the model with a representative saver and borrower provides a close approximation to a more realistic model without any representative household assumption. First, in the presence of uninsurable idiosyncratic shocks, the collateral constraint is less likely to be always binding. Second, in the underlying heterogeneous agent economy, households do not refinance their loans in every period. This has direct implications for the evolution of aggregate debt, since a reduction in the borrowing limit caused by a fall in house prices only directly affects those agents who refinance their loans in the current period. The ones who do not refinance are able to sustain their previous level of borrowing, regardless of changes in the value of their house. But in the standard saver-borrower model, the representative agent is subject to a fully renewed collateral constraint in each period. Thus, one can expect aggregate debt
to be much more elastic with respect to house prices changes in the standard model than in the heterogeneous agent economy.

Chapter 4 proposes an alternative borrowing constraint that requires mortgage debt to be refinanced only partially in a given period. In particular, the rate at which mortgage loans are refinanced equals the mobility rate. With this specification of the borrowing constraint, the model can be expected to imply a much more sluggish law of motion for aggregate debt than with a standard collateral constraint. However, the setup in Chapter 4 preserves the representative borrower assumption, which is very attractive for computational reasons.

This chapter presents a model with heterogeneous borrowers who face uninsurable income shocks and who move infrequently. Moreover, they only adjust levels of debt and housing in the event of moving and I allow the borrowing constraint to be non-binding. Taking this model as the truth, I then investigate the extent to which its predictions are matched by the aforementioned models with a representative borrower. I analyze the long-run properties of the models as well as transitions. Given that the heterogeneous borrower model is relatively difficult to solve, I consider partial equilibrium settings.

Section 5.2 describes the models and the results are presented in section 5.3. Section 5.4 links the findings to those in Chapter 4.

5.2 The models

In this section, I first present a heterogeneous borrower model in which borrowers move infrequently, and only refinance their mortgages when they move. Then I discuss a representative borrower model with a collateral constraint that is similar to the one in Chapter 4, which is a generalization of a representative borrower model with a standard collateral constraint.
5.2.1 A model with heterogeneous borrowers

There is a continuum of borrowers who consume non-durables and housing services. The utility flow of borrower \( i \) in period \( t \) is:

\[
U (c_{t,i}, h_{t,i}) = \ln c_{t,i} + \alpha \ln h_{t,i},
\]

where \( c_{t,i} \) is the amount of non-durables consumed in period \( t \), \( h_{t,i} \) is the stock of housing, and \( \alpha \) is a housing preference parameter. Agents can trade in housing and can take on mortgage debt, but the amount of mortgage debt cannot exceed a certain borrowing limit. No other assets than housing and mortgage loans are available. There is no aggregate risk, but borrowers face two types of idiosyncratic risk. First, their labor income is stochastic. Second, in each period borrowers receive idiosyncratic shocks that determine whether they move or not. With probability \( \theta \) a borrower moves and with probability \( 1 - \theta \) the borrower does not move. So unlike the model in Chapter 4, mobility is an exogenous event that borrowers have no control over.

The mobility status of a borrower affects her choices in two ways. First, only movers can change their housing stock, that is:

\[
h_{t,i} = h_{t-1,i} \quad \text{if borrower } i \text{ does not move in } t.
\]

Second, movers must refinance their loans and therefore face a renewed borrowing limit. As housing serves as collateral for loans, the borrowing limit in case of moving is a fraction \( \chi \) of the value of their house. Borrowers who do not move do not refinance their loans and therefore sustain their previous borrowing limits:

\[
d_{t,i} \leq \chi p_i h_{t,i} \quad \text{if borrower } i \text{ moves in period } t,
\]

\[
d_{t,i} \leq d_{t-1,i} \quad \text{if borrower } i \text{ does not move in period } t,
\]

\(^1\)I abstract from home equity loans.
where \( p_h \) is the relative price of housing. The budget constraint is:

\[
c_{t,i} + p_h (h_{t,i} - h_{t-1,i}) + rd_{t-1,i} = y_{t,i} + d_{t,i},
\]

where \( y_{t,i} \) is labor income and \( r \) is a fixed gross interest rate. Labor income is exogenous and follows an autoregressive process of order one in logs:

\[
\ln y_{t,i} = \rho \ln y_{t-1,i} + \varepsilon_{t,i}, \quad \varepsilon_{t,i} \sim N (0, \sigma_{\varepsilon}).
\]

**First-order conditions**

The optimization problem of the borrowers involves maximizing the present value of their expected future utility, using a factor \( \beta \). The value of the agent is:

\[
V_{t,i} = \max_{c_{t,i}, h_{t,i}, d_{t,i}} E_0 \sum_{t=0}^{\infty} \beta^t U \left( c_{t,i}, h_{t,i} \right),
\]

s.t.

\[
c_{t,i} + p_h (h_{t,i} - h_{t-1,i}) + rd_{t-1,i} = y_{t,i} + d_{t,i},
\]

\[
d_{t,i} \leq \chi p_h h_{t,i} \quad \text{if } m_t = 1,
\]

\[
d_{t,i} \leq d_{t-1,i} \quad \text{if } m_t = 0,
\]

\[
h_{t,i} = h_{t-1,i} \quad \text{if } m_t = 0,
\]

\[
P \left[ m_t = 1 \right] = 1 - P \left[ m_t = 0 \right] = \theta,
\]

\[
\ln y_{t,i} = \rho \ln y_{t-1,i} + \varepsilon_{t,i}, \quad \varepsilon_{t,i} \sim N (0, \sigma_{\varepsilon}),
\]

where \( m_t \) is an indicator variable that is one if the borrower moves in period \( t \) and is zero if the borrower does not move in period \( t \). Let \( \lambda_{t,i} \) be the Lagrange multiplier on the borrowing constraint, let subscript \( m \) denote the choice variables of the mover, and let subscript \( s \) denote the variables of households who stay at their current location. The
first-order conditions of the non-mover’s optimization problem are:

\[
\frac{1}{c_{s,t,i}} = \beta \theta E_t \frac{r}{c_{m,t+1,i}} + \beta (1 - \theta) E_t \left( \frac{r}{c_{s,t+1,i}} - \lambda_{s,t+1,i} \right) + \lambda_{s,t,i}, \tag{5.1}
\]

\[
\lambda_{s,t,i} \left( d_{t-1,i} - d_{s,t,i} \right) = 0,
\]

\[
\lambda_{s,t,i} \geq 0.
\]

Equation (5.1) is the non-mover’s Euler equation for debt. With probability \( \theta \), the borrower will move in the next period and refinance the mortgage loan. With probability \( 1 - \theta \), the borrower will not move in the next period. In that case, the borrower makes interest payments but the borrowing limit on mortgage debt remains unchanged. The equation reduces to a standard Euler equation if the borrowing constraint is not binding, i.e. when \( \lambda_{s,t,i} \) equals zero in both the current and the next period.

The first-order conditions for the mover are:

\[
\frac{1}{c_{m,t,i}} = \beta \theta E_t \frac{r}{c_{m,t+1,i}} + \beta (1 - \theta) E_t \left( \frac{r}{c_{s,t+1,i}} - \lambda_{s,t+1,i} \right) + \lambda_{m,t,i}, \tag{5.2}
\]

\[
\frac{p_h}{c_{m,t,i}} = \frac{\alpha}{h_{m,t,i}} + \beta \theta E_t \frac{p_h}{c_{m,t+1,i}} + \beta (1 - \theta) E_t \frac{\partial V_{s,t+1,i}}{\partial h_{m,t,i}} + \lambda_{m,t,i} \chi p_h,
\]

\[
\lambda_{m,c,t} \left( \chi p_h h_{m,t,i} - d_{t,i} \right) = 0,
\]

\[
\lambda_{m,t,i} \geq 0.
\]

Equation (5.2) is the first-order condition for debt and Equation (5.3) is the first-order condition for housing. The term \( \frac{\partial V_{s,t,i}}{\partial h_{t-1,i}} \) is the shadow value of housing conditional on not moving. This variable can be expressed recursively as follows:

\[
\frac{\partial V_{s,t,i}}{\partial h_{t-1,i}} = \frac{\alpha}{h_{t-1,i}} + \beta \theta E_t \frac{p_h}{c_{m,t+1,i}} + \beta (1 - \theta) E_t \frac{\partial V_{s,t+1,i}}{\partial h_{t-1,i}}.
\]
Solution method

The policy rules that maximize the value of the agent are functions of four state variables. The state variables are the amount of debt in the previous period, $d_{t-1}$, the amount of housing in the previous period, $h_{t-1}$, the current amount of labor income, $y_{t,i}$, and the current mobility status, $m_t$. Given that the borrowing constraint is potentially non-binding, I do not use standard perturbation methods to solve for the optimal policy rules. Instead, I use a projection method. These methods typically perform well in terms of accuracy and speed of the numerical algorithm (see e.g. Aruoba, Fernandez-Villaverde, and Rubio-Ramirez (2006)).

My approach is to approximate the policy functions on a grid, using linear interpolation to evaluate the functions between the nodes. I approximate the policy functions, conditional on the mobility status, on a grid for each of the remaining state variables, with ten grid points in each dimension. The numerical algorithm iterates on the policy functions and is carried out following five steps:

1. Guess initial values for the policy functions on the grid and specify a convergence criterion.

2. On each grid point, use the policy functions to evaluate the conditional expectations in the first-order conditions of the agent’s optimization problem.\(^2\)

3. Given the values of the conditional expectations, use the first-order conditions to solve for the new values of the policy function on each grid point.\(^3\)

\(^2\)To numerically approximate the conditional expectation, I use Gauss-Hermite quadrature with five nodes.

\(^3\)I apply the time iteration method and therefore use the policy functions of the previous iteration for nothing else than evaluating the conditional expectations. The new values of the policy functions are then solved for using a non-linear equation solver. The use of the solver is computationally intensive and may be avoided by applying fixed point iteration. This method uses the policy functions to evaluate values of both the conditional expectations and certain current-period variables. However, applying the fixed point iteration method makes convergence of the algorithm less likely.
4. Update the values of the policy functions on each grid point. Check if convergence has been reached. If not, go back to step 2.\textsuperscript{4}

5. Carry out a Monte Carlo simulation of a panel of agents and check for accuracy in the simulation.\textsuperscript{5}

The accuracy test follows Judd (1992) and is based on errors in the Euler equation for debt. At each point in the simulation, I evaluate the left- and the right-hand side of this equation and calculate the difference.

\textbf{5.2.2 A model with a representative borrower}

This subsection discusses a version of the model with a representative borrower. In this model there is no idiosyncratic risk or, alternatively, borrowers are able to insure among each other against the effects of idiosyncratic shocks on consumption. The representative borrower faces the following collateral constraint:

\[ d_t \leq \theta \chi p_h h_t + (1 - \theta) d_{t-1}. \]

As in Chapter 4, the borrower needs to refinance a fraction of the outstanding mortgage debt in each period. One can think of the representative household as consisting of a continuum of members that share consumption of non-durables and housing, with \( \theta \) being the mobility rate among the household members. Note that with \( \theta \) equal to one, the constraint reduces to a standard borrowing constraint that assumes a full renewal of the borrowing limit in each period.

\textsuperscript{4}I require the minimum of the mean absolute change in the two policy functions for consumption to be smaller than \( 10^{-5} \).

\textsuperscript{5}Given that the model is a partial equilibrium one, one can also simulate one agent over many time periods.
The first-order conditions of the representative household’s problem are:

\[
\frac{1}{c_t} = \beta E_t \left( \frac{r}{c_{t+1}} - (1 - \theta) \lambda_{t+1} \right) + \lambda_t, \tag{5.4}
\]

\[
\frac{p_h}{c_t} = \frac{\alpha}{h_t} + \beta E_t \left( \frac{p_h}{c_{t+1}} \right) + \theta \lambda_t \chi p_h, \tag{5.5}
\]

\[
\lambda_{c,t} (\theta \chi p_h h_{m,t,i} - (1 - \theta) d_{t-1}) = 0,
\]

\[
\lambda_t \geq 0,
\]

Note that the first-order condition for housing, Equation (5.5), is different from its equivalent in the heterogeneous agent model, Equation (5.3); only in Equation (5.5) \( \theta \) enters the third term of the shadow value of housing. The reason is that with a representative household, a marginal unit of housing purchased is shared among all household members, but only a fraction \( \theta \) of the members can use it as collateral for new loans. In the heterogeneous agent model, the entire marginal unit of housing can be used as collateral, conditional on being a mover.

**General equilibrium version**

In the models described above, the house price \( p_h \) and the interest rate \( r \) are fixed and exogenous. They can thus be treated as parameters. Calibrated values are taken from a general equilibrium model with a representative borrower and a representative saver. In this model, the representative saver is the same as the borrower, except that the saver has a higher discount factor. As a result, the saver is a net lender in equilibrium. The collateral constraint is assumed to be the standard one \( (\theta = 1) \), and the borrowers are assumed to make up 20 percent of the population. The supply of housing is fixed and normalized to one.
5.2.3 Calibration

The model period is one quarter. Otherwise, the calibration follows Chapter 4. The loan-to-value parameter $\chi$ is set to 0.8. The mobility parameter $\theta$ is calibrated to be 0.0193, which corresponds to an annual mobility rate of 7.5 percent. The discount factor, $\beta$, is set to 0.97. The parameters of the idiosyncratic income shock process, $\rho_y$ and $\sigma_y$, are set to 0.7 and 0.03, respectively. This generates income volatility of about 3.5 percent on an annual basis.\(^6\)

The calibrations of $r$, $\alpha$ and $p_h$ are based on the steady state of the general equilibrium model described in the previous subsection. The representative saver in this model is assumed to have a discount factor of 0.99, which results in parameter value of 1.01 for the interest rate $r$. Given that $\frac{1}{\beta} > r$, the collateral constraint of the borrower binds in the absence of any risk. The housing preference parameter $\alpha$ is set to be 0.06. In the general equilibrium model, this calibration yields a value of the aggregate housing stock that is about 140 percent of output. Based on the same model, I set $p_h$ equal to 5.69.

5.3 Results

This section compares the properties of four models. Model one is the heterogeneous borrower model with infrequent mobility as described in Section 5.2.1. Model two is a version of the heterogeneous borrower model in which all borrowers move in every period. This model is obtained by setting $\theta$ equal to one. In that case, the collateral constraint is completely standard. Model three is the model described in Section 5.2.2, in which a representative borrower refinances a fraction $\theta$ of its debt in each period. In this model, $\theta$ can be interpreted as a mobility rate among the members that make up the representative borrower household. Model four is a version of this model in which all debt has to be

\(^6\)This is less than what is typically assumed in the literature on incomplete market models. However, my heterogeneous agent model does feature an additional source of idiosyncratic income risk, namely mobility risk.
Table 5.1: Ergodic distributions.

<table>
<thead>
<tr>
<th>refinancing</th>
<th>heterogeneous agents</th>
<th>representative agent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>partial</td>
<td>full</td>
</tr>
<tr>
<td>Debt</td>
<td>mean</td>
<td>3.4243</td>
</tr>
<tr>
<td></td>
<td>standard deviation</td>
<td>0.0671</td>
</tr>
<tr>
<td>Housing</td>
<td>mean</td>
<td>0.7513</td>
</tr>
<tr>
<td></td>
<td>standard deviation</td>
<td>0.0147</td>
</tr>
<tr>
<td>Non-durables</td>
<td>mean</td>
<td>0.9664</td>
</tr>
<tr>
<td></td>
<td>standard deviation</td>
<td>0.0419</td>
</tr>
<tr>
<td>Borrowing constraint</td>
<td>percentage binding</td>
<td>100</td>
</tr>
<tr>
<td>Euler equation</td>
<td>root mean squared error</td>
<td>0.0004</td>
</tr>
</tbody>
</table>

Notes: numbers are based on a simulation are of one agent of length one million.

refinanced in each period. So in the fourth model θ equals one, in which case the collateral constraint reduces to a standard one.

Subsection 5.3.1 describes the ergodic distributions of the four models and transitions are presented in subsection 5.3.2.

5.3.1 Ergodic distributions

What implications does the presence of borrower heterogeneity have for the long-run properties of the model? Column 1 of Table 5.1 displays statistics describing the ergodic distributions of debt, housing and non-durables in the model with uninsurable income risk and infrequent mobility. The mean value of the house owned by the borrower is about equal to annual labor income. Column 2 displays the statistics for the model with heterogeneous borrowers who all move in every period. The means of the ergodic distributions of housing, non-durable consumption and debt are very similar to those predicted by the model with infrequent mobility. However, when borrowers move in every period, the cross-sectional dispersion of debt and housing is much higher than with infrequent mobility. In contrast, the cross-sectional dispersion of non-durable consumption is lower than with infrequent mobility. The borrowing constraint binds at all points in the simulation in both models. The table also shows that Euler equation errors in the
Columns 3 and 4 of Table 5.1 display steady-state values for the two representative agent models. Since there is no aggregate or idiosyncratic risk, these models are completely deterministic. The steady-state values for housing and debt in the model with partial mortgage refinancing, as displayed in the third column, are substantially lower than the long-run means in the other models. This seems directly related to the fact that in this model, only a fraction $\theta$ of a marginal unit provides collateral services, which reduces incentives to buy housing. The fourth column shows that the steady-state values of the representative borrower model with the standard collateral constraint are only somewhat lower than in its heterogeneous agent counterpart. Thus, without idiosyncratic income risk, borrowers accumulate slightly less wealth.

5.3.2 Transitions

The models discussed in this chapter do not feature any aggregate risk. Introducing such risk is possible, but adds another element to the vector of state variables and therefore further complicates finding a solution. Instead, I carry out two exercises in which I compute transition paths following a permanent and unanticipated change in the parameters of the model.

In the first exercise, I consider a fall in the housing preference parameter from 0.06 to 0.057, causing a permanent reduction in the demand for housing, keeping the house price fixed. Figure 5-1 plots the transition to the new long-run levels in the four models for aggregate debt, aggregate housing, and aggregate non-durable consumption.

In the heterogeneous borrower model with infrequent mobility ($\theta = 0.0193$), the transition of housing and debt is very gradual. Aggregate non-durable consumption displays a minor fall following the shock, despite the increased preference for non-durables relative to housing. In the representative borrower model with partial refinancing ($\theta = 0.0193$),

---

7 Scaled by the steady-state level of non-durable consumption the Euler equation errors are very similar, given that steady-state consumption of non-durables is close to one.
Figure 5.1: Transitions: decline in housing preference.

Notes: log deviations from the end-of-exercise steady state.
aggregate debt also converges to its new long-run level in a rather sluggish way. However, housing demand responds much quicker than in the heterogeneous borrower model. To understand this result, note that the representative borrower can freely adjust its housing stock, unlike the agents in the heterogeneous agent model who can only adjust their housing stock when they move. With a gradual decline in debt and a relatively rapid fall in housing, demand for non-durables by the representative borrower displays a brief spike following the fall in the relative preference for housing.

Now consider the models with the standard constraint ($\theta = 1$). Figure 5.1 shows that transitions in the heterogeneous agent version of the model, and in the representative agent version, are nearly identical. However, both models provide very poor approximations to the heterogeneous agent model that makes the more realistic assumption of infrequent mobility. In particular, debt and housing converge to their new steady-state levels very quickly. Moreover, both models predict a spike in non-durable consumption.

The exercise described above is somewhat unnatural in the sense that the relative preference for housing falls, but the relative price of housing does not. In a second exercise, I study a permanent and unanticipated fall in both housing preferences and the house price. The fall in the house price is set equal to the one that is obtained in the general equilibrium version of the representative agent model, as described in Subsections 5.2.2 and 5.2.3.

Figure 5.2 displays the transitions following the joint fall in housing preferences and the real house price. In the heterogeneous agent model with infrequent mobility, aggregate debt slowly converges to its new and lower long-run level, and there is some degree of overshooting. Housing also falls temporarily below its long-run level and there is a modest decline in non-durable purchases. In the representative borrower model with partial refinancing, debt gradually declines, but does not display any overshooting. Interestingly, housing hardly responds, despite of the lack of adjustment costs, and there is a very small decline in non-durable purchases. These observations contrast with the two models with the standard constraint ($\theta = 1$): both the representative agent and heterogeneous agent
Figure 5-2: Transitions: decline in housing preference and the house price.

Notes: log deviations from the end-of-exercise steady state. Simulation is based on a panel of 10,000 agents.
version display large negative spikes in debt, housing and non-durables.

5.4 Discussion

The results of the previous section indicate that introducing partial refinancing of mortgage debt allows a representative agent model to much better approximate the predictions of a heterogeneous agent economy with infrequent mobility. Still, the predictions of the representative agent model with partial refinancing do not coincide with those of the underlying heterogeneous agent economy. In particular, there are two issues. The first issue is that the representative agent model with partial refinancing predicts lower levels of housing and debt in the long run. Second, in the absence of any housing adjustment costs, the demand for housing is too flexible relative to the heterogeneous agent model in which agents can only adjust their housing stock when they move. This is true even though general equilibrium forces seem very powerful in dampening the sensitivity of housing demand. This subsection links these findings to calibration procedure in Chapter 4 and the results in that chapter.

5.4.1 Calibration of housing preferences

Recall that in Chapter 4, the housing preference parameters were calibrated such that the steady state value of the housing stock in the model matches the data. Moreover, the preference parameters were calibrated differently for borrowers and savers, in order to ensure that housing consumption of both types of households are equal. The analysis in the previous section suggests that in order to achieve these calibration targets, the housing preference parameter of the borrower, $\alpha$, is chosen to be high relative to the parameter value one would use in a version of the model with heterogeneous borrowers. The question arises how this changes the dynamics of the model.

Figure 5.3 displays the responses of housing and debt to a positive and temporary
Figure 5.3: Transitory housing preference shock.

Notes: Impulse response functions to a temporary increase in housing preferences in a partial equilibrium model with only borrowers. In the model with "higher housing preference", the housing preference parameter \( \alpha \) is set to 0.1 instead of 0.06.

A housing preference shock in the representative borrower model with \( \theta = 0.0193 \). The same figure displays the responses to the shock for an alternative calibration of the housing preference parameter \( \alpha \). In this version of the model, the housing preference parameter is set to 0.10 instead of 0.06, in order to match the steady-state level of debt in the model with the standard constraint. With a higher level of \( \alpha \), housing demand increases less during the first five years following the shock. Thus, setting a high value of \( \alpha \) may be preferable both in order to obtain reasonable steady-state values, and in order to reduce the elasticity of housing demand with respect to housing preference shocks.

\[^8\text{The autocorrelation coefficient of the shock is 0.95.}\]
5.4.2 Relation with Chapter 4

How could the results in Chapter 4 be affected if aggregate housing demand of the borrowers is too elastic? I revisit the benchmark model of Chapter 4, but also consider a version of the model with a utility cost on adjusting housing. This cost takes the following form:

$$\frac{\tau}{2} (h_t - h_{t-1})^2.$$

Figure 5.4 displays responses to a housing preference shock in the model with and without adjustment cost.\footnote{The parameter $\tau$ in the adjustment cost function is set to 2.5.}

The response of housing owned by the borrowers is indeed slower when the adjustment cost is in place. But note that in neither of the two models, the stock of housing owned by the borrowers displays a large jump, emphasizing the importance of general equilibrium effects in dampening the sensitivity of housing demand.

The effect of the adjustment cost on the decline of the mobility rate is negligible on impact. However, at intermediate horizons the adjustment cost leads to a smaller fall of the mobility rate. But the effects become more persistent, since the fall in the mobility rate is larger at longer horizons.

Figure 5.4 also shows that vacancies fall less in the presence of the adjustment cost. Recall from Chapter 4 that the fall in vacancies is due to the fact that following the shock, the savers decide to purchase more housing and invest less in vacancies. With the adjustment cost in place, such substitutions are more costly and thus less attractive.

5.5 Conclusion

In this chapter, I have compared representative borrower models to heterogeneous borrower models. The results indicate that a borrowing constraint with partial refinancing brings the representative borrower model much closer to the "true" underlying heteroge-
Figure 5-4: Transitory housing preference shock in the model of Chapter 4.

Notes: Responses to a negative housing preference shock in the benchmark model of Chapter 4.
neous borrower economy than a standard collateral constraint. However, it is important to emphasize that the results are based on partial equilibrium analysis. Comparing general equilibrium versions of the models remains a challenge for future work.
Chapter 6

Conclusion

This thesis analyzes the importance of frictions in household finance in affecting business cycle dynamics. Intuitively, it may strike one as obvious that such frictions are important for macroeconomic outcomes. It seems unlikely that since Gogol wrote *Dead Souls*, borrowers bettered themselves and have come to behave in line with the best interests of banks. Moreover, it has become very common for households to use mortgages and consumer credit to finance their purchases. The effects of adverse macroeconomic shocks may very well be exacerbated by increased difficulties in obtaining household credit. The chapters in this thesis study the extent to which theoretical models and empirical evidence support this type of idea. Below, I discuss some of the main findings and their implications for future research.

Chapter 2 discusses the effects of credit frictions in a basic model of the macro economy with durable and non-durable consumption goods. In particular, it is studied how the presence of collateral-constrained borrowers alters the transmission of a monetary policy shock. Conventional intuition suggests that credit frictions become more severe following a negative macroeconomic shock, exacerbating the decline in output. In accordance with this intuition, the model predicts that borrowers become more constrained in their spending opportunities after a monetary tightening. However, the presence of collateral constraints does not generate a larger decline in output, because in *general equilibrium*, savers and borrowers take nearly opposite spending decisions. This is a surprising finding that is obtained in a setting in which borrowers and savers are assumed to have very sim-
ilar characteristics. In reality, borrowers and savers may be quite different, for example because a typical borrower may be in a different stage of the life cycle than a typical saver. A useful direction for future research is to explore whether there are plausible forms of heterogeneity between borrowers and savers that could fundamentally change the transmission of shocks.

If frictions in household finance are important for macroeconomic dynamics, then innovations in markets for mortgages and consumer credit might have fundamentally changed the nature of the business cycle. Chapter 3 shows that aggregate data on mortgage debt and consumer credit provide surprisingly little support for this idea. Therefore, models with standard frictions in household borrowing may not be very helpful in explaining the observed change of the business cycle. However, the analysis also shows that once aggregate debt is split up into loans that are on the balance sheets of banks and loans that are not, substantial changes in business cycle behavior of these components are observed. Thus, models that provide more realistic descriptions of the complex decisions made by financial intermediaries, may be more promising in explaining changes in the business cycle than models that focus exclusively on constraints that limit the behavior of borrowers.

Chapter 4 shows that frictions in household borrowing can create a tight link between housing and labor markets. When house prices decline, it becomes unattractive for borrowers to accept job offers that necessitate a move to a distant location, since moving requires borrowers to refinance their mortgages. Credit frictions are shown to magnify and propagate the real effects of shocks that affect house prices.

The effects in Chapter 4 arise in a model with a new type of constraint. Under this new setup, collateral requirements apply only to new mortgage loans, which are taken out when a borrower moves. By contrast, standard credit friction models make the unrealistic assumption that collateral requirements are renewed in each and every period.

The newly introduced constraint has the appeal of realism, but it has not been derived as a feature of an optimal contract. I leave this exercise for further research, but it is
intriguing that in reality lenders usually do not demand any additional downpayments when house prices fall. This may be the result of problems in enforcing additional downpayments. Before a mortgage contract is written, a lender can simply refuse to make a loan unless a certain collateral requirement is met. But once the borrower has received the funds, additional downpayments are only viable if it is in the best interest of the lender to take possession of the collateral if the borrower refuses to comply with the contract. This may not be the case if foreclosures are costly to the lender or easily delayed by the borrower.

A second way to extend the analysis of Chapter 4 is to model homeownership as an endogenous choice. Providing homeowners with the opportunity to become renters may dampen the reduction in geographical mobility when house prices fall. However, a realistic model of renters and homeowners would take into account the benefits of homeownership versus renting. In particular, renters do not have full discretion over their house due to frictions between them and their landlords. Moreover, homeownership may have tax advantages or intrinsic benefits. As a consequence, a homeowner suffers a utility loss when becoming a renter. Such a utility loss obstructs geographical mobility, like the utility loss that is suffered when refinancing a mortgage after a fall in house prices.

Chapter 5 develops a model with heterogeneous borrowers and collateral requirements that are renewed infrequently at the individual level, as is observed in reality. It is shown that transitions in the aggregate demand for mortgage loans occur very gradually. A model without borrower heterogeneity, but with the constraint introduced in Chapter 4 is shown to reproduce this property. In models that follow the standard assumption that collateral requirements are renewed in every period, however, the aggregate demand for loans is very sensitive to shocks. This finding suggests that standard models overstate the effects of credit frictions on the magnification of shocks, but understate their effects on the propagation of shocks.
Samenvatting (summary in Dutch)


Hoofdstuk 2 onderzoekt de effecten van monetaire schokken in een Nieuw-Keynesiaans model waarin huishoudens zowel duurzame als niet-duurzame goederen consumeren. Doorgaans wordt aangenomen dat een verhoging van de rente door de centrale bank leidt tot een daling van de consumptie van beide typen goederen. Empirisch bewijs ondersteunt dit idee. Reguliere Nieuw-Keynesiaanse modellen hebben echter de problematische eigenschap dat de consumptie van duurzame consumptiegoederen juist stijgt na een monetaire verkramping.

In de economische literatuur is geopperd de problematische eigenschappen van de standaard modellen te corrigeren door het toevoegen van kredietrestricties. Indien een renteverhoging leidt tot een verkramping van kredietrestricties, dan zouden huishoudens die afhankelijk zijn van een lening worden gedwongen minder uit te geven aan zowel
duurzame als niet-duurzame goederen. Hoofdstuk 2 laat echter zien dat de introductie van kredietrestricties de problematische eigenschappen van het model juist verergert. Dit is een verrassende bevinding, te meer omdat het model bevestigt dat huishoudens met een lening worden gedwongen tot het terugschroeven van beide typen uitgaven na een monetaire verkrapping. De leningen aan deze huishoudens worden echter gefinancierd met de besparingen van de overige huishoudens in de economie en de spaarders blijken nagenoeg tegenovergesteld te reageren op een monetaire schok. Dit effect komt voort uit het feit dat, in algemeen evenwicht, een daling van de totale hoeveelheid leningen noodzakelijk gepaard gaat met een daling van de besparingen van de huishoudens die de leningen financieren. Deze spaarders hebben echter de beschikking over een alternatieve manier van sparen, namelijk het aanschaffen van extra duurzame consumptiegoederen.

De analyse in Hoofdstuk 2 onderstreep het belang van het rekening houden met algemeen evenwichtseffecten wanneer men nadenkt over de rol van kredietrestricties in de conjunctuur.

Hoofdstuk 3 is gezamenlijk werk met Wouter den Haan en onderzoekt of innovaties in de verlening van hypothecair en consumptief krediet hebben geleid tot kleinere conjunctuurverschommelingen. In de jaren tachtig van de vorige eeuw begon in veel landen een periode van lage macro-economische volatiliteit, die op zijn minst heeft geduurd tot het uitbreken van de recente financiële crisis. Door academici en beleidsmakers is vaak geopperd dat de macro-economische stabilisatie het gevolg kan zijn geweest van innovaties in de kredietverlening aan huishoudens. Deze innovaties zouden het gemakkelijker hebben gemaakt voor huishoudens om te blijven lenen gedurende recessies, met een kleinere daling in de vraag naar consumptiegoederen tot gevolg. Een opvallend empirisch gegeven dat dit idee ondersteunt, is dat in de Verenigde Staten de correlatie tussen het Bruto Binnenlands Product en de hoeveelheid leningen aan huishoudens sterk is gedaald sinds het begin van de jaren 1980.

Met behulp van econometrische methoden bezien we of de cyclische eigenschappen van de uitstaande hoeveelheid hypotheekschuld en consumptief krediet in de economie daad-
werkelijk is veranderd, *conditioneel* op verschillende typen macro-economische schokken. Een dergelijke conditionele analyse is belangrijk omdat correlaties eveneens kunnen veranderen door andere factoren dan financiële innovatie, zoals een verschuiving in de relatieve omvang van verschillende typen schokken. Onze bevinding is dat het conditionele gedrag van hypotheekleningen en consumptief krediet verrassend weinig is veranderd. De data bieden dus geen ondersteuning voor de hypothese dat de impact van macro-economische schokken is verminderd door kleinere effecten op de kredietverlening aan huishoudens.

Hoofdstuk 4 laat zien hoe fricties in de kredietverlening aan huishoudens kunnen leiden tot een nauwe band tussen ontwikkelingen op de huizenmarkt en de arbeidsmarkt. Een daling van huizenprijzen leidt tot een vermogensdaling onder huishoudens en dit vormt een belemmering voor de verhuismobiliteit, omdat voor het verkrijgen van een nieuwe hypotheek een bepaalde hoeveelheid vermogen is vereist. Een daling van de verhuismobiliteit heeft negatieve gevolgen voor de arbeidsmarkt, omdat het aannemen van een baan soms vereist dat men verhuist.


Een belangrijke innovatie in Hoofdstuk 4 is een nieuwe modellering van kredietrestricties. In de macro-economische literatuur is het gebruikelijk te veronderstellen dat kredietrestricties voor alle leningen elke maand of kwartaal worden herzien. Deze veronderstelling is erg onrealistisch in bijvoorbeeld het geval van hypotheken, maar maakt het mogelijk een model te analyseren zonder vermogensheterogeniteit onder huishoudens met een lening. Het vermijden van vermogensheterogeniteit heeft grote technische voordelen.
De nieuwe modellering maakt de realistische veronderstelling dat limieten op bestaande hypotheken niet worden herzien. Desondanks is het onder de nieuwe modellering mogelijk te abstraheren van heterogeniteit.

Hoofdstuk 5 introduceert onverzekerbare inkomens- en verhuisschokken in een model met kredietrestricties, waardoor heterogeniteit tussen leningnemers ontstaat. De eigenschappen van dit model worden vergeleken met twee modellen zonder heterogeniteit tussen leningnemers: één model met een standaard kredietrestrictie, en één model met een kredietrestrictie zoals geïntroduceerd in Hoofdstuk 4. Het doel is te onderzoeken in hoeverre de gebruikelijke veronderstelling dat leningnemers homogeen zijn, de modeleigenschappen vertekent. Een belangrijke bevinding is dat in het model met heterogene leningnemers, transities in de vraag naar hypotheekleningen zich zeer geleidelijk voltrekken. Van de twee modellen zonder heterogeniteit reproduceert alleen het model met de kredietrestrictie zoals in Hoofdstuk 4 deze eigenschap. In het model met de gebruikelijke kredietrestrictie is de vraag naar hypotheekleningen echter veel te gevoelig voor macro-economische schokken.
Bibliography


