

HOUSING AND BANKING OVER THE BUSINESS CYCLE

by

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Abstract

In this dissertation, I develop and study a dynamic general equilibrium (DSGE) model with housing and banking. The framework is used to explore several sets of issues related to housing and financial markets. In Chapter 2, I investigate the extent to which a disruption in banks' balance sheets affects the behavior of the housing market and the macroeconomy in an experiment that mimics the Great Recession. The model can qualitatively capture key features of the phenomenon of the Great Recession in response to a financial shock. In Chapter 3, I investigate the model's ability to more generally account for important features of the business cycle observed in the data. In particular, the model with estimated shocks replicates well several key features of housing and financial markets and the macroeconomy observed in the data. It can quantitatively account for the volatility and procyclicality of consumption, investment, house prices and some financial variables. It can also reproduce the co-movements among the quantities of interest. Moreover, I find that technology shocks are the main driving forces of fluctuations in the housing market and the macroeconomy, explaining more than 95 percent of the volatility in housing investment and house prices, and more than 85 percent of the volatility in consumption and GDP. Financial shocks and housing technology shocks are the primary driving forces of fluctuations in the financial market at business cycle frequencies, explaining more than 90 percent of the volatility in loans and net worth. In Chapter 4, I evaluate various macroprudential policies that might help to mitigate the volatility of house prices and household debts, both of which are perceived to be reliable indicators of financial distress historically. My simulation results show that countercyclical policies specifically designed to react to credit and house price growth are useful in stabilizing the financial and housing markets. Moreover, an asymmetric tax schedule that favours impatient households can reduce the volatility of both house prices and household debts without causing excess volatility in other macroeconomic variables. In this regard, this macroprudential policy can be viewed as an effective tool that can successfully contain both financial imbalances and housing market instability in a booming economy exhibiting rapid house price appreciation and credit expansion.

Dedication

This dissertation is dedicated to my parents for their endless love, support and sacrifice throughout my life, especially during my studies abroad.

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All errors in this dissertation are my own.

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Chapter 1

Introduction

In the aftermath of the Great Recession, there is a growing consensus among economists and policymakers that the genesis of the crisis was associated with the interaction between the financial system and the housing market. Not surprisingly, therefore, housing and banking are no longer perceived as side issues in the modern business cycle literature. Moreover, in light of the Great recession, many researchers now recognize the strong linkage between the housing market and financial system over the business cycle. In particular, the movement of the housing market is not just driven by non-financial factors, but is also driven by financial factors such as banks' balance sheets. Of course, this view is not new. Looking back at the financial crises which have occurred during the last century (e.g. the Asian Financial Crisis), housing and banking have always been at the center of the crises. Unfortunately, this has attracted relatively little attention from business cycle researchers to the linkage between housing and banking before the Great Recession. In retrospect many previous analyses in the housing literature, such as Iacoviello (2005) and Davis and Heathcote (2005), do not explicitly consider the role of financial intermediation in affecting the behavior

of the housing market. Consequently, they are not able to capture the interaction between the housing market and financial system. To address the drawbacks of this previous housing literature, in this dissertation I develop a dynamic stochastic general equilibrium (DSGE) model with housing and banking to study several sets of issues related to the housing market and financial system.

This dissertation mainly consists of three essays that focus on different aspects of the issues related to the U.S. economy. In Chapter 2, I construct a DSGE model in which the housing market interacts with the financial market over the business cycle. My baseline model consists of four main features: (i) sectoral heterogeneity in the final goods sector and the housing sector; (ii) heterogeneity across two types of households; (iii) borrowing frictions in the household sector; and (iv) financial frictions in the banking system. In this chapter, the model is used to conduct an experiment that mimics the Great Recession. I investigate the extent to which the model can qualitatively account for the key features of the Great Recession, especially the features of the housing market. Within the model, I consider a negative shock to capital quality as a trigger which generates a decline in capital/equity prices, causing a disruption in banks' balance sheets and, hence, a downturn in the housing market and the whole economy. Throughout the experiment, I find that the baseline model is successful in its ability to qualitatively capture the phenomenon of the Great Recession. More importantly, it allows me to explore the mechanism through which financial factors affect the behavior of the housing market in response to an exogenous financial shock.

In Chapter 3, I use the baseline model developed in Chapter 2, together with shock processes estimated using a Bayesian approach, to investigate how well the

model fits the data. I compare the business cycle properties reproduced by the model to those reproduced by the previous housing literature in order to investigate whether the model improves on them in some key dimensions such as the volatility of house prices. I find that the model with estimated shocks replicates well several key features of housing markets, financial markets and the macroeconomy observed in the data. In particular, it can quantitatively account for the volatility and procyclicality of consumption, investment, and several key financial variables. More importantly, it replicates well the volatility and procyclicality of house prices, which most existing DSGE models with housing capture quite poorly. Moreover, the model can reproduce the joint behavior among certain quantities of interest. Last, but not least, I find that technology shocks are the main driving force of fluctuations in the housing market and the macroeconomy, explaining more than 95 percent of the fluctuations in the housing market and more than 85 percent of the fluctuations in the macroeconomy. Financial shocks and housing technology shocks are the main driving forces of fluctuations in the financial market, explaining more than 90 percent of the fluctuations in this market.

In Chapter 4, I use the baseline model with technology and housing preference shocks to study the implications of macroprudential policies in stabilizing housing and financial markets. The results from my policy experiments suggest that countercyclical policy instruments (e.g. countercyclical loan-to-value ratios, countercyclical bank reserve ratios and countercyclical capital/leverage ratios), specifically designed to respond to credit and house price growth, work well to mitigate the volatility of household debts and house prices. These policy options can therefore be regarded as effective tools in addressing instability issues in the financial and housing markets in an economy exhibiting rapid house price appreciation and credit expansion. However,

the prudential authorities should be cautious about the use of countercyclical bank reserve ratios and countercyclical capital/leverage ratios in stabilizing the financial and housing markets, since these policy instruments may increase the volatility of business investment and bank net worth. Moreover, an asymmetric tax schedule that favours impatient households (net borrowers), namely macroprudential tax credits, has stabilization benefits from both the housing and financial market from the perspective of the prudential authorities. In particular, it reduces the volatility of house prices and household debts without causing excess volatility in other macroeconomic variables. In this regard, macroprudential tax credits can be viewed as an effective tool that can successfully contain both financial imbalances and housing market instability.

The rest of this chapter provides a broad overview of the literature related to housing, and of the literature related to macroprudential policies designed to address some instability issues in the housing and financial markets.

1.1 A Review of the Housing Literature

An older literature studying the responses of housing investment and house prices to changes in other factors such as interest rates, incomes, construction costs can be traced back to the period between 1960s and 1980s. A few notable papers include Alberts (1962), Fair (1972) and Poterba (1984). Aside from their modeling differences, they uniformly assume that interest rates are fixed, and are set outside of the model. More precisely speaking, interest rates in these papers are assumed not to be linked to changes in the marginal utility of consumption. In retrospect, they do not fit into the modern literature of business cycles while studying housing, because interest rates are an important price in any macroeconomic models.

By learning from the first set of real business cycle (RBC) models such as Kydland and Prescott (1982), researchers found that these older RBC models performed poorly in accounting for several key features of the business cycle observed in the data. For instance, the standard RBC model understates the volatility of hours since it does not distinguish housing investment from other forms of capital. To address the drawbacks of these older RBC models, researchers began to modify the Kydland and Prescott model by allowing for indivisible labor supply and home production in order for the standard RBC models to fit the data in the dimension of hours volatility.¹ Home production models, perhaps, were the first RBC models that explicitly distinguish housing investment from other forms of capital. Strictly speaking, they are the benchmark real business cycle models to the recent housing literature.

However, older home production models have been challenged in accounting for several important features of the business cycle observed in the data. As Davis (2010) notes, these home production models miss the empirical observations that the volatility of business investment is greater than that of home capital. More interestingly, they generate a counterfactual result that housing investment and business investment are negatively correlated. The failure to account for these facts in the home production models can be attributed to the following reasons. First, they assume that home capital is produced using the same technology as all other outputs, implying that real house prices are constant over time. No doubt, this is contrary to data. Second, houses and consumer durable goods are treated as having the same properties in these models. In general, houses depreciate at a significantly lower rate than other durable goods over time, and housing investment is much more volatile

¹See Hansen (1985) and Rogerson (1988) for the RBC models with indivisible labor supply; and see Chang and Hornstein (2006) for a summary of the home production models.

than other durable goods. More importantly, house prices are positively correlated with GDP, whereas other durable goods prices are negatively correlated with GDP, as argued by Davis and Heathcote (2005). All these misspecifications in the home production models inevitably lead to a lower degree of fit with the data.

Davis and Heathcote (2005), Fisher (2007) and Iacoviello and Neri (2010), perhaps, are ancestors of the well-defined business cycle models with housing in the recent housing literature. Davis and Heathcote (2005) develops a business cycle model with multiple production sectors to study the business cycle properties of housing. In their model, houses are assumed to be produced using a different technology from the other outputs (e.g. final goods). The Davis and Heathcote model is able to account for three important features of the business cycle. First, the model replicates well the volatility of residential investment, nonresidential investment and hours in the construction sector, and can account for the fact that residential investment is more volatile than nonresidential investment. Second, it can explain the procyclicality of consumption, residential investment and nonresidential investment. Last, it can capture the fact that hours and output in all production sectors are positively correlated.

Although the model replicates well several key features of the business cycle, the model performs poorly in three dimensions. First, the model misses the empirical correlation between residential investment and house prices. In particular, it reproduces a negative correlation between residential investment and house prices, which is contrary to the data. Second, the model is unable to capture the lead-lag pattern between residential investment and nonresidential investment. As observed in the data, residential investment should lead nonresidential investment. Last, but not least, it significantly understates the volatility of house prices, explaining only one fourth of

the volatility observed in the data.

Soon after the study of Davis and Heathcote (2005), researchers worked to modify the Davis and Heathcote model by allowing for household capital complementarity to business capital, collateral constraints tied to housing values and the heterogeneity of households in order to address the drawbacks of the model in accounting for the volatility of house prices or the joint behavior of residential investment with nonresidential investment and house prices. Fisher (2007) develops a home production model with household capital as a complement to business capital to study the lead-lag pattern between residential investment and nonresidential investment.² With household capital complementarity, traditional home production models are successful in their ability to account for the relative volatility of residential investment and nonresidential investment, and their lead-lag pattern and co-movement. However, Fisher (2007) primarily focuses on studying the business cycle properties of the two types of investment, and abstracts from other issues such as the volatility of house prices and the joint behavior between house prices and other quantities of interest.

Iacoviello and Neri (2010) develops a dynamic stochastic general equilibrium (DSGE) model to study the sources and consequences of fluctuations in the US housing market. Their model features three main frictions: sectoral heterogeneity in production sectors, heterogeneity of households and collateral constraints tied to housing values. They find that their model replicates well the second moments of consumption, housing investment, business investment, house prices and GDP, the procyclicality of consumption, housing investment, business investment and house

²The household capital complementarity is modeled by assuming that households supply “effective” hours to the firms; and that “effective” hours supplied depends on the stock of housing and hours supplied to the labor market.

prices, and the joint behavior of house prices with consumption and housing investment. Although their model seems to fit the data very well, their simulated volatilities and correlations rely heavily on the variety of shocks they used. With a few shocks, their model is unable to explain the business cycle properties of some variables. For example, their model with technology shocks alone fails to account for the volatility of house prices and the joint behavior between house prices and consumption observed in the data. Generally speaking, the models with too many shocks may bear some measurement errors if some of shocks are correlated with each other.³

In contrast, in this dissertation, I develop a variant of the Iacoviello and Neri (2010) model by allowing for financial frictions and show that my model can account for several key features of the business cycle properties even with just a few shocks. These include the volatility of house prices and the correlation between house prices and consumption. Moreover, since most of the previous housing literature does not explicitly consider the role of banking in the business cycle models, those models with housing only are unable to explain the co-movements and procyclicality of several key financial variables, and the joint behavior between housing and financial variables of interest. For the reasons above, I assemble both housing and banking in a DSGE framework to systematically study the relationship between housing and banking over the business cycle. Besides its ability to account for the business cycle properties, I find that my model also captures the main features of the phenomenon of the Great Recession.

³Suppose that some shock innovations are serially correlated, the estimated results would not be reliable.

1.2 A Review of the Literature on Financial Stability and Housing Market Stability

In this section, I review a broad literature of macroprudential policies in stabilizing the housing and financial markets. To organize my discussions on the related literature of macroprudential policies, I start with a review of the literature on the role of early warning indicators of the financial crises.

1.2.1 A Related Literature on the Early Warning Indicators of the Financial Crises

There is a vast recent literature on either the role of early warning indicators of the crises or whether the authorities should directly respond to those indicators in the context of a booming economy preceding the financial crises. Several well-known contributions to this literature are Eichengreen and Arteta (2000), Borio and Lowe (2002), Borio and Drehman (2009), Borge et al. (2009), Gerdesmeier et al. (2009), Alessi and Detken (2009), Fornari and Lemke (2009), Cecchetti et al. (2000), Kanan et al. (2012), Christiano et al. (2008) and Gray et al. (2011). For example, Eichengreen and Arteta (2000) find that a one percent increase in the rate of growth of domestic credit will increase the probability of the financial crisis in the following year by roughly 5%. Borio and Lowe (2002) present empirical evidence that financial imbalances can build up in a low inflation environment and that in some circumstances it is appropriate for the authorities to directly respond to credits and asset prices in order to mitigate the likelihood of financial distress. In particular, a combination of credit gap and asset price gap (deviating from their corresponding

trends) are reliable indicators that signal an impending crisis.⁴ Furthermore, Borio and Drehman (2009), Borge et al. (2009), Gerdesmeier et al. (2009), Alessi and Detken (2009) and Fornari and Lemke (2009) are examples that study early warning indicators associated with credit and asset markets. They find that these indicators work well in predicting episodes of financial distress over longer horizons. Cecchetti et al. (2000) conclude that central banks should react to asset prices, and Kannan et al. (2012) develop and study a DSGE model with housing and show that strong monetary reactions to accelerator mechanisms that push up credit growth and house prices can help to maintain a macroeconomic stability. Christiano et al. (2008) study a model with asset price booms and find that the central bank can improve welfare by targeting credit growth. Gray et al. (2011) argue that there is a role for financial stability indicators in the monetary rule function.

Though these articles differ from one to another in terms of the models and methodologies they adopted, and the specific issues they focus on, they share the common view that directly responding to early warning indicators such as credit and asset prices is appropriate and necessary since in doing so can mitigate the likelihood of financial distress. In accordance with this related literature, in Chapter 4 I extend the policy rule to include household credits and house prices as early warning indicators that signal financial crises, reflecting a concern for financial stability and housing market stability from the perspective of the prudential authorities. I use house prices rather than equity/stock prices as an indicator because housing wealth in general is more important than other financial assets from the perspective of households, and because the housing market has played a critical role in most recent financial crises.

⁴They find that the best combination appears to be for a credit gap of 4 percent and an asset price gap of 40 percent, and it can predict 42 percent of crises.

1.2.2 A Related Literature on Macroprudential Policies

There is a recent growing literature on macroprudential policies in containing financial imbalances and housing market instability. In particular, this literature primarily focuses on the role of macroprudential policies in mitigating the volatility of early warning indicators of the financial crises, such as the volatility in house prices and household debts.

De Walque et al. (2009) use a DSGE model to study the implications of monetary policy. They find that Taylor rules directly targeting some financial variables may perform better than standard Taylor rules targeting output and inflation. Angeloni and Faia (2009) also use a DSGE framework to investigate the implications of macroprudential policies and monetary policies. They find that a tightening of monetary policy can reduce bank leverage and risk when productivity and asset price booms increase it. In particular, in their model the optimal outcome is achieved by a combination of countercyclical capital ratios and a monetary policy rule that directly reacts to bank leverage or asset prices. N'Diaye (2009) finds that countercyclical prudential regulations can reduce fluctuations in output and mitigate the risks of financial instability. Specifically, countercyclical capital adequacy rules work well in reducing large swings in asset prices and the magnitude of the financial accelerator process. Nadauld and Sherlund (2009) argue that a tightening of capital requirements might help to prevent a growth of bubbles. Bianchi (2009) and Bianchi and Mendoza (2010) study the role of a procyclical tax on debt that leans against overborrowing by rational private-sector agents, and find that the tax should be imposed in relatively tranquil times in order to reduce leverage and the severity of financial crises. However, these papers do not distinguish housing from the other forms of financial assets so as to

not capture the implications of macroprudential policies in stabilizing the housing market. In general, housing is more important for households than financial assets, and is always at the center of the most recent financial crisis. In this regard, I use house prices rather than financial asset prices in Chapter 4 in order to investigate the role of macroprudential policies in stabilizing the housing market.

Similar to my study, Kannan et al. (2012) and Gelain, Lansing and Mendicino (2013) extend the Iacoviello and Neri model to investigate the role of macroprudential policies in stabilizing an economy exhibiting credit and house price booms. In particular, Kannan et al. (2012) extends the standard Taylor rule by including household debts to study whether interest rates and macroprudential policy instruments designed specifically to dampen credit market cycles can improve welfare.⁵ They find that in response to financial or housing demand shocks, macroprudential policies that react to household credit growth can improve welfare. In contrast, they undermine welfare when the economy is hit by productivity shocks. But, in their paper, they only consider the implications of interest rate and loan-to-value instruments (e.g. a constant loan-to-value policy) rather than that of other forms of macroprudential policy instruments.

Gelain, Lansing and Mendicino (2013) develops a variant of the Iacoviello and Neri model by introducing simple moving-average forecast rules for a subset of households (sticky information) to study the implications of macroprudential policies in stabilizing the financial and housing markets. In contrast to Kannan et al. (2012), they specifically focus on interest rate instruments designed to dampen both house price and household debt growth and other macroprudential policy instruments such as a

⁵The welfare criterion that they use to rank policy instruments follows a central bank loss function that includes the variance of inflation and output gaps.

debt-to-income lending requirement. They evaluate whether these policy instruments can mitigate the volatility of house prices and household debts without causing excessive volatility in other macroeconomic variables, such as inflation and output. The effects of macroprudential policies on the central bank loss function is also considered in their study.⁶ They find that interest rate policies designed to dampen house price growth can mitigate the volatility of household debts, but magnify the volatility of house prices and inflation. In addition, interest rate policies designed to dampen household debt growth is unable to mitigate the volatility in all variables. Therefore, interest rate instruments in their study are not regarded as effective tools in stabilizing the housing and financial markets. Furthermore, a tightening of loan-to-value ratios (e.g. a constant loan-to-value policy) can mitigate the volatility of household debts but magnify the volatility of output, implying that this policy instrument might not be a good candidate for stabilizing the financial market. Last, a debt-to-income type constraint (e.g. both income and housing enter the collateral constraints) is an effective tool in stabilizing the volatility in both house prices and household debts without causing excessive volatility in other macroeconomic variables.

Since Kannan et al. (2012) and Gelain, Lansing and Mendicino (2013) do not explicitly consider the role of financial frictions and the interaction between housing and banking over the business cycle, their models are unable to evaluate various macroprudential policy instruments that we have frequently seen in practice, such as a tightening of bank reserve requirements or capital/leverage requirements. In the macroprudential policy experiments conducted in Chapter 4, I specifically focus on the implications of these conventional macroprudential policies rather than that of

⁶In Gelain, Lansing and Mendicino (2013), the central bank loss function is a function of the volatility in inflation, output and household debts. In contrast to Kannan et al. (2012), they take household debts into account in the central bank loss function.

interest rate policies in stabilizing the housing and financial markets. In contrast to most current literature on macroprudential policies, in this dissertation I consider several countercyclical policy instruments that are specifically designed to react to household debt and house price growth, since most financial crises are typically associated with large swings in these variables. Theoretically, macroprudential policies designed to tighten the banks' lending/borrowing constraints can restrain the banks' ability to lend, and consequently, reduce house price and credit growth. In this way, the volatility of these quantities may decrease, leading to housing market stability and financial stability. For example, the People's Bank of China has implemented a variety of this type macroprudential policies since 2010, which include a tightening of loan-to-value ratios, bank reserve ratios and capital/leverage ratios in order to stabilize the housing market. Although the use of these macroprudential policies may lower investment, consumption and output, causing a decline in social welfare in the short run, in doing so can maintain relatively stable financial and housing markets in the long run. We should bear in mind that the costs of instability in these markets can be enormous, as suggested by the Great Recession.

This dissertation is organized as follows. Chapter 2 develops the baseline model with housing and banking, and conducts an experiment that mimics the Great Recession. Chapter 3 estimates the shock processes and investigates whether the model with estimated shocks fits the data. Chapter 4 studies the implications of macroprudential policies in stabilizing the housing and financial markets in a booming economy exhibiting rapid appreciation of house prices and credit expansion. Chapter 5 concludes.

Chapter 2

Housing and Banking over the Business Cycle: Financial Crisis Analysis

2.1 Introduction

During the early 1990s, U.S. house prices were relatively stable, but they began to rise sharply at the end of the decade and reached a peak in the second quarter of 2006. Between 2000 and the second quarter of 2006, house prices increased on average by 80%, causing a residential construction boom. Between the middle of 2006 and the first quarter of 2007, the housing boom quickly turned into a bust as house prices started to fall. Consequently, it led to a high level of mortgage delinquencies and defaults in the banking system, creating a vicious cycle that precipitated more and more losses on banks' balance sheets and subsequent declines in house prices. The rapid reversal of U.S. house prices ignited a chain of events that eventually led to a

credit crunch in the economy and a downturn of the housing market. Between 2007 and 2009, the United States experienced the worst financial crisis of the post-war era. Both the housing market and the financial market were brought to a halt during this period. The experience of the 2007 financial crisis has raised concerns that the movement of the housing market over the business cycle is not just driven by non-financial factors, but might also be driven by financial factors. In particular, the movements of house prices and quantities are associated with the condition of banks' balance sheets.

In order to study these issues, I construct a DSGE model that allows the housing market to interact with the financial market over the business cycle. In this chapter, the model is used to conduct an experiment that mimics the Great Recession. In particular, I investigate the extent to which the model can qualitatively account for key features of the Great Recession, especially those associated with the housing market. Following Gertler and Kiyotaki (2010), I consider a negative shock to capital quality as a trigger to generate a decline in capital/equity prices, causing a disruption in banks' balance sheets, and hence a downturn in the housing market and the whole economy. I find that the baseline model is successful in its ability to qualitatively capture key features of the phenomenon of the Great Recession. More importantly, it allows me to explore the mechanisms by which financial factors affect the behavior of the housing market in response to an exogenous financial shock.

My model builds on that of Iacoviello and Neri (2010) by introducing financial frictions along the lines of Gertler and Kiyotaki (2010). Specifically, my baseline model consists of four main features: (i) sectoral heterogeneity in the final goods sector and the housing sector; (ii) heterogeneity across two types of households; (iii) borrowing

frictions in the household sector; and (iv) financial frictions in the banking system. These features are primarily drawn from two strands of current literature which study the role of housing or the role of banking in business cycle models. The business cycle models with housing - Greenwood and Hercowitz (1991), Benhabib, Rogerson and Wright (1991), Gervais (2002), Davis and Heathcote (2005), Iacoviello (2005), Fisher (2007), Christensen, Corrigan, Mendicino and Nishiyama (2009), Iacoviello and Neri (2010), Iacoviello and Pavan (2011), Kiyotaki, and Michaelides and Nikolov (2011) - study the behavior of the housing market over the business cycle by dealing with some combination of (i), (ii) and (iii). Business cycle models with banking such as Meh and Moran (2004), Gertler and Karadi (2009), Gerali, Neri, Sessa and Signoretti (2009), Angeloni and Faia (2009), Gertler and Kiyotaki (2010), Gertler, Kiyotaki and Queralto (2011) and Gertler and Kiyotaki (2013) study the role of banks in the transmission of financial shocks. However, none of these focus on the interaction between the housing market and financial factors in a general equilibrium context, which is the focus of this paper. More importantly, none of them incorporates both (iii) and (iv) in a way that allows them to interact with each other in equilibrium, which is the main theoretical contribution of this paper.¹

To my knowledge, my model is the one of the few that combines both the housing and the financial literature in order to systematically investigate the link between the housing market and financial market over the business cycle. Although Iacoviello (2010a) also develops a DSGE model with housing and banking, aside from modeling differences, he mainly focuses on the effects of financial intermediations on the

¹Some recent notable papers that incorporate the collateral constraints alone are by Iacoviello(2005), Iacoviello and Neri (2010), and Monacelli (2009); others that incorporate the banks' incentive constraints alone are by Gertler and Kiyotaki(2010), Gertler, Kiyotaki and Queralto (2011), and Gertler and Kiyotaki (2013). None of those papers, however, consider both constraints working together in a way that allows them to interact with each other.

macroeconomy rather than that on the housing and financial markets. Moreover, within his framework, the formulation of the bankers' problem is analogous to the households' problem where bankers maximize a convex function of consumption, and operate on their own behalf. In contrast, in my model banks are firms rather than individuals. The formulation of the banks' problem is analogous to the firms' problem where banks maximize the expected life-time net worth (e.g. profits/dividends), and operate on the behalf of patient households (net savers). In practice, banks are owned by the wealthier, and they run the business to maximize their net worth rather than consumption in general. In this regard, the banks' problem formulated in Iacoveillo (2010a) lacks of microfoundations in the real world. Lastly, the initial exogenous shock in Iacoveillo (2010a) is the repayment shock - impatient households (subprimers) pay less than their obligations. Since the shock is persistent, in absence of any risk of default penalties, subprimers face a persistent positive wealth shock on the one hand, and banks face a persistent negative wealth shock on the other hand. But, this is not a case in the Great Recession since both households and banks are net losers in the crisis. In my model, I assume that the initial disturbance that worsens the banks' balance sheet is a capital quality shock, as in Gertler and Kiyotaki (2010). Though the 2007 financial crisis is initially triggered by a decline in housing values, I introduce the capital quality shock as a simple way to motivate an exogenous source that exacerbates the banks' balance sheet. The model with a capital quality shock can qualitatively capture key features of the phenomenon of the crisis. More importantly, the model is rich enough to capture the interactions between the housing market and financial factors during the financial crisis. Gertler and Kiyotaki (2010) is perhaps my closest antecedent since I adopt the same formulation of financial frictions in the

general equilibrium context. While both housing and banking are considered in this chapter, the baseline model can not only be used as a complement to its antecedents, but also provides an alternative framework to the family of business cycle models with housing and banking.

In what follows, Section 2.2 documents some of the key features of U.S. housing and financial time series from 1973 to 2011. Section 2.3 develops the baseline model. Section 2.4 characterizes the competitive equilibrium of the model. Section 2.5 reports the data description and parameter calibration. In Section 2.6, I carry out an experiment that mimics the Great Recession to investigate the dynamic implications of the financial shocks. Section 2.7 concludes. All proofs and extended derivations are given in the appendix.

2.2 Facts

There are several interesting dimensions that matter as far as housing, banking and some key components of GDP are concerned. In this section, I present several facts related to the topics addressed in this paper. Some of facts are not new, and have been frequently noted by other authors.² Others, however, are rarely noted in the housing literature.³

Figure 2.1 plots the main components of real GDP and real house prices (Freddie Mac House Price Index) together with real GDP for the United States from 1973 to 2011. From Figure 2.1, consumption is procyclical and less volatile than GDP in the sample period. Both nonresidential investment (business investment) and residential

²For instance, several key facts about housing have been documented in Iacoviello (2010b)

³To my knowledge, the facts about the comovement between housing and financial factors have not been systematically documented in the context of housing literature.

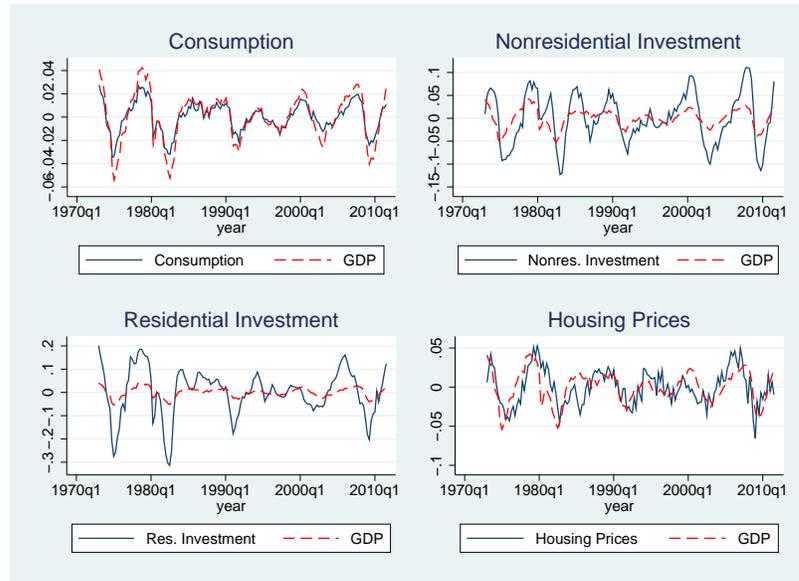


Figure 2.1: The Main Components of GDP and Real House Price Indices VS GDP (1973-2011)

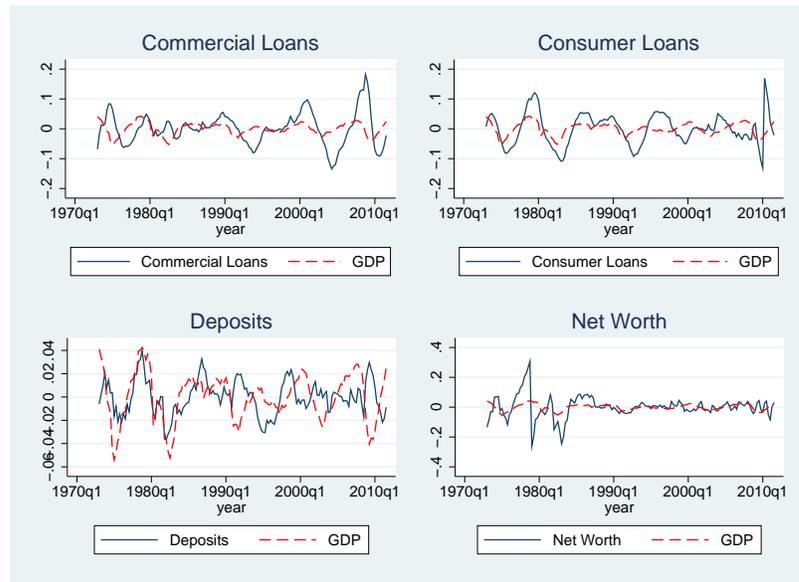


Figure 2.2: Financial Variables VS GDP (1973-2011)

investment (housing investment) are procyclical and much more volatile than GDP. Note that the percentage standard deviations of both nonresidential investment and residential investment are more than twice that of GDP. House prices are procyclical and more volatile than GDP. Moreover, consumption, nonresidential investment, residential investment, house prices and GDP all declined significantly between 2008 and 2010, implying that both the housing market and the macroeconomy suffered huge losses in the Great Recession. Although these facts have been frequently noted in the previous housing literature (see Davis and Heathcote (2005), Iacoviello (2010b), and Iacoviello and Neri (2010)), I revisit them in order to organize my discussions in the rest of this chapter.

Figure 2.2 plots several financial time series against real GDP for the United States. Commercial loans are only loosely related to GDP, but much more volatile. Consumer loans are procyclical and much more volatile than GDP. Deposits are weakly and positively related to GDP, and are slightly less volatile than the latter. Net worth is procyclical and much more volatile than GDP. The percentage standard deviation of net worth relative to GDP was high in 1970s and 1980s, but fell after 1990. I also observe from Figure 2.2 that both net worth and deposits started to fall in early 2007 and continued to fall until 2009. It was then followed by a decline in both commercial loans and consumer loans. In particular, they started to fall in early 2008, to the trough in 2010. These facts illustrate that the banking system experienced difficult times during the Great Recession.

Figure 2.3 plots the joint behavior of house prices with the main components of GDP and consumer loans. Consumption, nonresidential investment, residential investment and consumer loans are all positively correlated with house prices. These

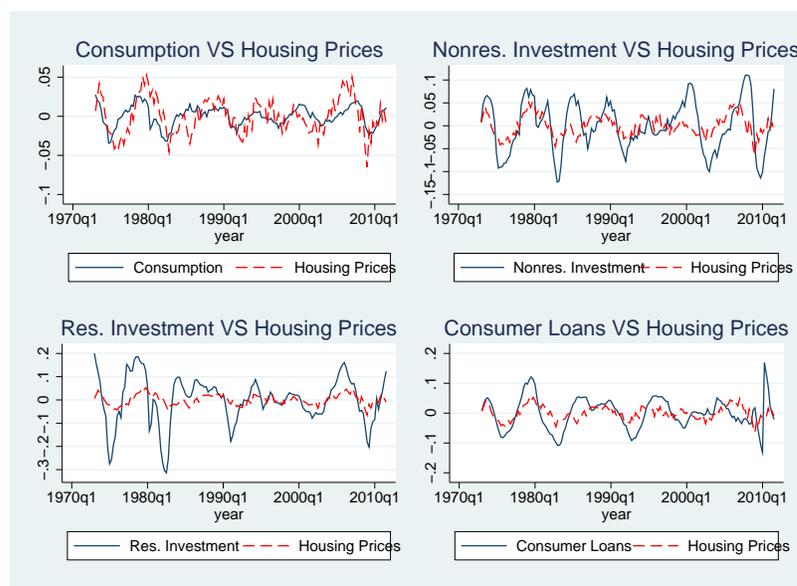


Figure 2.3: The Main Components of GDP and Consumer Loans VS Real House Price Indices (1973-2011)

facts are consistent with the now-famous quote by Ed Leamer that “housing is the business cycle”.

Figure 2.4 plots the joint behavior of financial factors with the main components of GDP, and the joint behavior of residential investment and nonresidential investment. From Figure 2.4, residential investment and nonresidential investment are positively correlated, and the former leads the latter. The pattern that peaks and troughs in residential investment precede peaks and troughs in nonresidential investment is also often used to support the view that “housing is the business cycle”. In addition, residential investment is more volatile than nonresidential investment by almost a factor of two. Commercial loans are positively correlated with nonresidential investment. Consumer loans are not only positively correlated with residential investment but also positively correlated with consumption. Combined with the observations from Figure 2.2, these stylized facts could be used to say that “banking is also the business

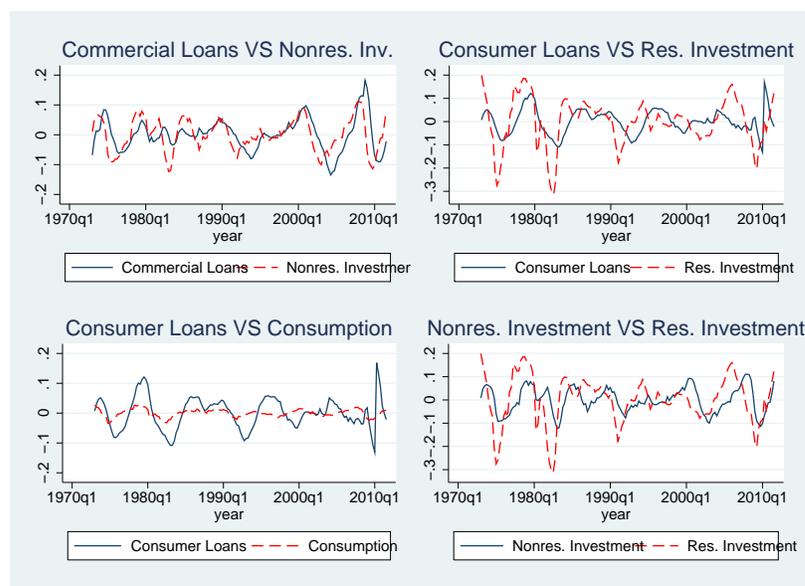


Figure 2.4: The Main Components of GDP VS Financial Variables and Nonresidential Investment VS Residential Investment (1973-2011)

cycle”.

Although I might have omitted other interesting facts about housing and banking that some readers might regard as equally important, the facts that have been documented in this paper should be considered as an important yardstick to measure the success of DSGE models with housing and banking.

2.3 The Model

The model features multiple production sectors, heterogeneity in discount factors between two types of households, a borrowing friction faced by borrowers, and a financial friction faced by intermediaries. Following Gertler and Kiyotaki (2010), I formulate the banking system in a way that reflects a financial constraint associated with the bank’s net worth when a bank issues deposits and makes loans. Aside from

the introduction of the banking system, the baseline model closely follows a modified version of Iacoviello and Neri (2010).

There are two groups of households in the economy and each group has a unit measure of households. One group consists of patient households (net savers), and the other consists of impatient households (net borrowers). The economic size of each group is measured by its wage share, which is constant due to a unit elasticity of substitution in production. Households do not hold physical capital directly. Rather, they work, consume final goods, buy houses and deposit funds into or borrow from banks. In the equilibrium that I describe below, patient households turn out to be net savers and lend funds to impatient households and non-financial firms through the banking system. Conversely, impatient households turn out to be net borrowers in equilibrium, and in general they borrow funds from the banking system against their collateral which is tied to their housing values.

I assume that both the final goods sector and the housing sector operate under perfect competition, and that they produce consumption/investment goods and houses respectively using two different technologies. Firms in the final goods sector hire labor from households, and borrow funds from a bank to purchase intermediate physical capital. For simplicity, it is assumed that the final goods sector faces no further borrowing constraint and can commit to repay its debt obligations with its future gross profits to the creditor bank. In particular, a final goods producer obtains funds from a creditor bank by issuing state-contingent equities, and each unit of equity is a state-contingent claim to the future returns from one unit of new capital investment. Firms in the housing sector also hire labor from households and rent land as an input from patient households in order to produce houses.

The capital producer purchases final goods to be used as inputs to produce new capital and is subject to an adjustment cost. Firms in the capital sector are assumed to be owned by patient households, and all profits are redistributed to patient households through a lump sum transfer.

Banks are assumed to operate in a national retail market only. At the beginning of each period, banks obtain deposits from patient households and make loans to impatient households (e.g. consumer loans/mortgages) and non-housing sectors (e.g. commercial loans). I rule out borrowing and lending in a wholesale market (e.g. inter-bank activities) since inter-bank activities are beyond the scope of this paper.⁴ As I mentioned earlier, banks are subject to an incentive constraint (deposit/lending constraint). Specifically, each bank with a given portfolio is constrained in its ability to issue deposits to savers and to make loans to borrowers. The incentive constraint can be motivated by government regulatory concerns or by standard moral hazard issues. Fundamentally, both incentive constraints and collateral constraints coexist and interact in the equilibrium so that banks are credit constrained in how much they can accept in the form of deposits from patient households, and impatient households are credit constrained in how much they can borrow from banks. These two frictions interact and reinforce each other to induce a credit crunch during a financial crisis, and thus amplify the resulting economic recession.

⁴A notable paper regarding the inter-bank borrowing/lending is by Gertler and Kiyotaki (2010). For the case where the interbank borrowing is frictionless, the implication of the model would be similar to the baseline model. Otherwise, the results may change since interbank rates will lie between deposit rates and loan rates. The addition of an imperfect wholesale financial market will make the model less tractable.

2.3.1 Households

Patient Households (Savers)

As in Iacoviello and Neri (2010), I formulate the heterogeneity of households in a way that allows each group of households to differ in their discount factors and labor supply parameters. In the economy, there is a unit measure of patient households indexed by p . A representative patient household maximizes its lifetime utility function given by

$$U_p = E_0 \sum_{t=0}^{\infty} \beta_p^t \left\{ \ln c_{p,t} + j \ln h_{p,t} - \frac{1}{1 + \eta_p} \left((l_{pc,t})^{1+\epsilon_p} + (l_{ph,t})^{1+\epsilon_p} \right)^{\frac{1+\eta_p}{1+\epsilon_p}} \right\}.$$

Here, c_p , h_p , l_{pc} and l_{ph} are consumption, housing, hours supplied to the final goods sector and hours supplied to the housing sector, respectively. The last term in the bracket is the labor disutility function where η and ϵ are parameters that capture some degree of sector specificity. The formulation of the labor disutility function follows Horvath (2000) and Iacovello and Neri (2010), and with some choices of parameters it allows for imperfect labor mobility across production sectors. That is, hours are less perfect substitutes if $\epsilon > 0$; otherwise, they are perfect substitutes (e.g. $\epsilon = 0$). The parameter j captures the degree of preference towards housing. The parameter β_p is denoted as the discount factor for patient households. I assume $\beta_p > \beta_i$ in order to ensure that both impatient households and banks will be credit constrained in a neighborhood of the steady state.

Patient households supply labor to producers, consume final goods, accumulate houses, and deposit or borrow funds with banks. They do not hold physical capitals directly. Rather, they hold land and rent it to the housing sector. Banks are assumed to be owned by patient households. In each period, patient households can receive

a lump sum transfer from banks. As I will discuss in the next subsection, banks divert funds only to patient households upon their exit. The representative patient household faces the following budget constraint,

$$c_{p,t} + q_t h_{p,t} + p_{x,t} x_t + d_t = w_{pc,t} l_{pc,t} + w_{ph,t} l_{ph,t} + q_t (1 - \delta_h) h_{p,t-1} + (p_{x,t} + R_t^x) x_{t-1} + R_t^d d_{t-1} + \Pi_t.$$

At the beginning of each period, the patient household chooses consumption $c_{p,t}$, housing $h_{p,t}$, land x_t , deposits d_t (loans if d_t is negative), hours $l_{pc,t}$ and $l_{ph,t}$ to maximize his/her utility subject this budget constraint. The parameter δ_h denotes the depreciation rate of housing. The terms q_t and $p_{x,t}$ denote house prices and land prices, respectively. The terms $w_{pc,t}$ and $w_{ph,t}$ are real wages from supplying labor hours to final good and housing sectors. Deposits, d_t , are set in real terms here, and will yield a riskless return of R_t^d from period $t - 1$ to period t . In addition, land is rented to the housing sector at a price of R_t^x . Finally, Π_t is the net average transfer received by the patient household from banks upon their exit.

The patient household's optimality conditions for consumption/deposits, houses, land, and hours taking prices as given are given by:

$$1 = \beta_p E_t \left(\frac{c_{p,t}}{c_{p,t+1}} R_{t+1}^d \right) \quad (2.1)$$

$$\frac{q_t}{c_{p,t}} = \frac{j}{h_{p,t}} + \beta_p E_t \left(\frac{(1 - \delta_h) q_{t+1}}{c_{p,t+1}} \right) \quad (2.2)$$

$$\frac{p_{x,t}}{c_{p,t}} = \beta_p E_t \left[\frac{p_{x,t+1} + R_{t+1}^x}{c_{p,t+1}} \right] \quad (2.3)$$

$$\frac{w_{pc,t}}{c_{p,t}} = (l_{pc,t}^{1+\epsilon_p} + l_{ph,t}^{1+\epsilon_p})^{\frac{\eta_p - \epsilon_p}{1+\epsilon_p}} l_{pc,t}^{\epsilon_p} \quad (2.4)$$

$$\frac{w_{ph,t}}{c_{p,t}} = (l_{pc,t}^{1+\epsilon_p} + l_{ph,t}^{1+\epsilon_p})^{\frac{\eta_p - \epsilon_p}{1+\epsilon_p}} l_{ph,t}^{\epsilon_p} \quad (2.5)$$

Impatient Households (Borrowers)

Impatient households are assumed to hold no land or physical capital.⁵ In addition, they do not own banks and production sectors.⁶ Rather, they work, consume, and are allowed to borrow funds from banks up to a fraction of the value of their houses. A representative impatient household chooses consumption $c_{i,t}$, housing $h_{i,t}$, hours $l_{ic,t}$ and $l_{ih,t}$, and loans b_t (saving if b_t is negative) to maximize its expected utility:

$$U_i = E_0 \sum_{t=0}^{\infty} \beta_i^t \left\{ \ln c_{i,t} + j \ln h_{i,t} - \frac{1}{1 + \eta_i} \left((l_{ic,t})^{1+\epsilon_i} + (l_{ih,t})^{1+\epsilon_i} \right)^{\frac{1+\eta_i}{1+\epsilon_i}} \right\},$$

subject to the following budget and collateral constraints:

$$\begin{aligned} c_{i,t} + q_t h_{i,t} + R_t^b b_{t-1} &= w_{ic,t} l_{ic,t} + w_{ih,t} l_{ih,t} + q_t (1 - \delta_h) h_{i,t-1} + b_t \\ b_t &\leq m E_t \left(\frac{q_{t+1} h_{i,t}}{R_{t+1}^b} \right), \end{aligned}$$

where $w_{ic,t}$ and $w_{ih,t}$ are real wage rates from supplying hours to final goods sector and housing sector, respectively; and R_t^b is the rate of return on loans/savings incurred at date $t - 1$. The collateral constraint characterizes the limit on the impatient household's ability to borrow up to the discounted future value of their houses. The term m is the loan-to-value (LTV) ratio that measures the effective degree of liquidity of houses. The larger m is, the greater is the value of housing as collateral to the

⁵Here, impatient households can be treated as those who are poor. In general, the amount of land and physical capital held by them are relatively small so that can be ignored in the model. One may assume that this type of household also accumulate these assets, but implications of the model are similar. For simplicity, I assume that impatient households do not hold both land and capital. This assumption is consistent with Iacoviello and Neri (2010).

⁶In the equilibrium, all production sectors earn zero profit so it does not matter for the results if one assume that impatient households also own production sectors. In addition, a lump-sum transfer between banks and households plays a trivial role in the model, as in Gertler and Kiyotaki (2010). In this regard, I do not assume that impatient households own banks for the sake of tractability.

impatient household. Here, β_i denotes the discount factor to the impatient household. Recall that we have $\beta_p > \beta_i$ in the model. This is a necessary condition that ensures impatient households are credit constrained in the neighborhood of the steady state, together with other parameters calibrated in the model.

The impatient household's first-order conditions with respect to consumption, houses, loans, and hours taking prices as given can be written as:

$$\frac{j}{h_{i,t}} + \beta_i E_t \left(\frac{(1 - \delta_h) q_{t+1}}{c_{i,t+1}} \right) = \frac{q_t}{c_{i,t}} - \lambda_{i,t} m E_t \left(\frac{q_{t+1}}{R_{t+1}^b} \right) \quad (2.6)$$

$$\frac{1}{c_{i,t}} = \beta_i E_t \left(\frac{R_{t+1}^b}{c_{i,t+1}} \right) + \lambda_{i,t} \quad (2.7)$$

$$\frac{w_{ic,t}}{c_{i,t}} = (l_{ic,t}^{1+\epsilon_i} + l_{ih,t}^{1+\epsilon_i})^{\frac{\eta_i - \epsilon_i}{1+\epsilon_i}} l_{ic,t}^{\epsilon_i} \quad (2.8)$$

$$\frac{w_{ih,t}}{c_{i,t}} = (l_{ic,t}^{1+\epsilon_i} + l_{ih,t}^{1+\epsilon_i})^{\frac{\eta_i - \epsilon_i}{1+\epsilon_i}} l_{ih,t}^{\epsilon_i} \quad (2.9)$$

$$b_t = m E_t \left(\frac{q_{t+1} h_{i,t}}{R_{t+1}^b} \right), \quad (2.10)$$

where $\lambda_{i,t}$ denotes the Lagrange multiplier on the collateral constraint. The collateral constraint is binding, if the multiplier is positive.⁷

2.3.2 Banks

There are a large number of banks operating in a national financial market. Within the national financial market, I assume banks raise funds from patient households in a retail market rather than funds from inter-bank borrowing in a wholesale market.

⁷From equation (2.7), one may find that the collateral constraint is binding ($\lambda_i > 0$) in the steady state if and only if $R^d < \frac{1}{\beta_i}$. Given parameters calibrated in the model, we will observe later that this condition is satisfied.

Because this paper primarily focuses on the interaction between the housing market and financial intermediation, the addition of inter-bank borrowing would go beyond the scope of this paper.

At the beginning of each period, a bank obtains deposits d_t from patient households, and pays a gross interest rate of R_{t+1}^d in the following period. In this economy, deposits are riskless one-period securities. At the same time, a bank makes consumer loans b_t to impatient households at a loan rate of R_{t+1}^b , and commercial loans to non-financial firms (e.g. final goods producers) in exchange for state-contingent equities from those firms at the price p_t . Consumer loans are subject to a friction because impatient households can only borrow up to a fraction of their housing values. For simplicity, I assume there are no frictions associated with commercial borrowing. Following Gertler and Kiyotaki (2010), I assume banks are not only more efficient at evaluating and monitoring all activities of non-financial sectors than households, but are also more effective in enforcing contractual obligations. To motivate the logic above, I assume there are no costs for a bank performing these activities. Given these assumptions, a bank can issue frictionless loans to the final goods sector on the one hand, and a borrowing firm is able to offer the bank state-contingent equity on the other hand. In particular, each unit of equity is a state-contingent claim to the future returns from one unit of new capital investment.

Let s_t be the quantity of equities held by a representative bank, and n_t be the net worth of the bank in period t . Then the bank's net worth is equal to the gross payoffs from its assets (e.g. commercial loans and consumer loans) incurred at period $t - 1$ net of deposit costs:

$$n_t = (Z_t + (1 - \delta_k)p_t)\psi_t s_{t-1} + R_t^b b_{t-1} - R_t^d d_{t-1}, \quad (2.11)$$

where the term δ_k is the capital depreciation rate. For simplicity, I assume the bank receives a unit of equity every time it issues commercial loans to non-financial firms to purchase an additional unit of capital. Accordingly, the quantity of equity in the economy remains the same as the quantity of capital.⁸ The variable Z_t denotes the dividends paid in period t on the equities issued in period $t - 1$. The variable ψ_t represents a capital quality shock, and follows an AR(1) process.⁹ As we will observe later, the market price of capital in the model is determined endogenously. Accordingly, one may think of this capital quality shock as an exogenous trigger to asset price dynamics. Note that the disturbance, ψ_t , is different from a standard rate of physical depreciation in that it can capture some forms of economic obsolescence.¹⁰ In the model, this capital quality shock initially induces a deterioration in the banks' balance sheet. When the losses on the balance sheet induced by the shock cannot be fully absorbed by banks, a credit crunch may arise for the whole economy.

In period t , the flow-of-funds constraint for a bank can be written as,

$$p_t s_t + b_t = n_t + d_t. \quad (2.12)$$

The equation above implies that the bank's assets (e.g. loans) must equal its net

⁸This assumption is widely used by papers like Kiyotaki, Michaelides and Nikolov (2011) and Kiyotaki and Gertler (2010). In the model, equity and capital exhibit a one-to-one relation in order to maintain tractability of the model. Thus, the price of equity equals to the price of capital in the model by this assumption.

⁹Following Gertler and Kiyotaki(2010), I introduce the capital quality shock as a simple way to motivate an exogenous source of variation in the value of capital.

¹⁰As Gertler and Kiyotaki (2010) argued, capital in general is good-specific once it is installed. Suppose that the final goods are produced by a composite of intermediate goods that are in turn produced by combining capital and labor in a Cobb-Douglas production function. The capital used to produce the goods become worthless if the goods are obsolete and the capital used to produce the new goods is not fully on line. In this case, a capital quality shock can capture some forms of economic obsolescence. Intuitively, this shock might be thought of as capturing a disturbance to agents' anticipations over the quality/utilization of capital.

worth plus liabilities (e.g. deposits).

In the absence of some motive for paying dividends to households, banks may find it optimal to accumulate assets to the point where the financial constraint they face is no longer binding. In order to limit banks' ability to save to overcome financial constraint, following Gertler and Kiyotaki (2010), I introduce an exogenous shock that induces the bank to leave the economy. In particular, a bank exits the economy. Upon exiting, a bank transfers all retained earnings to patient households.¹¹ At the same time, a new bank may, with probability $1 - \sigma$, be established, leaving the number of banks constant in each period. In particular, a new bank takes over the business of an exiting bank and in the process inherits the skills of the exiting bank at no costs. The new bank receives a small fraction of the total assets of an ongoing bank as a "startup" fund from patient households. Recall that in each period a representative patient household receives an average net transfer Π_t from banks. The net transfer then must equal the funds transferred from exiting banks minus funds transferred to start-ups.

As I mentioned earlier, an endogenous financial constraint (incentive constraint) is introduced into the model. To motivate the endogenous financial constraint on the bank's ability to obtain funds in the retail financial market, I assume that the bank may divert a fraction θ of its assets to its owners (e.g. patient households) after it obtains funds (e.g. deposits) from the retail financial market. The bank's assets comprise the total value of equities held by the bank, $p_t s_t$, and consumer loans to impatient households, b_t . If the bank diverts its assets to its owners, it defaults on its debts (e.g. deposits) and is then forced to shut down. The creditors may

¹¹The expected survival time of a bank, $\frac{1}{1-\sigma}$, is about 9 years. It is important that the survival time is finite in the model so that patient households would finally get paid with dividends from banks even though the financial constraints are still binding.

reclaim the remaining fraction $1 - \theta$ of funds. Given the risk of banks' default on their debts, creditors restrict the amount they lend to the bank at the beginning of each period. Accordingly, banks are constrained in their ability to obtain funds in the retail financial market, and in this way a financial constraint may arise. The bank's decision over whether to default on its debts must be made at the end of each period after the realization of the aggregate shock.

Let $V_t(s_t, b_t, d_t)$ be the value function of a bank at the end of period t , given its portfolio holdings (s_t, b_t, d_t) . A bank will not default or divert funds, if it satisfies the incentive constraint given by,

$$V_t(s_t, b_t, d_t) \geq \theta(p_t s_t + b_t). \quad (2.13)$$

Let $\Lambda_{t,t+i}$ be the stochastic discount factor, which is equal to the patient households' marginal rate of substitution between consumption in period $t+i$ and that in period t . Since in the model banks are owned by patient households, they act on their behalf. In this regard, banks are assumed to have the same discount factor as patient households, $\beta_b = \beta_p > \beta_i$. In each period t , a representative bank maximizes the present value of its expected future net worth,

$$V_t(s_t, b_t, d_t) = E_t \sum_{i=1}^{\infty} (1 - \sigma) \sigma^{i-1} \Lambda_{t,t+i} n_{t+i}, \quad (2.14)$$

subject to the incentive constraint and the flow-of-funds constraint given above. Recall that banks only pay dividends when they exit. Thus, the probability that a bank exits and pays the dividends after i periods from date t is $(1 - \sigma) \sigma^{i-1}$ for $i \in [1, \infty)$. Given the bank's problem above, one can easily write the Bellman equation as follows,

$$V_{t-1}(s_{t-1}, b_{t-1}, d_{t-1}) = E_{t-1} \Lambda_{t-1,t} \{(1 - \sigma)n_t + \sigma \max_{s_t, b_t, d_t} V_t(s_t, b_t, d_t)\}. \quad (2.15)$$

To solve the bank's problem, I first guess that the value function, V_t , is a time-varying linear function of (s_t, b_t, d_t) given by,

$$V_t(s_t, b_t, d_t) = \nu_{st}s_t + \nu_{bt}b_t - \nu_{dt}d_t \quad (2.16)$$

where ν_{st} is the marginal value of equities at the end of period t ; ν_{bt} is the marginal value of consumer loans; and ν_{dt} is the marginal cost of deposits. In particular, these coefficients do not depend on the choices of individual banks.¹²

Let λ_t^b be the Lagrangian multiplier associated with the bank's incentive constraint. Given the conjectured form of the value function, one may use the Bellman equation together with the bank's incentive constraint and the flow-of-funds constraint to solve the bank's problem.¹³ The objective function of the bank may be expressed as a Lagrangian,

$$\mathcal{L} = \nu_{st}s_t + \nu_{bt}(n_t + d_t - p_t s_t) - \nu_{dt}d_t + \lambda_t^b [(\nu_{bt} - \theta)n_t - (\nu_{bt} - \frac{\nu_{st}}{p_t})p_t s_t - (\theta - (\nu_{bt} - \nu_{dt}))d_t].$$

For the coefficients of the value function to be consistent with finite, positive choices

¹²One may treat these coefficients like prices. They are as being taken as given by individual banks.

¹³The nature of the maximization problem reflects the timing assumption that choices are made after the resolution of uncertainty

of s , b and d in equilibrium, they must satisfy

$$\frac{\nu_{st}}{p_t} - \nu_{bt} = 0 \quad (2.17)$$

$$(1 + \lambda_t^b)(\nu_{bt} - \nu_{dt}) = \theta \lambda_t^b \quad (2.18)$$

$$(\theta - (\nu_{bt} - \nu_{dt}))b_t + (\theta - (\frac{\nu_{st}}{p_t} - \nu_{dt}))p_t s_t \leq \nu_{dt} n_t. \quad (2.19)$$

Equation (2.17) indicates that the marginal value of equities must be equal to the marginal value of consumer loans, leading to no arbitrage opportunities across assets. That is, banks are indifferent between making commercial loans to non-financial sectors and making consumer loans to impatient households. Equation (2.18) implies that the marginal value of consumer loans exceeds the marginal cost of deposits if and only if the incentive constraint is binding ($\lambda_t^b > 0$). Accordingly, given equation (2.17) and equation (2.18), we will see later that in the model with financial frictions ($\lambda_t^b > 0$) there are excess returns on assets over deposits. This finding is consistent with that found by previous authors in the financial literature such as Gertler and Kiyotaki (2010) and Iacoviello (2010a). Equation (2.19) is the bank's incentive constraint, and it states that the value of the bank's net worth must be at least as large as a weighted average value of its assets. When equation (2.19) holds with equality, financial frictions may arise.¹⁴

Due to the linearity of the problem, the conditions (2.17), (2.18) and (2.19) must hold in order for the equilibrium in the asset markets to be interior. Otherwise, banks would choose corner solutions. If corner solutions were chosen, other equilibrium conditions would be violated.¹⁵

¹⁴The complementary slackness condition, $[\nu_{dt} n_t - ((\theta - (\nu_{bt} - \nu_{dt}))b_t + (\theta - (\frac{\nu_{st}}{p_t} - \nu_{dt}))p_t s_t)]\lambda_t^b = 0$, implies that the incentive constraint (2.19) binds if $\lambda_t^b > 0$; otherwise, it may not bind.

¹⁵Banks choose $d = 0$ if and only if $\nu_b < \nu_d$, in which case it would violate the equilibrium

In the next section, I proceed to characterize the model for two cases: with financial frictions ($\lambda_t^b > 0$) and without financial frictions ($\lambda_t^b = 0$). Furthermore, I will subsequently compare the models, and investigate how the financial friction amplifies the effect of an exogenous shock on the banks' balance sheet, and propagates this to the housing market and the economy as a whole. Note that whether the financial constraint is binding or not depends on the value of θ . When $\theta = 0.4253$, as calibrated by the model, the financial constraint is binding. When $\theta = 0$, it is not binding. Therefore, a critical value of θ must exist within a range between 0 and 0.4253 such that the financial constraint is binding.

Case 1: The Banking System with Financial Frictions

With financial frictions, banks are constrained in their ability to make loans to impatient households and non-financial firms. Given that the bank's incentive constraint is binding, equation (2.17) requires that the marginal value of equities relative to goods must equal the marginal value of consumer loans,

$$\frac{\nu_{st}}{p_t} = \nu_{bt}. \quad (2.20)$$

In addition, equation (2.18) implies that the marginal value of consumer loans exceeds the marginal cost of deposits,

$$\nu_{bt} - \nu_{dt} > 0. \quad (2.21)$$

condition $\nu_b \geq \nu_d$ for $\lambda^b \geq 0$; if banks choose $b = 0$, then the collateral constraint (2.10) implies either $q = 0$ or $h_i = 0$, in which case it would violate either the FOCs for housing or the necessary condition $h_i > 0$; if banks choose $s = 0$, then $k = 0$ and $c = 0$, in which case it would violate the necessary condition $c > 0$. In this regard, banks would not choose corner solutions when all equilibrium conditions hold.

Combining equation (2.20) and equation (2.21), we obtain

$$\mu_t = \frac{\nu_{st}}{p_t} - \nu_{dt} > 0, \quad (2.22)$$

where the term μ_t denotes the excess value of returns on assets over deposits.

Finally, given that banks are constrained by their funds to lend, one may rewrite equation (2.19) as,

$$p_t s_t + b_t = \phi_t n_t \quad (2.23)$$

with

$$\phi_t = \frac{\nu_{dt}}{\theta - \mu_t}. \quad (2.24)$$

where the time varying parameter, ϕ_t , represents banks' leverage ratio. Note that the tightness of the incentive constraint depends positively on the fraction of assets that banks can divert, θ , and negatively on the excess value of assets over deposits, μ_t . Intuitively, the greater the fraction of assets that a bank can divert, the more likely it is that the bank will default on its deposits. Moreover, the greater the dispersion of returns between assets and liabilities, the less likely it is that a bank will default.

Let Ω_{t+1} be the marginal value of net worth at period $t + 1$. Given the Bellman equation and the conjectured value function V_t , we can derive all undetermined coefficients of the conjectured value function, which are given as follows,

$$\nu_{bt} = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{t+1}^b \quad (2.25)$$

$$\nu_{dt} = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{t+1}^d \quad (2.26)$$

$$\nu_{st} = E_t \Lambda_{t,t+1} \Omega_{t+1} \psi_{t+1} (Z_{t+1} + (1 - \delta_k) p_{t+1}), \quad (2.27)$$

with

$$\Omega_{t+1} = 1 - \sigma + \sigma(\nu_{dt+1} + \phi_{t+1}\mu_{t+1}) \quad (2.28)$$

$$\mu_t = E_t \Lambda_{t,t+1} \Omega_{t+1} (R_{t+1}^k - R_{t+1}^d). \quad (2.29)$$

$$R_{t+1}^k = \psi_{t+1} \frac{Z_{t+1} + (1 - \delta_k)p_{t+1}}{p_t}. \quad (2.30)$$

Appendix B gives full details in the determination of the coefficients of the conjectured value function, and verifies that the conjectured value function is linear in (s_t, b_t, d_t) .

Proposition 1. *The value function $V_t(s_t, b_t, d_t)$ is linear in (s_t, b_t, d_t) if and only if equation (2.25) to equation (2.30) are satisfied.*

One may observe from equations (2.25) to (2.27), marginal values of assets and liabilities are equal to an augmented stochastic discount factor $\Lambda_{t,t+1}\Omega_{t+1}$ multiplied by their corresponding returns. Equation (2.28) states that the marginal value of net worth is a weighted average of the marginal values for exiting banks and ongoing banks. If an ongoing bank has an additional unit of net worth at date $t + 1$, not only can it save the cost of deposits ν_{dt+1} , but it can also get additional benefits from accumulating its assets by a factor equal to the leverage ratio ϕ_{t+1} . Equation (2.29) implies that the excess value of assets relative to deposits is equal to an augmented stochastic discount factor multiplied by the spread of returns between assets and liabilities. Lastly, equation (2.30) is an expression for the gross rate of returns on equities. If a bank holds an additional unit of equity at a price of p_t today, it will receive a dividend Z_{t+1} and the value of the equity at a price p_{t+1} tomorrow after depreciation. Here, the term ψ_{t+1} captures a persistent shock that takes place in the next period.

Given equations (2.20) and (2.22), one can easily derive a relationship between assets and liabilities in terms of their returns, which is given as

$$R_{t+1}^k = R_{t+1}^b > R_{t+1}^d. \quad (2.31)$$

During a financial crisis, the excess return on assets over liabilities (the spread) will increase. To reduce the spread, banks must deleverage or accumulate more assets relative to debts. However, this deleveraging process takes a long time. So long as the spread is above its trend, financial factors act as a drag on the whole economy. Hence, the deleveraging process will slow down the recovery of the economy.

In the exposition, lower-case letters represent individual decision variables, and upper-case letters represent aggregate variables. Since all banks are homogenous in the model, given equation (2.23) we can obtain an expression for banks' aggregate assets given by

$$p_t S_t + B_t = \phi_t N_t, \quad (2.32)$$

where the variable S_t denotes the aggregate equity holdings at date t ; B_t denotes the aggregate consumer loans; and N_t denotes the aggregate net worth of all banks. From now on, we drop all low-case letters and replace with upper-case letters to formulate the model.

Let N_{ot} be the aggregate net worth of ongoing banks at date t , and N_{yt} be the aggregate net worth of new banks. Then the aggregate net worth of all banks can be written as,

$$N_t = N_{ot} + N_{yt}. \quad (2.33)$$

Recall that banks may, with probability σ , survive to the next period. Thus, the

aggregate net worth of ongoing banks must equal the sum of gross repayments of loans net of aggregate debt obligations, multiplied by the survival rate,

$$N_{ot} = \sigma\{(Z_t + (1 - \delta_k)p_t)\psi_t S_{t-1} + R_t^b B_{t-1} - R_t^d D_{t-1}\}. \quad (2.34)$$

Moreover, at the end of period $t - 1$ banks may, with probability $1 - \sigma$, exit from the banking system, while new banks enter the market with a fraction of funds transferred by patient households. For simplicity, I assume that patient households transfer a fraction $\xi/(1 - \sigma)$ of the aggregate value of assets held by ongoing banks. Hence, the aggregate net worth of new banks is given by

$$N_{yt} = \xi\{(Z_t + (1 - \delta_k)p_t)\psi_t S_{t-1} + R_t^b B_{t-1}\}. \quad (2.35)$$

Finally, given the flow-of-funds constraints faced by individual banks, we can write the aggregate flow-of-funds constraint for all banks as follows,

$$p_t S_t + B_t = N_t + D_t. \quad (2.36)$$

Equation (2.36) states that the value of aggregate assets equals the sum of aggregate net worth and liabilities.

Before we proceed to the model without financial frictions in the next section, it is worth highlighting the mechanism by which an exogenous financial shock deteriorates the balance sheet of banks. During a financial crisis, a negative financial shock, directly reduces the value of assets (e.g. equities) held by banks and in turn puts downward pressure on the bank's net worth. Since banks are leveraged, the magnitude

of the effect on a bank's balance sheet depends on the leverage ratio. The larger is the leverage ratio, the greater is the impact of the financial shock on the bank's balance sheet. In addition, there will be a second round effect on the banks' balance sheet as their net worth worsens. A decline in a bank's net worth reduces its ability to borrow in the retail financial market, causing a fire sale of bank's assets that further depresses the value of assets. Hence, the bank's balance sheet is further deteriorated. When the real economy strongly relies on the flow of funds from banks, it will suffer a huge loss during the crisis. The Great Recession is a good illustration of this mechanism.

Case 2: The Banking System without Financial Frictions

If there are no financial frictions, banks now convert deposits to loans without any excess returns for any time (e.g. $R_t^b = R_t^k = R_t^d$). Hence, we can treat the financial sector as a veil in this case. This is equivalent to thinking of banks playing no role in the model, and patient households directly lending funds to impatient households and nonfinancial firms with no financial intermediation.

In this case, the incentive constraint is not binding ($\lambda_t^b = 0$), implying that banks are not constrained in how much they can lend to borrowers. Given equation (2.17) and equation (2.18), the marginal value of assets must equal the marginal cost of liabilities,

$$\frac{\nu_{st}}{p_t} = \nu_{bt} = \nu_{dt}. \quad (2.37)$$

Combining equation (2.37) with equations (2.25) to (2.27), we can derive a perfect arbitrage condition which keeps returns on assets and liabilities equal over time:

$$R_{t+1}^k = R_{t+1}^b = R_{t+1}^d. \quad (2.38)$$

As I discussed earlier, a financial crisis is associated with an increase in the excess returns on assets over liabilities. Since there is no excess return in this case, a negative exogenous shock does not generate an amplified effect on the real economy.

Because banks play no role in this case, it is equivalent to thinking of banks disappearing from the model so that $N_t = 0$.¹⁶ Moreover, all savings of patient households are converted to loans so that the aggregate flow-of-funds constraint, equation (2.36) is replaced by

$$p_t S_t + B_t = D_t. \quad (2.39)$$

It is straightforward to solve the model without financial frictions. Subsequently, I will compare the dynamic paths of the key variables of interest across two cases in order to investigate the role of financial frictions in this framework.

2.3.3 Nonfinancial Firms

The Final Goods Sector

At date t , each final goods producer hires labors $l_{pc,t}$ and $l_{ic,t}$ from patient and impatient households, and pays a real wage of $w_{pc,t}$ and $w_{ic,t}$ to them, respectively. As I mentioned earlier, final goods producers face no borrowing constraints. Instead, they borrow funds from banks by issuing new state-contingent equities at price p_t . In particular, each unit of equity is a state-contingent claim to the future returns from one unit of capital investment. Conditional on funds borrowed from banks, they purchase new capitals as intermediate inputs from capital producers. In addition, I assume that final goods producers combine labors and capitals to produce final goods under a CRS technology in a Cobb-Douglas fashion. Due to perfect competition, the

¹⁶One may solve the model with $N_t \neq 0$. But the implication of the model would be similar.

final goods producers earn zero profits state-by-state.

A representative final goods producer chooses hours $(l_{pc,t}, l_{ic,t})$ and intermediate capital k_t to produce final goods Y_t . The producer solves the firm's cost minimization problem as follows:

$$\min w_{pc,t}l_{pc,t} + w_{ic,t}l_{ic,t} + Z_t k_t.$$

subject to the production function given by,

$$Y_t = (A_{ct}(l_{pc,t}^\alpha l_{ic,t}^{1-\alpha}))^{1-\mu_c} k_t^{\mu_c}. \quad (2.40)$$

Here Z_t denotes the dividends per unit of equity paid to creditor banks, the parameter A_{ct} measures labor productivity in the final goods sector, the parameter α denotes the labor income share of patient households, reflecting labor complementarity across different labor skills among households and μ_c is the income share of capital used in the production of final goods. Note that the capital stock k_t is predetermined in period $t - 1$. The optimality conditions for the final goods producer's problem are given by

$$w_{pc,t} = \alpha(1 - \mu_c) \frac{Y_t}{l_{pc,t}} \quad (2.41)$$

$$w_{ic,t} = (1 - \alpha)(1 - \mu_c) \frac{Y_t}{l_{ic,t}} \quad (2.42)$$

$$Z_t = \mu_c \frac{Y_t}{k_t}. \quad (2.43)$$

Equation (2.41) and equation (2.42) are conditional wage functions for the final goods sector. Equation (2.43) states that dividends per unit of equity are equal to gross

profits per unit of capital.

The Housing Sector

Housing producers build new houses with a CRS technology under perfect competition, but using different intermediate inputs. They hire labor $(l_{ph,t}, l_{ih,t})$ from the two groups of households and rent land x_{t-1} from patient households to produce new houses I_{ht} . Thus, a representative housing producer solves the firm's cost minimization problem as follows;

$$\min w_{ph,t}l_{ph,t} + w_{ih,t}l_{ih,t} + R_t^x x_{t-1}.$$

subject to the production function given by,

$$I_{ht} = (A_{ht}(l_{ph,t}^\alpha l_{ih,t}^{1-\alpha}))^{1-\mu_h} x_{t-1}^{\mu_h}. \quad (2.44)$$

Here, the parameter A_{ht} measures labor productivity in the housing sector; the term R_t^x denotes the rental rate of land from period $t-1$ to period t ; the parameter μ_h is the income share of land used to produce new houses. The optimality conditions for a representative housing producer's problem is then given by

$$w_{ph,t} = \alpha(1 - \mu_h) \frac{q_t I_{ht}}{l_{ph,t}} \quad (2.45)$$

$$w_{ih,t} = (1 - \alpha)(1 - \mu_h) \frac{q_t I_{ht}}{l_{ih,t}} \quad (2.46)$$

$$R_t^x = \mu_h \frac{q_t I_{ht}}{x_{t-1}}. \quad (2.47)$$

The Capital Goods Sector

Capital goods producers produce new capital using final goods as inputs, and incur an adjustment cost. They sell capital to the final goods sector at price p_t . I assume that the adjustment cost function is convex in the net growth rate of capital investment and takes the following form:¹⁷

$$f\left(\frac{I_{kt}}{I_{kt-1}}\right)I_{kt} = \left(\ln\left(\frac{I_{kt}}{I_{kt-1}}\right)\right)^2 I_{kt}. \quad (2.48)$$

A capital producer chooses capital investment I_{kt} to maximize the objective function:

$$\max E_t \sum_{i=t}^{\infty} \Lambda_{t,i} \{p_i I_{ki} - [1 + (\ln(\frac{I_{ki}}{I_{ki-1}}))^2] I_{ki}\},$$

where $\Lambda_{t,i}$ is the patient household's stochastic discount factor from date i to date t .¹⁸ The optimality condition then yields the price function for capital given by,

$$p_t = 1 + \left[\ln\left(\frac{I_{kt}}{I_{kt-1}}\right)\right]^2 + 2\left[\ln\left(\frac{I_{kt}}{I_{kt-1}}\right)\right] - 2E_t \Lambda_{t,t+1} \left[\ln\left(\frac{I_{kt+1}}{I_{kt}}\right)\right] \frac{I_{kt+1}}{I_{kt}}. \quad (2.49)$$

Note profits will arise only outside of the steady state, and will be redistributed to patient households by a lump sum transfer.

¹⁷This cost function is drawn from Gertler and Kiyotaki (2010), and satisfies $f(1) = f'(1) = 0$ and $f''(\frac{I_{kt}}{I_{kt-1}}) > 0$. Therefore, the aggregate production function of capital goods producers exhibits a decreasing returns to scale in the short-run and a constant returns to scale in the long-run.

¹⁸Since patient households own capital firms, I assume that a capital producer is as patient as patient households.

2.3.4 Shock Processes

The capital quality shock and productivity shocks all follow AR(1) processes and evolve in a log-linear fashion:

$$\ln\psi_t = \rho_k \ln\psi_{t-1} + u_{kt} \quad (2.50)$$

$$\ln A_{ct} = \rho_c \ln A_{ct-1} + u_{ct} \quad (2.51)$$

$$\ln A_{ht} = \rho_h \ln A_{ht-1} + u_{ht}, \quad (2.52)$$

where ρ_k, ρ_c and ρ_h are persistence parameters; u_{kt}, u_{ct} and u_{ht} are innovations that are uncorrelated, with zero means and standard deviations σ_k, σ_c and σ_h , respectively.

In the financial crisis experiment conducted in this chapter below, I turn off the productivity disturbances and introduce the capital quality shock alone as the forcing process to explore how the deterioration of banks' balance sheets affects real activities during a financial crisis. In the next chapter, I use the baseline model with both productivity shocks and capital quality shock to investigate whether the model fits to the data in some dimensions. In particular, I compare the implications of the baseline model with those of Davis and Heathcote (2005) and Iacoviello and Neri (2010), and explore the extent to which my model improves on their ability to fit the data. I leave discussions on these issues to the next chapter. At this moment, I consider the model with capital quality shock only.

2.4 Equilibrium

To close the model, we require market clearing for goods, houses, and equities/capital as follows,

$$Y_t = C_t + (1 + (\ln(\frac{I_{kt}}{I_{kt-1}}))^2)I_{kt} \quad (2.53)$$

$$I_{ht} = H_t - (1 - \delta_h)H_{t-1} \quad (2.54)$$

$$S_t = I_{kt} + (1 - \delta_k)K_t \quad (2.55)$$

with

$$C_t = c_{p,t} + c_{i,t} \quad (2.56)$$

$$H_t = h_{p,t} + h_{i,t} \quad (2.57)$$

$$K_{t+1} = \psi_{t+1}(I_{kt} + (1 - \delta_k)K_t). \quad (2.58)$$

Note that equation (2.58) is the law of motion for capital in presence of an exogenous capital quality shock. Land per capita is fixed and normalized to one, that is $x_t = 1$.¹⁹

Definition 1. *A competitive equilibrium consists of a sequence of prices for $t \in [1, +\infty]$*

$$(p_t, q_t, p_{xt}, R_{t+1}^d, R_{t+1}^b, R_{t+1}^k, R_{t+1}^x, w_{pc,t}, w_{ph,t}, w_{ic,t}, w_{ih,t})$$

¹⁹In general, land is not fixed over time. But, land per capita is relatively fixed. One way to motivate the constant supply of land per capita is to assume that the growth rate of land equals that of population. For simplicity, I assume that there is no population growth in the economy so as to the supply of land per capita is fixed over time. This assumption is along the lines of Iacoviello and Neri (2010).

and the sequence of shadow prices $(\nu_{dt}, \nu_{bt}, \nu_{st}, \lambda_t^i, \mu_t)$ such that the sequence of individual quantities

$$(c_{p,t}, c_{i,t}, h_{p,t}, h_{i,t}, l_{pc,t}, l_{ph,t}, l_{ic,t}, l_{ih,t})$$

and the sequence of aggregate quantities

$$(Y_t, C_t, H_t, K_{t+1}, S_t, I_{ht}, I_{kt}, Z_t, N_t, B_t, D_t, \phi_t)$$

satisfy the following conditions:

1. Given prices, households maximize their expected life-time utility functions, (2.1)-(2.10).
2. Given prices, final good producers minimize their costs, (2.41)-(2.43).
3. Given prices, housing producers minimize their costs, (2.45)-(2.47).
4. Given prices, capital goods producers maximize their profits, (2.49).
5. Given the conjectured value function V_t , banks maximize their present value of future net worth, (2.17)-(2.19).
6. The conjectured value function V_t is linear and must satisfy equations (2.25) to (2.30).
7. Banks are indifferent between making commercial loans and consumer loans, (2.31).
8. The banks' leverage ratio satisfies equations (2.32) and (2.33).
9. All markets clear and satisfy equations (2.53) to (2.58).

10. The capital quality shock and the productivity shocks in the final goods sector and housing sector follow the $AR(1)$ process given by equations (2.50)-(2.52).

Then, given eleven prices $(p_t, q_t, p_{xt}, R_{t+1}^d, R_{t+1}^b, R_{t+1}^k, R_{t+1}^x, w_{pc,t}, w_{ph,t}, w_{ic,t}, w_{ih,t})$ together with five shadow prices $(\nu_{dt}, \nu_{bt}, \nu_{st}, \lambda_t^i, \mu_t)$, eight individual quantities $(c_{p,t}, c_{i,t}, h_{p,t}, h_{i,t}, l_{pc,t}, l_{ph,t}, l_{ic,t}, l_{ih,t})$ and twelve aggregate quantities $(Y_t, C_t, H_t, K_{t+1}, S_t, I_{ht}, I_{kt}, Z_t, N_t, B_t, D_t, \phi_t)$ can be determined by a dynamic system of 36 equations. Please see full details of the dynamic system of the model in Appendix C.

2.5 Data and Calibration

In this section, I calibrate the parameters used in the baseline model to match the targeted ratios of key economic quantities that are observed in the data. These targeted ratios are estimated by using nine time series from the first quarter of 1973 to the third quarter of 2011: real private consumption expenditure, real private residential fixed investment, real private non-residential fixed investment, real house prices, real commercial loans, real consumer loans, real deposits, real net worth and nominal interest rates. Each time series being used in the model is HP filtered with $\lambda = 1,600$ and detrended. See Appendix A for data descriptions. The model period is quarterly.²⁰In particular, depreciation rates for capital and housing, capital and

²⁰The model period used in existing literature varies from one to another. For instance, in Davis and Heathcote (2005) the model period is one year since they attempt to capture the length of time between starting to plan new investment and the resulting increase in the capital stock being in place. They find that business cycle statistics, however, are virtually same for both quarterly and annual period lengths. Others like Gomme et al. (2001) and Fisher (2007) set the time to built for residential investment to one quarter, and the time to built for non-residential investment to four quarters in order to account for the fact that nonresidential investment lags residential investment. Since the lead-lag pattern between residential investment and nonresidential investment is beyond our interest in this paper, the length of the time between starting to plan both residential and nonresidential investment and the resulting increase in their corresponding stocks being in place is then set to one quarter.

Table 2.1: Calibrated Parameters

Parameters	Description	Value
β_p	Discount factor for savers	0.9925
β_i	Discount factor for borrowers	0.965
δ_k	Depreciation rate of capital	0.0188
δ_h	Depreciation rate of houses	0.0106
μ_c	Share of capital	0.1795
μ_h	Share of land	0.2519
θ	Fraction of assets diverted by banks	0.4253
ξ	Fraction of funds transferred to new banks	0.0038
j	Housing preference weight	0.1339
m	Loan-to-value ratio	0.85
σ	Survival rate of banks	0.972

land shares in the production, and the housing preference parameter are calibrated to match consumption, residential investment, nonresidential investment, the value of land and housing wealth to GDP ratios observed in the US data. In addition, I calibrate parameters used in the bank's problem (θ, ξ) in order to match an average credit spread and an average economy-wide leverage ratio observed from the data in all US commercial banks. Following Iacoviello and Neri(2010), I do not use the time series of the labor employment to calibrate the labor supply parameters since in any multi-sector model the link between value added of the sector and available measures of total hours worked in the same sector is tenuous.²¹ For this reason, I allow for measurement error in total hours in the consumption and housing sectors.

The discount factors β_p and β_i , depreciation rates for capital and housing in each production sector δ_k and δ_h , capital and land shares in each production sector μ_c and μ_h , the housing preference weight in the utility function j , the fraction of funds transferred from patient households ξ , and the fraction of assets that can be

²¹See further discussions in Iacoviello and Neri (2010).

Table 2.2: Steady-State Ratios

Variables	Interpretation	Value
$4 \times (R_d - 1)$	Annual real interest rate	3%
$4 \times (R_k - R_d)$	Annual interest spread	1%
C/GDP	Consumption to GDP ratio	83%
I_k/GDP	Nonresidential investment to GDP ratio	11%
qI_h/GDP	Residential investment to GDP ratio	6%
$K/(4 \times GDP)$	Nonresidential capital stock to annual GDP ratio	1.46
$qH/(4 \times GDP)$	Housing wealth to annual GDP ratio	1.41
$p_x/(4 \times GDP)$	Value of land to annual GDP ratio	0.50
ψ	Average leverage ratio	3.32

Note: Our definition of GDP is the sum of consumption, residential investment and non-residential investment.

diverted from banks to patient households θ are calibrated by the model itself. Table 2.1 summarizes my calibrations. All calibrated parameters together with the other parameters that are set explicitly yield the steady-state ratios that are consistent with the data. A summary of steady-state ratios of the baseline model is presented in the Table 2.2.

The discount factor for patient households β_p is set to 0.9925, implying that a steady-state annual real interest rate of 3%. I arbitrarily set the discount factor for impatient households to $\beta_i = 0.965$ since the value of β_i has little effect on the dynamics of the model. The only restriction on β_i is that its value must be lower than β_p to ensure that the borrowing constraint of impatient households is binding around the neighborhood of the steady state. In general, the lower is the value of β_i , the more likely will the borrowing constraint bind away from the steady state.

The survival rate of banks is arbitrarily set equal to 0.972, implying that banks survive for nine years on average.²² Although the expected survival time of banks may

²²The survival time = $\frac{1}{1-\sigma}$. Here, I choose the same survival rate as the one used by Gertler and Kiyotaki (2010).

be longer than nine years, we only require that the expected time horizon is finite so that dividends paid by banks are guaranteed while the financial constraints are still binding. An alternative choice of the survival rate would not have a substantive effect on the business cycle properties reproduced by the model. A detailed discussion on this is given in the next chapter when I use the model to match the data. The fraction of funds transferred from patient households ξ , and the fraction of assets that can be diverted from banks to patient households θ are set equal to 0.0038 and 0.4253, respectively, in order to match two targets: an average leverage ratio of 3.32 from all US commercial banks and an average annual interest spread of 1%. According to the Table of Assets and Liabilities of All Commercial Banks in the United States from the Fed's, the average leverage ratio is 3.32 approximately.²³ Following other authors in the financial literature such as Gertler and Kiyotaki (2010) and Iacoviello (2010a), I set the target for the annual interest spread to 1%, based on the pre-2007 spread as a rough average of the following three spreads: BAA corporate bond rates versus government bonds, mortgage rates versus government bonds, and commercial paper rates versus T-Bill rates.

I choose the depreciation rates for capital $\delta_k = 0.0188$ and the capital share in the consumption goods sector $\mu_c = 0.1795$ together with other calibrated parameters to hit a steady-state nonresidential investment to GDP ratio of 11% and a steady-state nonresidential capital stock to annual GDP ratio of 1.46.²⁴ In addition, the depreciation rate for housing is set equal to $\delta_h = 0.0106$ and the land share in the

²³I use time series of total assets and total liabilities of all US commercial banks from 1973 : Q1 to 2011 : Q3 to calculate the average leverage ratio, that is, $LeverageRatio = \frac{Assets}{Assets - Liabilities}$.

²⁴Note that the depreciation rate for capital $\delta_k = 0.0188$ in my model is slightly lower than that in Iacoviello and Neri (2010) and Iacoviello (2005) while the target of the nonresidential investment to GDP ratio used in this paper is lower than the one used by those studies.

housing production function is set equal to $\mu_h = 0.2519$, implying a steady-state residential investment to GDP ratio of 6% and a steady-state land value to annual GDP ratio of 0.50. The calibrated value of δ_h is consistent with the calibration from most of the housing literature such as Davis and Heathcote (2005) and Iacoviello and Neri (2010).²⁵ The calibrated value of μ_h seems to be also consistent with previous housing literature, see Davis and Palumbo (2008), Saiz (2010), Kiyotaki, Michaelides and Nikolov (2011), and Lloyd-Ellis, Head and Sun (2011).²⁶ The preference weight for housing in the utility function is set at $j = 0.1339$. Given the value of input shares in the housing production function and other parameters calibrated, the choice of housing preference weight implies a steady-state housing wealth to annual GDP ratio of 1.41.

According to the data from the Finance Board's Monthly Survey of Rates and Terms on Conventional Single-Family Non-farm Mortgages Loans, the average loan-to-value ratio for homebuyers is about 0.76 between 1973 and 2006. Since the LTV ratio in the model refers to the fraction of housing value that can be borrowed by those who are credit constrained (impatient households), the value of the ratio for those credit constrained homebuyers might be greater than the average value for overall homebuyers. For example, in 2004 27% of new homebuyers borrowed funds from banks up to a fraction in excess of 80%, with an average ratio of 94% among them. Following the present housing literature using the conventional DSGE framework, I set the LTV ratio equal to 0.85. Alternative values of the LTV ratio will be taken into considerations in the robustness test for the model in the next chapter while

²⁵Greenwood and Hercowitz (1991) calibrate a larger depreciation rate of 0.078 for residential structures; but Davis and Heathcote (2005) calibrate a slightly smaller depreciation rate of 0.0157; and Iacoviello and Neri (2010) calibrate a depreciation rate of 0.01.

²⁶Those literature calibrate a relative share of land in the price of housing within a range from 25% to 30%.

matching the model to the data.

The labor income share of credit-constrained households, $1 - \alpha$, is difficult to estimate due to data availability. More importantly, different approaches and data sources generate different estimated values. Kiyotaki, Michaelides and Nikolov (2011) report that the fraction of constrained home owners in the population is 13.9%, and the fraction of tenants is 36% in the early 1990s. Suppose we treat tenants as constrained households, then the fraction of constrained households is about 50%. Jappelli (1990) uses the 1983 Survey of Consumer Finances to estimate a fraction of 20% population that are credit constrained. Iacoviello (2005) gives a wage share of credit constrained households of 36%, based on a limited information approach. In the model, I set $1 - \alpha = 0.36$, following Iacoviello (2005) since it is within the range of estimates reported by most of the existing literature.

I set the disutility function parameters $\eta_p = 0.52$ and $\eta_i = 0.51$. For the inverse elasticity of substitution across hours in the consumption goods and housing sectors, I fix $\epsilon_p = 0.66$ and $\epsilon_i = 0.97$.²⁷

Finally, I choose the persistence parameter for the capital quality shock, $\rho_k = 0.66$, with a standard deviation of 5%. As argued by Gertler and Kiyotaki (2010), the choice of these parameters would generate a downturn of similar magnitude to that which occurred during the 2007 financial crisis. Although I do not explicitly estimate the shock processes at this moment, with the shock parameters borrowed from Gertler and Kiyotaki (2010), the model is sufficient to capture qualitatively the key phenomenon of the Great Recession in the experiment. In the next chapter, I will estimate the shock processes using a Bayesian approach in order for the model to match the data.

²⁷Those parameters are estimated by the mean of posterior distribution in Iacoviello and Neri (2010).

2.6 Financial Crisis Experiment

I now turn to the financial crisis experiment. In the experiment, I mainly focus on the effects of a financial crisis rather than the cause itself. That is, I investigate how a deterioration in banks' balance sheets affects real activities during the crisis. The question of what is a financial shock is not the core of this paper since the literature regarding the 2007 financial crisis offers different interpretations of the cause. Iacoviello (2010a) interprets the financial shock as a repayment shock that is purely redistributive in nature. In particular, the shock is supposed to be a negative wealth shock from the perspective of borrowers on one hand, and a positive wealth shock from the perspective of lenders on the other hand.²⁸ Conversely, Gertler and Kiyotaki (2010) argue that what triggered the recent financial crisis was a decline in housing values that induces a wave of losses on mortgage backed securities (MBS) held by the banks. The true primary cause of the financial crisis still remains an open question. Although my model is not sufficient to capture precisely the main cause of the financial crisis, it can still give a full story about the consequences of a deterioration in banks' balance sheets during a crisis. For simplicity, the initial disturbance in this financial crisis experiment is an exogenous capital quality shock as in Gertler and Kiyotaki (2010), since it allows us to capture in a parsimonious way the mechanism by which an exogenous force worsens the banks' balance sheets, and in turn, puts downward pressure on output, investment, and asset prices in the financial crisis. Although the financial shock could also refer to a shock to the borrowing

²⁸The assumption used in Iacoveillo (2010a) that borrowers face a persistent and positive wealth shock is not appropriate when they default on their debts. Broadly speaking, borrowers who pay less than or default their obligations today would face a penalty of delinquency or a risk of seizure of their assets tomorrow. Accordingly, the assumption that borrowers persistently face a positive wealth shock during the financial crisis is too strong in their model.

constraints (e.g. liquidity shocks), as Shi (2012) argues, this type of shocks will generate an asset price boom, which is inconsistent with what happened in the Great Recession. For asset prices to fall, a negative liquidity shock must be accompanied or caused by other shocks that induce a significant decline in investment and relax the borrowing constraints on investment. In this regard, capital quality shock is a good candidate of the financial shocks, since it can serve as a primary driving force of the business cycle that generates the dynamics of asset prices observed in the Great Recession.

2.6.1 The Model without Financial Frictions

I start the analysis by considering the performance of the model without financial frictions. Figures 2.5 and 2.6 report the impulse responses of the key variables of interest following a 5% decline in capital quality. The solid line represents the dynamic paths for the baseline model with financial frictions, and the dotted line represents the model without financial frictions.

Initially, a negative capital quality shock generates a decline of the capital stock by about 3%. It is then followed by a decline in both output and employment. Since a high capital return is accompanied by the loss of capital, higher investment is induced. Recall that in the model without financial frictions, the bank acts as a veil and does not play any role in the economy. One may think of patient households lending funds to borrowers directly without any financial intermediation. In response to a negative capital quality shock, it is optimal for patient households to issue less commercial loans and consumer loans in order to smooth their consumption. Thus, both commercial loans and consumer loans fall. Note that in the model without

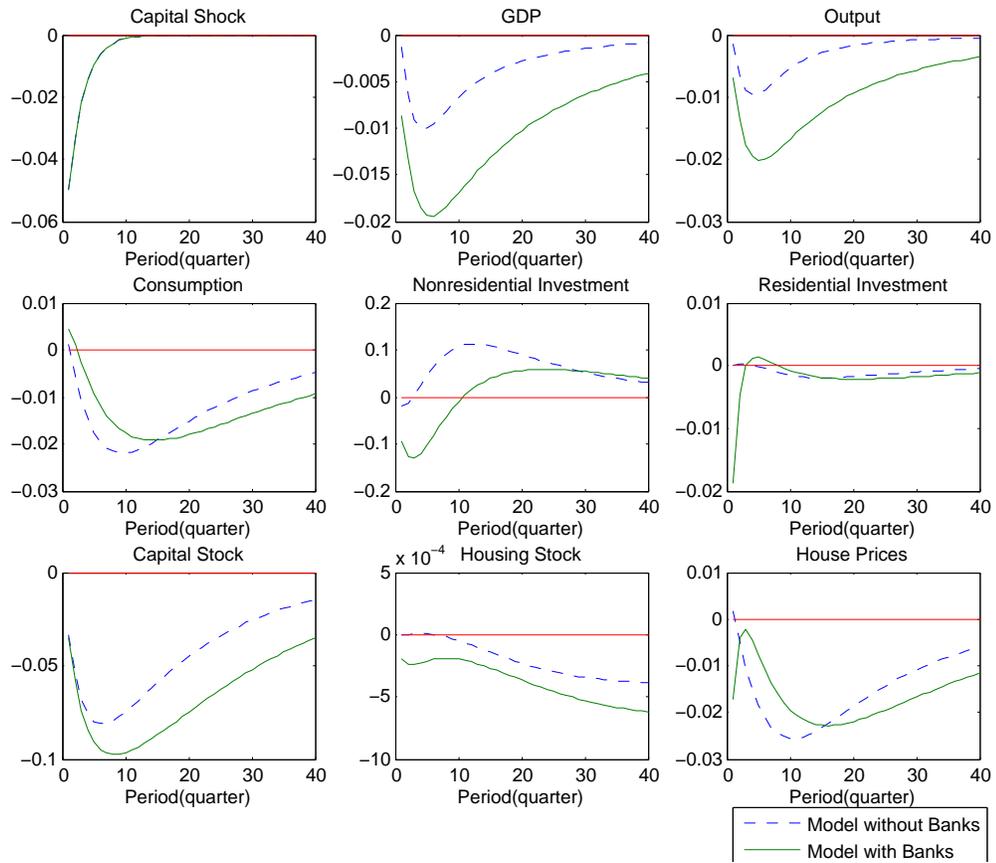


Figure 2.5: Financial Crisis Experiment (Housing and Macroeconomic Variables)– Impulse Response Functions to a Negative Capital Quality Shock (The Model with Financial Frictions VS The Model without Financial Frictions)

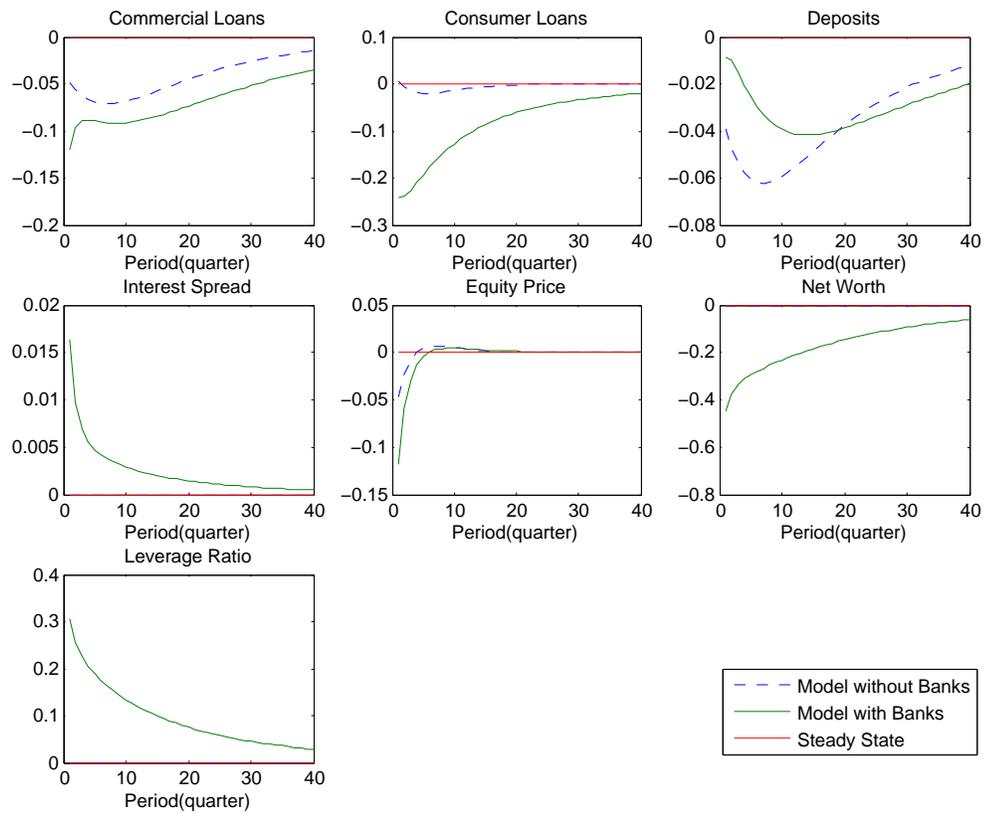


Figure 2.6: Financial Crisis Experiment (Financial Variables)–Impulse Response Functions to a Negative Capital Quality Shock (The Model with Financial Frictions VS The Model without Financial Frictions)

financial frictions, the change in consumer lending is minor and can be ignored. Since deposits are equal to the sum of commercial loans and consumer loans in this case, deposits also fall. The price of equity is positively associated with capital stock/equity holdings. Thus, the equity price falls as the capital stock decreases.

Recall that capital investment (business investment) in this economy is financed using funds borrowed from patient households. Ignoring, for now, any minor response of output and consumption, an initial decline in capital investment is mainly due to the fact that the aggregate capital stock initially decreases by less than commercial loans. Moreover, the decline in capital investment is reversed when the capital stock continues to fall over time. Housing stock and house prices respond to the capital quality shock in a way related to the movements in the aggregate housing demand. Houses demanded by impatient households are primarily financed by consumer loans. When consumer loans do not fall initially, the demand for housing does not jump down immediately, and thus the housing stock remains unchanged initially. Consequently, house prices do not jump down immediately. As the aggregate housing stock eventually declines over time, both housing investment and house prices fall. One may see from Figure 2.5 that the effects of a negative exogenous shock on the housing variables are minor since these effects are not magnified by the financial frictions in this case. Strictly speaking, a model without financial frictions cannot reproduce the dynamics of house prices and the quantity of the housing that were actually observed in the financial crisis.²⁹ More importantly, it generates a counterfactual outcome that housing investment and business investment negatively comove in response to an exogenous financial shock.

²⁹According to the data, both the housing price and quantities fall significantly over the short run in the Great Recession.

The definition of *GDP* in the model is the sum of output and the value of housing investment. When output, housing investment, and house prices all decrease over time, it is obvious that *GDP* must fall over time. In addition, the excess returns on loans over deposits (interest spread) remains unchanged over time since lenders are indifferent between loans and deposits. It follows that a capital quality shock in this case does not affect the real economy through financial frictions. We will see later that in the model with financial frictions, an increase in the interest spread feeds into the real economy as a drag on its growth during the financial crisis.

Eventually, as the capital stock reverts to its steady-state level, capital investment returns to its trend, as do employment, consumption and output. Similarly, both the housing market and the financial market converge to their long-run paths. Before we progress to the model with financial frictions, for the sake of comparison, it is worth pointing out that, in the absence of the financial frictions, the model cannot generate a positive co-movement between residential investment (housing investment) and nonresidential investment (business investment), which is inconsistent with the observation from the data. Moreover, such a model is silent in its ability to reflect the amplification effects of financial constraints on real activities during the crisis. Last, it cannot capture the mechanism in which the deleveraging process of banks slows down the recovery of the housing market and the whole economy after the crisis. Therefore, the model without financial frictions cannot qualitatively account for the real story of the Great Recession.

2.6.2 The Model with Financial Frictions

I now consider the performance of the model with financial frictions. The dynamic paths of the key variables are presented in Figures 2.5 and 2.6. For my baseline model, I find that the model can qualitatively capture the phenomenon of the 2007 financial crisis. In particular, a disruption in the banks' balance sheets induced by an exogenous decline in capital quality has a significant effect on the goods market, the housing market, the financial market and the economy as a whole.

With financial frictions, a 5% decline in capital quality immediately leads to a decrease in banks' net worth by roughly 50%. This huge decline in net worth is fundamentally a product of a high bank leverage ratio and a decline in the market price of equities arising from the fire sale of the bank's assets. In particular, an exogenous shock affects the banks' net worth in two ways. First, an initial capital quality shock directly reduces the value of equities held by banks, and hence their net worth. Because the bank is highly leveraged, the effect on its net worth would be magnified by a factor equal to the bank's leverage ratio. Second, the decline in the net worth then tightens the bank's borrowing constraint, causing a fire sale of the bank's assets (equities). Eventually, the price of the equity falls. This second round effect further depresses the value of the bank's equity and thereby induces a huge loss in the bank's net worth. In addition, although deposits slightly decrease initially, they eventually fall over time due to the increase in the tightness of the bank's borrowing constraint.

In order to respond to the decline in the bank's net worth, the bank reduces the amount of funds lent to impatient households and final goods firms. This leads to a roughly 12% decline in commercial loans and a roughly 25% decline in consumer loans.

Since the movement in commercial loans is ultimately responsible for the change in business investment, the latter falls by roughly 10% as commercial loans decline. As a result, the capital stock and output fall by about 10% and 2%, respectively.

The aggregate demand for housing or final goods depends on the movement of the individual demand in each group of households. For impatient households, individual demand for housing falls by about 25% as the amount of consumer loans received from banks decreases. Individual demand for final goods, however, initially increases by about 2.5%, reflecting the fact that impatient households substitute towards final goods and away from housing due to their low patience and the anticipated depreciation of house prices. Individual demand for final goods eventually falls as their budget constraints get tighter. For patient households, they respond to the shock in the opposite way. Specifically, individual demand for housing initially rises by 8% and continues to increase over time. This is because this group of households is patient enough that they can afford the losses arising from low anticipated house prices, and enjoy more housing service in the future. Because the losses from the temporary decline in house prices can be compensated by the future gains from enjoying more housing, the individual demand for housing increases. In order to accumulate more housing, patient households forgo some consumption and thus the individual demand for final goods decreases. Since the decrease in demand for housing from impatient households exceeds the increase in demand for housing from patient households, aggregate demand for housing falls initially. This subsequently depresses house prices and housing investment. The depreciation of house prices and the decline in housing investment are reinforced by the continuing decline in aggregate housing demand over time. As we can see from Figure 2.5, both house prices and housing investment decline

significantly in the short run. Note that both house prices and housing investment revert back immediately after an initial decline is a product of the interaction between the individual demand for housing from each group of households. Even if equilibrium aggregate consumption does not initially fall, it will eventually go down as the budget constraint of impatient households tightens over time. It is worth pointing out that in the model with consumption habits, aggregate consumption might fall immediately in response to the shock. In general, a larger degree of habits can offset the impact of the shock on aggregate consumption without affecting much else. Appendix D gives the impulse responses to a negative capital quality shock in a case with consumption habits. One may find that the implications of the model with consumption habits are quite similar to that of the baseline model, except that the impact on aggregate consumption is slightly smaller.³⁰

The financial frictions at work during the crisis are reflected in the spread between the expected return on assets and the expected cost of deposits. In the model with financial frictions, the spread increases as an outcome of the decline in the bank's net worth. In particular, when the spread rises, the cost of financing capital increases to the extent that debtor firms must downsize the amount of capital investment and reduce its volume of output. Therefore, the magnified declines in capital investment and output can be attributed to the increase in the spread during the financial crisis.

³⁰In the model with consumption habits, habit formation of consumption is modeled by using $\ln(c_t - \varphi c_{t-1})$ rather than $\ln c_t$ in the households' utility functions. The term, φ , measures the degree of consumption habits. For simplicity, I assume that the degree of consumption habits are the same between the two types of households. I set $\varphi = 0.50$ in the lines along with Gertler and Kiyotaki (2010). The results suggest that with a larger degree of consumption habits, the initial increase in aggregate consumption is smaller, relative to that in the baseline model, reflecting that the addition of consumption habits can offset the impact on consumption. In some exercises, I find that aggregate consumption would fall immediately when a large degree of consumption habit is allowed (e.g. $\varphi = 0.70$). The responses of the other variables are essentially unchanged.

During a financial crisis, banks can restore their leverage ratio either by deleveraging or accumulating more net worth. In the process of deleveraging, banks have to increase their net worth. As we can see from Figure 2.6, an increase in net worth is accompanied by a decline in the spread. So long as the spread is above its trend, net worth cannot immediately revert to its steady-state level. Throughout the transition path to the long-run trend, the convergence process is slow and it takes a long time for the bank to restore its leverage ratio (see Leverage Ratio panel in Figure 2.6). Strictly speaking, the change in the spread between expected returns on assets and costs on deposits induced by the financial frictions slows down the pace of recovery in the economy. In this way, our baseline model is successful in its ability to capture the mechanism through which the deleveraging process slows down the recovery of the economy during a financial crisis, which is consistent with Gertler and Kiyotaki (2010). The main discrepancy of the results generated between my model and Gertler-Kiyotaki model, in terms of the pace of the recovery process, is that consumption, business investment, output and deposits in my model tend to converge slightly faster than that in Gertler-Kiyotaki model. The underlying reason for this is mainly due to the substitution effects on houses and consumption goods induced by the financial shocks.³¹

Within the framework with financial frictions, the effects of the financial crisis induced by an exogenous shock are amplified and propagated over time by financial factors. Compared to the alternative model without financial frictions, the decline in both GDP and output are more than doubled. Nonresidential investment (business

³¹In Gertler and Kiyotaki (2010), their model does not consider the heterogeneity of households, and excludes houses. In the absence of these elements, the model is not able to generate the substitution effects on houses and consumption goods. In this regard, consumption, business investment, output and deposits all decline at a larger magnitude than that in my model. As a result, the pace of the convergence processes of these variables tends to be slower, relative to that in my model.

investment) and capital stock decline by a larger amount than that in the frictionless model. In the housing market, residential investment (housing investment) falls significantly in the short run, and the housing stock falls at a larger magnitude over time, relative to its counterparts. House prices in both the short run and long run decline at a larger magnitude than its counterpart. With financial frictions, the decline in both commercial loans and consumer loans are significantly larger than their counterparts. Deposits in the short run and medium run do not drop as much, and is only half of the decline in the frictionless model. However, it is slightly larger than its counterpart in the long run. Aggregate consumption in the short and medium run does not fall as much as in the frictionless case because impatient households are more willing to substitute towards consumption goods and away from houses. Without heterogeneity and housing, both deposits and consumption would fall by a larger amount than their counterparts, as illustrated in Gertler and Kiyotaki (2010). Moreover, in the frictionless model the spread does not change over time since the expected returns are equal across assets and deposits. Therefore, the spread does not serve as a barrier to the recovery of the economy from the financial crisis in such a model. Conversely, an increase in the spread is the key in the frictional model and generates a magnified effect, slowing down economic recovery from a financial crisis.

2.7 Concluding Remarks

This paper develops a variant of Iacoviello-Neri model by considering the financial frictions used by Gertler and Kiyotaki (2010), and creates a link between the housing market and the financial market in the context of the Great Recession. The dynamics

of housing and banking over the business cycle are realistic not only at the macroeconomic level, but also at the level of individual household behavior. The baseline model works well in two dimensions. First, it can qualitatively capture the behavior of the housing market, the financial market and the macroeconomy in the Great Recession. Second, it explores the mechanism by which a disruption in the banks' balance sheet affects the housing market and the macroeconomy during the crisis and the extent to which the deleveraging process of banks slows down the recovery from the crisis.

what has been learned from this exercise relative to Gertler and Kiyotaki (2010)? First, housing is an important element in the business cycle, and has always been at the center of the financial crises. Any neglect of housing in DSGE models may not provide a better understanding of key features of the business cycle. Second, the heterogeneity of households are also important from my perspective. The model without this friction in general glosses over distinct responses of households to exogenous shocks over the business cycle. Last, the impacts of a disruption in the banks' balance sheets on the housing market are enormous, especially during the financial crises. In this regard, it is sensible to create a linkage between the housing and financial markets in DSGE models in order to study the joint behavior among housing and financial quantities of interest over the business cycle.

However, this paper does not explicitly consider the default of indebted households. One may extend this model by including the risk of default to investigate the extent to which the presence of the default affects the financial market, the housing market and the whole economy over the business cycle. The model can also be used to investigate whether the model fits the data. Since most of DSGE models

with housing only fail to account for the volatility of house prices observed in the data, the model with housing and banking together might be a good candidate to address the drawbacks of those previous housing models. The primary advantage of using the DSGE models with housing and banking in accounting for the features of the business cycle, perhaps, is that it allows us to explain the second moments of financial variables, and the joint behaviors among financial and other macroeconomic quantities.

Chapter 3

Housing and Banking over the Business Cycle: Business Cycle Analysis

3.1 Introduction

In this chapter, I use the baseline model discussed in Chapter 2, together with shock processes estimated using a Bayesian approach, to investigate how well the model fits the recent time series data. In addition, I compare the business cycle properties generated by the baseline model to those produced by the previous housing literature in order to investigate whether the model improves on them in some key dimensions such as the volatility of house prices.¹

¹A notable housing paper, Davis and Heathcote (2005), performs poorly in three dimensions, and leaves them for future research. Firstly, their model fails to account for the lead-lag pattern between residential investment and nonresidential investment. Secondly, they produce a counterfactual (negative) correlation between house prices and housing investment. Lastly, their model does poorly in accounting for the volatility of house prices observed in the data. The first issue has been

I find that the model with estimated shocks replicates well several key features of housing and financial markets and the macroeconomy observed in the data. In particular, it can quantitatively account for the volatility and procyclicality of consumption, investment, house prices and some financial variables. In addition, the model can reproduce the observed co-movements among the quantities of interest. Moreover, I find that technology shocks are the main driving forces behind fluctuations in the housing market and macroeconomy, explaining more than 95 percent of the fluctuations in housing investment and house prices, and more than 85 percent of the fluctuations in consumption and GDP. Financial shocks and housing technology shocks are the primary driving forces of the fluctuations in the financial market at business cycle frequencies, explaining more than 90 percent of the fluctuations in most of financial variables such as loans and net worth.

Compared to previous housing papers such as Davis and Heathcote (2005) and Iacoveillo and Neri (2010), the most attractive finding in this chapter is that the baseline model replicates more closely the volatility of house prices and the correlation between house prices and consumption, conditional on technology shocks and financial shock alone. The model of Davis and Heathcote (2005) understates the volatility of house prices observed in the data when using sectoral technology shocks alone. Iacoveillo and Neri (2010) can replicate the high volatility of house prices only when a variety of shocks are introduced to the model.² Their model with technology shocks

addressed by Fisher (2007), and the second one has been addressed by Iacoveillo and Neri (2010). The third one can also be addressed by Iacoveillo and Neri (2010) as long as a variety of shocks are introduced. However, it is not clear whether the model with a few shocks (e.g. technology and financial shocks only) can replicate well the volatility of house prices and the joint behavior among quantities of interest, once it includes banking.

²In Iacoveillo and Neri (2010), they introduce nine shocks to the model. It goes without saying that using more shocks is not sensible to do. For example, the addition of demand-side shocks (e.g. housing preference shocks) allows the model to reproduce the correlation between housing and

alone, however, can explain only half of the volatility of house prices. Further, their model is unable to account for the volatility and procyclicality in financial variables, and the joint behavior among financial and other quantities of interest since they do not explicitly consider the role of financial intermediation in the business cycle.

That the volatility of house prices is high in my model is a product of three aspects. First, land acts as an adjustment cost on housing since it limits the extent to which the housing stock can be adjusted. Given the fixed land supply per capita, a larger share of land increases the volatility of house prices and decreases the volatility of housing investment. Second, the heterogeneity in discount factors across households is also responsible for a high volatility of house prices. With this heterogeneity, the two types of household respond differently to the shocks, causing a high volatility. Third, financial factors are also at work to increase the volatility of house prices since they exacerbate the responses of households to the shocks.

Before going further, I should be up front about a few apparent drawbacks of the model. First, the model overstates the volatility and procyclicality of deposits. Second, the model overstates the procyclicality of commercial loans. Third, in the data house prices and housing investment move in the same direction. In contrast, the model generates a negative correlation between the price and the quantity of housing. Moreover, consumer loans and housing investment move in the opposite direction, which is contrary to the data. Last, a striking drawback of the model is that it understates the correlation between housing investment and business investment. I will return to these issues, and provide some potential approaches that may address them in the main text.

business investment observed in the data. But, using more shocks may induce some measurement errors. To the extent that some shocks used in the model correlate with each other, some measurement errors may arise.

In what follows, Section 3.2 gives details on the Bayesian estimation of shock processes. Section 3.3 gives numerical analysis on the business cycle properties simulated by the baseline model with estimated shocks. Robustness analysis are presented in Section 3.4. The sources of business cycle fluctuations are investigated in Section 3.5. Section 3.6 concludes.

3.2 Bayesian Estimation

In this section, I estimate the underlying shock processes using a Bayesian approach. Before proceeding to the estimation, let's revisit the shock processes that will be used in this study. The capital quality shock and the technology shocks in the final goods and housing sectors all follow the AR(1) process and evolve in a log-linear fashion:

$$\ln\psi_t = \rho_k \ln\psi_{t-1} + u_{kt} \quad (3.1)$$

$$\ln A_{ct} = \rho_c \ln A_{ct-1} + u_{ct} \quad (3.2)$$

$$\ln A_{ht} = \rho_h \ln A_{ht-1} + u_{ht}, \quad (3.3)$$

where ρ_k , ρ_c and ρ_h are persistence parameters; u_{kt} , u_{ct} and u_{ht} are innovations that are uncorrelated, with zero means and standard deviations σ_k , σ_c and σ_h , respectively. In the estimation exercise below, I estimate the baseline model with financial and technology shocks together in order to investigate whether the model with my posteriors fits to the data in some dimensions, given the structural parameters of the model at the values calibrated in Chapter 2.

The approach used in this estimation is described as follows. First, I choose prior distributions for the shock parameters. In particular, I use beta priors for

Table 3.1: Prior Distribution of the Shock Processes

Parameters	Distribution	Mean	Standard Deviation
ρ_c	Beta	0.80	0.1
ρ_h	Beta	0.80	0.09
ρ_k	Beta	0.80	0.09
σ_c	Inverse Gamma	0.001	0.01
σ_h	Inverse Gamma	0.001	0.01
σ_k	Inverse Gamma	0.001	0.01

the persistence parameters of the shocks and inverse gamma priors for the standard errors of the shocks. My priors are given in Table 3.1.³ Second, I choose three observables: real private consumption, real residential investment and real consumer loans.⁴ In general, the choice of observables does matter for the posteriors. The reasons I select these observables in the estimation are that they are closely related to housing, banking and the macroeconomy since this study primarily focuses on these dimensions in the business cycle. With these selected observables, I can reproduce well several important features of the business cycle at the mode of the posterior distribution of the shock parameters. Third, I estimate the posterior distributions of the shock parameters using the Metropolis-Hastings algorithm. Table 3.2 reports the posterior mean and 95% confidence interval for the shock parameters.⁵

I find that the technology shocks in the final goods and housing sectors exhibit

³These priors are consistent with previous studies such as Iacoviello and Neri (2010).

⁴These observables are logged and detrended by HP filter with $\lambda = 1,600$ in order to be suitable for computing the likelihood function.

⁵The estimation is based on a sample of 5,000 draws. Draws from the posterior distribution of the shock parameters are obtained using the random walk version of the Metropolis-Hastings (MH) algorithm. The scale used for the jumping distribution in the MH algorithm is set to 0.2, reflecting an acceptance rate of 25% in the algorithm. The number of parallel chains for the MH algorithm is set to 2. Convergence was carefully assessed by using the ‘‘MCMC univariate diagnostics’’. In my case, I obtain relative stability and convergence in all measures of the parameter moments, implying that my posteriors are sensible. In addition, the posterior distributions are closed to normal, and the mode calculated from the numerical optimization of the posterior kernel seems not too far away from the mode of the posterior distribution, implying a strong confidence in my posteriors.

Table 3.2: Posterior Distribution of the Shock Processes

Parameters	Mean	2.5%	97.5%
ρ_c	0.9948	0.9912	0.9984
ρ_h	0.9989	0.9981	0.9998
ρ_k	0.51	0.3733	0.6609
σ_c	0.0077	0.0071	0.0084
σ_h	0.0395	0.0359	0.0437
σ_k	0.0093	0.0078	0.0112

a higher degree of persistence than the capital quality shock (financial shock), and that the standard error of the technology shock in the housing sector is greater than that of the other two shocks. Moreover, the persistence of the technology shock in the housing sector is slightly larger than that in the final goods sector along the lines of Iacoviello and Neri (2010).⁶ Though I obtain a slightly larger persistence rate of the technology shock in the final goods sector, relative to that in Iacoviello and Neri (2010), I can still replicate well several important business cycle properties of interest in my study. The main discrepancy between Iacoviello and Neri (2010) and my study is that the movements of key variables converge more slowly to their steady states than those in Iacoviello and Neri (2010) in response to the technology shocks. I will discuss the implications of these findings in the next section.

⁶In Iacoviello and Neri (2010), the persistence rate of the technology shock in the housing sector and the final goods sector are 0.997 and 0.95, respectively; and the standard errors are 0.01 and 0.0193, respectively.

3.3 Properties of the Estimated Baseline Model

3.3.1 Impulse Responses

Technology Shock in the Final Goods Sector

Figures 3.1 and 3.2 plot impulse responses to the estimated technology shock in the final goods sector. A positive technology shock in the final goods sector drives up the expected return to capital, and hence, business investment (see the Nonresidential Investment panel in Figure 3.1) and output. The response of bank net worth to the shock is magnified in two ways. First, because the bank is highly leveraged, the rise in the expected return to capital raises the value of its assets and, consequently, enhances its net worth by a factor equal to the leverage ratio. Second, the rise in the net worth relaxes the bank's borrowing constraint, causing an accumulation of its assets that further raises the asset prices. Both forces reinforce each other and generate a significant rise in the banks' net worth. With a high value of net worth, the bank can make more loans to its borrowers and accept more deposits from savers. Consequently, more funds are fed into the real economy, stimulating an increase in the capital stock, GDP, and house prices.

I now analyze the responses by each type of household to a positive technology shock in the final goods sector. For impatient households, both the demand for consumption goods and housing increase over time, thanks to the relaxation of their budget constraints. For patient households, the demand for consumption goods also rises. The demand for housing, however, declines over time due to a dominant substitution effect induced by the high price of houses relative to consumption goods. Overall, aggregate consumption rises and aggregate demand for housing falls slightly.

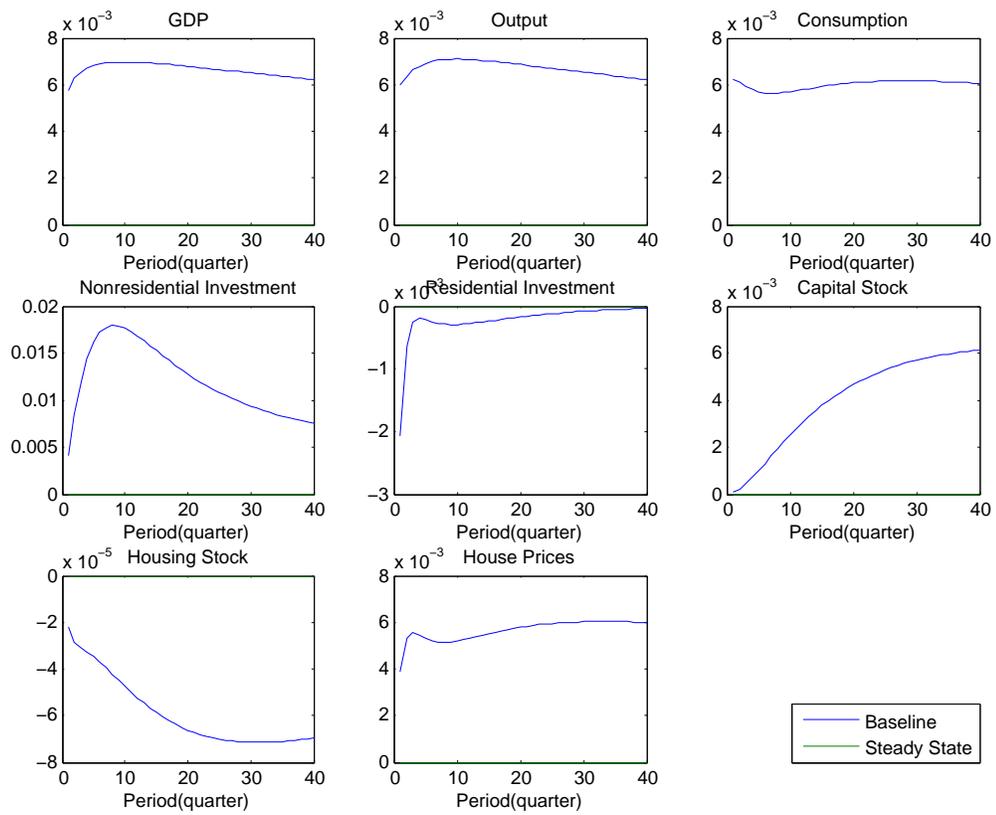


Figure 3.1: Impulse Response Functions (Housing and Macroeconomic Variables) to a Positive Productivity Shock in the Final Goods Sector

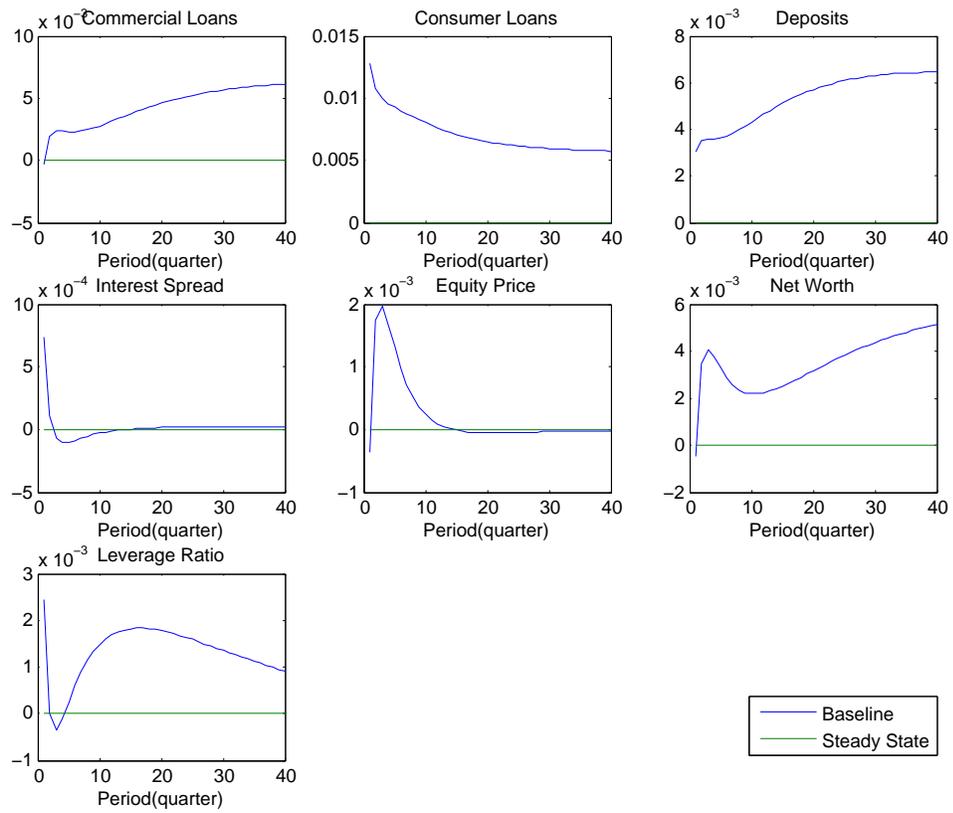


Figure 3.2: Impulse Response Functions (Financial Variables) to a Positive Productivity Shock in the Final Goods Sector

In addition, housing investment declines due to a rise in construction costs (e.g. wages and land rents) and weak demand for housing. But the magnitude of the decline in housing investment exceeds that of the aggregate demand for housing so that house prices rise over time. Note that a positive technology shock in the final goods sector generates a negative correlation between house prices and housing investment, which contradicts the data. Even if we allow for a positive shock in the housing sector, the negative correlation cannot be reversed. Specifically, the addition of a housing technology shock is needed to account for the volatility of house prices, but this shock still cannot reproduce a positive correlation between the price and quantities of housing. we will observe this fact in the next section. The inability of the model with supply-side shocks alone to account for the positive comovement between house prices and housing quantities is along the lines of the findings by Davis and Heathcote (2005) and Iacoviello and Neri (2010). This is a standard problem for any model driven by supply-side shocks.

The spread rises on impact as a product of the increase in the expected returns to capital (see the Interest Spread panel in Figure 3.2). In order for the spread to revert back to its trend, the bank has to deleverage or accumulate more assets relative to debts. As in the financial crisis experiment given in Chapter 2, this process takes time. Note that asset/capital prices do not rise immediately due to the fact that commercial loans do not change initially. Moreover, one may observe that macroeconomic variables converge slowly to their steady states, relative to that in Iacoviello and Neri (2010) as the persistence of the estimated shock is high in this study.

Technology Shock in the Housing Sector

Figures 3.3 and 3.4 plot impulse responses to the estimated technology shock in the housing sector. A positive technology shock in the housing sector directly drives up the marginal product of labor, and hence, housing investment, thanks to a decline in construction costs. The increase in housing investment is responsible for a drop in house prices. Further, changes in aggregate consumption and aggregate demand for houses depend on the interaction between household's individual demand for goods and houses. In particular, patient households are more likely to substitute towards houses away from goods, since they are willing to forgo goods and buy more houses at a low price today in order to enjoy more housing service tomorrow on the one hand. On the other hand, impatient households are more likely to forgo houses and consume more goods today as a low expected house price fundamentally depresses the amount of loans they can borrow from banks. Due to the offsetting mechanism, aggregate consumption increases initially and falls in the median run, and aggregate housing demand increases over time. A positive technology shock in the housing sector also raises business investment, the capital stock and output as the price of goods is high, relative to houses. Therefore, GDP increases over time.

Next, consider the movements of financial variables in this case. The decline in consumer loans is a product of the low expected house prices. With a low house price, banks are less willing to issue consumer loans to their borrowers, given houses as collateral. Commercial loans increase over time due to a rise in business investment. Moreover, deposits fall over time due to the fact that patient households tend to forgo goods and buy more houses at a low price today in order to enjoy more housing services tomorrow, and that to smooth their consumption, they have to decrease deposits.

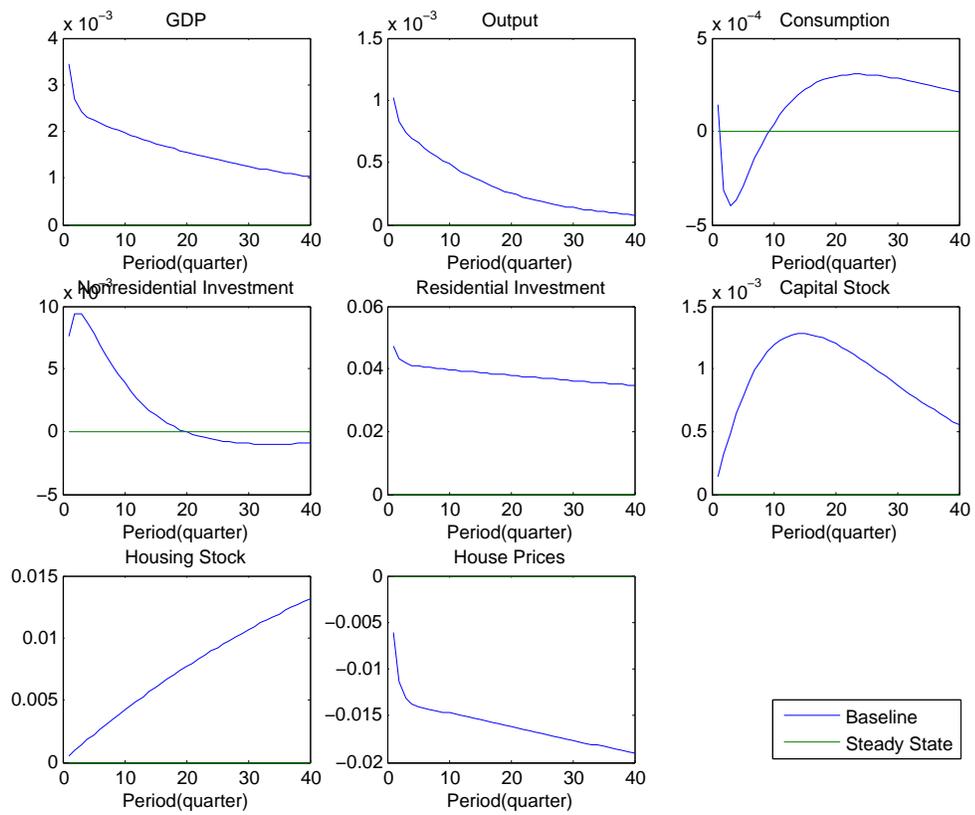


Figure 3.3: Impulse Response Functions (Housing and Macroeconomic Variables) to a Positive Productivity Shock in the Housing Sector

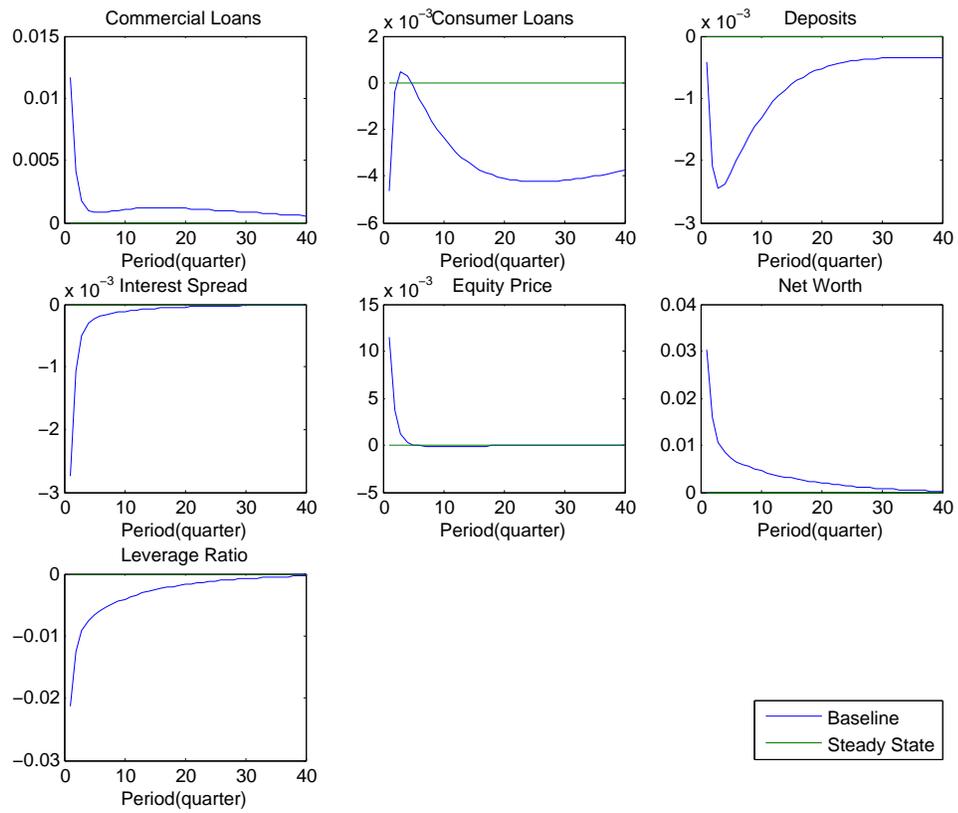


Figure 3.4: Impulse Response Functions (Financial Variables) to a Positive Productivity Shock in the Housing Sector

Recall that asset/capital prices are positively associated with commercial loans and business investment. When both commercial loans and business investment rise, asset/capital prices increase over time, causing a decline in the spread. The reason that net worth rises on impact is quite straightforward. So long as asset prices are above the trend, net worth rises. Last, when the increase in net worth dominates the increase in assets, bank leverage ratio must fall. Throughout the convergence process, banks effectively re-leverage since they are building up assets relative to debts.

Capital Quality (Financial) Shock

With a negative capital quality shock estimated in this chapter, the impulse responses are generally identical to that in the Financial Experiment I discussed in Chapter 2. Typically, a negative capital quality shock would reduce housing and business investment and asset and housing prices. In addition, other macroeconomic and financial variables such as capital stock, housing stock, output, GDP, loans, deposits and net worth all decline over time in response to the shock. Financial factors are at work to slow down the recovery of the economy during the convergence process, so long as the spread is above the trend. Further, the recovery is extremely tough and time consuming, since the deleveraging process of banks in this case has a magnified impact on the economy in a longer horizon. See full discussions and the impulse response functions in Section 2.6.

3.3.2 Cyclical Properties

In this section, I investigate whether the baseline model fits the business cycle properties observed in the data. Table 3.3 reports selected volatilities and correlations for

Table 3.3: Business Cycle Properties of the Baseline Model

Variables	Data	D-H	I-N	Model
<i>Panel A: %SD</i>				
<i>(Relative to GDP)</i>				
<i>GDP</i>	2.06	1.73	1.53	3.22
<i>C</i>	0.63	0.48	0.92	0.91
<i>I_k</i>	2.65	3.21	3.07	2.17
<i>I_h</i>	4.95	6.12	5.72	5.03
<i>q</i>	1.21(FMHPI)	0.40	0.90	2.87
	2.08(S&P HPI)			
<i>pS</i>	2.63	—	—	1.64
<i>B</i>	2.57	—	—	2.67
<i>D</i>	0.73	—	—	1.06
<i>N</i>	3.57	—	—	4.11
<i>Panel B: Correlations</i>				
<i>C, GDP</i>	0.97	0.95	0.83	0.94
<i>I_k, GDP</i>	0.73	—	0.84	0.71
<i>I_h, GDP</i>	0.86	—	0.54	0.19
<i>q, GDP</i>	0.36	0.65	0.73	0.16
<i>pS, GDP</i>	0.06	—	—	0.62
<i>B, GDP</i>	0.45	—	—	0.47
<i>D, GDP</i>	0.27	—	—	0.77
<i>N, GDP</i>	0.33	—	—	0.39
<i>q, C</i>	0.31	—	0.95	0.24
<i>q, I_k</i>	0.46	—	—	0.16
<i>q, I_h</i>	0.28	-0.20	0.17	-0.76
<i>q, B</i>	0.18	—	—	0.25
<i>pS, I_k</i>	0.46	—	—	0.33
<i>B, I_h</i>	0.43	—	—	-0.14
<i>B, C</i>	0.41	—	—	0.44
<i>I_k, I_h</i>	0.38	0.15	—	0.06

Note: D-H represents business cycle statistics reproduced by Davis and Heathcote (2005). They estimate the model with technology shocks only by using the data from 1948 to 2001, and these simulated statistics are obtained from the model with technology shocks only; I-N represents business cycle statistics reproduced by Iacoviello and Neri (2010). They estimate the model with nine shocks by using the data from 1965 to 2006, and these simulated statistics are obtained from the model with technology shocks only.

the data, the baseline model and the models from the previous housing literature.⁷ The simulated relative volatilities of the key variables of interest are presented in the Panel A, and the simulated correlations are presented in the Panel B. From Table 3.3, I find that the baseline model replicates well the volatility and procyclicality of consumption, investment, house prices and some financial variables as well as the joint behavior between house prices and macroeconomic quantities of interest over the business cycle in U.S. history. In particular, the model approximately reproduces the volatilities of all selected variables except for deposits. The volatility of deposits are overstated by the model, and contradict the data. Moreover, consumption, business investment, housing investment, and house prices are procyclical, as observed in the data. Of these, the model can reproduce the procyclicality of consumption, business investment and house prices observed in the data. The model also replicates well the correlations of house prices with consumption, business investment and consumer loans. Compared with the existing housing literature, Davis and Heathcote (2005) and Iacoviello and Neri (2010), the baseline model with technology and financial shocks alone improves its ability to account for the volatility in business investment, housing investment and house prices, procyclicality in business investment and house prices, and the joint behavior of house prices with consumption. Last, since my model explicitly considers the role of financial intermediaries, it is successful in its ability to account for the volatility in commercial loans, consumer loans and net worth, the procyclicality in consumer loans and net worth, the correlation between house prices and consumer loans, the correlation between business investment and commercial loans, and the correlation between consumption and consumer loans. In the absence

⁷Statistics are averages over 500 simulations and, for each of simulated time series, the length of the main variables equals to 155 periods, that of my data sample. The business cycle component of each simulated series is obtained using the HP filter with smoothing parameter equal to 1,600.

of financial frictions, the previous housing literature like Davis and Heathcote (2005) and Iacoviello and Neri (2010) is unable to account for these observations.

To my knowledge, most of existing housing literature fails to account for the high volatility of house prices observed in the data. For instance, the Davis-Heathcote model with technology shocks alone does poorly in accounting for the swings in house prices, and only reproduces one third of that observed in the data, implying that a model without the heterogeneity of households cannot generate a high volatility of house prices. In contrast, the Iacoviello-Neri model is successful in accounting for the high volatility of house prices only after a variety of exogenous shocks are introduced into their model. Fundamentally, a high volatility of house prices is generated in their model by dealing with the fixed supply of land, the heterogeneity of households, and a variety of exogenous shocks. Their model with technology shocks alone, however, reproduces a counterfactual outcome that house prices are less volatile than GDP. These earlier works fail to reproduce the high volatility of the house prices observed in the data because they cannot create an intensive interaction between individual demand for housing from the two types of household over the business cycle in determining the house prices. In particular, the volume of consumer loans issued by banks fundamentally affects the movement of the house prices over the business cycle. So long as the volatility of consumer loans is high, the demand for housing from impatient households side varies more than it otherwise would in the absence of financial factors. In contrast to the recent housing literature, my baseline model does a good job in accounting for the high volatility of house prices observed in the data even with just a few shocks. As Table 3.3 shows, the relative volatility of house prices is 2.87, which is significantly higher than those produced by previous authors. The volatility

of house prices reproduced by the baseline model seems overstated, relative to the data if I use the Freddie Mac House Price Index (FMHPI) as a measure of house prices. However, it is consistent with the one using the S&P/Case-Shiller Home Price Index as a measure of house prices. Note that the volatility of house prices in the data using the Freddie Mac House Price Index (FMHPI) as a measure of house prices is 1.21, which is much smaller than that using the S&P/Case-Shiller Home Price Index.⁸ Moreover, I find that house prices are procyclical in line with the observation from the data. Thus, the model can quantitatively explain the volatility and procyclicality of house prices, implying that my baseline model fits the data in the dimension of house price volatility.

However, there are few aspects in which the model performs poorly. First, it overstates the volatility and procyclicality of deposits. A simple way to reduce the volatility and procyclicality of deposits is to raise the banks' survival rates, and I will discuss it in the following section. Second, the model overstates the procyclicality of commercial loans. To address this issue, we have to weaken the dependence of business investment on commercial loans. The assumption that business investment is financed by only commercial loans might be too strong in the model. Third, in the data, house prices and housing investment move in the same direction. In contrast, the model generates a negative correlation between the price and investment. This is consistent with the findings of Davis and Heathcote (2005) and Iacoviello and Neri

⁸The volatility of house prices from the data is 2.08, using the S&P/Case-Shiller Home Price Index as a measure of house prices, which is higher than that using the FMHPI. Due to data availability, the starting year of the S&P/Case-Shiller Home Price Index is 1987. In general, the volatility of house prices in the data differs from one to another by using different source of house price indices. For instance, Davis and Heathcote (2005) calculates the volatility of house prices of 1.37 from the data, using the FMHPI from 1970 to 2001; and Iacoviello and Neri (2010) calculates the volatility of house prices of 1.87 from the data, using the U.S. Census House Price Index from 1965 to 2006.

(2010) that a model with only technology shocks cannot replicate a positive correlation between the price and the quantity of housing. As in Iacoviello and Neri (2010), the baseline model can reverse this counterfactual result once other exogenous shocks (e.g. demand-side shocks) are introduced into the model. In addition, consumer loans and housing investment move in the opposite direction, which is contrary to the data. This contradiction may be altered with the similar approach above and I reserve such an exploration for future research. Last, a striking drawback of the model is that it understates the correlation between housing investment and business investment. In general, they are positively correlated in the data, and the correlation is about 0.4.

It is worth pointing out that the model fails to account for the lead-lag correlations among housing investment, business investment and GDP as do most neoclassical models, since it does not allow for household capital complementarity.⁹ In general, housing investment leads business investment and GDP, as observed in the data. To my knowledge, Fisher (2007), perhaps, is the only one in the existing housing literature that can successfully account for these lead-lag patterns.

⁹The household capital complementarity hypothesis is first introduced by Fish (2007). In particular, it is modeled by assuming household capital (e.g. housing) as a complementary input in the production of final goods. The addition of household capital complementarity not only increases the positive correlations among housing investment, business investment and GDP, but also encourages households to accumulate household capital before business capital. This happens because household capital is a complementary input in the production, and it is useful for producing more goods than business capital. See a detailed discussion in Fisher (2007). In some exercises, I attempt to use the baseline model to reproduce cross correlations among housing investment, business investment and GDP, and the simulated results suggest that the model performs poorly in accounting for the lead-lag patterns of these variables observed in the data.

3.4 Robustness Analysis

In this section, I investigate the ability of the model to match certain statistics observed in the data by shutting off one or more frictions or shocks or by changing one or more parameters which are fixed in the baseline model each time. Table 3.4 reports the business cycle properties of the alternative models shutting off certain frictions. Table 3.5 reports the business cycle properties of the model with technology shocks only. Table 3.6 reports the business cycle properties of the models with alternative choices of the parameter values. The analytical results are given as follows.

3.4.1 The Model with Full Labor Mobility

Column (c) in Table 3.4 reports the business cycle statistics of the model with perfect labor mobility across production sectors. In this version of the model, I now assume that labor hours are perfect substitutes by setting the labor supply parameters ϵ_p and ϵ_i to zero. A model with perfect labor mobility exacerbates the volatilities of housing investment and house prices, and mitigates the volatilities of financial variables such as commercial loans, consumer loans and net worth without generating a positive correlation between housing investment and business investment. In particular, it generates a counterfactual result that two types of investment are negatively correlated. In addition, the friction of the perfect labor mobility does not help to improve the model's ability in accounting for a positive correlation between consumer loans and housing investment. Rather, the correlation between consumer loans and housing investment reproduced by this version of the model is even worse, relative to that in the baseline model. Last, a model with perfect labor mobility does not help to correct the counterfactual result that house prices and housing investment are

Table 3.4: Business Cycle Properties of the Alternative Models

Variables	Data	Baseline model	Full labor mobility	Same labor preferences	No financial constraints
	(a)	(b)	(c)	(d)	(e)
<i>Panel A: %SD (Relative to GDP)</i>					
<i>GDP</i>	2.06	3.22	3.18	3.15	3.07
<i>C</i>	0.63	0.91	0.91	0.91	0.91
<i>I_k</i>	2.65	2.17	2.16	2.19	2.30
<i>I_h</i>	4.95	5.03	6.99	5.35	5.16
<i>q</i>	1.21(FMHPI) 2.08(S&P HPI)	2.87	3.49	2.93	2.89
<i>pS</i>	2.63	1.64	1.55	1.56	1.20
<i>B</i>	2.57	2.67	2.52	2.56	1.73
<i>D</i>	0.73	1.06	1.06	1.03	1.41
<i>N</i>	3.57	4.11	3.88	3.95	7.23
<i>Panel B: Correlations</i>					
<i>C, GDP</i>	0.97	0.94	0.91	0.94	0.93
<i>I_k, GDP</i>	0.73	0.71	0.70	0.71	0.66
<i>I_h, GDP</i>	0.86	0.19	0.17	0.17	0.14
<i>q, GDP</i>	0.36	0.16	0.14	0.17	0.20
<i>pS, GDP</i>	0.06	0.62	0.58	0.59	0.61
<i>B, GDP</i>	0.45	0.47	0.43	0.45	0.34
<i>D, GDP</i>	0.27	0.77	0.72	0.78	0.39
<i>N, GDP</i>	0.33	0.39	0.34	0.36	0.17
<i>q, C</i>	0.31	0.24	0.28	0.27	0.30
<i>q, I_k</i>	0.46	0.16	0.18	0.16	0.18
<i>q, I_h</i>	0.28	-0.76	-0.76	-0.77	-0.74
<i>q, B</i>	0.18	0.25	0.23	0.27	0.39
<i>pS, I_k</i>	0.46	0.33	0.32	0.31	-0.03
<i>B, I_h</i>	0.43	-0.14	-0.21	-0.16	-0.59
<i>B, C</i>	0.41	0.44	0.44	0.43	0.48
<i>I_k, I_h</i>	0.38	0.06	-0.03	0.05	-0.04

negatively correlated. As I noted earlier, the negative co-movements between house prices and housing investment and between consumer loans and housing investment are a general result of any supply-side shocks. All other statistics reproduced by this version of the model are generally similar to that reproduced by the baseline model.

3.4.2 The Model with Homogenous Labor Preferences

Column (d) in Table 3.4 reports the business cycle statistics of the model with the same labor supply parameters. Recall that in the baseline model I assume that the two types of household differ in their labor supply parameters, reflecting the heterogenous labor supplied to a particular non-financial sector across households. Now, I constrain η and ϵ to be the same across the two types of household in order to investigate the role of homogenous labor preferences in accounting for several key properties of the business cycle. The business cycle statistics reproduced by the model with homogenous labor preferences are essentially unchanged, relative to that in the baseline model. Accordingly, the restriction of homogenous labor preferences does not matter for the simulated statistics of the business cycle. This finding is consistent with that obtained by Iacoviello and Neri (2010).¹⁰

3.4.3 The Model without Financial Constraints

Column (e) in Table 3.4 reports the business cycle statistics of the model without financial frictions. Here are several findings from the robustness test. First, a model

¹⁰In this chapter, I use the model with heterogenous preferences as the baseline model in order to investigate whether the friction of heterogenous preferences matters for the simulated statistics when it includes banking. Further, aside from the addition of the financial system in the model, I want to maintain my model as similar as the one used by Iacoviello and Neri (2010) for comparison purposes.

without financial frictions slightly increases the volatilities of business and housing investment, and significantly magnifies the volatilities of deposits and net worth. In the absence of the financial constraints, banks tend to accept more deposits from savers and accumulate more assets relative to debts, and hence, the volatilities of deposits and net worth rise. Further, both business and housing investment are more likely to rise since borrowers can now borrow more funds from the banks. As a result, their volatilities increase. Second, a model without financial constraints mitigates the volatilities of commercial and consumer loans. Without financial frictions, the impact of the shocks on loans would not be enhanced by a factor equal to the leverage ratio, so this version of the model generates a lower volatility of loans, relative to that in the baseline model. Third, the model reduces the procyclicality of financial variables when the financial frictions are removed. Last, shutting off the financial constraints does not address any counterfactual problems encountered by the baseline model. Surprisingly, it even reproduces a negative correlation between commercial loans and business investment and a negative correlation between business and housing investment. Therefore, this version of the model performs poorly in accounting for the business cycle properties of interest.

3.4.4 The Model with Technology Shocks Only

Table 3.5 reports the business cycle properties of the model with technology shocks only, shutting off the capital quality shock. The model with technology shocks alone generates a lower volatility of all variables except for housing investment and house prices. In particular, the addition of the capital quality shock generally magnifies

Table 3.5: Business Cycle Properties of the Model with Technology Shocks Only

Variables	Data	D-H	I-N	Baseline	Tech Shocks Only
<i>Panel A: %SD</i>					
<i>(Relative to GDP)</i>					
<i>GDP</i>	2.06	1.73	1.53	3.22	3.09
<i>C</i>	0.63	0.48	0.92	0.91	0.90
<i>I_k</i>	2.65	3.21	3.07	2.17	1.86
<i>I_h</i>	4.95	6.12	5.72	5.03	5.30
<i>q</i>	1.21(FMHPI) 2.08(S&P HPI)	0.40	0.90	2.87	2.99
<i>pS</i>	2.63	—	—	1.64	0.88
<i>B</i>	2.57	—	—	2.67	1.17
<i>D</i>	0.73	—	—	1.06	0.92
<i>N</i>	3.57	—	—	4.11	1.05
<i>Panel B: Correlations</i>					
<i>C, GDP</i>	0.97	0.95	0.83	0.94	0.96
<i>I_k, GDP</i>	0.73	—	0.84	0.71	0.87
<i>I_h, GDP</i>	0.86	—	0.54	0.19	0.18
<i>q, GDP</i>	0.36	0.65	0.73	0.16	0.16
<i>pS, GDP</i>	0.06	—	—	0.62	0.82
<i>B, GDP</i>	0.45	—	—	0.47	0.65
<i>D, GDP</i>	0.27	—	—	0.77	0.83
<i>N, GDP</i>	0.33	—	—	0.39	0.60
<i>q, C</i>	0.31	—	0.95	0.24	0.24
<i>q, I_k</i>	0.46	—	—	0.16	0.22
<i>q, I_h</i>	0.28	-0.20	0.17	-0.76	-0.75
<i>q, B</i>	0.18	—	—	0.25	0.48
<i>pS, I_k</i>	0.46	—	—	0.33	0.53
<i>B, I_h</i>	0.43	—	—	-0.14	-0.38
<i>B, C</i>	0.41	—	—	0.44	0.73
<i>I_k, I_h</i>	0.38	0.15	—	0.06	0.06

Note: D-H represents business cycle statistics reproduced by Davis and Heathcote (2005). They estimate the model with technology shocks only by using the data from 1948 to 2001, and these simulated statistics are obtained from the model with technology shocks only; I-N represents business cycle statistics reproduced by Iacoviello and Neri (2010). They estimate the model with nine shocks by using the data from 1965 to 2006, and these simulated statistics are obtained from the model with technology shocks only.

the volatility of all financial variables, and slightly reduces the volatility in housing investment and house prices. But the model with technology shocks alone can still reproduce the volatility of housing investment and house prices observed in the data. This model also generates a higher procyclicality of all financial variables and a higher correlation of house prices with business investment and consumer loans. In addition, it significantly magnifies the correlation between consumer loans and consumption. As in the baseline model, this model generates counterfactual results that house prices and housing investment are negatively correlated, and that consumer loans and housing investment are negatively correlated. According to the previous housing literature, supply-side shocks alone in general would miss the empirical correlation between these variables. Last, it does not improve its ability to account for the correlation between housing investment and business investment. Overall, the addition of the financial shocks, like the capital quality shock in my case, improves the model's ability to better account for the volatility and procyclicality of financial variables observed in the data without affecting much the implications for other variables.

Aside from the weakness of this model in reproducing the volatility and procyclicality of financial variables, it replicates well the volatility in business investment, housing investment and house prices, procyclicality in house prices, and the correlation between house prices and consumption, which are replicated poorly by most of the previous housing studies with technology shocks alone.

3.4.5 Effects of Lower Downpayment Requirements and Higher Banks' Survival Rates

In the rest of this section, I will investigate the roles of the downpayment requirements and banks' survival rates over the business cycle in the model. All results are reported in the Table 3.6. Column (a) reports the statistics of the baseline model. Column (b) reports the statistics of the model with a lower downpayment requirement. In the baseline model, the loan-to-value ratio is fixed at 0.85. I now raise the ratio to 0.95, reflecting that impatient households make less downpayment than before while borrowing funds from banks with their houses as a collateral. Column (c) reports the statistics of the model with higher bank's survival rates. Recall that in the baseline model the average survival time of the banks is 9 years ($\sigma = 0.972$). Instead, I now assume that the average survival time of the banks is doubled, which is 18 years ($\sigma = 0.986$). Column (d) reports the statistics of the model with both lower downpayment requirements and higher banks' survival rates.

Effects of Lower Downpayment Requirements: Lower downpayment requirements lead to a decrease in the volatility of business investment, commercial loans, consumer loans, and the banks' net worth, and leave the volatility of other variables virtually unchanged. The fact that a rise in the loan-to-value ratio leaves the volatility of housing investment and house prices unchanged in my model is a product of the interaction between housing purchases and labor supply. On the one hand, borrowers (impatient households) tend to mitigate aggregate volatility by working relatively less hours in response to positive technology shocks since they now can borrow more funds from banks than before, given their houses as a collateral. On the other hand, savers (patient households) tend to increase aggregate volatility by working relatively

Table 3.6: Business Cycle Properties: Changing Downpayment Requirements and Banks' Survival Rates

Variables	Data	(a) Baseline $m = 0.85$ $\sigma = 0.972$	(b) $m = 0.95$ $\sigma = 0.972$	(c) $m = 0.85$ $\sigma = 0.986$	(d) $m = 0.95$ $\sigma = 0.986$
<i>Panel A: %SD (Relative to GDP)</i>					
<i>GDP</i>	2.06	3.22	3.19	3.13	3.19
<i>C</i>	0.63	0.91	0.91	0.90	0.89
<i>I_k</i>	2.65	2.17	2.13	1.93	1.84
<i>I_h</i>	4.95	5.03	5.05	5.22	5.19
<i>q</i>	1.21(FMHPI) 2.08(S&P HPI)	2.87	2.92	2.99	2.96
<i>pS</i>	2.63	1.64	1.51	1.61	1.60
<i>B</i>	2.57	2.67	2.38	2.17	2.06
<i>D</i>	0.73	1.06	1.06	1.02	0.98
<i>N</i>	3.57	4.11	3.67	3.18	3.10
<i>Panel B: Correlations</i>					
<i>C, GDP</i>	0.97	0.94	0.94	0.94	0.94
<i>I_k, GDP</i>	0.73	0.71	0.74	0.79	0.81
<i>I_h, GDP</i>	0.86	0.19	0.15	0.18	0.25
<i>q, GDP</i>	0.36	0.16	0.18	0.16	0.13
<i>pS, GDP</i>	0.06	0.62	0.57	0.60	0.61
<i>B, GDP</i>	0.45	0.47	0.43	0.49	0.46
<i>D, GDP</i>	0.27	0.77	0.75	0.69	0.69
<i>N, GDP</i>	0.33	0.39	0.32	0.40	0.41
<i>q, C</i>	0.31	0.24	0.28	0.25	0.22
<i>q, I_k</i>	0.46	0.16	0.18	0.18	0.17
<i>q, I_h</i>	0.28	-0.76	-0.78	-0.77	-0.74
<i>q, B</i>	0.18	0.25	0.28	0.30	0.33
<i>pS, I_k</i>	0.46	0.33	0.30	0.47	0.45
<i>B, I_h</i>	0.43	-0.14	-0.17	-0.23	-0.19
<i>B, C</i>	0.41	0.44	0.42	0.49	0.46
<i>I_k, I_h</i>	0.38	0.06	0.07	0.08	0.15

Note: Baseline model and robustness analysis. (a) is the baseline model. (b) is the model with the loan-to-value ratio raising from 0.85 to 0.95. (c) is the model with the banks' survival rates raising from 0.972 to 0.986, reflecting that the average survival time of the banks increases from 9 to 18 years. (d) is the model with both the loan-to-value ratio and the banks' survival rates that are increased.

more hours in response to positive technology shocks. As long as the two effects offset each other, the volatility of housing investment and house prices remains unchanged as the loan-to-value ratio rises. This result, however, is contrary to Campbell and Hercowitz (2005) and Iacoviello and Pavan (2013).¹¹ In my model, consumer loans are used to finance housing purchases by indebted households, and the housing purchases of indebted households respond less to positive technology shocks as the loan-to-value ratio rises. In this regard, a rise in the loan-to-value ratio reduces the volatility of consumer loans, and sequentially, the volatilities of commercial loans and net worth. Since business investment is primarily financed by commercial loans, the volatility of business investment falls as well. The correlations of all variables simulated in this case are generally similar to that in the baseline model. See detailed statistics in Column (b) of Table 3.6.

Effects of Higher Banks' Survival Rates: A rise in the banks' survival rates raises the volatilities of housing investment and house prices, and reduces the volatilities of business investment, commercial loans, consumer loans, deposits and net worth. Recall that in the economy a bank only pays dividends to its owners while exiting from the banking system. When the survival time of a bank is longer, the bank has relatively less motive for paying dividends. Absent some motive for paying dividends, the bank may find it more optimal to accumulate its assets to the point where the

¹¹In Campbell and Hercowitz (2005), financial innovations account for more than half of the decrease in aggregate volatility in a model with borrowing constraints. Since they assume that labor supply of wealthier households is constant, the offsetting mechanism between the rich and the poor is silent, that is, the effect of labor supply on the aggregate volatility from the poor is not offset by that from the rich in their model. In Iacoviello and Pavan (2013), aside from modeling differences, the offsetting mechanism is at work to induce a decrease in aggregate volatility in response to positive technology shocks, which is contrary to my result. In the presence of the adjustment costs of housing in their model, the decline in aggregate volatility induced by reducing hours by indebted homeowners is not fully offset by the rise in aggregate volatility induced by increasing hours by wealthier homeowners (creditors). Therefore, the volatility of housing investment in their model is reduced as the loan-to-value ratio rises.

financial constraint it faces is no longer binding.¹² In this case, both types of loans respond less to the shocks, and so does net worth. Since commercial loans and consumer loans are used to finance business investment and the housing purchases of indebted households respectively, a rise in the banks' survival rates reduces the aggregate volatility of business investment and the aggregate volatility of housing purchases (housing investment). As I discussed above, savers (patient households), however, increase the aggregate volatility of housing purchases by working relatively more hours in response to the positive technology shocks. Due to this offsetting mechanism, a rise in the banks' survival rate slightly increases aggregate volatilities of housing investment and house prices. By learning about the bank's increased ability to save to overcome financial constraints, depositors are more likely to reduce the amount of deposits, and therefore the volatility of deposits slightly decreases as the banks' survival rates rise. Correlations simulated in this case are also similar to that in the baseline model, except for the correlation between business investment and commercial loans. In particular, a rise in the banks' survival rates magnifies the correlation between business investment and commercial loans. See detailed statistics in Column (c) of Table 3.6.

Effects of Lower Downpayment Requirements and Higher Banks' Survival Rates: Given both a lower downpayment requirement and a higher banks' survival rate, the volatilities of housing investment and house prices increase, and the volatilities of business investment, commercial loans, consumer loans, and net worth decrease. More importantly, this version of the model improves the correlation between housing investment and business investment, but still understates it, relative to the data. See

¹²Here, a rise in the banks' survival rates virtually enhances the banks' ability to save to overcome financial constraints.

Table 3.7: Decomposition of the Variance of the Forecast Errors

Variables	u_k	u_c	u_h
<i>GDP</i>	11.23	73.12	15.65
<i>C</i>	5.36	93.81	0.83
<i>I_k</i>	61.76	25.26	12.98
<i>I_h</i>	0.28	0.11	99.61
<i>q</i>	2.69	14.59	82.72
<i>pS</i>	72.14	1.51	26.34
<i>B</i>	92.00	7.19	0.81
<i>D</i>	29.58	42.14	28.28
<i>N</i>	88.04	0.34	11.62

Note: The table reports the decomposition of the variance of the forecast errors at business cycle frequencies (extracted using the HP filter with smoothing parameter equal to 1,600). All values are measured in percentage. u_k : standard error of the capital quality shock; u_c : standard error of the technology shock in the final goods sector; u_h : standard error of the technology shock in the housing sector.

detailed statistics in Column (d) of Table 3.6.

3.5 Sources of Business Cycle Fluctuations

Since the baseline model with estimated shocks replicates well some important properties of the business cycle in the housing and financial markets and the macroeconomy observed in the data, in this section I investigate what the main driving forces of fluctuations are in the housing and financial markets and the macroeconomy. Studying the sources of business cycle fluctuations can provide us with a better understanding of major features of the business cycle in the United States.

Table 3.7 reports the variance decomposition of the forecast errors at business cycle frequencies. Technology shocks in the housing sector explain almost all the variance of housing investment and about 80 percent of the variance of house prices at business cycle frequencies, implying that they are the primary driving forces of

fluctuations in the housing market. In addition, they explain less than 20 percent of the variance of business investment and GDP, and less than 30 percent of the variance of commercial loans, deposits and net worth. However, they only explain less than 1 percent of the variance of consumption and consumer loans. Technology shocks in the final goods sector explain most of the variance of consumption and GDP, implying that they are the main driving forces of fluctuations in the macroeconomy. But, they explain less of the variance of financial variables. For instance, they only explain less than 8 percent of the variance of commercial loans, consumer loans and net worth. Therefore, technology shocks in the final goods sector play a trivial role in the financial market. Financial shocks (e.g. capital quality shocks) explain more than 70 percent of the variance in all financial variables except for deposits. They only explain about 30 percent of the variance of deposits. These results indicate that financial shocks are the main driving forces of fluctuations in the financial market. However, financial shocks are not regarded as one of the main driving forces of fluctuations in the housing market, since they only explain less than 3 percent of the variance of housing variables.

What these facts tell us is that financial shocks and housing technology shocks are the main driving forces of fluctuations in the financial market at business cycle frequencies. Moreover, technology shocks in the final goods and housing sectors are the main driving forces of fluctuations in the housing market and the macroeconomy, implying that the model with technology shocks along can replicate well the second moments of major housing and macroeconomic variables. This is consistent with the findings from the robustness test on the model with technology shock only (see Table 3.5).

Although this study considers only a few potential shocks in the business cycle,

relative to Iacoviello and Neri (2010), it can still capture the fact that technology shocks are one of the main driving forces of fluctuations in the housing market and the macroeconomy along the lines of previous housing literature such as Iacoviello and Neri (2010). In the housing literature, any neglect of technology shocks would distort the main features of the housing market and the macroeconomy observed in the data. Further, financial shocks are not tiny things in the business cycle and can account for large fluctuations in the financial market, and hence, should be taken into account when we study the financial market over the business cycle.

3.6 Conclusion

The baseline model with estimated shocks is successful in its ability to account for several key features of the U.S. business cycle. The model replicates well the volatility and procyclicality of consumption, housing investment, house prices and some key financial variables, the volatility of business investment, and the co-movement between house prices and other quantities of interest such as consumption, business investment and consumer loans. Furthermore, the model can reproduce the correlation between business investment and commercial loans, and the correlation between consumption and consumer loans observed in the data. I find that technology shocks are the main driving forces of fluctuations in the housing market and the macroeconomy, and can account for more than 95 percent of the fluctuations in the housing market and more than 85 percent of that in the macroeconomy. On the other hand, financial shocks and housing technology shocks are the main driving forces of fluctuations in the financial market at business cycle frequencies, and can explain more than 90 percent of the fluctuations in this market.

The model, however, performs poorly in the following dimensions. First, it overstates the volatility and procyclicality of deposits. As I discussed earlier, a simple way to reduce the volatility and procyclicality of deposits is to raise the banks' survival rates. Second, it overstates the procyclicality of commercial loans. In the baseline model, business investment primarily depends on commercial loans, and is the main components of GDP. Within the framework, it inevitably strengthens the link between commercial loans and GDP. To address this issue, we have to weaken the dependence of business investment on commercial loans. One possible approach to address this drawback might be that business investment is assumed to be partially financed by commercial loans. Third, the model generates a counterfactual correlation between house prices and housing investment, and a counterfactual correlation between consumer loans and housing investment. Last, the model understates the positive co-movement between housing investment and business investment. These counterfactual results are the general outcome of the supply-side shocks in the current context of the DSGE models. They can be addressed once we introduce some forms of demand-side shocks, such as the housing preference shocks. Iacoviello and Neri (2010) provides a detailed discussion on the role of demand-side shocks of housing over the business cycle. The approaches to address these issues above are only meant to be suggestive. Here, I leave these open issues for future explorations.

Since the model replicates well the volatility of house prices observed in the data, one may extend this type of model to investigate the implications of macroprudential policies in mitigating this volatility. Given that house prices are relatively volatile in the data, it is not clear whether interest rate policies and other conventional policy instruments can successfully stabilize house prices, or provided they can do so, that

they can stabilize house prices without inducing excessive volatility in other macroeconomic quantities.¹³ If conventional policy instruments fail to stabilize house prices, it raises an open question: are there any unconventional policy instruments can be successful in stabilizing housing prices without causing excessive volatility in other macroeconomic quantities? It seems to me that addressing these issues in a DSGE model with frictions in the housing and banking sectors is a sensible thing to do and I leave them for future research.

¹³We should bear in mind that these policy instruments can be used to stabilize the volatility of house prices only in the case either where market imperfections exist in the economy, or where the volatility of house prices is too high so as to sow the seeds of financial imbalances and housing market instability. Otherwise, the outcomes would already be efficient.

Chapter 4

Financial Stability and Housing Market Stability: Implications of Macroprudential Policies

4.1 Introduction

In the many financial crises that occurred in both industrial and emerging market countries in the past, widespread financial distress typically arose from large swings in asset prices together with excess credit expansion. Examples in the last century include the crises in Latin America in the late 1970s-early 1980s, the Nordic countries in the late 1980s, and East Asia in the late 1990s. The most recent financial crises in the U.S. led to the Great Recession of 2007-2009. The genesis of the crisis is often argued to be a product of sustained rapid credit growth induced by a large increase in house prices in the mid-2000s. During that period, much of the prosperity

of the U.S. economy was linked to the boom in the housing market. Private spendings dramatically increased while households benefited from a rapid appreciation of their house values. Numerous jobs were created in sales, manufacturing, construction and the real estate sectors. Meanwhile, household debts relative to income (household leverage) and bank assets relative to net worth (bank leverage) tended to rise significantly during this period. At the end of 2006, the level of household debts and bank assets started to fall as house prices experienced a sharp drop. Real GDP, consumption, investment, house prices and other macroeconomic variables suffered severe declines from 2007 to 2009. The Great Recession has been the most severe economic contraction in the post-war period of the U.S. history.

Before the Great Recession, many economists and policymakers believed that the prosperity of the U.S. economy was driven by fundamental factors such as technological change and international trade rather than a rapid appreciation of house prices and excess credit expansion. They reached a consensus that responding directly to asset prices or other financial variables in a booming economy is too risky or politically impractical. There are three powerful objections that have been levied against the use of monetary and prudential policies in such a scenario. First, responding directly to asset prices or other financial variables is potentially harmful since the authorities have difficulties in defining and detecting asset price bubbles and financial imbalances in real time, as noted by Bernanke and Gertler (2001). Second, destabilizing the economy in good times could induce an unnecessary recession, and the associated costs may be enormous. Third, even if technically possible, any such intervention may be too hard to justified to the public. As Borio and Lowe (2002) point out, political

economy considerations always constrain the use of monetary instruments in a scenario where a booming economy is not under obvious inflationary pressures. In the absence of any evidence to the contrary, the use of interest instruments by the monetary authorities might expose them to the risk of aggressive criticism for undermining what many people would have regarded as a strong and sustainable boom.

But in retrospect, the economic boom of the mid-2000s could be largely attributed to overoptimistic projections about the growth of future house prices and easy lending standards. The experience of the Great Recession has highlighted that a rapid credit expansion induced by the unsustainable growth of house prices can easily threaten financial and housing market stability. In the aftermath of the Great Recession, there is a growing consensus among economists and policymakers that macroprudential approaches to financial regulation and supervision should be adopted in order to deal with financial imbalances and asset price bubbles. Many of them have suggested that the authorities need to go beyond their traditional emphasis on inflation and output gaps and extend their monetary policy rules to add additional indicators such as household debts and asset prices. There are several reasons why the authorities should respond to fluctuations in asset prices and credit in a booming economy. First, the difficulties in identifying asset price “bubbles” and financial imbalances may not be as daunting as some people believe. A growing body of empirical work has found that a rapid credit expansion, large appreciation of asset prices, and high levels of over-investment will inevitably lead to instability in the financial and housing markets. These variables work well as reliable indicators in signaling the risk of financial distress.¹ Second, the costs of the authorities’ failure to respond early might be much

¹See, for example, Borio and Lowe (2002), Borio and Lowe (2004), Eichengreen and Arteta (2000), Kannan et al.(2011), Dermirguc-Kunt and Detragiache (1997, 1998), Gourinchas, Valdes and

larger than most people realize. According to Borio and Lowe (2002), “if the economy is indeed robust and the boom is sustainable, actions by the authorities to restrain the boom are unlikely to derail it altogether. In contrast, failure to act could have much more damaging consequences, as the imbalances unravel.” The East Asia Financial Crisis in the late 1990s and the Great Recession in 2007-2009, perhaps, are prominent examples of this point. In particular, failing to act early can dampen the effectiveness of the policy instruments and undermine the credibility of the authorities when the crises actually materialize. This, in turn, will sow the seeds of financial imbalances and housing market instability in the real economy, causing costly fluctuations in macroeconomic variables. Last, while the use of monetary instruments in a case where the economy is not subject to obvious inflationary pressures could attract heavy criticism from the public, the use of prudential instruments aimed at stabilizing some specific variables for a while, for instance, house prices and household debts, may provoke less criticism. However, this does not mean that: monetary instruments are technically impractical, or that macroprudential instruments are superior to monetary instruments in containing financial imbalances and asset price “bubbles” in practice. Rather, it gives the authorities degree of flexibility to act early when signals of the risks are perceived.

For these reasons, I strongly agree with the view that the authorities should not only concentrate on inflation targeting, but also adopt an explicit goal of financial and housing market stability. As stated by the Governor to the Bank of England, Mervyn King, in 2012, “It would be sensible to recognize that there may be circumstances in which it is justified to aim off the inflation target for a while in order to moderate the

Landerretche (2001), Hardy and Pazarbasioglu (1999), Hutchinson and McDill (1999), Kaminsky (1999) and Kaminsky and Reinhart (1999) for discussion on leading indicators of financial crisis.

risk of financial crisis. Monetary policy cannot just mop up after a crisis. Risk must be dealt with beforehand.” When there are many rationales for the authorities to directly respond to financial imbalances and asset price “bubbles” in a booming economy, the question now is what actions they should take in order to successfully mitigate risks of financial crisis. The goal of this chapter is to use the DSGE model with inherent imperfections in the housing and banking sectors to study various macroprudential policy instruments that might work to stabilize the housing and financial markets. The objective of this study is to explore the volatility effects of these policies on key indicators that signal potential financial crises rather than the design of the optimal policy rule function.

In practice, there are four types of policy instruments that can be used by the authorities to tackle potential risks of crises in advance. First, they can directly respond to either house price growth or credit growth by using interest rate policies (monetary policy). Second, they can require commercial banks to raise downpayment requirements (a tightening of LTV ratios) when banks issue mortgages to their borrowers. Third, they can restrain credit expansion by raising bank reserve requirements (a tightening of bank reserve ratios). Fourth, they can also impose higher capital requirements on banks (a tightening of bank leverage ratios). There is some evidence that these policy instruments might be effective in stabilizing the financial system and housing market. If an economic boom is perceived to be generated by rapid appreciation of house prices and credit expansion, monetary policy and macroprudential policies noted above could help to smooth the flow of funds between borrowers and lenders, impeding excess run-ups in house prices and household debts. In doing so,

the economy may turn out to be more stable, relative to the case without interventions. Even if this is not the case, the use of these policies can be viewed as rational since they have often ensured a less painful period of readjustment while households abruptly returns to a normal basis of spending from a point where excess credit expansion is pervasive in the economy. In addition to these policy instruments we have frequently seen, an unconventional fiscal instrument, tax credits (for instance, the Worker, Homeownership, and Business Assistance Act of 2009), is also taken into my considerations. With a tax schedule that favours impatient households (for instance, tax credits to impatient households), they will be less likely to borrow and work, thanks to the relaxation of their budget constraints. In this way, household debts and demand for housing may respond less to the shocks (e.g. technology and housing preference shocks), causing a decline in the volatility of household debts and house prices. In this regard, tax credits may be a good candidate for stabilizing both financial and housing markets. Note that these policy instruments are used in periods where the economy is booming, especially in periods where credit expansion is fueled by unsustainable appreciation of house prices.² Specifically, in this study I primarily concentrate on those macroprudential policy instruments rather than monetary policy instruments.

The results from my policy experiments below suggest that countercyclical policy instruments (e.g. countercyclical loan-to-value ratios, countercyclical bank reserve ratios and countercyclical capital/leverage ratios) specifically designed to dampen credit and housing market cycles are quite useful in stabilizing the financial and housing market, since they are able to mitigate the volatility of household debts and house

²For policies dealt with credit crunch during the crisis, see Sargent and Wallace (1982), Curdia and Woodford (2009a, 2009b) and Gettler and Kiyotaki (2010).

prices. Therefore, these countercyclical policies can be regarded as effective tools in containing financial imbalances and housing market instability in an economy exhibiting a rapid growth of credits and house prices. The down-side, however, is that some policy instruments, such as countercyclical bank reserve ratios and countercyclical capital/leverage ratios, magnify the volatility of business investment or bank net worth. Moreover, an asymmetric tax schedule that favours impatient households (net borrowers), namely macroprudential tax credits, has stabilization benefits in both the housing and financial market from the perspective of the prudential authorities. In particular, it reduces the volatility of house prices and household debts without causing excess volatility of other macroeconomic variables. In this regard, macroprudential tax credits can be viewed as an effective tool that can successfully contain both financial imbalances and housing market instability in a booming economy exhibiting rapid house price appreciation and credit expansion.

How does this study compare with the previous literature on policies that lean against financial imbalances in the context of asset price or credit booms? There is a recent growing literature on the role of macroprudential policies and monetary policies in stabilizing the macroeconomy in DSGE models. Aside from the differences in model settings, shocks, or policy instruments of interest, Lambertini et al. (2011), Angelini, Neri and Panetta (2011), Kannan et al. (2012) and Gelain, Lansing and Mendicino (2013), perhaps, are the most relevant literature to my study. Lambertini et al. (2011) develops an expectation-driven business cycle model to study the role of extending monetary policy and macroprudential policies. They find that directly responding to credit aggregates using monetary policy or imposing a loan-to-value (LTV) rule on borrowers can mitigate the volatility of the output gap and credit

aggregates, conditional on news shocks. Angelini, Neri and Panetta (2011) study the role of macroprudential policies in a New Keynesian model with banking and financial accelerator effects on both households and firms. They find that macroprudential policies might be effective tools in restraining the effects of financial shocks on run-ups in credit and asset prices. Similar to my study, Kannan et al. (2012) and Gelain, Lansing and Mendicino (2013) adopt the Iacoviello-Neri stylized model with housing to examine the role of macroprudential policy instruments in stabilizing credit growth and house prices. In particular, Kannan et al. (2012) find that directly reacting to credit growth using an extended monetary policy rule will improve welfare if financial or housing demand shocks drive the credit and housing boom; and reduce welfare if the source of the housing boom is a productivity shock. However, because their model lacks an explicit bank's problem and just follows the financial accelerator idea of Bernanke, Gertler and Gilchrist (1998) for the spread of the bank lending rate over deposit rate, the characterizations of macroprudential instruments used in their paper is oversimplified and glosses over important questions about how exactly such instruments would be implemented and how effective they could be in the actual financial system.³

Gelain, Lansing and Mendicino (2013) show that the introduction of hybrid forecast rules for a subset of households can significantly increase the volatility of house prices and household debts relative to the model with fully rational expectations.⁴ This is an alternative approach to generating relatively large swings in house prices

³Kannan et al. (2012) adopt the idea that the supply of credit is an upward-sloping curve with respect to lending interest rates. Formally, the spread between loan and deposit rates is an implicit function of the amount of new credit in a given period.

⁴Gelain, Lansing and Mendicino (2013) assume that a fraction of households follows a fully rational forecast rule, and the remainder follow a moving average forecast rule (sticky information). The hybrid expectation is a weighted average of the two forecasts.

in DSGE models with housing. Moreover, they find that under hybrid expectations the use of a modified collateral constraint that takes the borrower's wage income into considerations is the most effective tool in mitigating the volatility of house prices and household debts in the model economy fueled by excess run-ups in these variables. An interest rate reaction to house price growth or credit growth can stabilize some macroeconomic variables, while simultaneously magnifying the volatility of others such as house prices and inflation. Their policy interventions, however, primarily rely on a tightening of lending standards through collateral constraints for households rather than other channels such as financial constraints for banks.

In contrast to this previous literature, I develop a DSGE model with housing and banking that explicitly includes both collateral and financial constraints to study the roles of several macroprudential policies that might work to mitigate the volatility of house prices and household debts. In particular, I pay more attentions to policy instruments that tighten lending standards through the channel of financial constraints. Further, in this study I also take into account the fiscal instruments that might help to stabilize housing and financial variables in the model economy. As Iacoviello (2010b) conjectures, tax credits turn out to be a good candidate for restraining the volatility of housing demand and house prices over the business cycle.

Iacoviello (2005) finds that monetary policy shocks affect house prices more than consumer prices, implying that monetary authorities may use interest rate policies as a tool to tackle large fluctuations in house prices. Because my model does not have a nominal side, the implications of monetary policy cannot be addressed at this moment. However, recent research has highlighted that interest rate policies are not that effective in stabilizing house prices. According to Gelain, Lansing and

Mendicino (2013), interest rate policies have no significant stabilization benefits by responding to the growth of house prices in a rational expectation model. Under hybrid expectations, responding to the growth of house prices magnifies the volatility of all variables except for household debts. Moreover, while responding to credit growth by using interest rate policies has significant stabilization effects on household debts, this policy magnifies the volatility of output and cannot stabilize house prices with rational expectations model. Under hybrid expectations, responding to credit growth magnifies the volatility of all variables including house prices and household debts.

In this chapter, I mainly focus on the macroprudential policies mentioned above and analyze how these policies work to mitigate the volatility of house prices and household debts, using the model developed in Chapter 2 and 3. One may view these policy instruments as “macroprudential”, since they are generally used to tackle issues of credit-fueled financial imbalances and unsustainable appreciation of house prices in a booming economy. Because financial imbalances and housing instability may exist in a low inflation environment (for example, the financial crisis of Japan in the late 1990s), as noted by Borio and Lowe (2002), the authorities can possibly ignore their inflation target for a while in order to moderate the risks of financial distress. In this regard, I do not consider the effects of standard monetary policy instruments. Rather, I study the effects of these macroprudential policy instruments on the macroeconomy in a parsimonious way. One may extend my model to include inflation in order to capture precisely the role of these policy instruments in the model environment. I conjecture that macroprudential policies used in this literature would not significantly magnify the volatility of inflation in goods and services since they are

specifically designed to lean against large fluctuations in house prices and household debts.

In this study, I follow the baseline model used in Chapter 2 and introduce technology shocks in the final goods sector and housing preference shocks only since this study focuses on the roles of macroprudential policies in containing the housing market instability and financial imbalances in a booming economy.⁵ Technology shock processes are those from the Bayesian estimation in Chapter 3. All else remains the same.⁶

The chapter is organized as follows. Section 4.2 describes the shock processes that will generate run-ups in house prices and household debts. Section 4.3 gives a detailed discussion on macroprudential policy instruments used in my policy experiments, and the implications of them. Other issues and future works are presented in Section 4.4. Section 4.5 concludes. The summary of the dynamic system of the model and all impulse response functions are presented in Appendix E and Appendix F, respectively.

4.2 Shock Processes

In this study, I assume that the causes of fluctuations in the business cycle are productivity shocks in the final goods sector and housing preference shocks. With these shocks, the model can generate a rapid increase in house price and credit growth that

⁵Formally, the baseline model used in this chapter is a variant of Iacoviello (2005) and Iacoviello and Neri (2010) with financial intermediaries that are abstracted from Gerler and Kiyotaki (2010). Positive technology shocks and housing demand shocks are treated as a trigger to generate a booming economy exhibiting rapid appreciation of house prices and credit expansion. Housing technology shocks, however, are not used as one of the driving forces in this chapter since it will generate a decline in house prices and household debts, which contradicts the movement patterns of these variables in the pre-crisis period.

⁶When the baseline model used in this study is identical to that in Chapter 2, parameters calibrated remain unchanged.

mimics the movement patterns of these variables in the pre-crisis period. The shocks follow the AR(1) process and evolve in a log-linear fashion,

$$\ln A_{ct} = \rho_c \ln A_{ct-1} + u_{ct} \quad (4.1)$$

$$\ln j_t = (1 - \rho_j) \ln j + \rho_j \ln j_{t-1} + u_{jt}, \quad (4.2)$$

where u_{ct} and u_{jt} are independently and identically distributed processes with variances σ_c and σ_j . The term A_{ct} denotes productivity shocks in the final goods sector as in previous chapters, and j_t denotes housing preference shocks in the household sectors, following Iacoviello and Neri (2010). Note that the housing preference weight in the households' utility functions is now a time-varying variable, j_t , rather than a constant value, j . However, $j_t = j$ in steady state. This ensures that all parameters calibrated remain the same as those in previous chapters. I choose $\rho_c = 0.9948$ and $\sigma_c = 0.0077$, as those estimated by a Bayesian approach in Chapter 3. Following Iacoviello and Neri (2010), I choose $\rho_j = 0.96$ and $\sigma_j = 0.0416$.⁷

4.3 Macroprudential Policy Experiment

In this section, I evaluate various policy instruments that might work to mitigate the volatility of house prices, household debts and output in the model with market imperfections in housing and banking. These policies are designed to lean against asset price (house price) instability and credit-fueled financial imbalances in the context of an economic boom driven by positive productivity shocks in the final goods

⁷In this chapter, I do not explicitly estimate the housing preference shock process and borrow it from Iacoviello and Neri (2010), since the choice of the housing demand shock parameters will not distort the implications of policies being considered in the policy experiments.

sector and housing preference shocks. I first examine the implications of three types of countercyclical policy instruments (e.g. countercyclical loan-to-value (LTV) ratios, countercyclical bank reserve ratios and countercyclical bank capital/leverage ratios) that are frequently used by prudential authorities to address systemic risks of financial instability and housing market instability. Then I investigate the implications of an unconventional macroprudential tax instrument that affects households' spending and lending behaviors in response to the shocks. Note that this experiment only considers the volatility implications rather than social welfare implications.⁸ Generally speaking, the objective of the prudential authorities could be financial stability or housing market stability. However, there is no consensus in the literature as of how this objective should be introduced in a macroeconomic model, as Kannan et al. (2012) argued. Since most recent financial crises are associated with large swings in output, household debts and house prices, I specifically pay more attentions to the volatility effects on these key variables. All policies being considered here may not increase the expected welfare of households.⁹

⁸Strictly speaking, the main goal of this chapter is to investigate the positive implications of macroprudential policies, but not the normative ones. The design of the optimal policy rule is beyond the scope of this study.

⁹Though some policy options being considered may reduce the social welfare, one may treat those social losses as the costs of interventions. As the Great Recession reveals, in the absence of any interventions in the pre-crisis period, the social welfare losses are enormous when the crisis materializes. For this reason, it is sensible for the prudential authorities to maintain financial stability and housing market stability in longer horizons in order to prevent the economy from a worse scenario like the Great Recession.

4.3.1 Lending Standards (Countercyclical Loan-to-value (LTV) Ratios)

What I mean by tightening lending standards is meant to broadly characterize the higher downpayments that banks require for mortgages issued to households. In general, banks decrease the maximum LTV ratio from a specific level in order to prevent themselves from risks of default. In this experiment, I use a time-varying policy instrument rather than a constant one. In particular, the prudential authorities change the maximum LTV ratio to changes in the level of household debts and house prices relative to their steady-state values. I assume that the maximum LTV ratio varies over time according to the following rule:

$$m_t = \bar{m} \left(\frac{B_t}{\bar{B}} \right)^{\alpha_b} \left(\frac{q_t}{\bar{q}} \right)^{\alpha_q}, \quad (4.3)$$

where m_t is a time-varying maximum LTV ratio, which depends on the level of household debts and house prices relative to their steady-state values. The terms with upper bar in equation (4.3) are steady-state values of the variables. In steady state, I set $\bar{m} = 0.85$ as in the baseline model. $\frac{B_t}{\bar{B}}$ and $\frac{q_t}{\bar{q}}$ are deviations of household debts and house prices from their steady-state values, respectively, and are regarded as the indicators of financial distresses. The terms α_b and α_q are parameters that govern the strength of the response of the prudential authorities to the fluctuations in indicators. Following Christensen and Meh (2011), I set $\alpha_b = -0.5$.¹⁰ For example, a one percent deviation of household debts from its steady-state level will decrease the maximum

¹⁰In contrast to the functional form of the policy rule as in 4.3, the policy rule used by Christensen and Meh (2011) includes credit gaps only, implying that the prudential authorities only care about financial stability rather than housing market stability.

Table 4.1: Macroprudential Policy Experiment: Counter-cyclical Loan-to-value Ratios

Aggregates	GDP	C	IK	IH	q	pS	B	D	N
Baseline	3.09	2.85	5.76	2.41	4.28	2.77	3.97	2.99	3.18
Policy	2.99	2.79	5.80	2.25	3.83	2.74	1.50	2.46	2.44
Volatility Ratio	0.97	0.98	1.01	0.93	0.90	0.99	0.38	0.82	0.77
Individuals	h_p	h_i	c_p	c_i					
Baseline	0.84	1.64	2.68	3.08					
Policy	0.94	2.03	2.50	3.32					
Volatility Ratio	1.12	1.24	0.94	1.08					

Note: Standard deviations are expressed as percent deviations from steady state. Standard deviations are averages over 500 simulations and for each of simulated time series, the length of the main variables equals to 155 periods, that of my data sample. The business cycle component of each simulated series is obtained by using HP filter with smoothing parameter equal to 1,600. All values in the table are rounded to 2 decimal places. Volatility Ratio = Standard Deviations (Policy)/Standard Deviations (Baseline).

LTV ratio by 0.5 percent. I also choose $\alpha_q = -0.5$, reflecting that the prudential authorities place equal weight on financial stability and housing market stability.

This experiment is intended to capture the effects of higher downpayments on financial stability and housing market stability, in terms of the volatility of house prices and household debts. Since in my model technology shocks in the final goods sector and housing preference shocks virtually increase household debt and house price growth, the maximum loan-to-value ratio declines over time. In this way, the use of countercyclical loan-to-value ratio can capture the implications of higher downpayment requirements. Table 4.1 shows results for a countercyclical policy that tightens lending standards by decreasing the maximum LTV ratio in equation (4.3) from a constant level ($m = 0.85$).

The countercyclical LTV policy leads to a decline in the volatility of household debts and house prices without causing excessive volatility in other macroeconomic

variables. This outcome implies that a countercyclical LTV policy can help to stabilize the financial and housing markets, and can be regarded as an effective tool in addressing instability issues in these markets. Interestingly, this result is contrary to that found by Gelain, Lansing and Mendicino (2013). In their paper, they find that a permanently tightening of the LTV ratio (a constant LTV policy) reduces the volatility of household debts but magnifies the volatility of house prices in their model without banking under fully rational expectations. This difference might be attributed to the fact that a constant LTV policy does not specifically target household debt and house price gaps in the policy rule. As a result, a constant LTV policy may not work well in a way that offsets the deviations of house prices from its steady-state level in some periods. In general, higher downpayments will impair the ability of impatient households to borrow funds from banks through their collateral constraint channel. Given the same quantity of housing as collateral, they can now borrow less from banks, and therefore, will be less likely to accumulate housing, and more likely to consume. In this way, their presence mitigates the volatility of house prices, housing investment and household debts, and magnifies the volatility of consumption as shown in Table 4.1. In contrast, patient households respond differently in this case. They are more likely to accumulate houses and less likely to consume due to the nature of “patientness”.¹¹ In this way, their presence mitigates the volatility of consumption but magnifies the volatility of housing investment. Due to the offsetting mechanism, a countercyclical LTV policy eventually reduces the volatility of housing investment and house prices. The volatility effects on aggregate consumption are relatively small

¹¹One way to motivate this logic is that patient households are beneficial from a decline in house prices induced by the diminishing demand of impatient households for houses. Since patient households are net savers, they are willing to buy more houses at a lower house price today, and enjoy more housing service tomorrow.

in this case. Note that the volatility of individual housing stocks rises due to the fact that a countercyclical LTV policy reduces the housing stocks at a relatively large magnitude in response to the technology shock in the final goods sector (see the Housing Stock panel in Figure F.1). One may find later that all countercyclical policy options being considered in this chapter can generate a high volatility of individual housing stocks.

It is worth discussing here whether a countercyclical LTV policy that reacts to household debt and house price growth can be beneficial from the perspective of policymakers. When central banks go beyond their traditional emphasis on inflation targeting by taking financial stability and housing market stability into considerations, whether the use of this type of macroprudential policies is beneficial depends on the volatility effects on some key variables, such as GDP, house prices and household debts. In my case, a countercyclical LTV policy reduces the volatility of all key aggregate variables, it can be regarded as an effective tool in maintaining financial stability and housing market stability.

4.3.2 Bank Reserve Requirements (Countercyclical Bank Reserve Ratios)

A tightening of bank reserve requirements is a market intervention employed by the central banks, that raises the minimum fraction of deposits and notes that each commercial bank must hold as reserves. These required reserves are normally in the form of cash stored physically in a bank vault or deposits made with a central bank. Typically, a tightening of bank reserve requirements is used to influence the amount of borrowing and interest rates by reducing the amount of funds available for banks

to lend. In general, central banks in OECD countries rarely alter their bank reserve requirements since doing so may induce immediate liquidity problems for banks with low excess reserves.¹² However, other central banks such as the People's Bank of China have frequently used a tightening of bank reserve requirements as a tool to lean against credit-fueled financial imbalances and housing market instability. For instance, the People's Bank of China raised the bank reserve ratio ten times in 2007 and eleven times since the beginning of 2010 in order to maintain macroeconomic stability. The reserve ratio was up to 20.50% for major Chinese banks, and a lower rate of 18.50% for small and medium-size banks in February 2012.

A distinguishing feature of tightening bank reserve requirements is that central banks can effectively raise the costs of financing by reducing the amount of funds available for banks to lend. Under some circumstances where the economy is experiencing a rapid credit expansion together with booming house prices, a tightening of bank reserve requirements can serve as a barrier to feeding excessive credit flows to the economy, promoting a financial stability or housing market stability. Of course, whether this type of macroprudential policy can mitigate the volatility of house prices depends on the offsetting mechanism between patient (net savers) and impatient households (net borrowers). With a tightening of bank reserve requirements, banks tend to reduce the amount of mortgages issued to their borrowers. In this case, impatient households are less likely to consume and accumulate houses due to a tightening of their budget constraints induced by the policy. Therefore, their presence dampens the aggregate volatility of housing investment, house prices and consumption. On the other hand, patient households are more likely to consume and

¹²Countries who do not have bank reserve requirements are Canada, the UK, New Zealand, Australia and Sweden. This does not mean that banks in these countries can create money without limit. Banks in these countries are constrained by the capital requirements.

accumulate houses since a countercyclical bank reserve policy fundamentally raises the returns to deposits, causing an increase in the volatility of housing investment, house prices and consumption. Due to the offsetting mechanism, a countercyclical bank reserve policy may mitigate the volatility of housing investment, house prices and consumption.

In this section, I conduct a policy experiment to illustrate whether a countercyclical policy tightening bank reserve requirements can work to stabilize the financial system and housing market in the model with housing and banking. To do so, I assume that banks are now allowed to convert deposits to loans up to a limit equal to $\omega_t \in (0, 1]$, and are required to store the remaining fraction of deposits, $1 - \omega_t$, into a bank vault when they accept deposits from their savers.¹³ Similar to the countercyclical LTV ratio, the fraction of deposits that can be converted to loans (call “convertible deposits” in the rest of the chapter) varies over time according to the following rule:

$$\omega_t = \bar{\omega} \left(\frac{B_t}{B} \right)^{\alpha_b} \left(\frac{q_t}{\bar{q}} \right)^{\alpha_q}, \tag{4.4}$$

where $\bar{\omega}$ is the steady-state fraction of convertible deposits, which is equal to 1 as in the baseline model. All else in the policy rule function above remains the same as before.

¹³In the United States, reserve ratios vary by the dollar amount of net transaction accounts held at the depository institution. According to the regulations set by the Board of Governors of the Federal Reserve System, effective on December 29, 2011, depository institutions with net transactions accounts of less than \$12.4 million have no minimum reserve requirement; depository institutions with net transactions accounts between \$12.4 million and \$79.5 million must have a reserve ratio of 3%; depository institutions with net transactions accounts over \$79.5 million must have a reserve ratio of 10%. For simplicity, in this experiment I assume that there is no bank reserve requirements in the baseline model. That is, $\omega_t = 1$ for all t .

The flow-of-funds constraint for an individual bank is given by,

$$p_t s_t + b_t = n_t + \omega_t d_t. \quad (4.5)$$

Equation (4.5) states that a bank's total assets are equal to the sum of net worth and convertible deposits.

As in equation (2.16) of Chapter 2, the value of banks, V_t , is a time-varying linear function of (s_t, b_t, d_t) given by

$$V_t(s_t, b_t, d_t) = \nu_{st}s_t + \nu_{bt}b_t - \nu_{dt}d_t.$$

The Bellman equation (2.15) and the incentive constraint (2.13) in this experiment remain the same as before. Given the conjectured value function (2.16) and new flow-of-funds constraint (4.5), one can easily solve the bank's problem. The optimality conditions for the bank's problem are given by

$$\frac{\nu_{st}}{p_t} = \nu_{bt} \quad (4.6)$$

$$(1 + \lambda_t^b)(\nu_{bt} - \frac{\nu_{dt}}{\omega_t}) = \theta \lambda_t^b \quad (4.7)$$

$$(\theta - (\nu_{bt} - \frac{\nu_{dt}}{\omega_t}))b_t + (\theta - (\frac{\nu_{st}}{p_t} - \frac{\nu_{dt}}{\omega_t}))p_t s_t \leq \nu_{dt}n_t. \quad (4.8)$$

One can see that equation (4.6) remains the same as equation (2.17), implying that the arbitrage condition across assets still holds in this case. Equations (4.7) and (4.8) now change slightly, relative to equations (2.18) and (2.19). Equation (4.7) states that the marginal value of consumer loans exceeds the marginal cost of deposits over a markup, ω_t , if the incentive constraint is binding. Note that the markup here

measures changes in the amount of deposits available for a bank to issue loans to its borrowers. Similar to the case without policies, equation (4.8) states that the value of the bank's net worth must be at least as large as a weighted average value of bank assets.

Because all banks are homogenous in the model, from now on, I replace all lower-case letters with upper-case ones to represent aggregate financial variables. Let μ'_t be the excess value of a unit of assets relative to deposits in the case where banks face reserve requirements under the central bank regulations. Given a binding incentive constraint, equations (4.6) and (4.7) imply that

$$\mu'_t = \frac{\nu_{st}}{p_t} - \frac{\nu_{dt}}{\omega_t} > 0. \tag{4.9}$$

It then follows that the incentive constraint (4.8) in this case can be written as,

$$p_t S_t + B_t = \phi_t N_t \tag{4.10}$$

with

$$\phi_t = \frac{\nu_{dt}}{\theta - \mu'_t}, \tag{4.11}$$

which are same as that in the baseline model.

Let Ω'_t be the marginal value of net worth in the case with bank reserve requirements. Given the Bellman equation and conjectured value function, one can verify

that the value function is linear in (S_t, B_t, D_t) if the following conditions are satisfied:

$$\nu_{bt} = E_t \Lambda_{t,t+1} \Omega'_{t+1} R_{t+1}^b \quad (4.12)$$

$$\nu_{dt} = E_t \Lambda_{t,t+1} \Omega'_{t+1} R_{t+1}^d \quad (4.13)$$

$$\nu_{st} = E_t \Lambda_{t,t+1} \Omega'_{t+1} (Z_{t+1} + (1 - \delta_k) p_{t+1}), \quad (4.14)$$

with

$$\Omega'_{t+1} = 1 - \sigma + \frac{\sigma}{\omega_{t+1}} (\nu_{dt+1} + \phi_{t+1} \mu'_{t+1}) \quad (4.15)$$

$$\mu'_t = E_t \Lambda_{t,t+1} \Omega'_{t+1} (R_{t+1}^k - \frac{R_{t+1}^d}{\omega_t}). \quad (4.16)$$

$$R_{t+1}^k = \frac{Z_{t+1} + (1 - \delta_k) p_{t+1}}{p_t}. \quad (4.17)$$

One can see that in the model with bank reserve requirements, all else remains unchanged except for the excess values of assets over deposits, μ'_t , and the marginal value of net worth, Ω'_{t+1} , relative to the baseline model.

Given equations (4.6) and (4.9), I get a relationship between assets and liabilities in terms of their returns in the case where the incentive constraints are binding, which is given as follows,

$$R_{t+1}^k = R_{t+1}^b > \frac{R_{t+1}^d}{\omega_t} \geq R_{t+1}^d \quad \forall \omega \in (0, 1], \quad (4.18)$$

with \geq holds with equality if and only if $\omega_t = 1$ and holds with strict inequality otherwise. In the model with policy interventions, the spread rises as a product of the decline in loans relative to deposits, causing an increase in the costs of loans to

Table 4.2: Macroprudential Policy Experiment: Counter-cyclical Bank Reserve Requirements

Aggregates	GDP	C	IK	IH	q	pS	B	D	N
Baseline	3.09	2.85	5.76	2.41	4.28	2.77	3.97	2.99	3.18
Policy	2.08	2.65	7.29	2.28	3.85	2.61	3.39	1.22	5.84
Volatility Ratio	0.67	0.93	1.27	0.95	0.90	0.94	0.85	0.41	1.84
Individuals	h_p	h_i	c_p	c_i					
Baseline	0.84	1.64	2.68	3.08					
Policy	2.57	6.98	3.08	2.47					
Volatility Ratio	3.06	4.26	1.15	0.80					

Note: Standard deviations are expressed as percent deviations from steady state. Standard deviations are averages over 500 simulations and for each of simulated time series, the length of the main variables equals to 155 periods, that of my data sample. The business cycle component of each simulated series is obtained by using HP filter with smoothing parameter equal to 1,600. All values in the table are rounded to 2 decimal places. Volatility Ratio = Standard Deviations (Policy)/Standard Deviations (Baseline).

borrowers. Subsequently, borrowers are less likely to borrow from the banks. In this way, credit expansion may slow down, alleviating credit-fueled financial imbalances in the economy.

In the rest of this section, I investigate whether a countercyclical policy of bank reserve requirements can stabilize the financial market and the housing market by observing impacts of the policy on the volatility of household debts and house prices. Table 4.2 presents the results for the volatility effects of the policy. The second row and third row show the volatility for the variables of interest in the model with and without bank reserve requirements, respectively. The fourth row shows the volatility ratios between two models.

From Table 4.2, my results suggest that a countercyclical bank reserve policy can significantly reduce the volatility of household debts and house prices, but magnifies the volatility of business investment and bank net worth. The volatility effects on

other variables are relatively large. Intuitively, the willingness of banks to issue loans is positively associated with the excess value of assets over liability (spread). The larger is the spread, the more likely is the bank to issue loans. Because a countercyclical bank reserve policy fundamentally increases the spread, banks tend to issue more loans to their borrowers, and their presence may magnify the volatility of net worth. But, on the other hand, a rise in the spread in general increases the costs of financing, and sequentially, undermines the demand for loans, causing a decline in the volatility of loans. Moreover, changes in the volatility of consumption, housing investment and house prices depend on the movement of demand between the two types of households. By observing a rise in the costs of loans, impatient households are less likely to consume and accumulate houses. In this regard, the volatility of consumption, housing investment and house prices decreases. In contrast, patient households respond differently in this case. They are more likely to consume and accumulate houses, thanks to the relaxation of their budget constraints.¹⁴ Therefore, their presence increases the volatility of consumption, housing investment and house prices. Due to an offsetting mechanism, a countercyclical bank reserve policy eventually decreases the volatility of consumption, housing investment and house prices. The reason that the volatility of business investment rises is due to the fact that a countercyclical bank reserve policy reduces business investment at a relatively large magnitude in my case (see Nonresidential Investment panel in Figure F.4).

A key question now is what we might learn from this experiment. Typically, a countercyclical bank reserve policy works well in mitigating the volatility of household debts and house prices without causing a large excess volatility in output, reflecting

¹⁴Within the model, a countercyclical bank reserve policy can raise the returns to deposits, and consequently, relaxes their budget constraints since they are net savers in the economy

stability benefits from using this type of macroprudential policies by the prudential authorities. For this reason, it can serve as an effective tool to lean against credit-fueled financial imbalances and housing market instability in practice. Of course, this type of macroprudential policies has its own weakness since it fails to stabilize the volatility in business investment and net worth. To the extent that an economy is undermined by excess fluctuations in investment, a countercyclical bank reserve policy may not be a good candidate for stabilizing the macroeconomy alone. But, this does not imply that this type of macroprudential policies should be abandoned. Rather, it might be used as a complementary tool to other policy instruments to address some instability issues in the real economy since both housing and banking play an important role in the business cycle.

4.3.3 Bank Capital Requirements (Countercyclical Leverage Ratios)

Though banks in some countries like Canada, the UK, New Zealand, Australia and Sweden do not have reserve requirements, they are constrained by capital requirements. In these countries, capital requirements are deemed to be more important than reserve requirements. Even in countries with reserve requirements like the United States, capital requirements are widely used by the central bank as a tool to avoid financial imbalances, since reserve requirements do not limit leverage. In general, capital requirement refers to the amount of capital banks have to hold as required by their financial authorities. This is usually expressed as a capital adequacy ratio of equity that must be held as a percentage of risk-weighted assets.¹⁵ The primary

¹⁵The capital ratio is often confused with the leverage ratio. They are in fact opposite. For instance, in my model $Capital\ Ratio = Net\ Worth/Assets$; and $Leverage\ Ratio = Assets/Net\ Worth$.

roles of capital requirements are to prohibit excess leverage of banks and to maintain a financial balance on the bank's balance sheets.

The Great Recession of 2007-2009 has shown that the severity of the crisis is associated with bank leverage. With highly leveraged banks, the impact of a decline in house prices on the banks' balance sheets is magnified by the leverage ratio, setting off a chain of events that leads to a financial crisis. Within my framework, the effect of an exogenous financial shock is magnified in two ways, as discussed in the financial crisis experiment conducted in Chapter 2. First, since banks are highly leveraged, the effect of a decline in asset values on bank net worth is enhanced by a factor equal to the bank leverage ratio. Second, the decline in net worth in turn further reduces asset values due to the fire sale of assets induced by the tightening of banks' borrowing constraints. In this way, financial distress may arise, causing a credit crunch in the real economy. In the aftermath of the Great Recession, it would be sensible to recognize that the risk of excess leverage must be dealt with beforehand by prudential authorities in order to moderate the severity of the financial crisis when it actually materializes. To avoid a scenario like the Great Recession, the bank leverage ratio should be tightened during periods when both collateral constraints and financial constraints are slack. According to Guerrieri and Iacoviello (2013), policy instruments aimed at either the housing market or the financial market can produce enormous spillovers to aggregate variables such as consumption, investment and financial factors in periods when collateral constraints and financial constraints are tight, either because of large declines in house prices or because credit supply standards have been made more stringent. These spillovers tend to be larger than those in periods when both collateral constraints and financial constraints are slack

in the context of booming housing prices. In another words, policy instruments undertaken by the authorities to restrain the boom are unlikely to dampen the health of the economy significantly in goods times. In this section, I use my model to analyze the role of a tightening of the bank leverage ratio induced by a countercyclical leverage policy in an experiment that mimics the economic boom in the pre-crisis period. In particular, I will concentrate on the effect of this type of macroprudential policies on the volatility of house prices and household debts, reflecting a concern for the stability of the housing market and the financial system.

Suppose that the maximum regulatory leverage on banks, ϕ_t^r , is lower than the privately determined ratio, ϕ_t , that is,

$$\phi_t^r < \phi_t.$$

In practice, banks operates under capital requirements imposed by the monetary authorities. In reaction to the requirements, they can always set up a special purpose vehicle (SPV) that is not subject to regulatory requirements on leverage. Typically, the SPV can be treated as an investment bank. With the SPV, banks can operate off the balance sheet and hold securitized assets. For simplicity, I rule out the scenario that banks can set up a special purpose vehicle (SPV) in this economy since the addition of the SPV and securitized assets do not alter the predictions of the model about feedbacks between financial and real sectors. According to Gertler and Kiyotaki (2010), the macroeconomic equilibrium remains unchanged when the SPV and securitized assets are introduced into the model. This can be attributed to the assumption that the bank and the SPV have a single ownership. With a single ownership, the universal bank can always find a division of assets and net worth of the bank

and the SPV which satisfies both the regulatory requirements on the bank and the privately determined leverage constraint for the universal bank.¹⁶ Of course, when the assumption of single ownership is relaxed, the bank and the SPV will not have a completely arms length relationship, and in this case, the addition of SPV and securitized assets may have excess effects on the equilibrium. Since exploring the role of the SPV and securitized assets in the economy is beyond the scope of my analysis at this moment, I leave it for future research.¹⁷ In this regard, the banks in my model are best thought of as commercial banks rather than investment banks.

Returning to my model, the bank now should satisfy the following leverage constraint,

$$p_t S_t + B_t \leq \phi_t^r N_t \tag{4.19}$$

with

$$\phi_t^r = \gamma_t \phi_t = \frac{\gamma_t \nu dt}{\theta - \mu_t} \quad \forall \gamma_t \in [0, 1], \tag{4.20}$$

where the term γ_t governs the degree of tightening the maximum bank leverage ratio under financial regulations. The lower is the value of γ_t , the more stringent are the regulatory leverage requirements imposed by the authorities.

Similar to the countercyclical policy experiments above, I assume that γ_t varies over time, and are specifically designed to react to household debt and house price growth. The policy rule is given by,

$$\gamma_t = \bar{\gamma} \left(\frac{B_t}{B}\right)^{\alpha_b} \left(\frac{q_t}{q}\right)^{\alpha_q}, \tag{4.21}$$

¹⁶A detailed discussion on this topic is given by Gertler and Kiyotaki (2010)

¹⁷See Shleifer and Vishny (2009) for the analysis on the role of securitized lending in the crisis.

Table 4.3: Macroprudential Policy Experiment: Counter-cyclical Bank Leverage Requirements

Aggregates	GDP	C	IK	IH	q	pS	B	D	N
Baseline	3.09	2.85	5.76	2.41	4.28	2.77	3.97	2.99	3.18
Policy	2.92	2.78	5.24	2.40	4.14	2.45	2.66	1.89	4.49
Volatility Ratio	0.94	0.98	0.91	1.00	0.97	0.88	0.67	0.63	1.41
Individuals	h_p	h_i	c_p	c_i					
Baseline	0.84	1.64	2.68	3.08					
Policy	1.19	2.72	2.67	3.01					
Volatility Ratio	1.41	1.66	1.00	0.98					

Note: Standard deviations are expressed as percent deviations from steady state. Standard deviations are averages over 500 simulations and for each of simulated time series, the length of the main variables equals to 155 periods, that of my data sample. The business cycle component of each simulated series is obtained by using HP filter with smoothing parameter equal to 1,600. All values in the table are rounded to 2 decimal places. Volatility Ratio = Standard Deviations (Policy)/Standard Deviations (Baseline).

where $\bar{\gamma}$ denotes the steady-state degree of tightening the bank leverage ratio, which is set to 1 as in the baseline model. Note that this policy rule is a bit different from the traditional approach used by the authorities to implement a tightening of leverage requirements since the maximum regulatory ratio in this experiment varies over time. In practice, the prudential authorities always set the maximum regulatory ratio to a fixed value for a finite horizon. Because the use of a time-varying regulatory ratio does not change the nature of tightening bank leverage requirements, it will not significantly distort the implications of this type of macroprudential policies. Further, a time-varying regulatory ratio is more effective than the fixed one since it allows the leverage ratio to be tightened over time in response to the shocks.¹⁸

Table 4.3 shows the results for a countercyclical policy that tightens the bank

¹⁸Supposed that, for instance, a fixed regulatory leverage ratio is greater than the privately determined ratio in some periods, the effects of tightening leverage requirements on macroeconomic variables in these periods are neutral. To avoid such a scenario, the use of a time-varying regulatory ratio is more relevant.

leverage requirements by reducing the term γ_t in equation (4.20) from its steady-state level over time. A countercyclical leverage policy reduces the volatility of house prices and household debts, but magnifies the volatility of bank net worth, implying that this type of macroprudential policies is able to contain financial imbalances and housing market instability in practice. More importantly, countercyclical leverage policy instruments are superior than countercyclical bank reserve policy instruments, since the former works well in mitigating the volatility of business investment. Therefore, a countercyclical leverage policy can be treated as an effective tool to stabilize the financial and housing markets without causing excessive volatility in other macroeconomic variables. The economic intuitions to this result are similar to that in the countercyclical bank reserve policy experiment.

Here, I restrict my attention to the model without the SPV that I think is absolutely essential to characterizing the implications of a tightening of bank leverage requirements as banks in this economy are treated as a consolidated representation of the financial system. To study the interaction between the commercial banks and the SPV in a case with a tightening of bank leverage requirements, we need to relax the assumption that they have a single ownership, as I discussed above. The model can be extended to capture the linkage between the commercial banks and the SPV as long as we can formulate the problem of the SPV in an appropriate setting. From my point of view, it is sensible to dig more into these issues since in many circumstances as in the real world commercial banks and the SPV do not have a completely arms length relationship.

4.3.4 Macprudential Tax Credits

In the previous sections, I have analyzed three conventional macroprudential policies we have seen frequently in the real world. Though these macroprudential policy instruments differ one to another in their ability to stabilize either the housing market or the financial system, all of them work in a way that directly tightens the borrowing/lending constraints associated with either the household sector or the financial sector. Within my model, any factor that might reduce loans available to borrowers by tightening the borrowing/lending constraints will generate a downward pressure on credit expansion, inducing stability effects on macroeconomic variables. Further, these conventional macroprudential policy instruments discussed above in general are implemented by financial authorities rather than fiscal authorities. In this section, I pay attention to policy instruments typically used by fiscal authorities, and determine whether they can be quantitatively successful in stabilizing the housing market and the financial system.

Within my model, the high volatility of house prices primarily relies on the heterogeneity of households, as discussed in Chapter 2. Patient households are more likely to contribute to increased aggregate volatility of house prices and housing investment by increasing their labor supply in response to the shocks. On the other hand, impatient households are more likely to dampen aggregate volatility by reducing their labor supply in response to the shocks, thanks to the relaxation of their budget constraints induced by the shocks. With this in mind, it is hard not to notice that any policy instrument that can either weaken the positive volatility effects from the patient households' side or reinforce the negative volatility effects from the impatient households' side might be a good candidate for stabilizing the housing market. In

this regard, I consider an asymmetric tax schedule that is in favor of impatient households by imposing an income tax on patient households and a lump sum tax credit to impatient households in the economy. In doing so, it allows the authorities to achieve the goal of stabilizing house prices, and at the same time, to promote a financial stability since a relaxation of impatient households' budget constraints induced by tax credits discourages impatient households from borrowing. Because this tax schedule is designed to prevent excess credit expansion and house price appreciation and embeds the nature of "macroprudential" regulation, it is so called "macroprudential" tax credits (e.g. the Worker, Homeownership, and Business Assistance Act of 2009). One remaining question now is whether "macroprudential" tax credits can stabilize both the housing market and the financial system without causing excess volatility in other macroeconomic variables. Throughout this experiment, I will provide a better understanding of the implications of this type of macroprudential policy in terms of its volatility effects on macroeconomic variables of interest.

To begin with, I assume that patient households now face an income tax at a rate of τ . For simplicity, the income tax rate sets to a fixed value equal to 0.3. In each period, the fiscal authorities transfer all tax revenues as a lump-sum tax credit to impatient households. There are no other types of taxes and government spending in this economy. In this way, the tax schedule used in this economy tends to be redistributive in nature. Leaving all else unchanged, a representative patient household solves the problem as follows,

$$U_p = E_0 \sum_{t=0}^{\infty} \beta_p^t \left\{ \ln c_{p,t} + j \ln h_{p,t} - \frac{1}{1 + \eta_p} \left((l_{pc,t})^{1+\epsilon_p} + (l_{ph,t})^{1+\epsilon_p} \right)^{\frac{1+\eta_p}{1+\epsilon_p}} \right\},$$

subject to the patient household's budget constraint,

$$c_{p,t} + q_t h_{p,t} + p_{x,t} x_t + d_t = (1 - \tau)(w_{pc,t} l_{pc,t} + w_{ph,t} l_{ph,t}) + q_t(1 - \delta_h) h_{p,t-1} + (p_{x,t} + R_t^x) x_{t-1} + R_t^d d_{t-1} + \Pi_t.$$

The patient household's optimality conditions for consumption/deposits, houses, land, and hours are given by:

$$1 = \beta_p E_t \left(\frac{c_{p,t}}{c_{p,t+1}} R_{t+1}^d \right) \quad (4.22)$$

$$\frac{q_t}{c_{p,t}} = \frac{j}{h_{p,t}} + \beta_p E_t \left(\frac{(1 - \delta_h) q_{t+1}}{c_{p,t+1}} \right) \quad (4.23)$$

$$\frac{p_{x,t}}{c_{p,t}} = \beta_p E_t \left[\frac{p_{x,t+1} + R_{t+1}^x}{c_{p,t+1}} \right] \quad (4.24)$$

$$\frac{(1 - \tau) w_{pc,t}}{c_{p,t}} = (l_{pc,t}^{1+\epsilon_p} + l_{ph,t}^{1+\epsilon_p})^{\frac{\eta_p - \epsilon_p}{1+\epsilon_p}} l_{pc,t}^{\epsilon_p} \quad (4.25)$$

$$\frac{(1 - \tau) w_{ph,t}}{c_{p,t}} = (l_{pc,t}^{1+\epsilon_p} + l_{ph,t}^{1+\epsilon_p})^{\frac{\eta_p - \epsilon_p}{1+\epsilon_p}} l_{ph,t}^{\epsilon_p}, \quad (4.26)$$

which are similar to that in the baseline model except for equations (4.25) and (4.26).

A representative impatient household chooses consumption $c_{i,t}$, housing $h_{i,t}$, hours $l_{ic,t}$ and $l_{ih,t}$, and loans b_t (saving if b_t is negative) to maximize its expected utility,

$$U_i = E_0 \sum_{t=0}^{\infty} \beta_i^t \left\{ \ln c_{i,t} + j \ln h_{i,t} - \frac{1}{1 + \eta_i} \left((l_{ic,t})^{1+\epsilon_i} + (l_{ih,t})^{1+\epsilon_i} \right)^{\frac{1+\eta_i}{1+\epsilon_i}} \right\},$$

subject to the following budget and collateral constraints,

$$\begin{aligned} c_{i,t} + q_t h_{i,t} + R_t^b b_{t-1} &= w_{ic,t} l_{ic,t} + w_{ih,t} l_{ih,t} + q_t(1 - \delta_h) h_{i,t-1} + b_t + \tau(w_{pc,t} l_{pc,t} + w_{ph,t} l_{ph,t}) \\ b_t &\leq m E_t \left(\frac{q_{t+1} h_{i,t}}{R_{t+1}^b} \right). \end{aligned}$$

Table 4.4: Macroprudential Policy Experiment: Macroprudential Tax Credits

Aggregates	GDP	C	IK	IH	q	pS	B	D	N
$\tau = 0$ (baseline)	3.09	2.85	5.76	2.41	4.28	2.77	3.97	2.99	3.18
$\tau = 0.30$ (policy)	2.98	2.76	5.41	2.32	4.17	2.65	3.72	2.91	3.03
Volatility Ratio	0.96	0.97	0.94	0.96	0.97	0.96	0.94	0.97	0.95
Individuals	h_p	h_i	c_p	c_i					
$\tau = 0$ (baseline)	0.84	1.64	2.68	3.08					
$\tau = 0.30$ (policy)	1.17	1.42	2.59	3.09					
Volatility Ratio	1.39	0.87	0.97	1.00					

Note: Standard deviations are expressed as percent deviations from steady state. Standard deviations are averages over 500 simulations and for each of simulated time series, the length of the main variables equals to 155 periods, that of my data sample. The business cycle component of each simulated series is obtained by using HP filter with smoothing parameter equal to 1,600. All values in the table are rounded to 2 decimal places. Volatility Ratio = Standard Deviations (Policy)/Standard Deviations (Baseline).

The impatient household's optimality conditions for consumption, houses, loans, and hours are given as follows,

$$\frac{j}{h_{i,t}} + \beta_i E_t \left(\frac{(1 - \delta_h) q_{t+1}}{c_{i,t+1}} \right) = \frac{q_t}{c_{i,t}} - \lambda_{i,t} m E_t \left(\frac{q_{t+1}}{R_{t+1}^b} \right) \quad (4.27)$$

$$\frac{1}{c_{i,t}} = \beta_i E_t \left(\frac{R_{t+1}^b}{c_{i,t+1}} \right) + \lambda_{i,t} \quad (4.28)$$

$$\frac{w_{ic,t}}{c_{i,t}} = (l_{ic,t}^{1+\epsilon_i} + l_{ih,t}^{1+\epsilon_i})^{\frac{\eta_i - \epsilon_i}{1+\epsilon_i}} l_{ic,t}^{\epsilon_i} \quad (4.29)$$

$$\frac{w_{ih,t}}{c_{i,t}} = (l_{ic,t}^{1+\epsilon_i} + l_{ih,t}^{1+\epsilon_i})^{\frac{\eta_i - \epsilon_i}{1+\epsilon_i}} l_{ih,t}^{\epsilon_i} \quad (4.30)$$

$$b_t = m E_t \left(\frac{q_{t+1} h_{i,t}}{R_{t+1}^b} \right), \quad (4.31)$$

which are similar to that in the baseline model.

Table 4.4 shows the results for the model with and without macroprudential tax credits in terms of the volatility of key variables. Macroprudential tax credits help to reduce the volatility of house prices and household debts without causing excess

volatility of other macroeconomic variables, reflecting the stability benefits from both the housing and financial market by implementing the policy instrument. When the tax credit succeeds in reducing the volatility in house prices and household debts without causing excess volatility in other macroeconomic variables, it can be treated as an effective tool in addressing housing market instability and financial imbalances in practice.

The macroprudential tax credit reduces the volatility of house prices in two ways. First, the income tax depresses the patient households' incentive to work, and their presence dampens aggregate volatility by reducing labor supply in response to positive shocks. Second, because impatient households are net borrowers in the economy, a tax credit will relax their budget burdens, and consequently, they are allowed to smooth their consumption bundles over time with less labor supply. When impatient household become less likely to work, their presence also dampens aggregate volatility in response to the shocks. These two effects reinforce each other, inducing a drop in the volatility of house prices. Further, tax credits are also responsible for a drop in the volatility of household debts. With tax credits, impatient households are now more likely to borrow less from banks, and in this way, the policy reduces the volatility of household debts.

These findings are only meant to be suggestive for the ongoing debate on the design of new macroprudential regulations for preventing financial instability and housing market instability in the context of the current financial crisis. With tax tools, fiscal authorities may coordinate with monetary authorities to achieve the goal of stabilizing the financial market and the housing market. Fiscal policy instruments

like tax credits, at least, can serve as a supplementary tool to the existing conventional macroprudential policy instruments to address some instability issues we have encountered in the real activity. At the same time, I acknowledge that designing and implementing macroprudential policies, like the tax credits I have studied in this section, in practice remains a challenging task. Nevertheless, my findings suggest that tax credits can work well to stabilize house prices and household debts in a booming economy exhibiting rapid appreciation of house prices and credit expansion.

4.4 Other Issues and Future Works

This study uses a real business cycle model with frictional housing and banking sectors to explore the implications of macroprudential policies designed to stabilize housing and financial markets. But it does not consider the nominal side. Therefore, the model cannot capture precisely the impacts of the policy instruments on the macroeconomy since it does not include nominal rigidities. One may extend the model to include the nominal side in order to better account for the implications of the policy instruments.

Interest rate instruments are not regarded as an effective tool in addressing the housing market instability and financial imbalances, as noted by many recent literature related to financial crises. However, it does not mean that digging more into this dimension is not sensible. After all, interest rate instruments are still a primary measure for addressing instability issues in practice from the perspective of monetary authorities. It is still not clear, however, how macroprudential policies can be coordinated with monetary policies in order to effectively reduce the likelihood of financial distress in practice. As I discussed earlier, some conventional macroprudential policies have their own weakness in mitigating both house prices and household debts

without causing excess volatility in other macroeconomic variables. This leaves an open question of whether a combination of measures among existing macroprudential and monetary policy instruments can work better than using a particular measure alone.

As noted by Kannan et al.(2012), the sources of the fluctuations in the housing and financial market are critical in designing monetary and macroprudential policies. In their study, they find that the interest rate instrument designed to depress credit market cycles would induce stabilization benefits when the economy is hit by financial and housing demand shocks on the one hand. On the other hand, the interest rate instrument would reduce welfare when the economy is hit by productivity shocks. In my policy experiments, positive technology shocks in the final goods sector and housing preference shocks work together to generate credit and house price booms that mimic the movement patterns of the financial and housing markets in the pre-crisis period. In the presence of other shocks such as financial and monetary shocks, it is not clear whether the macroprudential policies discussed above would produce the same outcomes as those produced in my policy experiments. At this moment, we are still far from fully understanding the implications of macroprudential policies in addressing financial and housing market instability since the sources of business cycle fluctuations are more complicated than depicted here.

4.5 Conclusion

The experience of the many financial crises occurring in past decades has highlighted that excess credit expansion induced by a rapid house price boom can have a significant impact on the health of the macroeconomy when asset price and credit busts

materialize. The consequences of failing to act early enough can be enormous. In the aftermath of the Great Recession, there is a growing consensus that monetary authorities should extend their policy rule function to include asset price and credit growths, and deal with potential risks of financial imbalances and housing market instability in the periods preceding the crises. In addition, since interest rate policies aimed at house price and credit growth have a limited ability in stabilizing these variables without causing excessive volatility in other macroeconomic variables, any considerations on the use of other macroprudential policy instruments seems sensible.

This chapter uses a DSGE model with housing and banking frictions to evaluate various macroprudential policies that might work to mitigate the volatility of house prices and household debts. My simulation results show that countercyclical loan-to-value ratios, countercyclical bank reserve ratios and countercyclical capital/leverage ratios work well in stabilizing the financial and housing markets, and can be regarded as effective tools in addressing instability issues in these markets. Moreover, an asymmetric tax schedule that favours impatient households can generate stabilization benefits from both the housing and financial market. In particular, it reduces the volatility of both house prices and household debts without causing excess volatility in other macroeconomic variables. In this regard, macroprudential tax credits can be viewed as an effective tool that can successfully contain both financial imbalances and housing market instability.

However, the results from this chapter are only meant to be suggestive since it glosses over important questions about to what extent an optimal policy rule that includes both house prices and household debts can be achieved, and how macroprudential and

monetary policies can be coordinated in order to reduce the likelihood of financial distress in practice. To address these questions, more rigorous analysis and sophisticated DSGE models should be developed for future research. In addition, we should bear in mind that the source of shocks driving changes in house prices and credit growth is also important. In the presence of other shocks, for instance, financial shocks, the implications of the macroprudential policies we have studied in this chapter may be altered. In this regard, the authorities need to correctly identify the source of driving forces in the business cycle in order to avoid policy mistakes when they implement these macroprudential policies. Although there are still many aspects and issues I have omitted in this study, the bottom line of this study is to provide a better understanding of the importance of macroprudential policies in stabilizing the financial and housing market boom-bust cycles in the context of an imminent financial crisis.

Chapter 5

Conclusion

Since most of the previous housing literature does not explicitly consider the relationship between the housing market and the financial market, it fails to capture the key mechanisms by which these markets interact each other in affecting the movements of housing, financial and macroeconomic variables over the business cycle. Moreover, both housing and banking are not tiny elements in the business cycle. A better understanding of the linkage between housing and banking holds the key to a better understanding of macroeconomic swings in general. Thus, an extension of the existing housing models by including banking provide us with a better framework to study the business cycles along many key dimensions.

In this dissertation, I develop a DSGE model which allows for the housing market to interact with the financial system over the business cycle. The model proves to be extremely useful in studying many aspects of interest. First, the model can be used to investigate the phenomenon of the Great Recession. Throughout the experiment that mimics the Great Recession, it is verified that the model with housing and banking is capable of capturing several key features of the Great Recession. Second, the model

might be useful to better account for the business cycle properties observed in the data. As long as both housing and banking are considered in the DSGE framework, it is possible to account for second moments, procyclicality and joint behavior among housing and financial quantities. Third, because the model incorporates frictions in financial and housing markets, it allows us to study the implications of policy instruments specifically designed to tighten collateral or/and financial constraints in order to stabilize housing and financial markets. Last, the model is not limited to studying the issues considered in this dissertation, but can be generalized to study broader issues of interest. For instance, one may use the model to explore either the extent to which default on mortgages or subprime loans affect the behavior of financial and housing markets, or the impacts of the sovereign debt crisis on these markets.

This dissertation specifically focuses on several sets of issues related to the U.S. economy, such as the phenomenon of the Great Recession, the business cycle properties observed in the U.S. data, and the implications of macroprudential policies in stabilizing the housing and financial markets. My results suggest that the model with housing and banking can qualitatively explain several key features of the Great Recession, and more importantly, capture the key mechanism by which a disruption in the bank's balance sheets affects the behavior of the housing market and macroeconomy. Compared to the model used by Gertler and Kiyotaki (2010), the model succeeds in its ability to better account for the phenomenon of the Great Recession since it explicitly includes housing.

Furthermore, the model can quantitatively account for several important properties of the business cycle observed in the data. In particular, it can reproduce

the volatility and procyclicality in consumption, investment and some financial variables, and the joint behavior among the quantities of interest. More importantly, it replicates well the volatility and procyclicality of house prices, unlike most existing DSGE models with housing. I also find that technology shocks are the main driving forces of fluctuations in the housing market and the macroeconomy, and can explain large swings in housing and macroeconomic variables observed in the data. Financial shocks and housing technology shocks are the main driving forces of fluctuations in the financial market, and can explain large swings in financial variables observed in the data.

Lastly, the results from the policy experiments show that countercyclical policy instruments specifically designed to respond to credit and house price growth are quite useful in mitigating the volatility of household debts and house prices, implying that they are effective tools in addressing instability issues in the financial and housing markets. But, the prudential authorities should bear in mind that some countercyclical policy options, such as countercyclical bank reserve ratios and countercyclical capital/leverage ratios, may induce large swings in business investment and bank net worth. For this reason, the prudential authorities should be cautious about the use of these policies in addressing economic instability issues in practice. To the extent that a high volatility of business investment induced by the policies significantly undermines the health of the economy, these policy options may not be appropriate. An asymmetric tax schedule that favours impatient households can reduce the volatility of house prices and household debts without causing excess volatility in other macroeconomic variables. In this regard, macroprudential tax credits can be viewed

as an effective tool that can successfully contain both financial imbalances and housing market instability in a booming economy exhibiting rapid appreciation of house prices and credit expansion.

To conclude, this dissertation provides a framework with rigorous microfoundations to study the importance of the linkage between housing and banking in the business cycle. Aside from a few drawbacks of the model, it works well in accounting for the key phenomenon of the Great Recession, several important business cycle properties observed in the data, and underlying implications of macroprudential policies in stabilizing the housing and financial markets. In writing this dissertation, my hope is that the next generation of DSGE models will devote more attention to the linkage between housing and banking while studying the housing market in the business cycle. After all, housing and banking have always been at the center of the business cycle, and any neglect of the linkage between housing and banking in modeling the housing market may result in misleading implications.

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Appendix A

Data and Sources

Real Aggregate Consumption: Real Personal Consumption Expenditures (seasonal adjusted, billions of chained 2005 dollars, table 1.1.6, line 2). Source: NIPA, Bureau of Economic Analysis (BEA).

Real Nonresidential Investment: Real Private Nonresidential Fixed Investment from 1995:QI to 2011:QIII (seasonally adjusted, billions of chained 2005 dollars, table 1.1.6, line 9). Real Private Nonresidential Fixed Investment from 1973:QI to 1994:QIV is unavailable in BEA and is calculated by Nominal Private Nonresidential Fixed Investment at base year 2005 multiplied by Quantity Indexes for Real Nonresidential Fixed Investment (seasonally adjusted, index numbers:2005=100, table 5.3.3, line 2) and divided by quantity index 100 at base year 2005. Source: NIPA, Bureau of Economic Analysis (BEA).

Real Residential Investment: Real Private Residential Fixed Investment from 1995:QI to 2011:QIII (seasonally adjusted, billions of chained 2005 dollars, table 1.1.6,

line 9). Real Private Residential Fixed Investment from 1973:Q1 to 1994:Q4 is unavailable in BEA and is calculated by Nominal Private Residential Fixed Investment at base year 2005 multiplied by Quantity Indexes for Real Residential Fixed Investment (seasonally adjusted, index numbers:2005=100, table 5.3.3, line 17) and divided by quantity index 100 at base year 2005. Source: NIPA, Bureau of Economic Analysis (BEA).

Real Gross Domestic Product: Sum of Real Personal Consumption Expenditures, Real Private Nonresidential Fixed Investment and Real Private Residential Fixed Investment (seasonally adjusted, billions of chained 2005 dollars, table 1.1.6). Source: NIPA, Bureau of Economic Analysis (BEA).

Real House Prices: Freddie Mac House Price Index (FMHPI). The FMHPI only accounts for houses with mortgages within the conforming amount limits, and does not account for jumbo mortgages. The FMHPI series is only available from 1975. To ensure compatibility across all time series used in this paper, I extrapolate the FMHPI series backwards for the period 1973-1974 using the growth rate of the U.S. Census Bureau House Price Index during the same period. The series is deflated by Implicit Price Deflator for the Nonfarm Business Sector (seasonally adjusted, index: 2005=100, BLS). Source: Freddie Mac and Bureau of Labor Statistics (BLS); and S&P/Case-Shiller Home Price Index (seasonally adjusted). The series is also deflated by Implicit Price Deflator for the Nonfarm Business Sector (seasonally adjusted, index: 2005=100, BLS). Due to data availability, the starting year is 1987. Source: Standard & Poor's and Bureau of Labor Statistics (BLS).

Real Commercial Loans: Nominal Commercial Loans (seasonally adjusted, all banks, Assets and Liabilities of Commercial Banks in the United States, Table H8) divided by Price Index for Personal Consumption Expenditures (seasonally adjusted, index numbers: 2005=100, table 1.1.4, line 2). Source: Board of Governors of Federal Reserve System (FRS) and NIPA, Bureau of Economic Analysis (BEA).

Real Consumer Loans: Nominal Consumer Loans (seasonally adjusted, all banks, Assets and Liabilities of Commercial Banks in the United States, Table H8) divided by Price Index for Personal Consumption Expenditures (seasonally adjusted, index numbers: 2005=100, table 1.1.4, line 2). Source: Board of Governors of Federal Reserve System (FRS) and NIPA, Bureau of Economic Analysis (BEA).

Real Deposits: Nominal Deposits (seasonally adjusted, all banks, Assets and Liabilities of Commercial Banks in the United States, Table H8) divided by Price Index for Personal Consumption Expenditures (seasonally adjusted, index numbers: 2005=100, table 1.1.4, line 2). Source: Board of Governors of Federal Reserve System (FRS) and NIPA, Bureau of Economic Analysis (BEA).

Real Net Worth: Nominal Residual: Assets less Liabilities (seasonally adjusted, all banks, Assets and Liabilities of Commercial Banks in the United States, Table H8) divided by Price Index for Personal Consumption Expenditures (seasonally adjusted, index numbers: 2005=100, table 1.1.4, line 2). Source: Board of Governors of Federal Reserve System (FRS) and NIPA, Bureau of Economic Analysis (BEA).

Appendix B

Proof of Proposition 1

In this appendix, I give full details in deriving undetermined coefficients for the conjectured value function. I first guess the value function $V_t(s_t, b_t, d_t)$ is linear in (s_t, b_t, d_t) ,

$$V_t(s_t, b_t, d_t) = \nu_{st}s_t + \nu_{bt}b_t - \nu_{dt}d_t.$$

Given the flow-of-funds constraint (2.12), the incentive constraint (2.13) can be rewritten as

$$V_t \geq \theta(n_t + d_t). \tag{B.1}$$

Then I replace V_t in equation (B.1) with equation (2.16) together with the flow-of-funds constraint (2.12) to get an alternative expression for the incentive constraint, that is

$$[\theta - (\nu_{bt} - \nu_{dt})]d_t + \left(\nu_{bt} - \frac{\nu_{st}}{p_t}\right)p_t s_t \leq (\nu_{bt} - \theta)n_t. \tag{B.2}$$

where equation (B.2) holds with equality if $\lambda_t^b > 0$, and with strict inequality if $\lambda_t^b = 0$. The first order condition (2.17) implies that

$$\frac{\nu_{st}}{p_t} = \nu_{bt}, \quad (\text{B.3})$$

where the marginal value of equity is always equal to the marginal value of consumer loans no matter the incentive constraint is binding or not, implying that banks are indifferent between issuing commercial loans to non-financial firms and issuing consumer loans to impatient households. Moreover, I rewrite the first order condition (2.18) as follows,

$$\nu_{bt} - \nu_{dt} = \frac{\theta \lambda_t^b}{1 + \lambda_t^b}. \quad (\text{B.4})$$

Substituting equation (B.3) and (B.4) into the incentive constraint (B.2) yields

$$d_t \leq \frac{1 + \lambda_t^b}{\theta} (\nu_{bt} - \theta) n_t. \quad (\text{B.5})$$

Similarly, the conjectured value function (2.16) together with equation (B.3) and (B.4) yields

$$V_t = \frac{\theta \lambda_t^b}{1 + \lambda_t^b} d_t + \nu_{bt} n_t. \quad (\text{B.6})$$

While substituting equation (B.5) into equation (B.6) to replace d_t , I get an new expression for the value function,

$$V_t = [\lambda_t^b (\nu_{bt} - \theta) + \nu_{bt}] n_t \quad (\text{B.7})$$

where the term in the bracket is the marginal value of net worth to the ongoing bank. Intuitively, with an additional unit of net worth, the bank can issue an additional

consumer loans to impatient households by obtaining a benefit of ν_{bt} , and in turn, relax the incentive constraint by $\nu_{bt} - \theta$, which increases the value of the bank by a factor equal to λ_t^b .

Finally, I substitute equation (B.7) for date $t + 1$ into the Bellman equation (2.15) to yield

$$V_t(s_t, b_t, d_t) = E_t \Lambda_{t,t+1} \Omega_{t+1} n_{t+1} \quad (\text{B.8})$$

with

$$\Omega_{t+1} = 1 - \sigma + \sigma [\lambda_{t+1}^b (\nu_{bt+1} - \theta) + \nu_{bt+1}] \quad (\text{B.9})$$

where Ω_{t+1} is the marginal value of net worth at date $t + 1$.

Given equations (B.3) and (B.4), I can derive an expression for the excess value of returns on assets over deposits,

$$\mu_t = \frac{\nu_{st}}{p_t} - \nu_{dt} = \nu_{bt} - \nu_{dt} = \frac{\theta \lambda_t^b}{1 + \lambda_t^b}. \quad (\text{B.10})$$

Combining equation (B.10) for date $t + 1$ with equation (B.9), I can obtain an new expression for the marginal value of net worth at date $t + 1$, that is

$$\Omega_{t+1} = 1 - \sigma + \sigma (\nu_{dt+1} + \phi_{t+1} \mu_{t+1}) \quad (\text{B.11})$$

with

$$\phi_{t+1} = \frac{\nu_{dt+1}}{\theta - \mu_{t+1}} \quad (\text{B.12})$$

where ϕ_{t+1} is the bank's leverage ratio at date $t + 1$.

By applying the method of the undetermined coefficients to equation (B.8), we

can easily determine all coefficients to the conjectured value function as follows,

$$\nu_{st} = E_t \Lambda_{t,t+1} \Omega_{t+1} [Z_{t+1} + (1 - \delta_k) p_{t+1}] \psi_{t+1} \quad (\text{B.13})$$

$$\nu_{bt} = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{t+1}^b \quad (\text{B.14})$$

$$\nu_{dt} = E_t \Lambda_{t,t+1} \Omega_{t+1} R_{t+1}^d \quad (\text{B.15})$$

Therefore, the conjectured value function V_t is linear in (s_t, b_t, d_t) if and only if the conditions (B.13), (B.14), and (B.15) are satisfied. **QED**

Appendix C

Dynamic System of the Baseline Model

$$1 = \beta_p E_t \left(\frac{c_{p,t}}{c_{p,t+1}} R_{t+1}^d \right) \quad (\text{C.1})$$

$$\frac{q_t}{c_{p,t}} = \frac{j}{h_{p,t}} + \beta_p E_t \left(\frac{(1 - \delta_h) q_{t+1}}{c_{p,t+1}} \right) \quad (\text{C.2})$$

$$\frac{p_{x,t}}{c_{p,t}} = \beta_p E_t \left[\frac{p_{x,t+1} + R_{t+1}^x}{c_{p,t+1}} \right] \quad (\text{C.3})$$

$$\frac{w_{pc,t}}{c_{p,t}} = (l_{pc,t}^{1+\epsilon_p} + l_{ph,t}^{1+\epsilon_p})^{\frac{\eta_p - \epsilon_p}{1+\epsilon_p}} l_{pc,t}^{\epsilon_p} \quad (\text{C.4})$$

$$\frac{w_{ph,t}}{c_{p,t}} = (l_{pc,t}^{1+\epsilon_p} + l_{ph,t}^{1+\epsilon_p})^{\frac{\eta_p - \epsilon_p}{1+\epsilon_p}} l_{ph,t}^{\epsilon_p} \quad (\text{C.5})$$

$$\frac{j}{h_{i,t}} + \beta_i E_t \left(\frac{(1 - \delta_h) q_{t+1}}{c_{i,t+1}} \right) = \frac{q_t}{c_{i,t}} - \lambda_{i,t} m E_t \left(\frac{q_{t+1}}{R_{t+1}^b} \right) \quad (\text{C.6})$$

$$\frac{1}{c_{i,t}} = \beta_i E_t \left(\frac{R_{t+1}^b}{c_{i,t+1}} \right) + \lambda_{i,t} \quad (\text{C.7})$$

$$\frac{w_{ic,t}}{c_{i,t}} = (l_{ic,t}^{1+\epsilon_i} + l_{ih,t}^{1+\epsilon_i})^{\frac{\eta_i - \epsilon_i}{1+\epsilon_i}} l_{ic,t}^{\epsilon_i} \quad (\text{C.8})$$

$$\frac{w_{ih,t}}{c_{i,t}} = (l_{ic,t}^{1+\epsilon_i} + l_{ih,t}^{1+\epsilon_i})^{\frac{\eta_i - \epsilon_i}{1+\epsilon_i}} l_{ih,t}^{\epsilon_i} \quad (\text{C.9})$$

$$b_t = mE_t\left(\frac{q_{t+1}h_{i,t}}{R_{t+1}^b}\right) \quad (\text{C.10})$$

$$c_{i,t} + q_t h_{i,t} + R_t^b b_{t-1} = w_{ic,t} l_{ic,t} + w_{ih,t} l_{ih,t} + q_t(1 - \delta_h)h_{i,t-1} + b_t \quad (\text{C.11})$$

$$w_{pc,t} = \alpha(1 - \mu_c) \frac{Y_t}{l_{pc,t}} \quad (\text{C.12})$$

$$w_{ic,t} = (1 - \alpha)(1 - \mu_c) \frac{Y_t}{l_{ic,t}} \quad (\text{C.13})$$

$$Z_t = \mu_c \frac{Y_t}{K_t} \quad (\text{C.14})$$

$$Y_t = (A_{ct}(l_{pc,t}^\alpha l_{ic,t}^{1-\alpha}))^{1-\mu_c} K_t^{\mu_c} \quad (\text{C.15})$$

$$w_{ph,t} = \alpha(1 - \mu_h) \frac{q_t I_{ht}}{l_{ph,t}} \quad (\text{C.16})$$

$$w_{ih,t} = (1 - \alpha)(1 - \mu_h) \frac{q_t I_{ht}}{l_{ih,t}} \quad (\text{C.17})$$

$$R_t^x = \mu_h q_t I_{ht} \quad (\text{C.18})$$

$$I_{ht} = (A_{ht}(l_{ph,t}^\alpha l_{ih,t}^{1-\alpha}))^{1-\mu_h} \quad (\text{C.19})$$

$$p_t = 1 + \left[\ln\left(\frac{I_{kt}}{I_{kt-1}}\right)\right]^2 + 2\left[\ln\left(\frac{I_{kt}}{I_{kt-1}}\right)\right] - 2E_t\beta_p \frac{c_{p,t}}{c_{p,t+1}} \left[\ln\left(\frac{I_{kt+1}}{I_{kt}}\right)\right] \frac{I_{kt+1}}{I_{kt}} \quad (\text{C.20})$$

$$\nu_{bt} = E_t\beta_p \frac{c_{p,t}}{c_{p,t+1}} [1 - \sigma + \sigma(\nu_{dt+1} + \phi_{t+1}\mu_{t+1})] R_{t+1}^b \quad (\text{C.21})$$

$$\nu_{dt} = E_t\beta_p \frac{c_{p,t}}{c_{p,t+1}} [1 - \sigma + \sigma(\nu_{dt+1} + \phi_{t+1}\mu_{t+1})] R_{t+1}^d \quad (\text{C.22})$$

$$\nu_{st} = E_t\beta_p \frac{c_{p,t}}{c_{p,t+1}} [1 - \sigma + \sigma(\nu_{dt+1} + \phi_{t+1}\mu_{t+1})] \psi_{t+1} (Z_{t+1} + (1 - \delta_k) p_{t+1}) \quad (\text{C.23})$$

$$\mu_t = E_t\beta_p \frac{c_{p,t}}{c_{p,t+1}} [1 - \sigma + \sigma(\nu_{dt+1} + \phi_{t+1}\mu_{t+1})] (R_{t+1}^k - R_{t+1}^d) \quad (\text{C.24})$$

$$R_{t+1}^k = \psi_{t+1} \frac{Z_{t+1} + (1 - \delta_k) p_{t+1}}{p_t} \quad (\text{C.25})$$

$$R_{t+1}^k = R_{t+1}^b \quad (\text{C.26})$$

$$p_t S_t + B_t = N_t + D_t \quad (\text{C.27})$$

$$p_t S_t + B_t = \phi_t N_t \quad (\text{C.28})$$

$$\phi_t = \frac{\nu_{dt}}{\theta - \mu_t} \quad (\text{C.29})$$

$$N_t = (\sigma + \xi) \{ (Z_t + (1 - \delta_k) p_t) \psi_t S_{t-1} + R_t^b B_{t-1} \} - \sigma R_t^d D_{t-1} \quad (\text{C.30})$$

$$Y_t = C_t + (1 + (\ln(\frac{I_{kt}}{I_{kt-1}}))^2) I_{kt} \quad (\text{C.31})$$

$$I_{ht} = H_t - (1 - \delta_h) H_{t-1} \quad (\text{C.32})$$

$$S_t = I_{kt} + (1 - \delta_k) K_t \quad (\text{C.33})$$

$$C_t = c_{p,t} + c_{i,t} \quad (\text{C.34})$$

$$H_t = h_{p,t} + h_{i,t} \quad (\text{C.35})$$

$$K_{t+1} = \psi_{t+1} (I_{kt} + (1 - \delta_k) K_t) \quad (\text{C.36})$$

$$\ln \psi_t = \rho_k \ln \psi_{t-1} + u_{kt} \quad (\text{C.37})$$

$$\ln A_{ct} = \rho_c \ln A_{ct-1} + u_{ct} \quad (\text{C.38})$$

$$\ln A_{ht} = \rho_h \ln A_{ht-1} + u_{ht} \quad (\text{C.39})$$

Appendix D

The Model with Consumption

Habits: Impulse Responses

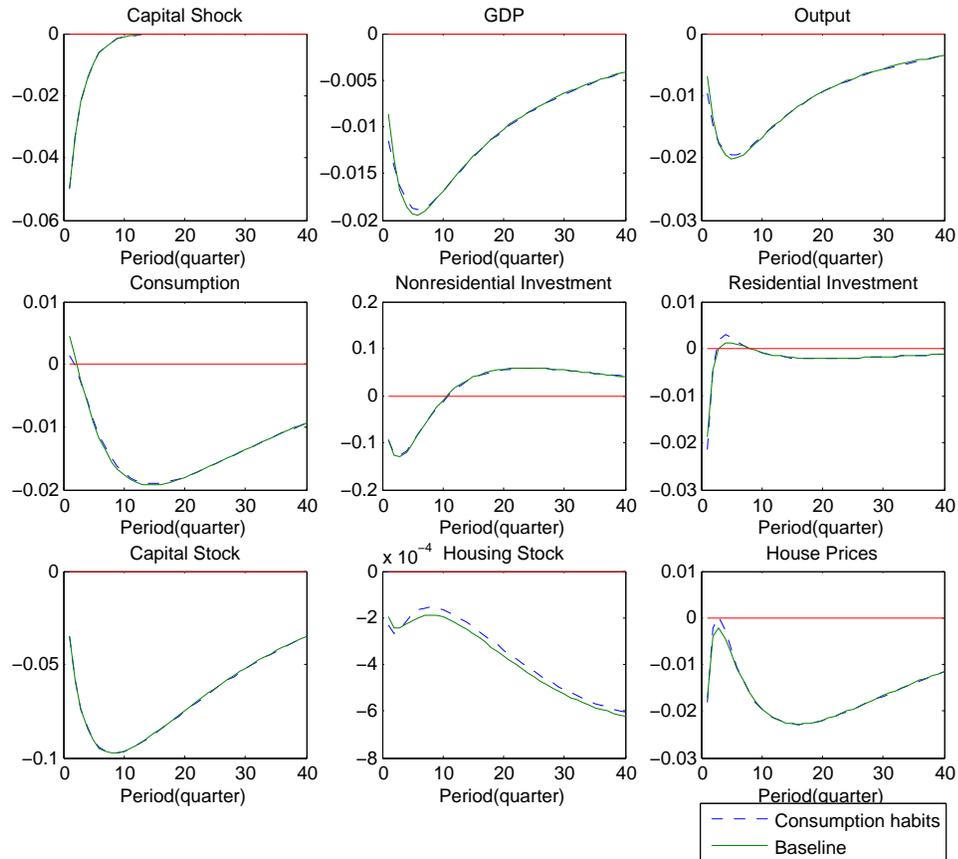


Figure D.1: Financial Crisis Experiment (Housing and Macroeconomic Variables)– Impulse Response Functions to a Negative Capital Quality Shock (The Baseline Model VS The Model with Consumption Habits)

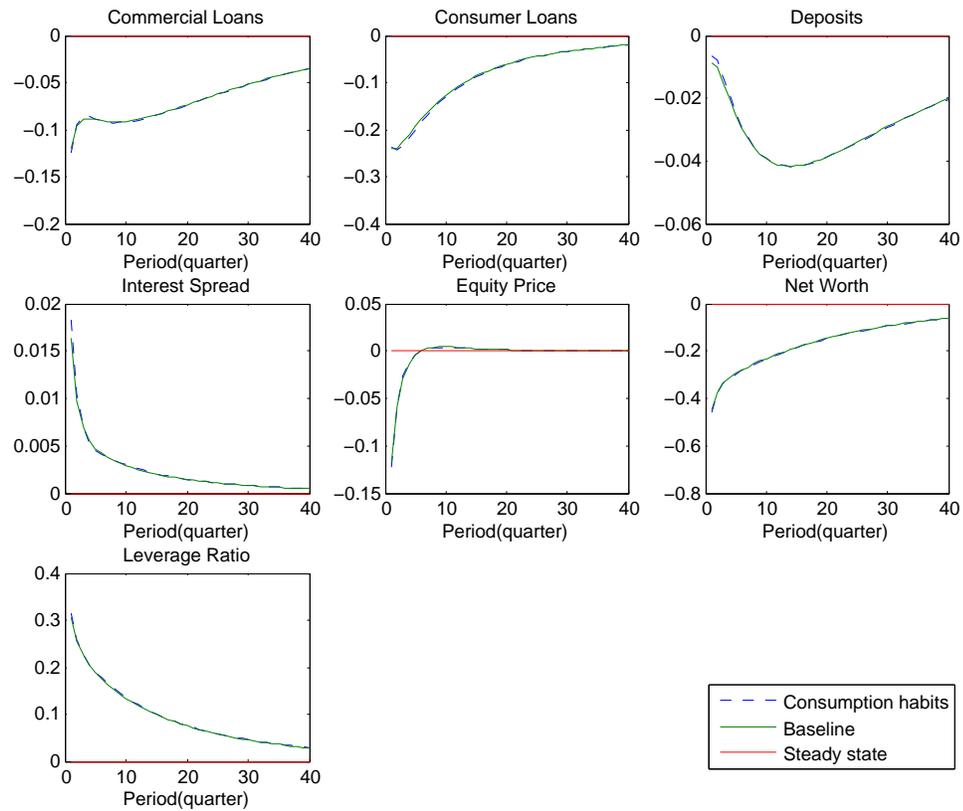


Figure D.2: Financial Crisis Experiment (Financial Variables)–Impulse Response Functions to a Negative Capital Quality Shock (The Baseline Model VS The Model with Consumption Habits)

Appendix E

Dynamic System of the Model (Macprudential Policies)

$$1 = \beta_p E_t \left(\frac{c_{p,t}}{c_{p,t+1}} R_{t+1}^d \right) \quad (\text{E.1})$$

$$\frac{q_t}{c_{p,t}} = \frac{j_t}{h_{p,t}} + \beta_p E_t \left(\frac{(1 - \delta_h) q_{t+1}}{c_{p,t+1}} \right) \quad (\text{E.2})$$

$$\frac{p_{x,t}}{c_{p,t}} = \beta_p E_t \left[\frac{p_{x,t+1} + R_{t+1}^x}{c_{p,t+1}} \right] \quad (\text{E.3})$$

$$\frac{(1 - \tau) w_{pc,t}}{c_{p,t}} = (l_{pc,t}^{1+\epsilon_p} + l_{ph,t}^{1+\epsilon_p})^{\frac{\eta_p - \epsilon_p}{1+\epsilon_p}} l_{pc,t}^{\epsilon_p} \quad (\text{E.4})$$

$$\frac{(1 - \tau) w_{ph,t}}{c_{p,t}} = (l_{pc,t}^{1+\epsilon_p} + l_{ph,t}^{1+\epsilon_p})^{\frac{\eta_p - \epsilon_p}{1+\epsilon_p}} l_{ph,t}^{\epsilon_p} \quad (\text{E.5})$$

$$\frac{j_t}{h_{i,t}} + \beta_i E_t \left(\frac{(1 - \delta_h) q_{t+1}}{c_{i,t+1}} \right) = \frac{q_t}{c_{i,t}} - \lambda_{i,t} m_t E_t \left(\frac{q_{t+1}}{R_{t+1}^b} \right) \quad (\text{E.6})$$

$$\frac{1}{c_{i,t}} = \beta_i E_t \left(\frac{R_{t+1}^b}{c_{i,t+1}} \right) + \lambda_{i,t} \quad (\text{E.7})$$

$$\frac{w_{ic,t}}{c_{i,t}} = (l_{ic,t}^{1+\epsilon_i} + l_{ih,t}^{1+\epsilon_i})^{\frac{\eta_i - \epsilon_i}{1+\epsilon_i}} l_{ic,t}^{\epsilon_i} \quad (\text{E.8})$$

$$\frac{w_{ih,t}}{c_{i,t}} = (l_{ic,t}^{1+\epsilon_i} + l_{ih,t}^{1+\epsilon_i})^{\frac{\eta_i - \epsilon_i}{1+\epsilon_i}} l_{ih,t}^{\epsilon_i} \quad (\text{E.9})$$

$$b_t = m_t E_t \left(\frac{q_{t+1} h_{i,t}}{R_{t+1}^b} \right) \quad (\text{E.10})$$

$$c_{i,t} + q_t h_{i,t} + R_t^b b_{t-1} = w_{ic,t} l_{ic,t} + w_{ih,t} l_{ih,t} + q_t (1 - \delta_h) h_{i,t-1} + b_t + \tau (w_{pc,t} l_{pc,t} + w_{ph,t} l_{ph,t}) \quad (\text{E.11})$$

$$w_{pc,t} = \alpha (1 - \mu_c) \frac{Y_t}{l_{pc,t}} \quad (\text{E.12})$$

$$w_{ic,t} = (1 - \alpha) (1 - \mu_c) \frac{Y_t}{l_{ic,t}} \quad (\text{E.13})$$

$$Z_t = \mu_c \frac{Y_t}{K_t} \quad (\text{E.14})$$

$$Y_t = (A_{ct} (l_{pc,t}^\alpha l_{ic,t}^{1-\alpha}))^{1-\mu_c} K_t^{\mu_c} \quad (\text{E.15})$$

$$w_{ph,t} = \alpha (1 - \mu_h) \frac{q_t I_{ht}}{l_{ph,t}} \quad (\text{E.16})$$

$$w_{ih,t} = (1 - \alpha) (1 - \mu_h) \frac{q_t I_{ht}}{l_{ih,t}} \quad (\text{E.17})$$

$$R_t^x = \mu_h q_t I_{ht} \quad (\text{E.18})$$

$$I_{ht} = (l_{ph,t}^\alpha l_{ih,t}^{1-\alpha})^{1-\mu_h} \quad (\text{E.19})$$

$$p_t = 1 + \left[\ln \left(\frac{I_{kt}}{I_{kt-1}} \right) \right]^2 + 2 \left[\ln \left(\frac{I_{kt}}{I_{kt-1}} \right) \right] - 2 E_t \beta_p \frac{c_{p,t}}{c_{p,t+1}} \left[\ln \left(\frac{I_{kt+1}}{I_{kt}} \right) \right] \frac{I_{kt+1}}{I_{kt}} \quad (\text{E.20})$$

$$\nu_{bt} = E_t \beta_p \frac{c_{p,t}}{c_{p,t+1}} \left[1 - \sigma + \frac{\sigma}{\omega_{t+1}} (\nu_{dt+1} + \phi_{t+1} \mu_{t+1}) \right] R_{t+1}^b \quad (\text{E.21})$$

$$\nu_{dt} = E_t \beta_p \frac{c_{p,t}}{c_{p,t+1}} \left[1 - \sigma + \frac{\sigma}{\omega_{t+1}} (\nu_{dt+1} + \phi_{t+1} \mu_{t+1}) \right] R_{t+1}^d \quad (\text{E.22})$$

$$\nu_{st} = E_t \beta_p \frac{c_{p,t}}{c_{p,t+1}} \left[1 - \sigma + \frac{\sigma}{\omega_{t+1}} (\nu_{dt+1} + \phi_{t+1} \mu_{t+1}) \right] (Z_{t+1} + (1 - \delta_k) p_{t+1}) \quad (\text{E.23})$$

$$\mu_t = E_t \beta_p \frac{c_{p,t}}{c_{p,t+1}} \left[1 - \sigma + \frac{\sigma}{\omega_{t+1}} (\nu_{dt+1} + \phi_{t+1} \mu_{t+1}) \right] \left(R_{t+1}^k - \frac{R_{t+1}^d}{\omega_t} \right) \quad (\text{E.24})$$

$$R_{t+1}^k = \frac{Z_{t+1} + (1 - \delta_k) p_{t+1}}{p_t} \quad (\text{E.25})$$

$$R_{t+1}^k = R_{t+1}^b \quad (\text{E.26})$$

$$p_t S_t + B_t = N_t + \omega_t D_t \quad (\text{E.27})$$

$$(p_t S_t + B_t) = \phi_t N_t \quad (\text{E.28})$$

$$\phi_t = \gamma_t \frac{\nu dt}{\theta - \mu_t} \quad (\text{E.29})$$

$$N_t = (\sigma + \xi) \{ (Z_t + (1 - \delta_k) p_t) S_{t-1} + R_t^b B_{t-1} \} - \sigma R_t^d D_{t-1} \quad (\text{E.30})$$

$$Y_t = C_t + (1 + (\ln(\frac{I_{kt}}{I_{kt-1}}))^2) I_{kt} \quad (\text{E.31})$$

$$I_{ht} = H_t - (1 - \delta_h) H_{t-1} \quad (\text{E.32})$$

$$S_t = I_{kt} + (1 - \delta_k) K_t \quad (\text{E.33})$$

$$C_t = c_{p,t} + c_{i,t} \quad (\text{E.34})$$

$$H_t = h_{p,t} + h_{i,t} \quad (\text{E.35})$$

$$K_{t+1} = I_{kt} + (1 - \delta_k) K_t \quad (\text{E.36})$$

$$\ln A_{ct} = \rho_c \ln A_{ct-1} + u_{ct} \quad (\text{E.37})$$

$$\ln j_t = (1 - \rho_j) \ln j + \rho_j \ln j_{t-1} + u_{jt} \quad (\text{E.38})$$

$$m_t = \bar{m} \left(\frac{B_t}{\bar{B}} \right)^{\alpha_b} \left(\frac{q_t}{\bar{q}} \right)^{\alpha_q} \quad (\text{E.39})$$

$$\omega_t = \bar{\omega} \left(\frac{B_t}{\bar{B}} \right)^{\alpha_b} \left(\frac{q_t}{\bar{q}} \right)^{\alpha_q} \quad (\text{E.40})$$

$$\gamma_t = \bar{\gamma} \left(\frac{B_t}{\bar{B}} \right)^{\alpha_b} \left(\frac{q_t}{\bar{q}} \right)^{\alpha_q} \quad (\text{E.41})$$

Appendix F

Impulse Responses

(Macroprudential Policies)

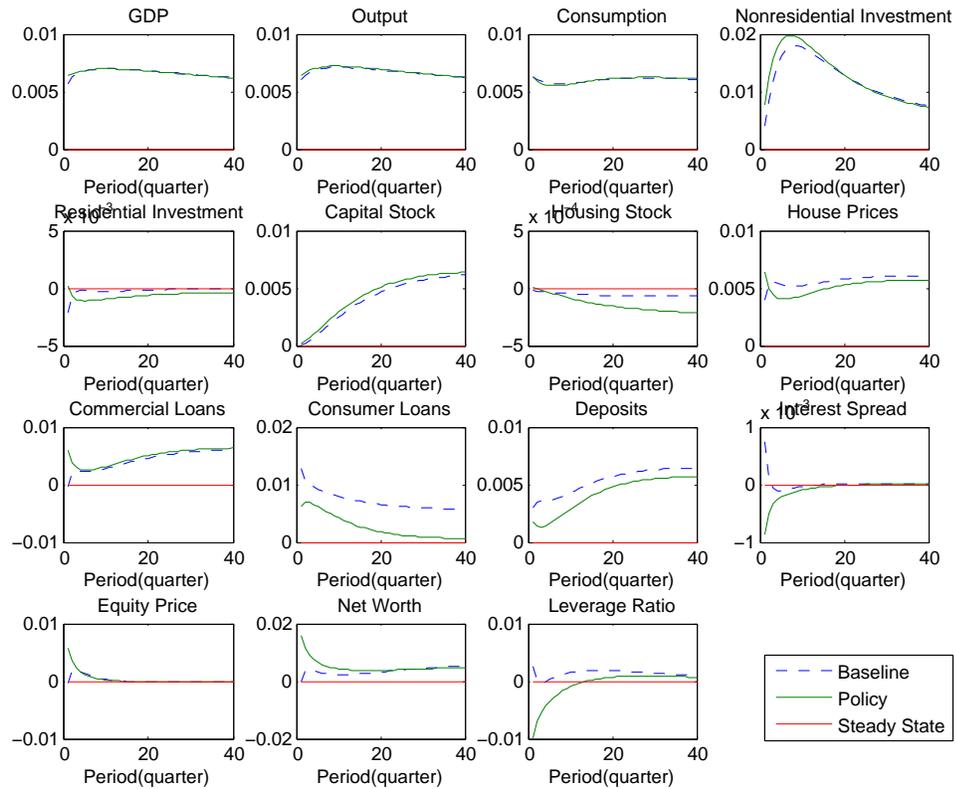


Figure F.1: A Tightening of LTV Ratios: Impulse Responses to a Positive Productivity Shock in the Final Goods Sector

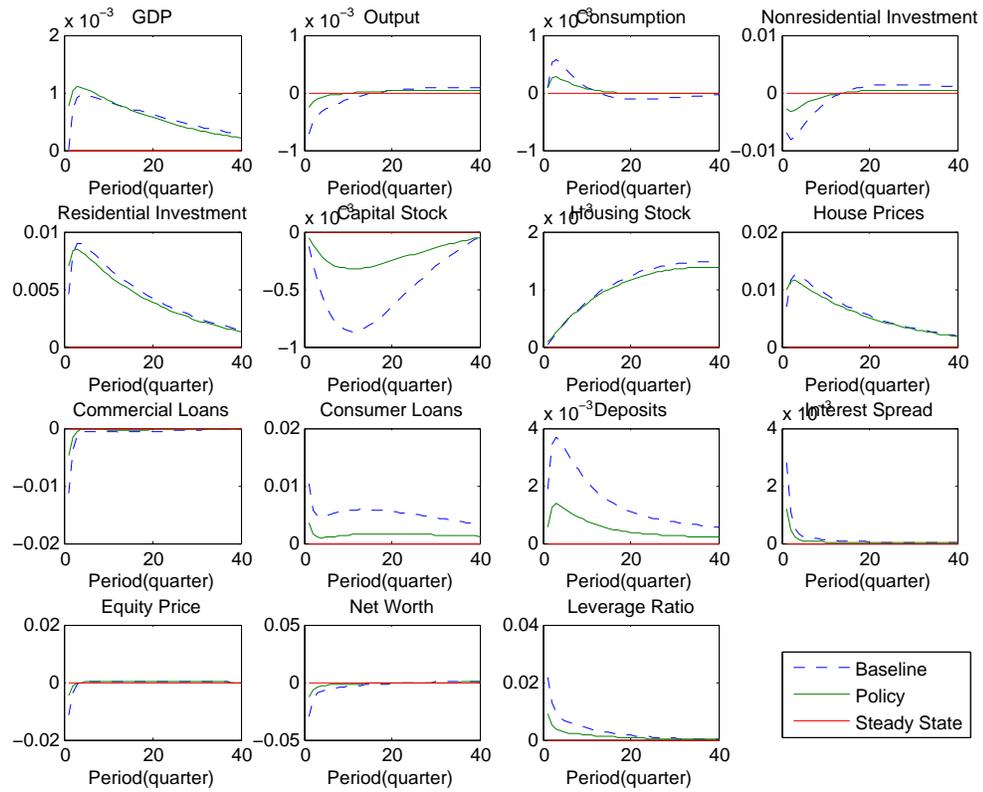


Figure F.2: A Tightening of LTV Ratios: Impulse Responses to a Positive Housing Preference Shock

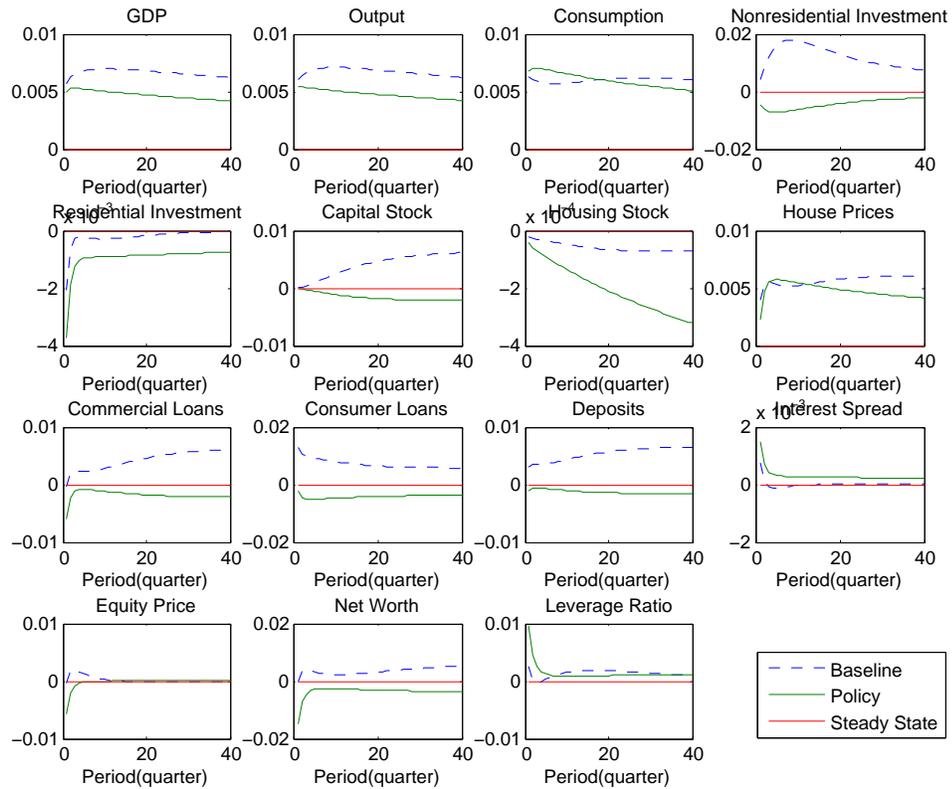


Figure F.3: A Tightening of Bank Reserve Ratios: Impulse Responses to a Positive Productivity Shock in the Final Goods Sector

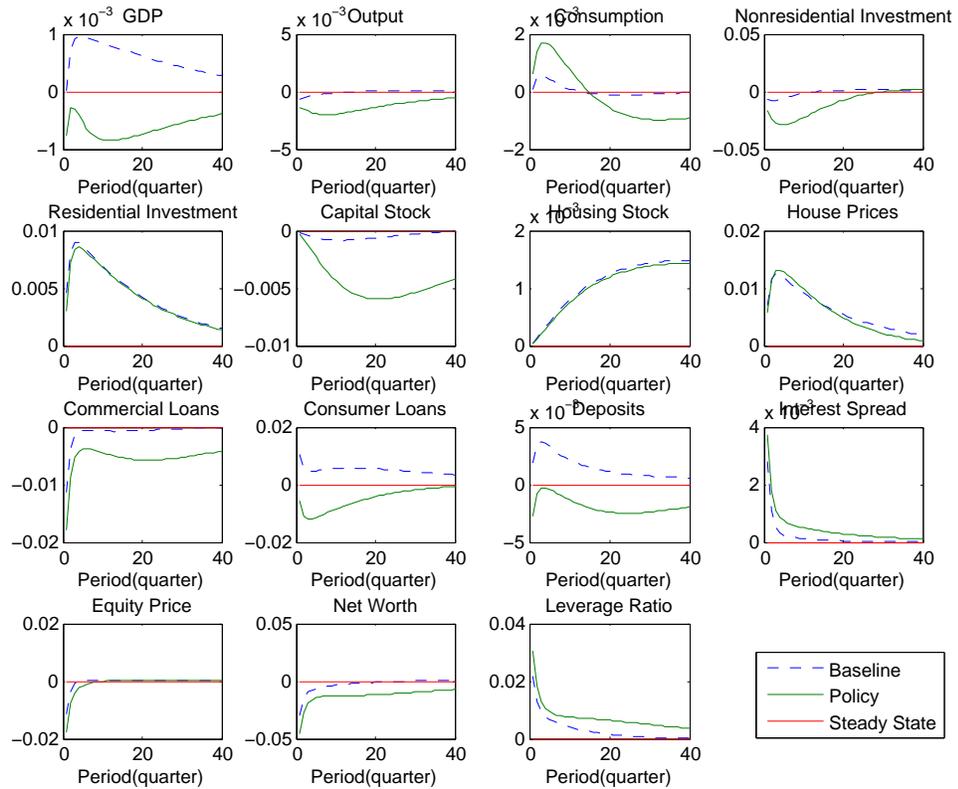


Figure F.4: A Tightening of Bank Reserve Ratios: Impulse Responses to a Positive Housing Preference Shock

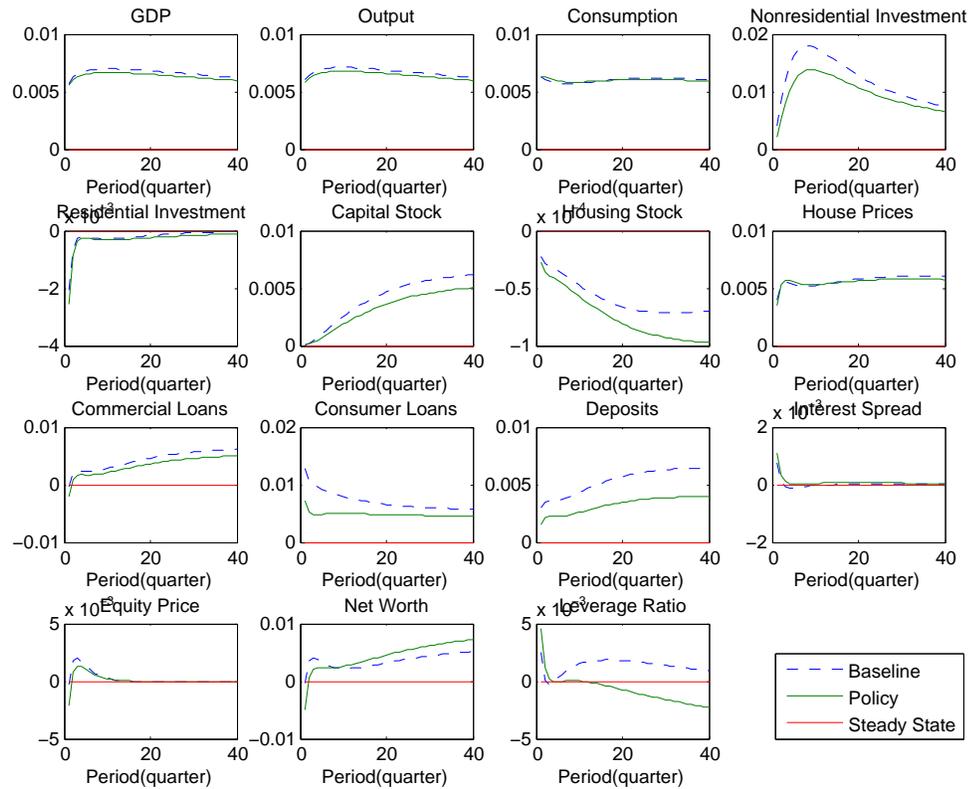


Figure F.5: A Tightening of Bank Leverage Ratios: Impulse Responses to a Positive Productivity Shock in the Final Goods Sector

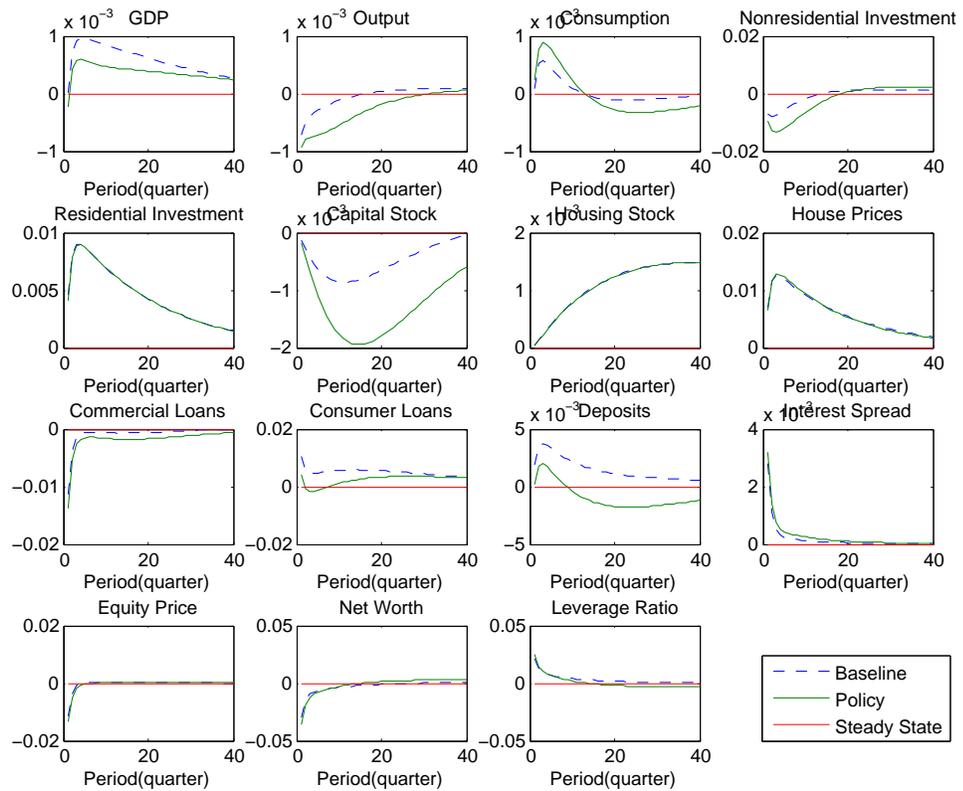


Figure F.6: A Tightening of Bank Leverage Ratios: Impulse Responses to a Positive Housing Preference Shock

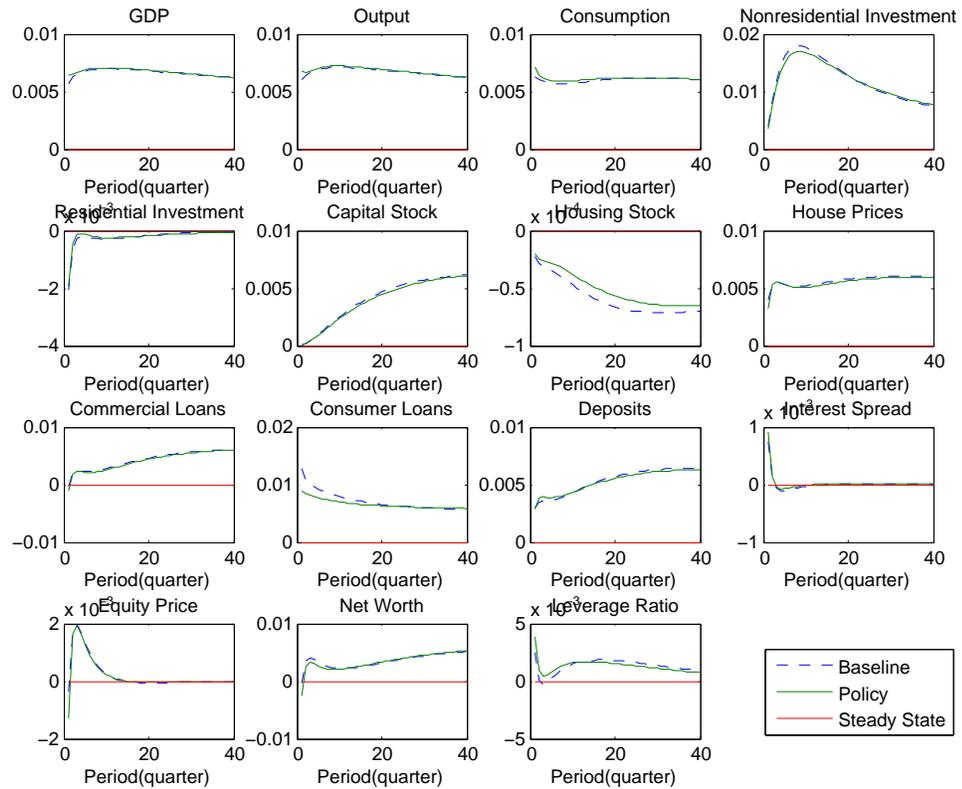


Figure F.7: Macroprudential Tax Credits: Impulse Responses to a Positive Productivity Shock in the Final Goods Sector

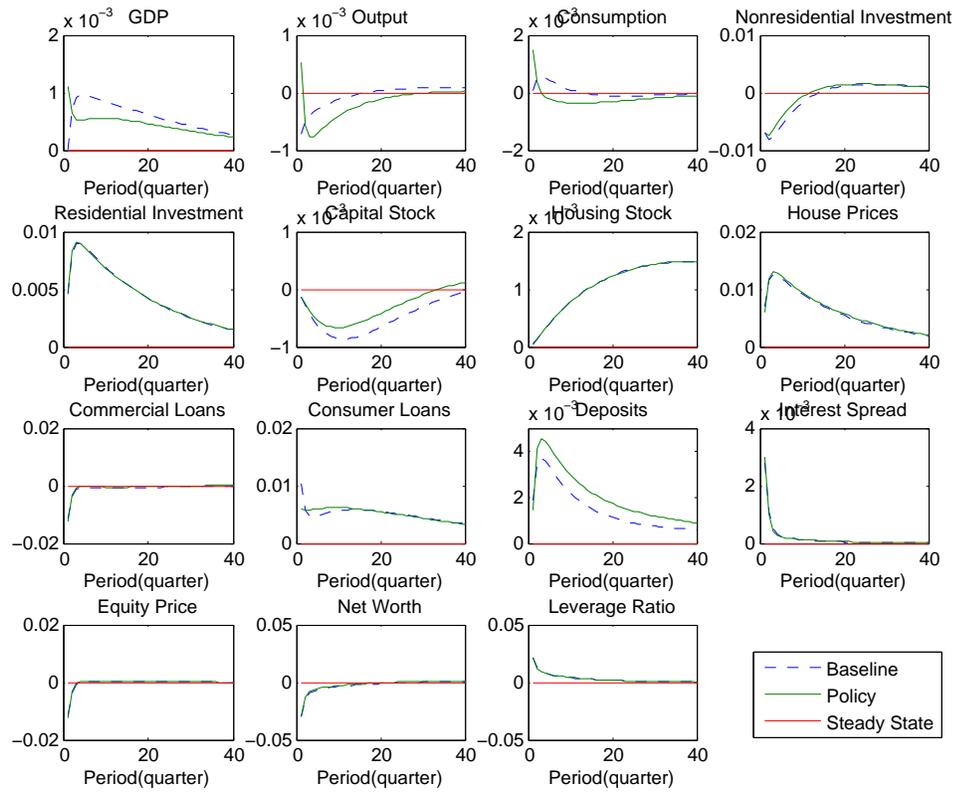


Figure F.8: Macroprudential Tax Credits: Impulse Responses to a Positive Housing Preference Shock