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Theoretical and Empirical Investigations

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of the requirements for the degree of

Doctor of Philosophy

in

Economics

by

MeiChi Huang

December 2009

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ABSTRACT OF THE DISSERTATION

The U.S. Housing Market and the Business Cycle—
Theoretical and Empirical Investigations

by

MeiChi Huang

Doctor of Philosophy, Graduate Program in Economics
University of California, Riverside, December 2009
Dr. Marcelle Chauvet, Chairperson

This dissertation is composed of three essays on theoretical and empirical investigations into the U.S. housing market. Chapter 1 is to extend a two-sector dynamic general equilibrium model from Ravn, Grohe, and Uribe (2006) deep-habit framework to study asset pricing, particularly housing price. It allows interaction between nondurable and housing markets on both the supply-side and the demand-side. Due to the interaction between the two sectors, the parameter change in the single sector can affect markups of both goods at the steady-state. The findings indicate that the interaction between these two sectors reflects important cross-sector roles of these influential factors in explaining markups.

Chapter 2 is to investigate the seeds of the recent housing and economic crisis by investigating the interrelationship between the recent bust in the housing market,
economic recession, and related monetary policies undertaken by the Federal Reserve.

A bi-factor dynamic factor model is developed to represent the housing market and
the business cycles, and they are allowed to follow different two-state
Markov-switching processes. They are linked through monetary policy as reflected in
interest rates movements. We find a strong correlation between the business cycle and
interest rates, and between the housing cycle and interest rates, and between the two
cycles. However, the close relationship changes since the 2001 recession as interest
rates end its low-level due to the uncertainty and the slow recovery after this recession.
The missed linkage between the business cycle and the housing cycle worked as a
seed of the housing market bust and the economic recession in 2007-2009.

Chapter 3 aims to investigate the effect of a potential important driver of the
recent housing price boom and bust – people's expectations on the U.S. housing asset
returns. Particularly, it extends the volatility feedback model proposed in Kim,
Morley and Nelson (KMN 2004) to study the relationship between housing volatility
and returns during 1963-2007. The analysis considers two alternative
breakpoints--1984Q1 and 1999Q1-- to distinguish permanent structural breakpoints
from Markov-switching. The results indicate that the relationship between the U.S.
housing volatility and the expected returns is significantly positive. Thus, the
important role of people’s expectation is strongly supported. The current U.S. housing bubble can be explained by the relationship between housing volatility and realized returns, and that between housing volatility and expected returns. Corresponding to Chapter 2, this chapter also indicates a strong association between housing cycles and business cycles, and a remarkable uncertainty in the U.S. housing market during the post-1999.
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INTRODUCTION

The literature on the housing market is remarkably growing after the current housing boom and bust in the U.S. The importance of the housing sector mainly lies in the three perspectives. First, consumption spending of housing goods occupies significant wealth of households. Second, movements in the housing sector are closely interrelated with other vital macroeconomic variables, such as GDP and inflation. Third, the investigation of the housing market is able to provide insights into the monetary policy. In particular, the housing market crisis triggers the financial crisis and the economic recession since the end of 2007. Thus, it becomes a spotlight of researches on Economics.

My dissertation is devoted to addressing some interesting issues about the housing market. Especially, the cross-sector role of housing goods in asset pricing, the causes of the recent housing boom and bust, the macroeconomic implication of high housing volatility, the effect of revision of people’s expectation on the housing asset returns, and the close association between the U.S. housing cycle and the business cycle are analyzed in the following three chapters.

Chapter 1 proposes a housing deep-habit model which is extended from standard
framework of Ravn, Schmitt-Grohe, and Uribe (RSU 2006). In the monopolistically-competitive equilibrium model, deep habits assume that agents can form preferences over the good-by-good basis rather than based on the composite final good. Thus, firms will then take this into account and plan future demand of the housing goods based on their present sales. Due to households’ gradual habit formation over individual varieties of housing goods, firms have the incentive to attract customers by reducing prices today in order to form the customer base for the future.

The novelty of the model is that it sheds light on the interaction between the two markets on both the supply and the demand sides while the existing literature on housing asset pricing focuses the single side only. Besides, the parameter change in one sector can affect markups of both sectors at the steady-state. This chapter aims to use the proposed model to emphasize the important cross-sector roles of some influential factors in explaining markups of housing goods and nondurable goods.

Chapter 2 is to explore the seeds of the current housing and economic crisis in the U.S. Especially, it examines if the recent surge of housing prices and the subsequent drop are unique in the last five decades. It is empirically motivated by the close relationship between the U.S housing market and economic activities. The dynamic bi-factor model with two different Markov-switching processes is developed
to separately represent the U.S. business cycles and housing cycles. Besides, their linkage is modeled through the dependence structure of the factors in the transition equations and their covariance between innovations.

Further, augmented version of model with Markov-switching components in the coefficients of lagged interest rates in transition equations is established to examine the role of interest rates which shed light on the missed linkage between housing and business cycles since the early 2000s. The flexibly-set framework which is motivated by Chauvet (1998/1999,2009) and Senyuz (2008,2009) remarkably facilitates the investigation of the time-varying interaction between the phase of the housing market and that of the business cycle. Importantly, the chapter suggests that the recent housing bust and economic recession since the end of 2007 were catalyzed by the monetary policy which affected expectation of housing investors significantly.

Chapter 3 aims to investigate the effect of a potential important driver of the recent housing price boom and bust – people's expectations on the U.S. housing asset returns during 1963-2007. Particularly, it examines the positive relationship between housing market volatility and the expected housing asset returns by extending the volatility feedback model proposed in Kim, Morley and Nelson (KMN 2004), Turner, Startz, and Nelson (1989) and Campbell and Hentschel (1992).
Motivated by KMN, this study assumes that volatility of the U.S. housing market follows a Markov switching process, and considers two alternative assumptions about information availability to examine the volatility feedback effect: partial revelation and full revelation. The former assumes that people only can observe past asset returns at the true state of the market volatility, while the latter assumes that people are able to recognize the volatility regime in the asset market. The realized asset return is composed of people’s expected return, volatility feedback effect, and shock (news) to the asset market. Importantly, people’s updated expectation has an influence on asset returns through volatility feedback effect.

KMN framework has three characteristics which facilitate its application to the U.S. housing market. First, it emphasizes that volatility feedback is able to capture the comprehensive effects of housing market volatility on all future discounted expected housing asset returns, not only contemporaneous expected returns. Second, the high housing volatility regime in the proposed model is able to capture the U.S. housing cycle very well. Third, Hansen’s (2001) application of Bai and Perron (1998) sequential estimation of breakpoints is utilized to distinguish a one-time permanent structural break component from a temporary but persistent Markov-switching component. Importantly, the finding of this chapter points out high uncertainty in the
housing market around and after the 2001 recession as Chapter 2 proposes.

The dissertation aims to investigate the U.S. housing market from both theoretical and empirical perspectives. The theoretical discussion delivers the mutual implication of Macroeconomics and asset pricing. The empirical investigation sheds insight into the close linkage between housing cycles and business cycles, and explores the driver of the recent U.S. housing bubble.
Chapter 1: Mutual Implication of Asset Pricing and Macroeconomics in a Housing Deep-Habit model

1. Introduction

The goal of this chapter is to develop a two-sector dynamic general equilibrium model to study asset pricing, particularly housing prices. While the existing literature on housing asset pricing focuses either only on the demand or only on the supply side, the proposed model is able to address both sides simultaneously.

The economy is composed of monopolistically-competitive firms that produce nondurable goods and housing goods. Housing goods are assumed to display remarkably heterogeneous characteristics due to differences in style (decoration, structure, and details of the facility such as with or without swimming pool, etc.), location, environmental views (mountain, sea, trees, etc.), and so on.

In this chapter, we adopt the generalized definition of habit formation proposed in Ravn, Schmitt-Grohe, and Uribe (RSU 2006), named “deep habits”. While the standard framework assumes that agents form habits from their overall consumption levels, deep habits assume that agents can form preferences over the consumption of individual goods. In our particular case, we allow for the possibility that agents form
their habits from housing goods and nondurable goods, with a higher level of habit for housing goods.

The assumption of habit formation changes the propagation of macroeconomic shocks the extent to which it modifies how aggregate demand and supply respond to these shocks. In the case of the deep-habit framework, the demand side is not affected. However, there are profound changes in the supply side. In particular, when habit is formed with respect to housing goods, this implies that consumers will be prone to buy more of these goods in the future. Firms will then take this into account and plan future demand of the housing goods based on their present sales. This framework allows examination of the linkage between demand and supply sides of the housing goods sector. The firms’ pricing decision does not only depend on households’ current demand, but also on their expected future demand. Hence, firms have the incentive to attract customers by reducing prices due to households’ gradual habit formation over individual varieties of housing goods, since today’s customers are likely to remain customers in the future.

Our proposed model differs from RSU’s deep-habit model in several ways. In particular, it has three more characteristics than their original framework on both the demand and the supply sides. First, on the demand side, a habit-adjusted housing good
is added into the households’ utility function. This setup allows investigation of the intratemporal elasticity of substitution between the housing and nondurable goods (which are assumed to be imperfect substitutes). As in Piazzesi, Schneider and Tuzel (PST 2007), the asset pricing kernel proposed reflects the composition risk between housing and non-housing consumption. The idea is that the intratemporal elasticity of substitution is larger than the inter-temporal elasticity of substitution because people tend to smooth consumption over time more than across different goods within a period of time. Noticeably, people do not substitute housing goods as much as nondurable goods because the transaction costs of the former are higher than the latter. In order to reflect this feature of housing goods, the model assumes lower intratemporal elasticity of substitution among varieties of housing goods compared to nondurable goods.

Second, also due to the higher transaction costs of housing goods compared to nondurable goods, the model assumes higher level of deep habits for housing goods than for nondurable goods. This feature reflects the fact that people are more likely to stick to consumption of the same housing good than that of nondurable goods.

Third, residential investment share is incorporated into the housing deep-habit model to reflect the relative shares of the investment components (without deep habits).
of both housing and nondurable goods. This is also used to capture the housing goods
dual characteristics of consumption and investment.

On the supply side, there are three important features of the proposed housing
deep-habit model. First, the monopolistically-competitive firms produce two kinds of
goods—nondurable goods and housing goods. Based on households’ different
preferences and needs, they purchase housing goods from these
monopolistically-competitive firms.

Second, the market value share of housing production firms make is
endogenously determined by firms’ production decisions. If the market value of both
goods productions rise, it is important that the market value of housing production
rises more than that of nondurable goods so that its market value share can be higher.
In other words, not only the direction of change, but also the relative magnitude of the
changes in the aggregate demands of the two goods affect the market value share of
housing production.

Third, the technology of these two goods is assumed to be different. In particular,
we assume that housing goods are more capital-intensive than nondurable goods.
Thus, the capital share of the housing production is larger than that of nondurable
goods production. This feature enables the investigation of how firms’ resource
allocation affects markups of these two goods.\textsuperscript{1}

Based on these features of the proposed housing deep-habit model, the framework shows that firms’ production decisions about market value shares of the two sectors and residential investment share integrate these two goods sectors.

The novelty of the proposed model is that it allows interaction between the housing goods sector and the nondurable goods sector, which can generate interesting insights into asset pricing. In fact, parameter changes in one sector, such as the elasticity of substitution among varieties of housing goods, the level of housing goods’ deep habits, and the production share of capital in one market can affect markups of both goods at the steady-state. Thus, the model sheds light on the interaction between the two markets on both the supply and the demand sides. While existing studies only consider substitution between nondurable goods and housing goods, the proposed housing deep-habit model allows us to additionally consider substitution among various comparable goods in the same sector. The main goal of this paper is to use the proposed model to examine the linkage between endogenous macroeconomic decisions and asset pricing of nondurable and housing goods.

The structure of this chapter is as follows. Section 2 reviews the closely-related

\textsuperscript{1} Markup is defined as price divided by marginal cost.
literatures. Section 3 introduces the housing deep-habit model with households’ and firms’ problems. Section 4 examines the effects of some influential factors on markups of nondurable goods and housing goods in a calibration exercise. Section 5 concludes.

2. Literature Review

The housing deep-habit model proposed in this chapter is primarily motivated by RSU’s deep-habit framework. The original setup of RSU has three main features. First, it yields mutual implication of asset prices and macroeconomics because consumption and pricing decisions are both endogenous variables in this model. Second, it assumes a monopolistically-competitive equilibrium framework. On the supply side, firms that produce comparable goods have the market power because they determine prices based on demand-side decisions. On the demand side, consumers form their preferences on a good-by-good basis rather than based on a composite final good, and they tend to keep buying the specific brand of goods over time. Third, the framework assumes markup dynamics. While the no-habit model results in a time-invariant markup, the deep-habit model implies a countercyclical markup because of both the short-term price-elasticity and the long-term inter-temporal effects of deep habits on
asset prices. The price-elasticity effect implies that an increase in the aggregate demand reduces markups. The inter-temporal effect shows that in order to gain more market share in the future, firms are willing to reduce prices today because of the gradual formation of households' habits over time. Also, the demand composition effect, which is the substitution between the investment component without deep habits and the consumption component with deep habits, can affect the strength of the long-term inter-temporal effect.

Based on the above characteristics, the factors that lead to countercyclical markups in RSU are a rise in the aggregate demand of goods, an increase in the price-elasticity, a fall in the interest rate (or a rise in the discount rate), and a rise in the shadow value of sales. All of these factors can drive markups down.

Additionally, this chapter is motivated by implications of the existing literatures that focus either on asset pricing or on cyclical properties of markups. The housing good is not only an important asset, but also a consumption substitute of nondurable goods\(^2\). Hence, the study of the housing market allows investigation of mutual implications of the asset market and macroeconomic decisions.

Two seminal papers on asset pricing relevant for our framework are Campbell

\(^2\) Note that it is a substitute but not a perfect substitute.
and Cochrane’s (1999) Habit-Based Model (External Habit - EH), and Bansal and Yaron’s (2004) long-run risk model (LRR). Campbell and Cochrane (1999) propose that risk aversion is the key channel of asset prices, while Bansal and Yaron (2004) argue that persistent shocks to cash-flows are the driving force of asset prices. The main characteristic of the EH model is habit persistence, whereas that of LRR model is the long-term integration between consumption and dividends.

The main limitation of these asset pricing models is their assumption that macroeconomic variables are exogenous. For example, Campbell and Cochrane (1999) assume that consumption growth is i.i.d. On the other hand, rather than taking macroeconomic decisions as given, the deep-habit model proposed in this chapter addresses how households and firms’ endogenous decisions affect asset prices.

Some recent studies document the important role of demand-side shocks in housing asset pricing, such as the consumption decision of housing services. Other recent papers focus on how supply-side shocks, such as technology, affect cyclical properties of the housing investment.

On the demand side, Piazzesi, Schneider and Tuzel (PST 2007) use the Consumption-Based Capital Asset Pricing Model (CCAPM) with the housing good into the utility function to study housing asset pricing. They show that the stochastic
discount factor (SDF) has two components – the consumption risk and the composition risk.\(^3\) Based on the model’s pricing kernel, they show that if the inter-temporal elasticity of substitution between current and future consumption is smaller than the intratemporal elasticity of substitution between non-housing consumption and housing consumption, the equity premium is higher in bad times (e.g. recessions). On the other hand, they suggest that the composition risk is lower in bad times, since the expenditure fraction of non-housing consumption is higher during these periods than the proportion of expenditure of housing consumption. Because the intratemporal elasticity of substitution between non-housing and housing consumption in PST sheds light on the important role of cross-sector interactions to asset pricing, we also included the characteristics of this composition effect in the proposed deep-habit housing model.

Lustig and Nieuwerburgh (2006) also propose a CCAPM with the housing good, but including one more component into the SDF – heteroskedasticity due to scarcity of the collateral. The model suggests that risk-sharing is lower in bad times because the value of the collateral is also lower and departure from perfect insurance is higher

\(^3\) The composition risk corresponds to fluctuations in the relative expenditure share of housing in the total consumption basket.
during these periods. Thus, in this framework the SDF is higher and more volatile in bad times, and the equity premium is countercyclical. Additionally, Fillat (2007) argues that the inter-temporal composition risk (the long-run consumption growth) helps asset valuation because the housing sector is subject to "long-term risks". Using Epstein and Zin’s (1989) recursive utility function, it adds persistent long-term risk into the SDF. It finds that the risk premia are time-varying (with heterogeneity). In particular, if the housing stock and corporate earnings predict lower future housing services or consumption growth, prices of risk will be higher.

An important paper on the supply-side is Davis and Heathcote (2003), which establish a model with four sectors (assuming no demand-side shock) to examine three facts: (1) residential investment is more volatile than business investment; (2) there is a positive co-movement among consumption, residential and non-residential investment; and (3) residential investment leads the business cycle while non-residential investment lags it. The model is able to explain the first two facts, but fails to show the cyclical properties of residential and non-residential investment.

There are other papers that propose various reasons for cyclical properties of markups. Some representative examples are Mark Bils (1987,1989), Rotemberg and Woodford (1992, 1999), Warner and Barsky (1995), Chevalier and Scharfstein (1996),
and Gali, Gertler, and Salido (2002), among others.

This chapter aims to examine the interaction between the demand and supply sides of asset markets, and to investigate how the interaction of the two goods sectors affects asset prices of housing and nondurable goods at the steady-state. These features of the proposed housing deep-habit model allow more robust investigation of the mutual implication on the asset market and macroeconomic decisions.

3. A Two-Sector Model with Deep Habits

This section describes our proposed housing deep-habit model and seven main assumptions made.

First, utility is assumed to be separable in consumption and leisure, but non-separable in habit-adjusted consumption of nondurable goods \( (x_t^c) \) and housing goods \( (x_t^h) \). Second, there is homotheticity between housing consumption \( (c_t^h) \) and nondurable goods consumption \( (c_t^c) \), which implies that the share of consumption expenditure over the total expenditure does not increase with an increase in income (i.e. stable evolution of the expenditure). Third, the intratemporal elasticities of substitution of the habit-adjusted nondurable goods \( (\eta^c) \) and that of the habit-adjusted housing goods \( (\eta^h) \) consumption across different varieties are both greater than one.
and smaller than infinity. In addition, the former is larger than the latter due to the higher transaction costs of housing goods. Fourth, also because of the higher transactions cost of housing goods, it is assumed that housing goods have higher level of deep habits than nondurable goods ($\theta^h > \theta^c$). Fifth, the preference shift parameter ($\alpha$) in the consumption bundle is unity. Sixth, formation of deep habits is external. External deep habits imply that households are catching up with their neighbors on a good-by-good basis rather than at the level of the composite final good, and the current demand is independent of future expected relative prices of individual goods. Finally, housing production is more capital-intensive than nondurable goods production, so the capital share of production for housing goods is higher than that of nondurable goods ($\phi^h > \phi^c$).

The following sections illustrate the fully fledged dynamic general equilibrium model of the business cycle.

3.1 Households

We are looking for a symmetric equilibrium, so each household $j$ is identical. The utility function of the household with separable consumption ($C_t$) and leisure ($1-l_t$) is:

$$U(C_t, l_t) = \frac{(C_t^{\alpha-1})}{1-\alpha} + A \frac{(1-l_t)^{1-\gamma}-1}{1-\gamma}$$
where $\sigma$ and $\chi$ are the curvatures of the utility function with respect to the consumption bundle and leisure, and $l_t$ is the total labor provided by the household to production of goods. $A$ is a parameter that determines how much time households devote to market production.

The consumption bundle is of the form:

$$C_t = [(x_t^c)^{(\epsilon-1)/\epsilon} + \alpha(x_t^h)^{(\epsilon-1)/\epsilon}]^{\epsilon/(\epsilon-1)}$$

where $C_t$ denotes the consumption bundle with the habit-adjusted consumption of nondurable goods and housing goods. For each household $j$, $x_t^c$ and $x_t^h$ are habit-adjusted consumption of nondurable and housing goods, respectively. $\epsilon$ is the intratemporal elasticity of substitution between habit-adjusted consumption $x_t^c$ and $x_t^h$ and $\alpha$ is the preference shift parameter. This parameter measures shifts in preferences towards housing goods within a period, and it captures secular trends in the observed relative consumption of nondurable and housing goods. This parameter is assumed to be "unity" ($\alpha=1$) in this chapter.

Habit-adjusted nondurable goods consumption for each household $j$ is defined as:

$$x_t^c = \left( \int_{0}^{1} (C_u^c - \theta^c s_{u-1}^c)^{1-1/\eta^c} du \right)^{1/(1-1/\eta^c)}$$

while habit-adjusted housing goods consumption for each household $j$ is defined as:
\[ x_t^h = \frac{1}{\eta^h} \left( (c^h_{it} - \theta^h s^h_{it-1})^{1-1/\eta^h} \right)^{1/(1-\eta^h)} \]  

where \( c^c_{it} = \int_0^1 c^c_{it} \, dx \) and \( c^h_{it} = \int_0^1 c^h_{it} \, dx \) are the average level of nondurable goods and housing goods consumption of variety \( i \) in time \( t \), respectively. \( \theta^c \) and \( \theta^h \) represent the degree of external habit formation in the variety of nondurable goods consumption and housing goods consumption, respectively. \( \eta^c \) and \( \eta^h \) represent the intratemporal elasticity of substitution among varieties of nondurable goods and housing goods, respectively.

The law of motion of the external habit stock \((s^c_{it} \text{ and } s^h_{it})\) is assumed to be based on a weighted average of consumption in "all" past periods. So it can be written in the following form:

\[ s^c_{it} = \rho^c s^c_{it-1} + (1 - \rho^c) c^c_{it} + \varepsilon^c_{it} \quad (1)' \]
\[ s^h_{it} = \rho^h s^h_{it-1} + (1 - \rho^h) c^h_{it} + \varepsilon^h_{it} \quad (2)' \]

\[ \varepsilon^c_{it} \sim \mathcal{N}(0, \sigma_{eci}) \text{ and } \varepsilon^h_{it} \sim \mathcal{N}(0, \sigma_{esh}) \]

where \( \rho \in [0,1] \) is the adjustment speed of the external habit stock to variations in the average consumption of variety \( i \). \( \varepsilon^c_{it} \) and \( \varepsilon^h_{it} \) are the preference (demand) shocks of nondurable goods and housing goods, which are assumed to be i.i.d. Physical capital \((k_t)\) is assumed to be owned and invested by households. For each household \( j \), nondurable investment \((\bar{r}_i^c)\) and housing investment \((\bar{r}_i^h)\) are assumed to be composite...
goods as follows:

\[ i_t^c = \left( \int_0^1 \left( \frac{i_t^c}{P_i} \right)^{1/n_t} \, dt \right)^{1/(1-n_t)} \]  

(3-1)

\[ i_t^h = \left( \int_0^1 \left( \frac{i_t^h}{P_i} \right)^{1/n_t} \, dt \right)^{1/(1-n_t)} \]  

(3-2)

Total investment is the sum of these two composite goods:

\[ i_t = i_t^h + i_t^c \]

\[ i_t^h = \pi_t \cdot i_t \text{ and } i_t^c = (1 - \pi_t) i_t \]

where \( \pi_t \) is residential (housing goods) investment share, and \((1-\pi_t)\) is nondurable goods investment share.

By minimizing the total expenditure of nondurable goods:

\[ \int_0^1 P_{it}^c c_{it}^c \]

subject to the aggregate constraint in equation (1), we can get the optimal level of nondurable goods consumption \( i^c \in [0,1] \) in (4):

\[ c_{it}^c = \left( \frac{P_{it}}{P_i^c} \right)^{-\eta_t} x_t^c + \theta c_{it-1} = \left( P_{it}^c \right)^{-\eta_t} x_t^c + \theta c_{it-1}^c \]  

(4)

where \( x_t^c = \int_0^1 x_t^c \, df \) represents the aggregate habit-adjusted consumption of nondurable goods. \( P_i^c \) is the nominal price index of nondurable goods, which is represented as follows:
\[ P_t^c = \left[ \int_0^1 P_{it}^{1-n^c} \, di \right]^{1/(1-n^c)} \]

where \( P_{it} \) is the nominal price of the nondurable good \( i \) at time \( t \) and \( p_{it}^c \) is the relative price of the nondurable good \( i \):

\[ \left( \frac{p_{it}^c}{P_t} \right) = P_{it}^c \]

Similarly, for housing goods and investment goods of both sectors, we obtain the following expressions by minimizing the expenditure subject to the aggregate constraint, for each household \( j \):

\[ c^h_t = \left( \frac{p_{ih}}{P_{ih}} \right)^{-\eta^h} x_{ih}^h + \theta^h s_{ih-1}^h = \left( p_{it}^h \right)^{-\eta^h} x_{it}^h + \theta^h s_{it-1}^h = \left( p_{it}^h \right)^{-\eta^h} \left( \frac{\eta^h - \theta^h s_{it-1}^h}{\eta^h - \theta^h s_{it-1}^h} \right) + \theta^h s_{it-1}^h \]

(5)

\[ i_t^c = \left( \frac{p_{it}^c}{P_t} \right)^{-\eta^c} \dot{i}_t^c = \left( p_{it}^c \right)^{-\eta^c} \dot{i}_t^c = \left( p_{it}^c \right)^{-\eta^c} \left( 1 - \pi_t \right) i_t \]

(6)

\[ i_t^h = \left( \frac{p_{ih}}{P_{ih}} \right)^{-\eta^h} i_t^h = \left( p_{it}^h \right)^{-\eta^h} i_t^h = \left( p_{it}^h \right)^{-\eta^h} \left( \pi_t i_t \right) \]

(7)

where \( x_{ih}^h\int_a^t x_{ih}^h \, dj \) represents the aggregate habit-adjusted consumption of housing goods, \( \ddot{i}_t = \int_0^t \ddot{i}_j \, dj \) is the aggregate investment (without deep habits) of nondurable goods, and \( \dddot{i}_t = \int_0^t \dddot{i}_j \, dj \) is the aggregate investment (without deep habits) of housing goods.

For each household \( j \), the two constraints in the households' problem are:

\[ Er_{t+1} d_{t+1} + \sigma^c + \bar{w} + x_c^c + x_h^h + i_t = d_t + \omega l_t + u_t \Phi_t + \Phi_t \]

(8)

\[ i_t = k_{t+1} - (1-\delta) k_t \]

(9)

Equation (8) is the budget constraint of each identical individual household \( j \); \( d_t \) is the
random nominal payment (initial asset holdings); \( \Phi_t \) is the profit from ownership of firms. Physical capital \( (k_t) \) can be rented out by households to generate dividends \( (u_t) \).

Equation (9) describes the law of motion of the capital stock \( (k_t) \). \( \omega \) denotes the real wage rate with:

\[
\omega_t^c = \int_0^\infty \theta^c p_{it+1}^c s_{it}^c dt, \quad \omega_t^h = \int_0^\infty \theta^h p_{it+1}^h s_{it}^h dt
\]

Based on the above illustration, the sum of discounted expected utility is maximized to solve the household's problem:

\[
E \sum_{t=1}^\infty \beta^t U(C_t, l_t)
\]

where \( E \) is the expectation operator, and \( \beta \in (0, 1) \) is a subjective discount factor.

Subject to equation (8), (9) and no-Ponzi game borrowing constraint, the first-order conditions with respect to \( x_t^c, x_t^h, l_t, d_{t+1}, k_{t+1} \) are as follows:

\[
x_t^c : \xi_t = [(x_t^c)^{(1-\xi)} + a(x_t^h)^{(1-\xi)} / (1-\sigma)]^{-1}(x_t^c)^{-1/\xi}
\]

(10)

\[
x_t^h : \xi_t = [(x_t^c)^{(1-\xi)} + a(x_t^h)^{(1-\xi)} / (1-\sigma)]^{-1}(x_t^h)^{-1/\xi}
\]

(11)

\[
l_t : \omega_t \xi_t = A(1 - l_t)^{-\xi}
\]

(12)

\[
d_{t+1} : \beta E \xi_{t+1} = \xi_t E r_{t+1}
\]

(13)

\[
k_{t+1} : \xi_t = \beta E \xi_{t+1} (1 - \delta + u_{t+1})
\]

(14)

where \( \xi_t \) is the Lagrangian multiplier for equation (8).
3.2 Firms

As stated in households’ problem, a symmetric equilibrium is assumed in the proposed model. Therefore, each individual firm is assumed to have the same market value share of housing goods production in the aggregate economy, and each firm is assumed to levy the same price in the symmetric equilibrium.

There are two sectors in this model – nondurable goods and housing goods. $\lambda_t$ represents the market value share of housing production, and $(1-\lambda_t)$ represents that of nondurable goods. $\lambda_t$ is an endogenous choice variable (chosen by firms) because firms allocate the input (labor and capital) into two sectors. The more they allocate inputs into the housing-sector production, the more housing goods are produced.

The nondurable goods production function of each firm $i$ is assumed to be of the form:

$$ y_{it}^c = z_t(k_{it}^c)^{\phi_c}(l_{it}^c)^{1-\phi_c} $$

and the housing goods production function of each firm $i$ is:

$$ y_{it}^h = z_t(k_{it}^h)^{\phi_h}(l_{it}^h)^{1-\phi_h} $$

where $z_t$ is a technology (supply) shock, and it is assumed to be common to the production of both nondurable and housing goods. For the individual firm $i$, the total labor $(l_{it})$ is the sum of the labor devoted to nondurable goods production $(l_{it}^c)$ and the
labor devoted to housing goods production ($l^h_t$). The total capital ($k_t$) is the sum of the capital allocated to production of these two goods ($k^c_t$ and $k^h_t$).

$$l_t = l^c_t + l^h_t$$

$$k_t = k^c_t + k^h_t$$

Importantly, the market value share of housing production $\lambda_t$ for each firm $i$ is defined as follows:

$$\lambda_t = \frac{p^h_t y^h_t}{p^c_t y^c_t + p^h_t y^h_t} = \frac{p^h_t(e^h_t + i^h_t)}{p^c_t(e^c_t + i^c_t) + p^h_t(e^h_t + i^h_t)}$$

The market value share of housing production $\lambda_t$ can be incorporated into firms’ profit to obtain the housing marginal cost ($mc^h_t$). For each firm $i$, the firm’s problem is to maximize the sum of discounted expected profits:

$$\sum_{t=0}^{\infty} r_0^t \Phi_{it} = \sum_{t=0}^{\infty} r_0^t [p^c_t y^c_t + p^h_t y^h_t - \omega_t(l^c_t + l^h_t) - \omega_t(k^c_t + k^h_t)]$$

$$= \sum_{t=0}^{\infty} r_0^t \left( \frac{1}{1} (p^h_t e^h_t + \pi_t (p^h_t)^{1-\eta} i_t) - \omega_t(k^c_t + k^h_t) \right)$$

where $r_0^t$ is the stochastic discount factor, subject to the following six constraints:

1) the production constraint of nondurable goods:

$$z_t(k^c_t)^{\phi_c} (l^c_t)^{1-\phi_c} - c^c_t - (1 - \pi_t)(p^c_t)^{-\eta^c} i_t = 0 \quad (15-1)$$

2) the production constraint of housing goods:

$$z_t(k^h_t)^{\phi_h} (l^h_t)^{1-\phi_h} - c^h_t - \pi_t(p^h_t)^{-\eta^h} i_t = 0 \quad (15-2)$$

where the marginal cost $mc^c_t$ is the Lagrangian multiplier of (15-1), and the marginal cost $mc^h_t$ is the Lagrangian multiplier of (15-2).
3) the optimal nondurable goods consumption level obtained from the household’s problem:

\[(p^c_t)^{-h^c}x^c_t + \theta^c s^c_{it-1} - c^c_t = 0 \]  \hspace{1cm} (16-1)

4) the optimal housing goods consumption level obtained from the household’s problem:

\[(p^h_t)^{-h^h}x^h_t + \theta^h s^h_{it-1} - c^h_t = 0 \]  \hspace{1cm} (16-2)

Note that the shadow value of nondurable goods sales \(v^c_t\) (per unit of discounted future profit, which is driven by one-unit increase in today’s sales of nondurable goods) is the Lagrangian multiplier of (16-1) and the shadow value of housing goods sales \(v^h_t\) is the Lagrangian multiplier of (16-2).

5) the evolution of nondurable goods’ habit stock stated in the household’s problem:

\[\rho^c s^c_{it-1} + (1 - \rho^c)c^c_{it} + e^c_{it} = 0 \]  \hspace{1cm} (17-1)

6) the evolution of housing goods’ habit stock stated in household’s problem:

\[\rho^h s^h_{it-1} + (1 - \rho^h)c^h_{it} + e^h_{it} = 0 \]  \hspace{1cm} (17-2)

Note that the shadow value of nondurable goods habit stock \(\kappa^c_t\) is the Lagrangian multiplier of (17-1); the shadow value of housing goods habit stock \(\kappa^h_t\) is the Lagrangian multiplier of (17-2).

Solving the maximization problem, the following first order conditions are
obtained:

\[ l^c_t : \omega_t = mc^c_t z_t (1 - \phi^c) (k^c_{it})^{\phi^c} \]  
\[ (18-1) \]

\[ l^h_t : \omega_t = mc^h_t z_t (1 - \phi^h) (k^h_{it})^{\phi^h} \]  
\[ (18-2) \]

\[ k^c_t : u_t = mc^c_t z_t \phi^c (k^c_{it})^{\phi^c-1} (l^c_{it})^{1-\phi^c} \]  
\[ (19-1) \]

\[ k^h_t : u_t = mc^h_t \phi^h (k^h_{it})^{\phi^h-1} (l^h_{it})^{1-\phi^h} \]  
\[ (19-2) \]

\[ c^c_{it} : mc^c_t + v^c_t - \kappa^c_t (1 - \rho^c) = 0 \]  
\[ (20) \]

\[ c^h_{it} : \frac{p^h_{it}}{\lambda^t} - mc^h_t - v^h_t + \kappa^h_t (1 - \rho^h) = 0 \]  
\[ (21) \]

\[ s^c_{it} : Er_{t+1}[v^c_{it+1} \theta^c + \rho^c \kappa^c_{it+1}] - \kappa^c_t = 0 \]  
\[ (22) \]

\[ s^h_{it} : Er_{t+1}[v^h_{it+1} \theta^h + \rho^h \kappa^h_{it+1}] - \kappa^h_t = 0 \]  
\[ (23) \]

\[ p^c_{it} : (1 - \pi_t) mc^c_t \eta^c (p^c_{it})^{-\eta^c-1} i_t - \eta^c v^c_t x^c_t (p^c_{it})^{-\eta^c-1} = 0 \]  
\[ (24) \]

\[ p^h_{it} : \frac{p^h_{it}}{\lambda^t} + \frac{(1 - \eta^h)}{\lambda^t} \eta^h \pi^h_i i_t + \pi_t mc^h_t \eta^h (p^h_{it})^{-\eta^h-1} i_t - \eta^h v^h_t x^h_t (p^h_{it})^{-\eta^h-1} = 0 \]  
\[ (25) \]

3.3 Markups

The equilibrium marginal cost of housing goods \((mc^h_t)\) can be obtained by obtaining \(\kappa^h_t\) and \(v^h_t\) from (23) and (25), respectively, plugging them into (21) and applying the following two forms:

\[ i^h_t = \frac{p^h_{it}}{\lambda^t} \eta^h \theta^h \]  

\[ x^h_t = (c^h_{it} - \theta^h s^h_{it-1})(p^h_{it})^{\eta^h} \]

The marginal cost of housing goods \((mc^h_t)\) represented in terms of housing goods’
parameters is as follows:

\[ mc_t^h = \frac{1}{\tilde{\xi}_t} p_t^h \left[ 1 - \frac{1}{\eta^h (1 - \frac{\rho^h \lambda_{t+1}}{y_{t+1}^h})} \right] + \left( \frac{c_{y_t} - \phi_{y_t}^h}{y_{t+1}^h - y_{t}^h} \right) (1 - \rho^h) E_{t,t+1} \left[ v_{t+1}^h \theta^h + \rho^h \kappa_{t+1}^h \right] \]

Thus, the markup of housing goods is represented as:

\[ \mu_t^h = \frac{p_t^h}{mc_t^h} \]

which can be decomposed into three components as follows:

1. \( \frac{1}{\tilde{\xi}_t} p_t^h \left[ 1 - \frac{1}{\eta^h (1 - \frac{\rho^h \lambda_{t+1}}{y_{t+1}^h})} \right] \): the short-term price-elasticity effect
2. \( E_{t,t+1} \left[ v_{t+1}^h \theta^h + \rho^h \kappa_{t+1}^h \right] \): the long-term inter-temporal effect
3. \( \frac{c_{y_t} - \phi_{y_t}^h}{y_{t+1}^h - y_{t}^h} \): the composition effect on the strength of the inter-temporal effect

In the proposed housing deep-habit model, the market value share of housing production (\( \lambda_t \)) works as the linkage between nondurable goods and housing goods sectors. Notice that not only \( \lambda_t \), but also the aggregate demands of the two goods (\( y^c \) and \( y^h \)) affect the pricing decision of firms. In other words, not only the "direction" of change in \( y^c \) and \( y^h \) matters for markups, but also the relative "magnitude" of change in \( y^c \) and \( y^h \). This is one of the main differences between the conventional deep-habit model with only one sector and the housing deep-habit model in this chapter. This will be illustrated through three influential factors, as described in Section 4.
3.4 Steady-State

The stationary competitive equilibrium is defined as a set of 31 variables which satisfy the 31 equations below given \( s_{t-1}, k_{t-1} \). At the steady-state, the relative price \( p_i = 1 \) for all \( i \), and the exogenous stochastic process is set to \( z_t = 1 \).

\[
\begin{align*}
\mathcal{C} = \{ & c_i^c, c_h^h, l_t, h_t, \tilde{p}_t^c, \tilde{p}_t^h, x_t^c, x_t^h, s_t^c, s_t^h, y_t^c, y_t^h, i_t, \hat{i}_t, k_t^c, k_t^h, R_t, \zeta_t, \omega_t, u_t, \\
& mc_t^c, mc_t^h, v_t^c, v_t^h, k_t^c, k_t^h, \mu_t^c, \mu_t^h, \pi_t, \lambda_t \} \\
\zeta &= (x^c)^{-1/e}[(x^c)^{(e-1)/e} + (x^h)^{(e-1)/e}]^{-\sigma/e + 1} \\
\zeta &= (x^h)^{-1/e}[(x^c)^{(e-1)/e} + (x^h)^{(e-1)/e}]^{-\sigma/e + 1} \\
\omega \zeta &= A(1 - l)^{-\chi} \\
\beta R &= 1(R = 1/r) \\
1 &= \beta(1 - \delta + u) \\
\omega &= mc^c(1 - \phi^c)(k^c)^{\phi^c}c^{-\phi^c} \\
\omega &= mc^h(1 - \phi^h)(k^h)^{\phi^h}c^{-\phi^h} \\
u &= mc^c \phi^c(k^c)^{\phi^c-1}(c)^{1-\phi^c} \\
u &= mc^h \phi^h(k^h)^{\phi^h-1}(c)^{1-\phi^h} \\
mc^c + v^c - \kappa^c(1 - \rho^c) &= 0 \\
\frac{1}{\chi} - mc^h - v^h + \kappa^h(1 - \rho^h) &= 0 \\
r\nu c^c \theta^c &= (1 - \rho^c) \kappa^c
\end{align*}
\]
\[
rv^h \theta^h = (1 - r \rho^h)k^h
\]

\[
(1 - \pi)mc^e \eta^c i - \eta^e v^e x^c = 0
\]

\[
\frac{c^h}{\lambda} + \frac{(1 - \eta^h)}{\lambda} \pi i + \pi mc^h \eta^h i - \eta^h v^h x^h = 0
\]

\[
i = \delta k \quad i^c = \delta k^c \quad i^h = \delta k^h
\]

\[
i = i^c + i^h
\]

\[
l = l^c + l^h
\]

\[
k = k^c + k^h
\]

\[
y^c = (k^c)^\phi^c (l^c)^{1-\phi^c}
\]

\[
y^h = (k^h)^\phi^h (l^h)^{1-\phi^h}
\]

\[
x^c = (1 - \theta^c)s^c
\]

\[
x^h = (1 - \theta^h)s^h
\]

\[
s^c = c^c
\]

\[
s^h = c^h
\]

\[
\mu^c = \frac{1}{mc^c}
\]

\[
\mu^h = \frac{1}{mc^h}
\]

\[
\pi = \frac{\rho^h}{i}
\]

\[
\lambda = \frac{c^h + i^h}{c^c + i^c + c^h + i^h}
\]
4. Calibration: Analysis of Factors that Influence Markups

The main goal of this section is to examine the interaction between nondurable goods sector and the housing goods sector. In particular, it investigates how three main factors affect markups of both goods at the steady-state in the housing and nondurable markets, which reflect the main differences between these two sectors: a) the intratemporal elasticity of substitution among varieties of housing goods; b) the level of deep habits; and c) the production share of capital.

Changes in markups of both goods due to the change in one parameter in a single sector illustrate the contribution of the proposed housing deep-habit model – the interaction between these two sectors reflects the important cross-sector roles of these influential factors in explaining markups.

Table 1.1 to 1.3 specifies the influential parameters taken under different scenarios. All values of the parameters are shown in Table 1.4 in the Appendix. The parameterization of $\sigma$, $\chi$, $\eta^c$, $\rho^c$, $\delta$, $\beta$, and $\Phi^c$ is based on Uhlig (2004) and on RSU (2006), in which $\sigma=2$, $\chi=3.08$, $\eta^c=5.3$, $\rho^c=0.85$, $\delta=0.025$, $\beta=0.99$, and $\Phi^c=0.25$. For housing goods, the values applied to the adjustment speed of the external habit stock ($\rho^h$) and the level of deep habits ($\theta^h$) are the same as in RSU (i.e. $\rho^h=0.85$ and $\theta^h=0.86$). The intratemporal elasticity of substitution between nondurable and housing
goods ($\varepsilon = 1.25$) is based on Piazzesi, Schneider and Tuzel (2007). The level of deep habits of nondurable goods is based on Van Binsbergen (2007), which uses 0.72 in the calibration. The share of capital ($\Phi^h$) in the housing sector is based on Jaccard (2007), in which the structure and the land in the housing production function totally occupy about 40%.

The effects of some influential parameters on the steady-state markups are analyzed in the following sections. By changing different values of these parameters (so that some of them deviate from the values suggested in the literatures), the effects on markups can be examined and compared in this housing deep-habit model.

The steady-state markups are quite sensitive to these influential parameters. In the following analyses, various values of these three parameters are set in order to facilitate investigation of their influences on the steady-state markups. Given the values of all parameters, we find that some markups are lower than unity (especially for markups of nondurable goods) in the following sections.

4.1 Intratemporal Elasticity of Substitution among Varieties of Housing Goods

This section analyzes how the intratemporal elasticity of substitution among varieties of housing goods on the demand side affects the steady-state markups of
both goods.

Because transaction costs of housing goods are empirically higher compared to those of nondurable goods, the intratemporal elasticity of substitution among varieties of housing goods is assumed to be lower, $\eta^h$, than that of nondurable goods, $\eta^c$. Table 1.1 shows that, when $\eta^h$ is higher, the steady-state aggregate demands of both sectors ($y^c$ and $y^h$) are higher, and eventually the steady-state markups of both goods ($\mu^c$ and $\mu^h$) and firms’ profit are correspondingly lower. As the elasticity of substitution among varieties of housing goods is higher, firms need to reduce prices (thus the markups are lower) in order to form the customer base. Thus, firms’ profit is lower.

As the steady-states indicate, markups are lower as outputs are higher for both goods. Importantly, as the intratemporal elasticity of substitution among varieties of housing goods is higher, not only markups of housing goods decline, but also those of nondurable goods. This reflects the cross-sector role of the intratemporal elasticity of substitution among varieties of housing goods.

### 4.2 Preference (Level of Deep Habits)

This section analyzes how the level of deep habits of housing goods ($\theta^h$) on the demand side affects markups of both goods. Table 1.2 shows that, overall, as the deep
habits level of housing goods ($\theta^h$) rises, the steady-state aggregate demand of housing sector ($y^h$) rises, while that of nondurable goods sector ($y^c$) declines. Thus, the market value of housing production ($\lambda$) increases, and it drives marginal cost of housing goods down. Eventually, the steady-state markups of both goods and the total profit increase.

The result shows that a change in the level of deep habits of a single sector can affect markups in both sectors through the market value of housing production ($\lambda$). Also, firms’ endogenous production decision is closely related to the level of deep habits. Importantly, it reflects that the relative magnitude of change in outputs matters for markups of both goods. In the model with two sectors, markups are determined by outputs of both sectors instead of by the demand of the single market.

4.3 Technology (Production Share of Capital)

This section analyzes how the production share of capital on the supply side affects markups of both goods.

Table 1.3 shows that as the housing production share of capital ($\Phi^h$) rises, such as that the steady-state moves from scenario 3 towards scenario 1 ($\Phi^h$ increases from 0.35 to 0.4), and from scenario 4 towards scenario 5 ($\Phi^h$ increases from 0.35 to 0.4),
the steady-state aggregate demands of both sectors ($y^c$ and $y^h$) and the market value of housing production ($\lambda$) rise. Eventually, the steady-state markups of nondurable goods decline, while those of housing goods rise. The total profit also declines as markups of nondurable goods decrease in these two cases. Otherwise, as the steady-state moves from scenario 1 toward scenario 5 ($\Phi^c$ increases from 0.25 to 0.3), or from scenario 3 to scenario 4 ($\Phi^c$ increases from 0.25 to 0.3), the steady-state markups of housing goods decline while those of nondurable goods and total profit increase.

These results indicate that as technology changes, markups of both goods move in different directions, and the change in the total profit depends on the relative change in the aggregate demands and markups of the two sectors.

5. Conclusion

This chapter extends the Ravn, Grohe, and Uribe (2006) deep-habit framework to a two-sector dynamic general equilibrium model with nondurable and housing goods in order to get insight into asset pricing. The proposed housing deep-habit model sheds light on the interaction between the nondurable goods sector and housing goods sector both from the supply and from the demand sides. Housing goods are appropriate to be incorporated into the deep-habit framework because of their
remarkably heterogeneous characteristics.

The model incorporates both the market value share of housing production and residential investment share, which act as the linkage between the two sectors in the model. Calibration of the model shows that the change in the influential parameter of the single sector, such as the intratemporal elasticity of substitution among varieties of housing goods, the level of housing goods’ deep habits, and the production share of capital in one sector can affect the steady-state markups and profits in both sectors. This interaction between these two sectors reflects the important cross-sector roles of these influential factors in explaining markups.
References


Table 1.1 Elasticity of Substitution among Varieties of Housing Goods

<table>
<thead>
<tr>
<th>Scenario</th>
<th>1</th>
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1 Introduction

In the last decade, the movement of U.S. house prices departed dramatically from historical patterns. The developments in the housing market were the focus of increased attention because of their potential impact on the economy. The big gains in housing prices raised concerns about the impact on aggregate economic activity and credit markets if this trend was reversed. These concerns were materialized to an unexpected large scale. Housing prices began a downward fall movement in 2006. By 2007, the collapse in the values of subprime mortgages was accompanied by a substantial increase in foreclosures, and unusually large declines in house prices in some states. The housing crisis triggered a financial crisis and a recession—the longest since the Great Depression, and only paralleled in severity by the U.S. recessions that took place in the 1970s and 1980s.

This chapter investigates the relationship between the U.S. housing cycle and the business cycle in the last decades. In particular, it examines whether the recent run up in housing prices, and the subsequent decline is part of recurrent dynamics in the last
few decades or whether this time was unique. The goal is to shed light on the possible origins of the recent boom and bust in the housing market, the linkages with the broad economy, and assessment on future prospects. We find that the crisis in the housing market sector is associated with the particular features of the 2001 recession. The question then is what has changed in the last decade to explain these dramatic shifts?

Figure 2.1 shows the U.S. Census regional and national real median price of houses sold. The shading in the graph indicates the NBER recession dates. The substantial increase in real home prices was observed across all regions of the U.S. The boom started with real home price increases in the West coast, but quickly spread to the Northeast, and to a lesser extent to the Midwest and the South. Even during the 2001 recession, there was real price increases in the West and the Northeast. The result of this rise in regional prices has been a massive increase in national home prices over a period of nearly a decade, which increased by almost 50% from 1996 to 2006.¹ Figures 2.2 to Figure 2.4 show that the dramatic rise in house prices was accompanied by similar rises in ownership rate, house construction, and mortgage growth rate by households. The boom in the housing market ended with a sharp turnaround in real home prices as seen in Figures 2.1 and Figure 2.2. Since the peak in

¹ The median house prices are obtained from the U.S. Census Bureau and are deflated by the U.S. core Consumer Price Index.
the first quarter of 2006 to the third quarter of 2009, the declines in real house prices were around 20%. The rapid growth in mortgage credit and house prices was substituted by record levels mortgage defaults, while the market value of mortgage securities fell sharply. By the end of 2007, the U.S. economy had entered a recession, which started as a mild downturn but turned into a deep contraction with the progression and ramifications of the housing crisis.

Historically, there is a strong link between the business cycle and the housing market cycle. Noticeably, house prices and construction are very closely linked to the U.S. economy until around 2000 (Figures 2.1-2.3), reaching peaks close to NBER recessions and troughs around their end. However, after 2000, prices and construction soared for six years in despite of the 2001 recession. Interestingly, the subsequent housing downturn took place almost for two years before the 2007-2009 recession, the longest lead in the sample. Previously, housing only fell shortly before or with the aggregate economic activity.

In order to investigate the interrelationship among the recent bust in the housing market, economic recession, and related monetary policy actions undertaken by the Federal Reserve, this chapter proposes a nonlinear two-factor model to represent the phases of the housing market cycle and the phases of the business cycle. The business
cycle is represented by the same coincident economic variables considered by the NBER Business Cycle Committee, the official arbiter of business cycle chronology. A latent factor is extracted from these variables, which summarizes their underlying common cyclical movements. A second latent factor is extracted from real housing prices across the four regions of the U.S. to represent the housing sector. The latent factors are assumed to follow distinct two-state Markov switching processes. The Markov process for the business cycle factor represents recession and expansions phases, whereas the Markov process for the housing factor corresponds to high or low phases in the housing market. These cyclical phases of the economy and the housing are linked through the dependence structure of the factors in the transition equations and their covariance.

The Markov probabilities allow analysis of the interactions between the phase of the housing market and the phases of the business cycle. Since the lead-lag relationship between the phases can vary over time, rather than pre-imposing a structure to their linkages, the proposed flexible framework enables us to study their specific lead-lag relationship over each one of the expansions and recessions that occurred in the U.S. in the last 50 years. The advantages of the proposed model are that the common variation and asymmetries in the phases of housing market and the
business cycle are modeled in a flexible setting. In addition, the relationship between the two cycles is analyzed simultaneously in a unified framework. The combined information from the business cycle, interest rates, and the housing market sheds light on the housing market bubble and bust. The Markov switching dynamic bi-factor model is closely related to the framework used in Chauvet (1998/1999), Senyuz (2008), and Chauvet and Senyuz (2009), which apply this approach to study the relationship between the stock market, the bonds market, and the economy.

We find that there is a strong correlation between business cycles and housing market cycles. Generally, low housing prices phases tend to slightly lead economic recessions. During expansions, the probabilities of low housing prices are close to zero, and a couple of months before the beginning of recessions, the probabilities of low housing prices rise substantially. The end of low housing price phases tends to coincide or slightly lag the end of economic recessions.

However, this relationship has changed over time. Noticeably, the housing market did not exhibit a regular cycle during the 2001 recession compared to the historical pattern. For the first time in the sample studied, variables measuring housing supply, demand, and prices did not fall during a recession. Another interesting aspect of the housing cycle in the last decade is that generally the
downturn in housing takes place right before economic recessions. After 2007, the contraction in the housing market led the economic contraction by 2 years.

In summary, the relationship between housing market and business cycle changed remarkably in the last decade. There is a missed link between housing cycle and the business cycle in the early 2000s. Interestingly, while the interrelationship between the housing cycle and the business cycle went missing during the 2001 recession, the link became remarkably strong in the subsequent 2007-2009 recession.

In order to investigate the missed link between the housing cycle and the business cycle, we examine the role of interest rates. Interest rates generally rise during expansions, reaching a peak towards its end. Before the beginning of economic recessions, interest rates start to fall and stay low until the early stages of the subsequent economic expansion. The results show that interest rates are an important factor in the relationship between the business cycle and the housing cycle. There is an inverse relationship between housing prices and the level of and changes in interest rates. In particular, interest rates movements lead housing market cycle: increases in interest rates are related to subsequent decreases in housing prices and housing starts, whereas increases in interest rates are related to subsequent decreases in economic activity.
Thus, it is worth exploring the causes of the changes in the housing cycle by examining the role of interest rates. Given the unique dynamics of the housing cycle since the mid 1990s, we extend the model to allow changes in the relationship between the housing cycle, the business cycle, and interest rates. In order to capture the recent changes between the housing cycle and the business cycle, we allow each of the coefficients of lagged interest rates in the transition equations to follow distinct Markov processes. The results from the model are somewhat striking. The linkage between business cycle factor and interest rate weaken during the 2002-2004 recovery. On effect, the Federal Reserve kept interest rates at low levels during this expansion period due to the uncertainty regarding the end of 2001 recession, and the slow recovery in 2002-2004. On the other hand, the association between lagged interest rates and the housing market factor became much stronger since the 2001 recession.

This suggests that the run up of housing prices, especially since 2001 is associated with the low level of interest rate, which on its turn is associated with the particular features of the 2001 recession and subsequent recovery. In particular, differently from other early stages of expansions, the jobless recovery led the Federal Reserve to keep interest rates at low levels for quite some time. This monetary expansion catalyzed an abrupt increase in housing prices, housing starts, and
ownership. The unique features of the cycle led investors to be uncertain about the possible end of the monetary expansion phase, and the strength of its effect on the housing sector. When interest rates start rising in June 2004, it had a strong negative effect on the housing sector and was associated with a subsequent drastic fall in housing prices. This led many to own negative equity, which induced a wave of default and foreclosures. This was the beginning of the subprime crisis, which evolved into the longest recession since the Great Depression.

The chapter is organized as follows. Section 2 introduces the nonlinear factor model of the housing market and the business cycle that allows examination of the interrelations between the phases of these sectors. Section 3 discusses the data, and Section 4 presents the estimation results. Section 5 extends the model to include the link between business cycles and housing cycles – the interest rate. Section 6 presents the results when this third variable is considered. Section 7 concludes.

2. Literature Review

Some related literature focus on U.S. metropolitan-level housing market. Clayton, Miller, and Peng (2008) build a bivariate panel VAR model to analyze housing markets in 114 metropolitan areas in the U.S. during 1990-2002. They find that both
home prices (nominal) and trading volume (i.e. Turnover, which is defined as sales of existing single family home to its stock) are affected by some exogenous variables, such as the labor employment, the mortgage interest rate, and the stock index. The effect of these exogenous variables on housing markets is particularly significant in low supply-elasticity market. Noticeably, trading volume reacts much more significantly to these exogenous shocks than do prices. In addition, they find that decreases in home prices decrease (and not increases) Granger cause decreases in trading volume. On the other hand, turnover Granger causes prices in tight housing markets with low supply elasticity. Finally, the results indicate that the positive price-volume correlation is primarily explained by their co-movement due to exogenous shocks.

Wheaton and Lee (2007) examine the causality between housing sales (effective sales rate) and house prices using a panel estimation approach (with 101 MSA market in U.S.) between 1980 and 2006. They investigate the causality based on both levels and first differences of these housing variables. They find that higher sales always lead to higher subsequent prices, while higher prices always generate lower subsequent sales volume. Using a VAR system, they conclude that housing markets essentially react to demand shocks, such as the permanent drop of employment and
mortgage rates.

Some studies focus on regional house prices in other countries. For example, Dijk Franses and Raap (2008) develop a panel model to examine the existence of distinct clusters of regions with different house price dynamics in the Netherlands between 1985 and 2005. They find that in different two clusters – rural regions close to large cities; and larger cities and remote rural regions – housing prices behave differently. For example, the average growth rate of housing prices and the magnitude of responses to changes in GDP both differ. In addition, the speed at which regions reacts to price changes in other regions differ for these two distinct clusters. Grimes and Aitken (2005) examines why regional house prices have diverged in New Zealand since 1981. Further, they discuss how housing demand and supply affect house prices in a certain region, and this is the important cause of divergence of regional house prices. If supply’s responsiveness to demand change is fast and sufficient, house prices are not affected a lot by extra demand. Housing supply is affected by land prices and other construction costs, which differ across regions. Because the rate of new regional housing starts (supply), regional demographic and economic developments vary significantly, housing prices diverge across regions.

Divergence among country-specific prices is discussed in Ceron and Suarez
(2006). They apply a two-state Markov switching model to examine housing prices for 14 developed countries from 1970 to 2003. The latent two states, representing hot and cold phases of the housing market, are common for these countries, and capture cyclical component of the housing price growth. In addition, they consider country-specific components. The combination of common cyclical feature and country heterogeneity sheds insight on changes in volatility of housing price growth across two states – during cold phases volatility of prices growth is larger. They find that these volatility phases are quite persistent (about 6 years on average), which has important implication for risk management in housing markets.

Miles (2007) compares housing prices forecasting performance of linear and nonlinear models. The paper examines whether the boom-bust nature of housing market leads non-linear models to better capture asymmetries in price changes. The paper finds that regions with high volatility, such as California, benefit most from nonlinear models. The author argues that GAR model (linear autoregressive model and squares and other powers added – generalized autoregressive model) does the best in forecasting house prices out-of-sample, while Markov-switching model only has a good in-sample fit, as Crawford and Fratantoni (2003) suggest.

This chapter is motivated by Chauvet (1998), Kim and Nelson (1998), and some
other literature, which discuss how to capture business cycle well. Chauvet (1998) establishes a dynamic factor model which integrates the nonlinear regime-switching model of Hamilton (1989), and the spirits of Stock and Watson (1989, 1991, 1993) as suggested by Diebold and Rudebusch (1996). Chauvet (1998) estimates the switching common factor by maximum likelihood method. The four observed individual coincident indicators are total manufacturing and trade sales in 1982 dollars, total personal income less transfer payments in 1987 dollars, employees on nonagricultural payrolls, and industrial production. Based on the proposal of Stock and Watson (1989), there exists an unobserved variable which is defined by assuming that the co-movement of these four observed coincident indicators depend on movement of this unobserved common factor. Each of these four observed indicators is assumed to be uncorrelated with each other in individual's idiosyncratic component, so the common factor summarizes all the covariance among them. Importantly, the movement of this common factor relies on state of economy.

The Markov switching dynamic bi-factor model is closely related to the framework used in Chauvet (1998/1999), Senyuz (2008), and Chauvet and Senyuz (2009), which apply this approach to study the relationship between the stock market, bonds market, and the economy.
3. The Basic Model

We propose a model that accounts for the dynamic links between the housing market cycle and the business cycle. The model is a tool to investigate the historical relationship between the housing market and the business cycle, and the recent bubble-bust in the housing market. The model is composed of two unobserved factors, representing these two sectors. The latent housing market factor, $F_t^H$, is extracted from regional housing prices, while coincident indicators of the economy are used to construct the latent business cycle factor, $F_t^{BC}$. The dynamic factor model is cast in the state-space, which allows simultaneous estimation of the two unobservable factors as well as their intertemporal relationship. The measurement equations are:

$$ Y_{it} = \lambda_i^H F_t^H + \lambda_i^{BC} F_t^{BC} + v_{it} \quad i = 1, 2, \ldots, 8 $$  \quad (1)$$

$$ \psi(L)v_{it} = \varepsilon_{it} \quad \varepsilon_{it} \sim i.i.d. N(0, \sigma_i^2) $$  \quad (2)

Where $Y_{it}$ is the 8 x 1 vector of observable variables in the housing sector and in the business cycle. In particular, it includes the growth rate of median housing prices in the Northeast, the Midwest, the South, and the West, and the growth rate of industrial production, the real personal income, the employment, and manufacturing and trade sales. $\lambda_i^H$ and $\lambda_i^{BC}$ are, respectively, the factor loadings corresponding to the housing
indicators and economic indicators. The idiosyncratic terms, $v_t$, are allowed to be serially correlated with autoregressive coefficients $\psi_i$, whereas $\epsilon_t$ are the measurement errors. The factors are assumed to be uncorrelated with the idiosyncratic terms, $v_t$, at all leads and lags.

Each factor follows a latent vector autoregressive process with the drift term as a function of different Markov switching processes. $S_t^H$ represents low and high price phases in the housing market, and $S_t^{BC}$ represents economic recessions and expansions phases. The transition equations are:

$$F_t^{BC} = \mu_{S_t^{BC}} + \phi F_{t-1}^{BC} + \beta F_{t-1}^{H} + \eta_t^{BC}$$  \hspace{1cm} (3)$$

$$F_t^{H} = \mu_{S_t^{H}} + \phi F_{t-1}^{H} + \beta F_{t-1}^{BC} + \eta_t^{H}$$  \hspace{1cm} (4)$$

with

$$\mu_{S_t^{BC}} = \mu_1^{BC} S_t^{BC} + \mu_0^{BC} (1 - S_t^{BC}) \quad S_t^{BC} = 0, 1$$

$$\mu_{S_t^{H}} = \mu_1^{H} S_t^{H} + \mu_0^{H} (1 - S_t^{H}) \quad S_t^{H} = 0, 1$$

where $\mu_{S_t^{H}}$ is the mean growth rate of housing price in high ($S_t^{H} = 1$) and low states ($S_t^{H} = 0$), whereas $\mu_{S_t^{BC}}$ is the mean growth rate of economic indicator in expansions ($S_t^{BC} = 1$) and recessions ($S_t^{BC} = 0$). The model does not impose a priori restrictions on the relationship between $S_t^{BC}$ and $S_t^{H}$. The consideration of two potentially independent Markov processes allows the factors to represent the housing market
markets and the real economy to switch between phases at different leads or lags. The transition probabilities are:

\[
\begin{align*}
P[S^H_t = 0 | S^H_{t-1} = 0] &= q^H, \quad P[S^H_t = 1 | S^H_{t-1} = 1] = p^H \\
P[S^{BC}_t = 0 | S^{BC}_{t-1} = 0] &= q^{BC}, \quad P[S^{BC}_t = 1 | S^{BC}_{t-1} = 1] = p^{BC}
\end{align*}
\]

with \( \sum_{j=0}^{1} p^{BC}_{ij} = 1, i, j = 0, 1. \)

Thus, the linkages between the two factors are modeled by specifying the factors as following a vector autoregressive system, by their covariance, and by the Markov processes. The coefficients \( \beta^{BC} \) and \( \beta^H \) capture the lead-lag relationship between the housing factor and the business cycle factor, while we assume that variance covariance matrix of the common shocks to each factor, \( \Omega_t \), is non-diagonal. The two factors and the Markov probabilities are simultaneously estimated from the observable variables and from their relationship with each other.

All parameters and factors are simultaneously estimated in one step. The models are first cast in state space form and then a nonlinear discrete version of the Kalman filter is combined with Hamilton’s (1989) algorithm to estimate the models. The increasing number of Markov cases is truncated at each iteration using an approximation suggested by Kim (1994). The nonlinear Kalman filter is initialized using the unconditional mean and unconditional covariance matrix of the state vector.
A nonlinear optimization procedure is used to maximize the likelihood function, which is obtained as a by-product of the probabilities of the Markov states. In particular, the Gauss-Newton and Berndt–Hall–Hall–Hausman algorithm is used, which is based on numerical derivatives and optimal step size. The convergence criterion for the change in the norm of the parameter vector at each iteration is set to 1e-5. For maximization of the likelihood, the parameters are constrained so that the autoregressive processes are stationary, the innovation covariance matrices are positive definite, and the transition probabilities are between 0 and 1. The predictions of the unobserved factors and of the probabilities of the Markov states are obtained as final pass of the nonlinear filter based on the maximum likelihood estimates.

4. Data

The business cycle factor is extracted from the same series used by the NBER Business Cycle Dating Committee to date business cycle turning points. The four economic indicators that move simultaneously with the business cycle are Industrial Production index, obtained from the Federal Reserve Board of Governors, Manufacturing and Trade Sales and Real Personal Income Less Transfer Payments, from the Bureau of Economic Analysis, and Employees on Nonagricultural Payroll,

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from the Bureau of Labor Statistics.

The housing market factor is obtained from quarterly median sales prices of houses sold considering the same regional division used by the US Census Bureau, which consists of four regions: West, Northeast, Midwest, and South. Since the median price of houses sold by region is available in quarterly frequency from 1963Q1, the sample considered is from 1963Q1 to 2007Q4.

Our goal is not to study local factors, but national comovements in housing prices that correlate with the business cycle and with monetary policy. Thus, it is crucial that the sample is long enough to include several housing market and business cycle phases, in order to allow historical analysis of their interaction. We extract this national common cycle from the Census regional level data because these are the longest disaggregate series available. While city or Metropolitan Statistical Data (MSA) may provide a more refined picture of housing price movements, the multivariate framework considered does not allow starting aggregating from these data – it is not computationally feasible to consider all the U.S. MSA due to the size of the matrix of unobserved features involved. In addition, they are only available since 1975, which excludes two full business cycles.³

³ Alternative price indexes are only available at smaller samples that do not consider several past recessions and expansions. For example, the Office of Federal Housing Enterprise Oversight (OFHEO)
The housing series are deflated using the Consumer Price Index (CPI for All Urban Consumers: All Items Less Food & Energy), from the Bureau of Labor Statistics. All variables are considered in the log first difference form.

5. Empirical Results

5.1 Business Cycles

Table 2.2.1 reports the maximum likelihood estimates from the model. The Markov process captures the switches to business cycle phases underlying the four coincident variables. State 0 displays a negative mean (μ_0^{BC} = -0.5) and a shorter average duration, which is associated with economic recessions. State 1 exhibits a positive mean (μ_1^{BC} =1.5) and longer average duration, depicting the features of expansions. In particular, the probability of staying in expansion, p_{11}^{BC}, is higher than the probability of staying in a contraction, p_{00}^{BC}. The expected duration for recession and expansion implied by the switching model is, respectively, 3.7 and 11.1 quarters, compared to 3.6 and 10.8 quarters implied by the NBER dating.4

---

4 For example, the expected duration of recession from the model is determined by the formula: ∑_{k=1}^{∞} p_{00}^{BC} j^k = 1/(1 - p_{00}^{BC}).
Figure 2.5 shows the extracted business cycle factor and the associated smoothed probabilities of recessions, \( P(S_t^{BC} = 0 | T) \). The shading area in the graphs indicates the NBER recession dates. The Markov-switching model captures each of the NBER business cycle peaks and troughs in the sample, which the probabilities of recession closely match. During periods that the NBER classifies as expansions, the probabilities of recession are close to zero. At around the date where the NBER recessions begin, the probabilities of recession spike upward and remain high until around the time when the NBER dates the end of the recessions.

As extensively discussed in the media and in the business cycle literature, both the 1990-1991 and the 2001 recessions were not followed by rapid revival periods as in the previous recessions. This is particularly the case for the 2001 recession, which was followed by a jobless recovery (e.g. Chauvet and Hamilton 2006, Chauvet and Piger 2008, among several others, etc). The probabilities of recession reflect the sluggish recovery – they increase in early 2001 but remain high until mid 2003. Notably, there was a great deal of uncertainty in real time regarding the state of the economy between 2001 and 2003. On effect, the NBER Business Cycle Dating Committee only announced that the 2001 recession ended in November 2001.
months later, in July 2003. This was the longest delay in calling a business cycle turning point by the Committee since its inception in 1978.

5.2 Housing Cycles

The empirical results provide support to the Markov switching framework in the housing sector. The asymmetries in the phases of the housing cycle are also well characterized by the switching dynamic factor, which shares very similar patterns to the business cycle. As for the business cycle, the housing factor displays a significant positive mean ($\mu_1^H = 3.5$) in State 1 and a significant negative mean in State 0 ($\mu_0^H = -2.5$). State 1 exhibits a longer duration, corresponding to high housing price phases, whereas State 0 has a much shorter duration. The expected duration implied by the model for the low housing cycle phase is 8 quarters, and the expected duration of the high housing cycle phase is 34 quarters.

These features can be observed in Figure 2.6, which plots the extracted housing factor and the smoothed probabilities of low housing prices. The probabilities display a clear dichotomous pattern, remaining close to zero during high housing phases and

---

5 An interesting observation is that the probabilities of recession do not remain high after the 2001 recession when the model is estimated using other measures of employment rather than payroll employment. The probabilities of recession in this case signal the end of the recession in November 2001, as does the NBER. This indicates that the “jobless recovery” is intrinsically associated with the formal labor market.
spiking upward close to one during low housing market phases. There have been five low housing phases in the sample studied. The most recent low housing phase started in early 2006, and it had not ended until the last observation in the sample-- 2007Q4.

Figure 2.7 compares the housing factor extracted from the four regional housing prices with the aggregate U.S. house prices, also obtained from the Census. The factor is substantially smoother than the U.S. house prices. The model extracts only the common cyclical fluctuations underlying the four regions, as represented by the factor, while it separates out the idiosyncratic movements that are peculiar to each region. The resulting factor is a national index of housing prices.

5.3 Links between the Housing Cycle and the Business Cycle

The estimated contemporaneous covariance parameter between the housing cycle factor and the business cycle is 0.40. The non-contemporaneous linear relationship between the housing market factor and the economic factor is represented by the coefficients of the vector autoregression in the transition equations (3-4). The coefficient of the lagged business cycle factor in the housing market factor, $\beta^H$, and the coefficient of the lagged housing market factor in the business cycle factor, $\beta^{BC}$ are both positive. That is, on average, a positive economic growth is
followed by a positive housing market growth and vice-versa.

Notice that the vector autoregressive coefficients in the transition equations reflect the average linear relationship between the two factors over the entire sample, without taking into account potential asymmetries before, during, and after recessions or low housing market phases. The lead-lag dynamics of the housing market and the real economy are better depicted by examining their relationship around the transitions between their cyclical phases. This can be directly examined within our proposed nonlinear framework, which allows two distinct (but potentially dependent) Markov processes to represent the housing market and the business cycle. Figure 2.8 plots the smoothed probabilities of recessions and the smoothed probabilities of low housing prices. The graph indicates that the phases of the housing factor are closely associated with the phases of the business cycle. Low housing prices phases tend to slightly lead economic recessions. During expansions, the probabilities of low housing prices are close to zero, and a couple of months before the beginning of recessions the probabilities of low housing prices rise substantially. The end of low housing price phases tends to coincide or slightly lag the end of economic recessions. On average, the housing cycle factor leads the business cycle factors by two quarters.

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6 This indicates that around the end of recessions and beginning of expansions the non-contemporaneous relationship between the housing factor and the business cycle is negative.
5.4 Housing Market Since 2000

An interesting feature of the smoothed probabilities of low housing market phase in Figure 2.8 is that they do not increase during the 2001 recession. Noticeably, the housing market did not exhibit a regular cycle during this period compared to the historical pattern. For the first time in the sample studied, variables measuring housing supply, demand, and prices did not fall during a recession. Figures 1 to 3 show that housing prices and new house construction (housing start and housing permit) are very closely linked until the around 2000. After that, construction continues to increase in spite of the recession in 2001, and continue the upward movement until 2006. The national and regional median prices of houses also sold did not display a typical behavior during this recession. Remarkably, the median prices in the West and Northeast regions presented a steep increase – rather than the expected fall – during the 2001 recession. In fact, there was a continuous increase in prices from 1995 to 2006, with the steepest rise taking place between 2002-2006, when US real housing prices increased by 31%.

Another factor that has changed in the last ten years is the soaring national rate

---

7 Notice that the smoothed probabilities also do not increase during the 1974-1975 recession. During this period, however, even though housing prices were relatively flat, other measures of the housing market such as housing start and housing permit displayed a strong cyclical fluctuation during this recession (Figures 2.1-2.3).
of homeownership. Between 1965 and 1995 the homeownership rate fluctuated between 62 and 64 percent with little discernable trend. After 1995, it jumped 5 percentage points and at the end of 2006 stood at 69% (Figure 2.3). Since then it has retreated down to 67% as of the second quarter of 2009. These movements were so pronounced that from 1998-2006 the total number of renters in the US actually declined for the first time since WWII. That rise meant that approximately 4-1/2 million more families that otherwise would have been renters owned their homes. Investors and second-home buyers also purchased a growing number of properties, accounting for more than one-sixth of all first-lien loans to purchase one-to-four-family site-built homes in 2005 and 2006. A movement in demand this large would certainly be expected soften rents and put great pressure on prices. Since 2006, the number of renters has grown sharply and the number of owners has actually declined.

Another interesting aspect of the housing cycle in the last decade is that generally the downturn in housing takes place right before economic recessions. After 2007, the contraction in the housing market led the economic contraction by 2 years.

In summary, the relationship between housing market and business cycle changed remarkably in the last decade. There is a missed link between housing cycle
and the business cycle in the early 2000s. Interestingly, while the interrelationship between the housing cycle and the business cycle went missing during the 2001 recession, the link became remarkably strong in the subsequent 2007-2009 recession.

6. Housing Market and Interest Rates – Augmented Bi-factor Nonlinear Model

In order to investigate the missed link between the housing cycle and the business cycle, we examine the role of interest rates. Figure 2.9 plots the growth rate of U.S. housing prices, the Federal Funds Rate, the 30-year Mortgage Rate, and NBER recessions. Interest rates generally rise during expansions, reaching a peak towards its end. Before the beginning of economic recessions, interest rates start to fall and stay low until the early stages of the subsequent economic expansion. As it can be observed in Figure 2.9, interest rates are an important factor in the relationship between the business cycle and the housing cycle. There is an inverse relationship between housing prices and the level of and changes in interest rates. In particular, interest rates movements lead housing market cycle: increases in interest rates are related to subsequent decreases in housing prices and housing starts,

---

8 The Effective Federal Funds Rate and the 30-Year Conventional Mortgage Rate (available from 1971Q2) are obtained from the Federal Reserve Bank of Saint Louis.
whereas increases in interest rates are related to subsequent decreases in economic activity.

Thus, it is worth exploring the causes of the changes in the housing cycle by examining the role of interest rates. As it can be observed, a striking feature of the period before, during, and right after the 2001 recession is the level of interest rates compared to historical records. Mortgage rates and the Federal Funds Rate were at their lowest levels since the beginning of the sample (Figure 2.9).

### 6.1 Augmented Model 1 – Introducing Interest Rates

In order to investigate the relationship between interest rates, the housing market, and the business cycle, the proposed model is extended to include interest rates. We consider the same measurement equations as in (1)-(2), but now the transition equations are:

\[
F_t^{BC} = \mu^{BC} + \phi^{BC} F_{t-1}^{BC} + \beta^{H} F_{t-1}^{H} + \phi^{BC} r_{t-1} + \eta_{t}^{BC}
\]  \tag{5}

\[
F_t^{H} = \mu^{H} + \phi^{H} F_{t-1}^{H} + \beta^{BC} F_{t-1}^{BC} + \phi^{H} r_{t-1} + \eta_{t}^{H}
\]  \tag{6}

where \( r_t \) is Federal Funds Rate. Now, the linkages between the housing factor and the business cycle also occur through their relationship with interest rates.

---

9 Notice that this is a common element in 1974-75 recession as well, during which house prices also did not fall.
Table 2.2 shows the estimated lagged interest rate coefficients in the transition equations of the housing factor and business cycle factor, which are negative and highly significant. This highlights the importance of interest rate as a link between housing cycle and business cycle factor. Increases in interest rates are associated with subsequent decreases in the housing sector and in the economic activity.

6.2 Augmented Model 2 – Recent Changes in Interest Rates

Given the unique dynamics of the housing cycle since the mid 1990s, we extend the model to allow changes in the relationship between the housing cycle, the business cycle, and interest rates. In order to capture the recent changes between the housing cycle and the business cycle, we allow each of the coefficients of lagged interest rates in the transition equations to follow distinct Markov processes:

\[
F_{t}^{BC} = \mu_{S_t}^{BC} + \phi_{t}^{BC} F_{t-1}^{BC} + \beta_{t}^{H} F_{t-1}^{H} + \phi_{t}^{BC} r_{t-1} + \eta_{t}^{BC}
\]  
\[ (5') \]

\[
F_{t}^{H} = \mu_{S_t}^{H} + \phi_{t}^{H} F_{t-1}^{H} + \beta_{t}^{BC} F_{t-1}^{BC} + \phi_{t}^{H} r_{t-1} + \eta_{t}^{H}
\]  
\[ (6') \]

with

\[
\phi_{S_t}^{BC} = \phi_{t}^{BC} S_{t}^{BC} + \phi_{0}^{BC} (1 - S_{t}^{BC}) \quad S_{t}^{BC} = 0, 1
\]

\[
\phi_{S_t}^{H} = \phi_{t}^{H} S_{t}^{H} + \phi_{0}^{H} (1 - S_{t}^{H}) \quad S_{t}^{H} = 0, 1
\]

and transition probabilities:
where \( \sum_{j=0}^{1} p_{ij}^{BC} = \sum_{j=0}^{1} p_{ij}^{H} = 1, i, j = 0, 1. \)

6.3 Housing Market, Interest Rates, and the 2001 Recession

The results from the model are somewhat striking. As shown in Table 2.2, there are two significant states for the interest rate coefficients in the business cycle equation as well as in the housing market equation. The estimates show substantially lower interest rate coefficient in the business cycle factor transition equation in State 0, and significantly higher in State 1 (in absolute value). This asymmetry is also observed in the relationship between interest rate and the housing market – the interest rate coefficient in the housing factor transition equation is significantly lower in State 0 and significantly higher in State 1 (in absolute value).

The smoothed probabilities reveal the intuition for these results. Figure 2.10 shows the smoothed probabilities of low interest rate coefficient in the business cycle equation, \( P(S_{t}^{BC*} = 0 | T) \). Over the entire sample until 2002, these probabilities are close to zero. After this year, the probabilities spike upward to values close to one, and stay high until around 2004. That is, the linkage between the business cycle factor
and interest rates weakened during the 2002-2004 recovery. On effect, the Federal Reserve kept interest rates at low levels during this expansion period due to the uncertainty regarding the end of 2001 recession, and the slow recovery in 2002-2004.

On the other hand, the smoothed probabilities of high interest rate coefficient in the housing cycle factor, $P(S_{h^*} = 1 \, | \, T)$, are close to zero until mid 2001. After that date, the probabilities spike upward to values close to one, and stay high until the end of the sample. That is, the association between lagged interest rates and the housing market factor became much stronger since the 2001 recession.
7. Conclusion

This paper examines the historical linkage between business cycles and housing market cycles in order to understand whether the recent boom and bust in the housing sector in the last decade is unique or whether it had historical precedents.

We propose a nonlinear dynamic factor of the joint relationship between the housing market, the business cycle, and interest rates. We find a strong linkage between the business cycle and interest rates, and the housing market cycle and interest rates. However, these relationships have changed during the 2001 recession and subsequent recovery. In particular, we find that the housing market became more sensitive – to a higher extent than the historical record – to interest rates throughout the 2000s.

This suggests that the run up of housing prices, especially since 2001, is associated with the low level of interest rate. The process started in early 2001 when interest rates decreased substantially to minimize the economic recession that had started in March 2001. Differently from other early stages of expansions, the jobless recovery led the Federal Reserve to keep interest rates at low levels for quite some time. The ‘missed’ low housing market cycle during the 2001 recession, the continued growth in house demand and prices, and the record low interest rates led investors to
believe that more likely returns would be realized in good states of the economy, when those returns are higher. The argument is that the monetary expansion during this first period led to both speculation and leveraging, especially regarding lending practices in the housing sector. In other words, this expansion made it possible for marginal borrowers to obtain loans with lower collateral values. These dynamics accentuated in 2003, when the economy was in a full recovery with still low level of interest rates – this catalyzed an abrupt increase in housing prices, housing starts, and the homeownership.

The unique features of the cycle led investors to be uncertain regarding the possible end of the monetary expansion phase, and on the strength of its effect on the housing sector. When interest rates start rising in June 2004, it had the reverse effect in the housing sector. As the previous low interest rates stimulated the sector, the new upward trend in interest rates had a strong negative effect in the housing sector and was associated with a subsequent drastic fall in housing prices. This led many to own negative equity, and induced a wave of default and foreclosures.

The negative developments in the housing market impacted the aggregate economy through reduced investment in housing; a reduction in consumer spending because of decreases in household wealth; contagion in financial markets, which has
negative effects on business investment and consumption of durable goods, in addition to consumers’ and businesses’ confidence about the future, which can constrain plans for future demand and supply. In the end of 2007, the economy entered a recession, which started as a mild contraction. With the ramifications of the subprime crisis and financial contagion in mid 2008, the recession became much more severe and lasted longer than any other recession since the Great Depression.
References


### Table 2.1: Maximum Likelihood Estimates – Basic Model

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Notes: Asymptotic standard errors in parentheses
Table 2.2: Maximum Likelihood Estimates—
Augmented Model with Interest Rates

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Notes: Asymptotic standard errors in parentheses
### Table 2.3: Maximum Likelihood Estimates - Augmented Model with Markov Switching in the Interest Rates Coefficients

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<tr>
<td>$\lambda_{Sales}$</td>
<td>0.81 (0.03)</td>
<td>$\lambda_{Midwest}$</td>
<td>1.36 (0.41)</td>
</tr>
<tr>
<td>$\lambda_{Employment}$</td>
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<td>$\lambda_{South}$</td>
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<tr>
<td>$\sigma_{v,Production}^2$</td>
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<td>$\sigma_{v,Northeast}^2$</td>
<td>38.14 (3.92)</td>
</tr>
<tr>
<td>$\sigma_{v,Income}^2$</td>
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<td>$\sigma_{v,West}^2$</td>
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<td>$\sigma_{v,Sales}^2$</td>
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<td>$\sigma_{v,Employment}^2$</td>
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</tr>
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<td>$\beta^H$</td>
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<td>$\psi_{Northeast}$</td>
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</tr>
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<td>$\varphi^H_1$ (2001 on)</td>
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Notes: Asymptotic standard errors in parentheses
Figure 2.1 – Real Median Prices of Houses Sold by Region in the U.S. and NBER Recessions (Shaded Area)

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Chapter 3 The Role of People's Expectation in the U.S. Housing Market

1. Introduction

Housing asset returns are of great interest in the studies on macroeconomics, asset pricing, and housing market cycles. In particular, the recent U.S. housing boom that started around 1999 and the subsequent bust in the mid 2000s has attracted many discussions and a large number of literature on the housing market aiming to explain the key drivers underlying the sharp recent changes in housing prices.

This chapter investigates the effect of a potential important driver of the recent housing price boom and bust – people's expectations on the U.S. housing asset returns. In particular, this chapter extends the volatility feedback model proposed in Kim, Morley and Nelson (KMN 2004), Turner, Startz, and Nelson (1989), and Campbell and Hentschel (1992) to study the relationship between volatility and returns in the housing market in the last 50 years, assuming different information sets. Exogenous volatility feedback occurs when people modify their future expected asset returns as they observe new information about volatility in the asset market during the current period.
KMN extend the volatility feedback models of Turner, Startz, and Nelson (1989), and Campbell and Hentschel (1992) by assuming that volatility of the U.S. stock market follows a Markov switching process.

As in KMN, this chapter considers two alternative assumptions about information availability to examine the volatility feedback effect: partial revelation and full revelation. The former assumes people can only observe past returns at the true state of the market volatility. The realized asset return is composed of people’s expected return, volatility feedback effect, and shock (news) to the asset market. Thus, people’s updated expectation has an influence on asset returns.

The model has three characteristics, which facilitates its application to the U.S. housing market. First, it emphasizes that volatility feedback is able to capture the comprehensive effects of housing market volatility on all future discounted expected housing asset returns. Some related literature incorporate only partial effects of the Markov-switching in volatility of the housing market on the contemporaneous expected return. For example, Roche (2001) and Ceron and Suarez (2006) restrict the high-volatility state of the housing market to have lower housing asset returns than the low-volatility state. The model considered in this chapter does not have this restriction. Thus, it allows examination of the relationship between housing market volatility and
future expected housing asset returns.

Second, the high-volatility regime of the housing asset returns in the proposed model is able to represent well features of the U.S. housing cycle. Noticeably, the 2001 recession has different characteristics compared to other NBER-dated recessions, and some chapters focus on capturing them. For instance, Kim, Piger and Startz (2007) decompose the business cycle into permanent and transitory components, and Kim, Morley and Piger (2005) introduce a business cycle "bounce-back effect". The model considered in this chapter, which incorporates people’s expectation, is able to capture the 2001 recession due to the volatility feedback effect. Therefore, it proposes an insightful way to characterize the business cycle through cyclical movements in housing prices.

Third, KMN distinguish a one-time permanent structural break component from a temporary but persistent Markov-switching component in the U.S. stock market. This chapter uses Hansen’s (2001) application of Bai and Perron (1998) sequential estimation of breakpoints to identify a potential permanent structural breakpoint in the U.S housing asset returns during the period analyzed. This method allows identification of structural changes at unknown dates in the autoregressive process of time series.
The tests find two significant structural breaks in the U.S. housing market: a break in volatility in 1984Q1 and a break in the mean in 1999Q. The breakpoint in volatility of housing price 1984Q1 coincides with the break towards stabilization found in the US GDP and many other macroeconomic variables, as documented in a vast literature that include McConnell and Perez-Quiros (2000), Kim and Nelson (1999), Chauvet and Potter (2001), Kim, Morley and Piger (2005), Kim, Piger and Startz (2007), Stock and Watson (2008), and Vargas-Silva (2008), among many others. On the other hand, the breakpoint in 1999Q1 identifies a permanent structural change in the U.S. housing market related to the housing price surge that initiate the bubble.

The results indicate a strong positive relationship between the U.S. housing market volatility and the expected housing asset returns. Interestingly, the volatility feedback effect is the most important in the post-1999 period among alternative sub-periods. Further, the high-volatility regime in the proposed model with volatility feedback effect succeeds in matching all NBER-dated recessions, with the exception of the 1973-1975 recession. The findings are of a strong association between people’s expectation and the great uncertainty around the 2001 recession. Additionally, the findings support the assumption that people’s expectation on positive expected housing returns may have played an important role in the dynamics of the housing
bubble in the early 2000s.

This chapter proceeds as follows. Section 2 reviews related literature on the housing market. Section 3 introduces the models and the different assumption regarding information availability in the formation of people’s expectations. Section 4 discusses the methods used to determine the permanent breakpoint. Section 5 shows the empirical results, and Section 6 concludes.

2. Motivation and Literature Review

There is vast literature that emphasizes different aspects of the role of the housing asset in the economy. A strain of the literature regards the housing market as another source of asset returns other than the stock market. For example, Mills (1989) discusses the efficiency of capital stock allocation and divides the real capital returns into two types – returns to housing and to non-housing capital. Cannon, Miller, and Pandher (2006) investigate asset pricing using a cross-sectional approach of risk and returns across the U.S. stock market and the metropolitan housing market at the ZIP code level. Piazzesi, Schneider and Tuzel (2007) and Lustig and Nieuwerburgh (2006) use CCAPM (Consumption-based Capital Asset Pricing Model) to investigate dynamics of the equity premium including the housing market.
According to the recent literature, people's expectation of housing price plays a key role in the U.S. housing market. For example, Glaeser and Gyourko (2007) suggest that the housing price is predictable due to predictability of wages and construction. They argue that a bust follows a quick boom in prices and housing supply. This finding of the housing dynamics supports the implication of their “rational expectation” model. Similarly, Glaeser and Gyourko (2008) emphasize the role of housing supply in the boom-bust housing cycle. They classify the housing bubble into two types – an exogenous irrational bubble and an endogenous self-reinforcing bubble with adaptive expectation of irrational buyers. Further, they argue that the latter bubble results from self-sustaining over-optimism, which is likely to occur in inelastic-supply areas. On the other hand, Davis and Palumbo (2007) argue that the housing market is demand-driven between 1998 and 2004. They propose that both appreciation and volatility of home prices are even more likely to be determined by demand-side factors currently than before due to the sharp rise in prices of the real residential land.

This chapter is partially motivated by the work of Kim, Morley and Nelson (KMN 2004) to investigate the role of volatility feedback and people's future expected housing returns in explaining the dynamics of the U.S. housing market. KMN assume
that volatility of the equity premium follow a two-state Markov-switching process in
the prewar and postwar periods, assuming different assumptions regarding
information availability, which people can utilize to assess the relationship between
variance and the expected mean of the equity premium. Their finding is that there is a
positive relationship between stock market volatility and the equity premium if
volatility feedback affects the current stock prices negatively.

This chapter is also motivated by the literature that assumes a Markov-switching
component in the housing market volatility. For example, Roche (2001) applies the
framework of Schaller and van Norden (1997) to model the housing market by
assuming the existence of two states – a high variance (bad) state and a low variance
(good) state. Also, Ceron and Suarez (2006) discuss the relationship between housing
price volatility and the housing price growth rate, applying a two-state
Markov-switching model to examine housing price dynamics in 14 developed
countries between 1970 and 2003. The common latent two-state variable and the
country-specific component collectively give insights into the change in volatility of
the housing markets across cold and hot states. They find that the volatility is larger
during cold phases, which is associated with low housing market growth.

The related literature which discusses greater stabilization in the U.S. since the
mid-1980s was initiated with the work McConnell and Perez-Quiros (2000). For example, Stock and Watson (2008) use a factor model with different specifications to examine when the instability occurs. They suggest a single breakpoint in 1984Q1 which is associated with the "Great Moderation of output" in accord with the previous literature. Interestingly, 1984Q1 also represents shifts in other macroeconomic variables, such as in the inflation-output relationship. In addition, Kim, Morley and Piger (2005), and Kim, Piger and Startz (2007) use 1984Q1 as the breakpoint based on Kim and Nelson (1999), and McConnell and Perez-Quiros (2000).

Regarding the breakpoints in the housing market, Vargas-Silva (2008) suggest that housing starts are less volatile in all of the four U.S. regional housing markets after 1980, because of the deregulation in the housing financial system. Moreover, Kim, Leatham and Bessler (2007) investigate the dynamic behavior of monthly returns on real estate (REITs), equity markets, and related macroeconomic variables during 1971 to 2004. They find that the real estate market shows a stronger casual relationship with other variables in the post-breakpoint period. Further, they show different dynamic impulse response patterns and forecast error variance decompositions between the pre-break and post-break period. Therefore, they conclude that REITs play a more important exogenous role in the U.S. economy after
the 1980 breakpoint.

The applied model in this chapter is able to identify the 2001 recession, which is markedly different from other NBER-dated recessions. Stock and Watson (2003) find that recessions in the 1980s and the 1990s are a result of the Fed's monetary policies or the sharp decline in the household consumption, while the 2001 recession results from the sharp cut in business investment – especially in information technology.

Some chapters have addressed different features in order to capture the 2001 recession. For example, Kim, Piger and Startz (2007) show that only the permanent factor or only the transitory Markov-switching factor fails to capture the 2001 recession, and both components are needed to identify it. Kim, Morley and Piger (2005) introduce a "bounce-back effect" to capture the business cycle. They assume that instead of the two typical regimes – expansion and recession phases, there is a third one – a high growth-recovery phase in the post-recession period. The model with three regimes still fails to capture the 1970 and 2001 recessions by the smoothed inferences. However, after they consider the structural break in 1984Q1, the model succeeds in capturing these two recessions.

The model considered in this chapter allows an insightful investigation of the U.S. housing market primarily because it incorporates people’s expectation as a driver
of housing prices, and it distinguishes temporary switches between low and high phases of the housing market from permanent switches in the form of breakpoints.

3. The Models

This section introduces the basic models underlying the framework used in this chapter to investigate the U.S. housing market with Markov-switching in volatility.

The Campbell-Shiller’s (1988) framework allows investigation of how the U.S. housing asset return is affected by people’s changing expectation of the housing price. Let the one-period housing asset return be represented as the log-linear approximation:

\[ r_{t+1} = \log(X_{t+1} + D_{t+1}) - \log(X_t) \]  (1)

where \( X_t \) is the housing price, and \( D_{t+1} \) represents the housing rent. As Meese and Wallace (1990) suggest, the housing rent can be used as dividends on the housing asset. Taking the first-order Taylor expansion of equation (1), we obtain:

\[ r_{t+1} = \kappa + \rho x_{t+1} + (1 - \rho) d_{t+1} - x_t \]  (2)

where lower-case letters denote the log of the series. At time \( t+1 \), the housing asset return \( r_{t+1} \) is the sum of a weighted (\( \rho \) and \( 1 - \rho \)) average of log housing price \( x_{t+1} \) (the percentage change in the housing price) and log housing rent \( d_{t+1} \) (the percentage...
change in the housing rent). $\kappa$ is a nonlinear function of $\rho$, which is defined as the average ratio of the quarterly housing price to the sum of the quarterly housing price and the quarterly housing rent. $\rho$ is very close to one because the percentage change in the housing price contributes to housing asset returns much more than the change in the housing rent. Then ex-ante version of (2) can be solved forward to obtain the percentage change in the housing price at time $t$ ($x_t$) in (3):

$$x_t = \frac{\kappa}{1-\rho} + (1-\rho)E_t(\sum_{j=0}^{\infty} d_{t+j} | \Psi_t) - E_t(\sum_{j=0}^{\infty} \rho^j r_{t+j} | \Psi_t)$$  (3)

Applying Kim, Morley and Nelson (KMN 2004) which extend the framework of Campbell and Hentschel (1992) by adding three components of the asset returns – people’s expected returns, a volatility feedback effect, and shocks (news) to the asset market, the proposed model which is to investigate the housing asset market is represented as following:

$$E[r_{t+j} | \Psi_j] = \mu_0 + \mu_1 Pr[S_{t+j} = 1 | \Psi_j] = \mu_0 + \mu_1 Pr[S_t = 1] + \mu_1 \lambda j (Pr[S_{t+j} = 1 | \Psi_j] - Pr[S_t = 1])$$  (4)

$$\sigma_{s_t}^2 = \sigma_0^2 (1 - S_t) + \sigma_1^2 S_t, \quad \sigma_0^2 < \sigma_1^2 ; \quad S_t = 0, 1$$  (5)

$$r_t = E[r_t | \Psi_{t-1}] + f_t + \varepsilon_t, \quad \varepsilon_t \sim N(0, \sigma_{s_t}^2)$$  (6)

where $r_t$ is the housing asset return at time $t$, and it is assumed to consist of three components. First, $E[r_{t+j} | \Psi_j]$ is the expected housing asset return at time $t+j$ under available information set ($\Psi_t$) at the end of time $t$. Second, $f_t$
represents the volatility feedback. Third, \( \epsilon_t \) represents the shocks to the housing market. \( \sigma_{\epsilon_t}^2 \) is the variance of \( \epsilon_t \), which is new information (available during time \( t \)) about future housing rent. \( \mu_0 \) is the mean housing asset return in the low-volatility regime, and \( \mu_1 \) is the volatility-state-dependent housing asset returns. \( S_t=1 \) is the high-volatility regime, and \( S_t=0 \) is the low-volatility regime. Thus, \( (\mu_0+\mu_1) \) is the mean housing asset return in the high-volatility regime which is perfectly expected.

The transition probabilities that govern the evolution of \( S_t \) are \( Pr[S_t=1|S_{t-1}=1]=p \), \( Pr[S_t=0|S_{t-1}=0]=q \), and \( \lambda=p+q-1>0 \) reflects the persistence of volatility regimes because \( \lambda \) is the autoregressive coefficient of volatility state \( S_t \) which is assumed to have a AR(1) strictly stationary stochastic process (Hamilton 1989).

Volatility feedback, \( f_t \), allows revision of future expected housing asset returns due to new information obtained during time \( t \). Housing investors observe the new available information about volatility of housing market through past returns (partial revelation) or through volatility regimes (full revelation) during period of time \( t \), and update their expectation about future housing asset returns. Thus, by definition, it is represented as the expected sum of returns under two different information sets:

\[
  f_t = E\left[ \sum_{j=0}^{\infty} \varphi_j r_{t+j} | \Psi_{t-1} \right] - E\left[ \sum_{j=0}^{\infty} \varphi_j r_{t+j} | \Psi_t' \right]
\]
The information set $\Psi'_t = \Psi_t - r_t > \Psi_{t-1}$. $\Psi_t$ is the information set at the end of time $t$ and it contains the realized housing asset return at time $t$ ($r_t$).

If no volatility feedback is considered, we consider the case in which people are only able to observe past housing asset returns at the beginning of time $t$ in the partial revelation case ($\Psi'_t = \Psi_t = \{r_{t-1}, r_{t-2}, \ldots \}$). Another case considered is that people are able to recognize the volatility regime of the housing market at the beginning of time $t$ in the full revelation case ($\Psi'_t = \Psi_t = \{S_t\}$). Otherwise, if there is volatility feedback effect, information set $\Psi'_t = \{r_{t-1}, r_{t-2}, \ldots \}$, $\Psi_t = \{S_t\}$ is for the partial revelation case, and that is $\Psi'_t = \{S_{t-1}\}$, $\Psi_t = \{S_t\}$ for the full-revelation case.

The news about the housing market $\epsilon_t$ can be decomposed as:

$$\epsilon_t = E[\sum_{j=0}^\infty \Delta d_{t+j} | \Psi'_t] - E[\sum_{j=0}^\infty \Delta d_{t+j} | \Psi_{t-1}]$$

where the change in the housing rent ($\Delta d_t$) can be regarded as the proxy of the housing market condition at time $t$.

Based on (4), the discounted sum of future expected housing asset returns is:

$$E[\sum_{j=0}^\infty \theta^{t+j} | \Psi_t] = \frac{1}{(1-\rho)} + \frac{\mu^2}{(1-\rho)^2} Pr[S_t=1] + \frac{\mu^2}{(1-\rho)} (Pr[S_t=1 | \Psi_t] - Pr[S_t=1])$$

Therefore, volatility feedback is represented as.
\[ f_i = \frac{\mu_1}{1 - \delta \sigma_i^2} (Pr[S_i = 1 | \Psi_{t-1}] - Pr[S_i = 1 | \Psi_t]) = \delta (Pr[S_i = 1 | \Psi_t'] - Pr[S_i = 1 | \Psi_{t-1}]) \]  
\hspace{1cm} (8)

where \( \delta = -\frac{\mu_1}{1 - \sigma_i^2} \).

Finally, combining (6) and (8), the housing asset return \( r_t \) is represented as:

\[ r_t = \mu_0 + \mu_1 Pr[S_i = 1 | \Psi_{t-1}] + \delta (Pr[S_i = 1 | \Psi_t'] - Pr[S_i = 1 | \Psi_{t-1}]) + \epsilon_t \]  
\hspace{1cm} (9)

This chapter extends this framework to investigate the U.S. housing market with Markov-switching in volatility. The relationship between housing volatility and the expected housing asset returns is discussed under four different assumptions regarding information available to agents:

**Model 1:**

\[ r_t = \mu_0 + \epsilon_t \hspace{1cm} \epsilon_t \sim N(0, \sigma_{s_t}^2) \]

\[ \sigma_{s_t}^2 = \sigma_0^2 (1 - S_t) + \sigma_1^2 S_t, \hspace{0.5cm} \sigma_0^2 < \sigma_1^2 ; \hspace{0.5cm} S_t = 0, 1 \]

\[ Pr[S_i = 1 | S_{i-1} = 1] = p, \hspace{0.5cm} Pr[S_i = 0 | S_{i-1} = 0] = q. \]

**Model 2:**

\[ r_t = \mu_0 + \mu_1 Pr[S_i = 1 | \Psi_{t-1}] + \epsilon_t \hspace{1cm} \epsilon_t \sim N(0, \sigma_{s_t}^2) \]

\[ \sigma_{s_t}^2 = \sigma_0^2 (1 - S_t) + \sigma_1^2 S_t, \hspace{0.5cm} \sigma_0^2 < \sigma_1^2 ; \hspace{0.5cm} S_t = 0, 1 \]

\[ Pr[S_i = 1 | S_{i-1} = 1] = p, \hspace{0.5cm} Pr[S_i = 0 | S_{i-1} = 0] = q. \]

\[ \Psi_{t-1} = \Psi_t' = \{r_{t-1}, r_{t-2}, \ldots\} \text{ in the partial revelation case} \]

\[ \Psi_{t-1} = \Psi_t' = \{S_t\} \text{ in the full revelation case} \]
Model 3:

\[ r_t = \mu_0 + \mu_1 \Pr[S_t = 1|\Psi_{t-1}] + \delta (\Pr[S_t = 1|\Psi_{t}'] - \Pr[S_t = 1|\Psi_{t-1}]) + \epsilon_t \]

\[ \epsilon_t \sim N(0, \sigma_{st}^2) \]

\[ \sigma_{st}^2 = \sigma_0^2 (1 - S_t) + \sigma_1^2 S_t, \quad \sigma_0^2 < \sigma_1^2 ; \quad S_t = 0, 1 \]

\[ \Pr[S_t = 1|S_{t-1} = 1] = p, \quad \Pr[S_t = 0|S_{t-1} = 0] = q. \]

\[ \delta = -\frac{\mu_1}{1-\lambda_0} \] for restricted volatility feedback; \( \Psi_{t-1} = \{r_{t-1}, r_{t-2}, \ldots\} \), \( \Psi_t' = \{S_t\} \)

Model 4:

\[ r_t = \mu_0 + \mu_1 \Pr[S_t = 1|\Psi_{t-1}] + \delta (\Pr[S_t = 1|\Psi_{t}'] - \Pr[S_t = 1|\Psi_{t-1}]) + \epsilon_t \]

\[ \epsilon_t \sim N(0, \sigma_{st}^2) \]

\[ \sigma_{st}^2 = \sigma_0^2 (1 - S_t) + \sigma_1^2 S_t, \quad \sigma_0^2 < \sigma_1^2 ; \quad S_t = 0, 1 \]

\[ \Pr[S_t = 1|S_{t-1} = 1] = p, \quad \Pr[S_t = 0|S_{t-1} = 0] = q. \]

\[ \delta = -\frac{\mu_1}{1-\lambda_0} \] for restricted volatility feedback; \( \Psi_{t-1} = \{S_{t-1}\}, \quad \Psi_t' = \{S_t\} \)

Model 1 examines whether or not there is Markov-Switching in housing market volatility. Model 2 assumes no volatility feedback (i.e. \( \delta = 0 \)) and can be used to examine if there is a significant volatility-state-dependent housing asset return (\( \mu_1 \neq 0 \)) in two separate samples under two different information availability assumptions (full and partial revelation in information about volatility).

Model 3 assumes the existence of volatility feedback (i.e.\( \delta \neq 0 \)), and it can be
used to investigate the relationship between volatility and housing asset returns due to partial revelation ($\Psi_{t-1} = \{r_{t-1}, r_{t-2}, \ldots\}$, $\Psi_t = \{S_t\}$). In the partial revelation case, people are only able to observe past housing asset returns at the beginning of time $t$.

Finally, Model 4 can be used to investigate the relationship between return volatility and expected asset returns under full revelation ($\Psi_{t-1} = \{S_{t-1}\}$, $\Psi_t = \{S_t\}$). In this case, people can recognize the volatility regime of the asset market at the beginning of time $t$.

We consider both the restricted volatility feedback ($\delta = -\frac{1}{1-\rho}$) and the unrestricted volatility feedback cases, assuming $\rho=0.997$ as suggested in the existing literature.

4. Breakpoint Determination

4.1 Data

The U.S. housing price $y_t$ is the quarterly Median Sales Prices of House, which is obtained from the U.S. Census Bureau. The data span from 1963Q1 to 2007Q4. The Consumer Price Index (CPI for All Urban Consumers: All Items Less Food & Energy) from the Bureau of Labor Statistics is used as the deflator to obtain the real housing price. The housing asset return $r_t$ in this chapter is defined as log first difference of
the real housing price $100 \log(y_t) - 100 \log(y_{t-1})$.

4.2 Results

Hansen (2001) applies Bai and Perron (1998) sequential estimation test for breakpoints to determine potential structural changes in U.S. labor productivity. This framework is utilized in this chapter to determine the breakpoint of the U.S. housing market. The main advantage of this approach over the conventional Chow’s structural change test is that it allows identification of unknown breakpoints.

Let $y_t$ represents the housing market return, which follows an AR (1) process:

$$y_t = \alpha + \theta y_{t-1} + \epsilon_t$$

$$E\epsilon_t^2 = \sigma^2$$

The test indicates a complete structural change in 1982Q2 based on the least sum of squared errors (minimum of residual variance). The autoregressive parameter ($\theta$) in the pre-break period is 0.15, while it is -0.31 in the post-break period. Further, applying Quandt-Andrews Sup Test (1993) and Andrews-Ploberger Exp Test (1994), the null hypothesis that there is no break change is rejected (asymptotic $p$-value is 0.037 and 0.012, respectively). Thus, there is a statistically significant change in the autoregressive coefficient for the series of housing asset returns.
Additionally, the break in the error variance of the housing asset returns AR(1) ($\sigma^2$) is 2001Q2. In the pre-break period, the standard deviation is 2.64, while in the post-break period, the standard deviation is 3.82. Applying Quandt-Andrews Sup Test (1993) and Andrews-Ploberger Exp Test (1994), we can reject the null hypothesis that there is no break change (asymptotic $p$-value is 0.014 and 0.0475, respectively).

Using Bai’s 90% confidence interval, the uncertainty on the exact date of the breakpoints is large, spanning a period of almost a decade. Thus, we investigate additional breakpoints in the interval.

As it can be observed in Figure 3.3, the housing price soars remarkably around 1998-1999. It suggests that this period might mark important changes in the volatility of the housing market. In addition, giving the important findings and implications regarding the break in volatility in the U.S. output in 1984, we also investigate the behavior of the housing market before and after this date. As discussed below, these dates, which are very close to the ones found in the breakpoint tests turn out to be very important in the analysis of the relationship between volatility feedback and housing asset returns.¹

¹ The results using other breakpoints are available upon request.
5. Empirical Results

5.1 Volatility Feedback Effect on U.S. Housing Asset Returns

5.1.1 Model 1: No volatility-state-dependent housing asset returns and volatility feedback effect

This model examines if there exists Markov-switching in housing market volatility. When 1984Q1 is used as the breakpoint, there is a significant Markov-switching volatility. In particular, the transition probabilities $p$ ($Pr[S_t=1|S_{t-1}=1]$) and $q$ ($Pr[S_t=0|S_{t-1}=0]$) are significant for both subsamples as shown in Part 3 of Table 3.1. When 1999Q1 is used as the breakpoint, the pre-1999 Markov-Switching is significant ($t$-statistics of $q=13.2$ and $t$-statistics of $p=3.6$), but Markov-Switching in the high-volatility regime in the post-1999 is not significant ($t$-statistics of $p=0.16$). The standard deviation in the post-1999 period is almost the same in the high volatility and low-volatility regimes ($\sigma_0=\sigma_1=3.52$), and this corresponds to the result of no significant Markov-switching in this period. This result of Model 1 implies that in the post-1999 there is only a permanent structural change in the housing asset returns, and there is no temporary Markov-switching in volatility.

In both high and low-volatility regimes, the difference of the standard deviation between the pre-period and the post-period is larger for 1999Q1 breakpoint than for
the 1984Q1 breakpoint. For example, in the case without switching variance, the standard deviation is 2.7 in the pre-1999 and 3.5 in the post-1999 period. The difference is about 0.8, while there is almost no difference between the pre-1984 and the post-1984 periods. This result is similar when Markov-switching variance is considered. For example, in the low-volatility regime, the difference of between the pre-1999 and the post-1999 is about 1.4, while the difference is only about 0.1 as 1984Q1 is used as the breakpoint.

This supports our argument that there is a permanent structural change in volatility in the post-1999. The housing price surges remarkably, and the housing asset returns are more volatile during the post-1999 period. As many studies on the U.S. housing market have shown, this period was characterized by a housing boom and bust.

5.1.2 Model 2: Volatility-state-dependent housing asset returns

This model allows investigation of the evidence of the volatility-state-dependent housing asset returns ($\mu_{1}\neq 0$) due to full revelation and partial revelation of information on housing market volatility (Table 3.2).

Only the pre-1984 period with full revelation information has significant
volatility-state-dependent housing asset returns. The high-volatility regime of the pre-1984 has a lower "realized contemporaneous housing asset return" since it is associated with a negative mean ($\mu_1 = -4.92$, $t$-statistic = $-2$).

This result raises two noticeable points. First, full revelation leads to a significant of volatility-state-dependent housing asset returns. Second, because no volatility feedback effect is assumed, the underlying reason for the existence of a “negative correlation" between variance and mean of the housing asset return is uncertain. This is an issue that Models 3 and 4 are able to address.

5.1.3 Model 3: Volatility feedback effect due to partial revelation

The existence of volatility feedback for both cases of freely-estimated and restricted volatility feedback due to partial revelation is investigated in Model 3. Volatility feedback reflects people’s modification of expectation of the future expected housing asset returns because of news about the U.S. housing market during the current period of time.

Part1 of Table 3.3 shows the empirical results without considering the permanent breakpoint in order to highlight its influence on the housing asset returns. It shows that volatility feedback effects are not significant for both the partial and the full
revelation cases at the 5% significance level (the $t$-statistic of $\delta$ is $-1.27$ for the partial revelation case, and $-1.74$ for the full revelation case). In addition, the volatility-state-dependent asset returns ($\mu_1$) are not significant in both cases (the $t$-statistic of $\mu_1$ is $-0.68$ for the partial revelation case, and of $\mu_1$ is $-0.53$ for the full revelation case).

On the other hand, if a permanent breakpoint is considered, all the models have significant negative volatility feedback, except for the post-1984 period (Part 2 of Table 3.3). This illustrates the importance of analyzing the permanent breakpoints in the empirical investigation of volatility feedback effect.

In addition, without imposing a negative sign restriction on volatility feedback, all sub-periods still show significantly negative volatility feedback effect except the post-1984 (which has negative but insignificant feedback effect). In addition, without restriction on volatility feedback, the post-1999 and the pre-1984 have significant volatility-state-dependent housing asset returns (Table 3.3).

For the two alternative breakpoints, volatility feedback effects are stronger in the pre-break periods if no restriction on volatility feedbacks is employed ($\delta$ and $\mu_1$ are estimated separately). On the other hand, volatility feedback effects are weaker in the pre-break periods if the restriction is employed.
5.1.4 Model 4: Volatility feedback effect due to full revelation

The existence of volatility feedback for both restricted and unrestricted volatility feedback due to full revelation is investigated in Model 4. Interestingly, there are three noticeable findings that are similar to the ones found in Model 3. First, in the case of unrestricted volatility feedback, all sub-periods considered show significant negative volatility feedback, with the exception of post-1984. Second, in the case of restricted volatility feedback, only the post-1999 displays significant volatility-state-dependent housing asset returns ($\mu = 2.12$, $t$-statistics = 3.22 for partial revelation case, and $\mu = 1.87$, $t$-statistics = 1.96 for full revelation case). Third, for both the restricted and unrestricted volatility feedback, post-break periods have larger standard deviation ($\sigma_j - \sigma_0$) than the corresponding pre-periods (i.e. the standard deviation is higher post-1984 than pre-1984, and the standard deviation post-1999 is higher than the pre-1999).

In the case of unrestricted volatility feedback, the pre-1999 ($\mu = -2.06$, $t$-statistics = $-1.95$) and the pre-1984 ($\mu = -2.58$, $t$-statistics = $-2.45$) show significant volatility–state-dependent housing asset returns. Noticeably, unrestricted volatility feedback is stronger and more significant in the post-1999, compared to all other sub-periods ($\delta = -6.76$, $t$-statistics = $-11.72$).
5.2 Smoothed Probability of the High-Volatility Regime vs. the Business Cycle

In this section, we interpret the estimated smoothed probabilities of the high-volatility regime in the U.S. housing market. The first goal is to examine the similarity of the smoothed probability inferences across the different proposed models. In particular, the evidence of the volatility feedback effect on asset returns entails exogeneity of market volatility. Although the smoothed probabilities of these two models (full revelation and partial revelation) display different persistence of high-volatility regimes around some recessions, in both cases they lag the 2001 recession and lead the 2007 recession. The smoothed probability inferences support exogeneity of the housing market volatility because the models with full revelation and the models with partial revelation deliver the similarity for both alternative breakpoints.

The second goal is to investigate how the housing cycle represented by the proposed models empirically associate with the U.S. business cycle through housing asset returns. Notice that many other chapters have failed to detect the 2001 recession, since it is quite different from other NBER-dated recessions. The proposed model in this chapter displays that high-volatility probabilities start to rise before the 2001 recession when the 1984Q1 breakpoint is considered, while the probabilities start to
rise with a small lag when the 1999Q1 breakpoint is considered.

The smoothed probabilities of the model with unrestricted volatility feedback due to full revelation and partial revelation are investigated for the two breakpoints—1999Q1 (Figure 3.1) and 1984Q1 (Figure 3.2). The smoothed probabilities of the high-volatility regimes capture high and low phases of the housing market. High volatility means high uncertainty and this happens when the housing market is in a low-price phase. Importantly, high volatility implies low realized returns during current period of time, and high realized returns in the future. Interestingly, this negative relationship between volatility and returns indicate a strong association between the U.S. housing market cycle and the business cycle.

In the pre-1999 period, the probability of high volatility goes up when realized housing returns goes down which occurs around recessions except the 1973-75 recession which was caused by the oil shock from the supply side. However, in the post-1999, probabilities of high volatility did not coincide with the 2001 recession. This reflects that the housing market didn’t experience a low-return phase in this recession.

The current housing bubble can be detected by the realized housing asset returns in the model. The negative relationship between housing volatility and asset returns
always holds before 2001 and after 2004. Otherwise, during 2001-2004, realized returns were very high, but housing volatility was also very high. This was the only time in which the negative relationship between high volatility and low returns was broken.

The expected housing asset returns also can explain the current housing bubble. Volatility went up during the slow recovery phase after the 2001 recession reflecting that revised expectations dominate expectations without using revised information. The special story was that volatility went up in 2001-2003 which can anticipate the housing boom in 2003-2005. In the model, high volatility between 2001 and 2003 implies low realized returns in 2001-2003 and high expected returns in 2003 -2005. Therefore, volatility feedback (revised expected returns) anticipated the bubble in 2003- 2005.

Importantly, the probability of the high-volatility regime continues to be at very high level up to the most current recession since 2007Q4. This reflects there is a significant uncertainty in the U.S. housing market around and after the 2001 recession. The model indicates that the recent housing crisis was associated with a high level of uncertainty or ‘risk’, as measured by the probabilities of high volatility in housing prices. Also, it indicates a strong association between the U.S. housing cycle and the
business cycle.

6. Conclusion

This chapter uses a model that incorporates people’s expectation into the housing asset market to investigate the dynamics of this sector in the last five decades. The analysis is undertaken for the full sample as well as considering two breakpoints in order to distinguish permanent structural breakpoints from the temporary Markov-switching. In particular, two dates are considered---1984Q1 and 1999Q1, which are associated, respectively, with the great moderation and with the start of the boom cycle in the U.S. housing market breakpoints.

The results indicate that the relationship between the U.S. housing market volatility and the expected housing asset returns is significantly positive. Particularly, the important role of people’s expectation on the demand side is strongly supported as the volatility feedback effect is employed.

The post-1999 period is worth the closer investigation because many chapters on the U.S. housing market propose that there is a boom during 1999-2005 and a corresponding bust since the end of 2005. The results of the model in this chapter show three main features of the U.S. housing price in the post-1999. First, if no
volatility feedback effect is considered, there is only a permanent structural change, but no significant temporary Markov-switching in housing volatility and no significant volatility-state-dependent housing asset return in the U.S. housing market. Otherwise, if it is considered, the latter two can be found in the post-1999 and other subsamples. Second, the unrestricted volatility feedback effect is strong with the most significance in the post-1999 among all sub-periods. Third, the difference between high and low volatility is much larger in the post-1999 than in the pre-1999.

Importantly, the negative relationship between volatility and returns indicate a strong association between the U.S. housing market cycle and the business cycle. The current housing bubble can be explained by the realized and expected housing asset returns in the housing market. Noticeably, the significant volatility feedback effect and the smoothed probability inferences indicate a remarkable uncertainty in the U.S. housing market during the post-1999 period.
References


### Table 3.1 No volatility-state-dependent housing returns and volatility feedback

**Part 1: Constant Variance: \( \sigma_0^2 = \sigma_1^2 \)**

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Pre-1999</th>
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</table>

Notes: This table shows Model 1:

\[ r_t = \mu_0 + \varepsilon_t, \varepsilon_t \sim N(0, \sigma^2). \]
Table 3.1 No volatility-state-dependent housing returns and volatility feedback

**Part 2: Independent Switching Variance: p=1-q**

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Notes: This table shows Model 1:

$r_t = \mu_0 + \varepsilon_t \sim N(0, \sigma_{st}^2)$

$\sigma_{st}^2 = \sigma_0^2 (1-S_t) + \sigma_1^2 S_t, \sigma_0^2 < \sigma_1^2 ; S_t = 0, 1$

$Pr [S_t = 0 | S_{t-1} = 0] = q, p = 1-q.
Table 3.1 No volatility-state-dependent housing returns and volatility feedback

Part 3: Markov Switching Variance

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Log Likelihood: -340.145

Markov Switching Variance

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Log Likelihood: -204.596

Notes: This table shows Model 1:

$r_t = \mu_0 + \epsilon_t; \epsilon_t \sim N(0, \sigma_{st}^2)\n
\sigma_{st}^2 = \sigma_0^2 (1-S_t) + \sigma_1^2 S_t, \sigma_0^2 < \sigma_1^2 ; S_t = 0, 1

Pr[S_t = 1 | S_{t-1} = 1] = p, Pr[S_t = 0 | S_{t-1} = 0] = q.
Table 3.2 Volatility-state-dependent housing asset returns

Part 1: Partial Revelation: $\Psi_{t-1} = \Psi_t = \{r_{t-1}, r_{t-2}, \ldots\}$

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No volatility feedback effect
Partial-Revelation (people only observe past asset returns)

Pre-1999

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Notes: This table shows Model 2:

$r_t = \mu_0 + \mu_1 Pr[S_t = 1 | \Psi_{t-1}] + \varepsilon_t, \varepsilon_t \sim N(0, \sigma_{\varepsilon}^2)$

$\sigma_{\varepsilon}^2 = \sigma_0^2 (1 - S_t) + \sigma_1^2 S_t, \sigma_0^2 < \sigma_1^2, S_t = 0, 1$

$Pr[S_t = 1 | S_{t-1} = 1] = p, Pr[S_t = 0 | S_{t-1} = 0] = q.$

$\Psi_{t-1} = \Psi_t = \{r_{t-1}, r_{t-2}, \ldots\}.$
Table 3.2 Volatility-state-dependent housing asset returns

Part 2: Full revelation: $\Psi_{t-1} = \Psi_{t} = \{S_t\}$

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No volatility feedback effect
Full-Revelation (people observe true state of volatility)

<table>
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Notes: This table shows Model 2:
\[ r_t = \mu_0 + \mu_1 \Pr[S_t = 1 | \Psi_{t-1}] + \varepsilon_t; \varepsilon_t \sim N(0, \sigma_{\varepsilon_t}^2) \]
\[ \sigma_{S_t}^2 = \sigma_0^2 (1 - S_t) + \sigma_1^2 S_t; \sigma_0^2 < \sigma_1^2; S_t = 0, 1 \]
\[ \Pr[S_t = 1 | S_{t-1} = 1] = p, \ Pr[S_t = 0 | S_{t-1} = 0] = q. \]
\[ \Psi_{t-1} = \Psi_t = \{S_t\}. \]
Table 3.3 Volatility feedback effect due to partial revelation

Part 1: Full Sample with Volatility feedback effect

<table>
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<tr>
<th>Parameters</th>
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<th>Partial-Revelation (people only observe past asset returns)</th>
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<td>$\delta$</td>
<td>-1.735 -0.680</td>
<td>-1.441 -1.268</td>
</tr>
<tr>
<td>Log Likelihood</td>
<td>-436.662</td>
<td>-189.136</td>
</tr>
</tbody>
</table>

Notes: This table shows Model 3:

$r_t = \mu_0 + \mu_1 Pr[S_t=1|\Psi_{t-1}^i] + \delta (Pr[S_t=1|\Psi_{t}^i] - Pr[S_t=1|\Psi_{t-1}]) + \epsilon_t; \epsilon_t \sim N(0, \sigma_{\epsilon_t})$

$\sigma_{\epsilon_t}^2 = \sigma_\epsilon^2 (1-S_t) + \sigma^2 S_t , \sigma_\epsilon^2 < \sigma^2 ; S_t = 0, 1$

$Pr[S_t=1|S_{t-1}=1] = p , Pr[S_t=0|S_{t-1}=0] = q .

\Psi_{t-1} = \{r_{t-1}, r_{t-2}, \ldots\}, \Psi_t^i = \{S_t^i\}.$
### Table 3.3 Volatility feedback effect due to partial revelation

#### Part 2: Sub-sample with volatility feedback due to partial revelation (Restricted)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Pre-1999</th>
<th>Post-1999</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>σ₀</strong></td>
<td>1.341</td>
<td>1.646</td>
</tr>
<tr>
<td><strong>σ₁</strong></td>
<td>2.268</td>
<td>2.640</td>
</tr>
<tr>
<td><strong>q</strong></td>
<td>0.210</td>
<td>0.843</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td>0.967</td>
<td>0.794</td>
</tr>
<tr>
<td><strong>μ₀</strong></td>
<td>6.092</td>
<td>-0.124</td>
</tr>
<tr>
<td><strong>μ₁</strong></td>
<td>0.071</td>
<td>2.115</td>
</tr>
<tr>
<td><strong>δ</strong></td>
<td>-0.086</td>
<td>-0.189</td>
</tr>
<tr>
<td>Log Likelihood</td>
<td>-337.784</td>
<td>-92.110</td>
</tr>
</tbody>
</table>

#### Partial-Revelation (people only observe past asset returns)

Notes: This table shows Model 3:

\[ r_t = \mu_0 + \mu_1 Pr[S_t=1|\Psi_{t-1}] + \delta (Pr[S_t=1|\Psi_t] - Pr[S_t=1|\Psi_{t-1}]) + \varepsilon_t \]

\[ \sigma_{t}^2 = \sigma_0^2 (1-S_t) + \sigma_1^2 S_t, \quad \sigma_0^2 > \sigma_1^2 \]

\[ Pr[S_t=1|S_{t-1}=1] = p, \quad Pr[S_t=0|S_{t-1}=0] = q. \]

\[ \Psi_{t-1} = \{r_{t-1}, r_{t-2}, \ldots\}, \quad \Psi_t = \{S_t\}; \quad \delta = -\frac{\mu_1}{1-\delta}. \]
### Table 3.3 Volatility feedback effect due to partial revelation

**Part 2: Sub-sample with volatility feedback due to partial revelation**

(Freely-estimated)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Pre-1999</th>
<th>Post-1999</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \sigma_0 )</td>
<td>2.121</td>
<td>2.157</td>
</tr>
<tr>
<td>( \sigma_1 )</td>
<td>2.225</td>
<td>2.752</td>
</tr>
<tr>
<td>( q )</td>
<td>0.486</td>
<td>0.866</td>
</tr>
<tr>
<td>( p )</td>
<td>0.967</td>
<td>0.803</td>
</tr>
<tr>
<td>( \mu_0 )</td>
<td>-1.224</td>
<td>-1.490</td>
</tr>
<tr>
<td>( \mu_1 )</td>
<td>0.400</td>
<td>6.002</td>
</tr>
<tr>
<td>( \delta )</td>
<td>-6.506</td>
<td>-4.831</td>
</tr>
</tbody>
</table>

Log Likelihood: -337.400

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Pre-1984</th>
<th>Post-1984</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \sigma_0 )</td>
<td>2.280</td>
<td>1.961</td>
</tr>
<tr>
<td>( \sigma_1 )</td>
<td>2.766</td>
<td>4.064</td>
</tr>
<tr>
<td>( q )</td>
<td>0.966</td>
<td>0.950</td>
</tr>
<tr>
<td>( p )</td>
<td>0.837</td>
<td>0.903</td>
</tr>
<tr>
<td>( \mu_0 )</td>
<td>0.820</td>
<td>0.741</td>
</tr>
<tr>
<td>( \mu_1 )</td>
<td>-2.209</td>
<td>-0.087</td>
</tr>
<tr>
<td>( \delta )</td>
<td>-5.207</td>
<td>-0.493</td>
</tr>
</tbody>
</table>

Log Likelihood: -200.676

Notes: This table shows Model 3:

\[
\begin{align*}
r_t &= \mu_0 + \mu_1 Pr[S_t = 1|\Psi_{t-1}] + \delta (Pr[S_t = 1|\Psi_{t-1}'] - Pr[S_t = 1|\Psi_{t-1}]) + \varepsilon_t; \varepsilon_t \sim N(0, \sigma_s^2) \\
\sigma_s^2 &= \sigma_0^2 (1 - S_t) + \sigma_1^2 S_t; \sigma_0^2 < \sigma_1^2; S_t = 0, 1 \\
Pr[S_t = 1|S_{t-1} = 1] &= p; Pr[S_t = 0|S_{t-1} = 0] = q \\
\Psi_{t-1} &= \{r_{t-1}, r_{t-2}, \ldots\}, \Psi_t = \{S_t\}.
\end{align*}
\]
### Table 3.4 Volatility feedback effect due to full revelation (Restricted)

Restricted volatility feedback effect ($\delta = -\mu_1/(1-\rho \lambda)$)

Full-Revelation (people observe the true state of volatility)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Pre-1999</th>
<th>Post-1999</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>value</td>
<td>t-statistic</td>
</tr>
<tr>
<td>$\sigma_0$</td>
<td>2.218</td>
<td>9.441</td>
</tr>
<tr>
<td>$\sigma_1$</td>
<td>3.892</td>
<td>2.162</td>
</tr>
<tr>
<td>$q$</td>
<td>0.950</td>
<td>14.307</td>
</tr>
<tr>
<td>$p$</td>
<td>0.428</td>
<td>0.938</td>
</tr>
<tr>
<td>$\mu_0$</td>
<td>0.145</td>
<td>0.466</td>
</tr>
<tr>
<td>$\mu_1$</td>
<td>2.611</td>
<td>0.529</td>
</tr>
<tr>
<td>$\delta$</td>
<td>-4.190</td>
<td>-5.556</td>
</tr>
<tr>
<td>Log Likelihood</td>
<td>-338.456</td>
<td>-96.104</td>
</tr>
</tbody>
</table>

Restricted volatility feedback effect ($\delta = -\mu_1/(1-\rho \lambda)$)

Full-Revelation (people observe the true state of volatility)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Pre-1984</th>
<th>Post-1984</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>value</td>
<td>t-statistic</td>
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<tr>
<td>$\sigma_0$</td>
<td>0.698</td>
<td>2.102</td>
</tr>
<tr>
<td>$\sigma_1$</td>
<td>2.497</td>
<td>11.526</td>
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<tr>
<td>$q$</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>$p$</td>
<td>0.948</td>
<td>34.474</td>
</tr>
<tr>
<td>$\mu_0$</td>
<td>7.628</td>
<td>13.824</td>
</tr>
<tr>
<td>$\mu_1$</td>
<td>-0.069</td>
<td>-0.165</td>
</tr>
<tr>
<td>$\delta$</td>
<td>0.066</td>
<td>-3.485</td>
</tr>
<tr>
<td>Log Likelihood</td>
<td>-202.057</td>
<td>-232.639</td>
</tr>
</tbody>
</table>

Notes: This table shows Model 4:

$r_t = \mu_0 + \mu_1 Pr[S_t = 1|\Psi_{t-1}] + \delta (Pr[S_t = 1|\Psi_t'] - Pr[S_t = 1|\Psi_{t-1}']) + \epsilon_t; \epsilon_t \sim N(0, \sigma_{\epsilon t}^2)$

$\sigma_{\epsilon t}^2 = \sigma_0^2 (1 - S_t) + \sigma_1^2 S_t$. $\sigma_0^2 < \sigma_1^2$ ; $S_t = 0, 1$

$Pr[S_t = 1|S_{t-1} = 1] = p$, $Pr[S_t = 0|S_{t-1} = 0] = q$

$\Psi_{t-1} = \{S_{t-1}\}$, $\Psi_t' = \{S_t\}$; $\delta = -\frac{\mu_1}{1-\rho \lambda}$
Table 3.4 Volatility feedback effect due to full revelation (Freely-estimated)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Pre-1999</th>
<th>Post-1999</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>value</td>
<td>t-statistic</td>
</tr>
<tr>
<td>$\sigma_0$</td>
<td>2.174</td>
<td>14.636</td>
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<tr>
<td>$\sigma_1$</td>
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<td>4.394</td>
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<tr>
<td>$q$</td>
<td>0.973</td>
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<td>$p$</td>
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<td>6.523</td>
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<td>$\mu_0$</td>
<td>0.586</td>
<td>2.502</td>
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<tr>
<td>$\mu_1$</td>
<td>-2.058</td>
<td>-1.953</td>
</tr>
<tr>
<td>$\delta$</td>
<td>-6.125</td>
<td>-4.004</td>
</tr>
<tr>
<td>Log Likelihood</td>
<td>-336.780</td>
<td>-91.064</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Pre-1984</th>
<th>Post-1984</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>value</td>
<td>t-statistic</td>
</tr>
<tr>
<td>$\sigma_0$</td>
<td>2.263</td>
<td>10.580</td>
</tr>
<tr>
<td>$\sigma_1$</td>
<td>2.758</td>
<td>4.697</td>
</tr>
<tr>
<td>$q$</td>
<td>0.963</td>
<td>33.538</td>
</tr>
<tr>
<td>$p$</td>
<td>0.853</td>
<td>8.539</td>
</tr>
<tr>
<td>$\mu_0$</td>
<td>0.906</td>
<td>2.732</td>
</tr>
<tr>
<td>$\mu_1$</td>
<td>-2.578</td>
<td>-2.450</td>
</tr>
<tr>
<td>$\delta$</td>
<td>-5.810</td>
<td>-3.489</td>
</tr>
<tr>
<td>Log Likelihood</td>
<td>-200.997</td>
<td>-232.807</td>
</tr>
</tbody>
</table>

Notes: This table shows Model 4:
\[ r_t = \mu_0 + \mu_1 Pr[S_t = 1 | \Psi_{t-1}] + \delta (Pr[S_t = 1 | \Psi_t] - Pr[S_t = 1 | \Psi_{t-1}]) + \epsilon_t; \epsilon_t \sim N(0, \sigma_st^2) \]
\[ \sigma_st^2 = \sigma_0^2 (1 - S_t) + \sigma_1^2 S_t, \quad \sigma_0^2 < \sigma_1^2; \quad S_t = 0, 1 \]
\[ Pr[S_t = 1 | S_{t-1} = 1] = p, \quad Pr[S_t = 0 | S_{t-1} = 0] = q \]
\[ \Psi_{t-1} = \{S_{t-1}\}, \quad \Psi_t = \{S_t\}. \]
Figures

Figure 3.1: Smooth Probabilities -1999 Breakpoint

Figure 3.1A: Smoothed probabilities of high volatility regimes (in solid blue ink) for the model with freely-estimated feedback due to *full* revelation – Pre-1999

![Graph showing smoothed probabilities for the model with freely-estimated feedback due to full revelation - Pre-1999.](image)

Notes: The shaded areas are NBER recessions.

Figure 3.1B: Smoothed probabilities of high volatility regimes (in solid blue ink) for the model with freely-estimated feedback due to *full* revelation – Post-1999

![Graph showing smoothed probabilities for the model with freely-estimated feedback due to full revelation - Post-1999.](image)

Notes: The shaded areas are NBER recessions.
Figure 3.1C: Smoothed probabilities of high volatility regimes (in solid blue ink) for the model with freely-estimated feedback due to partial revelation – Pre-1999

Notes: The shaded areas are NBER recessions.

Figure 3.1D: Smoothed probabilities of high volatility regimes (in solid blue ink) for the model with freely-estimated feedback due to partial revelation – Post-1999

Notes: The shaded areas are NBER recessions.
Figure 3.2: Smooth Probabilities- 1984 Breakpoint

Figure 3.2A: Smoothed probabilities of high volatility regimes (in solid blue ink) for the model with freely-estimated feedback due to full revelation – Pre-1984

Notes: The shaded areas are NBER recessions.

Figure 3.2B: Smoothed probabilities of high volatility regimes (in solid blue ink) for the model with freely-estimated feedback due to full revelation – Post-1984

Notes: The shaded areas are NBER recessions.
Figure 3.2C: Smoothed probabilities of high volatility regimes (in solid blue ink) for the model with freely-estimated feedback due to partial revelation – Pre-1984

Notes: The shaded areas are NBER recessions.

Figure 3.2D: Smoothed probabilities of high volatility regimes (in solid blue ink) for the model with freely-estimated feedback due to partial revelation – Post-1984

Notes: The shaded areas are NBER recessions.
Figure 3.3 U.S. Real Housing Price (1963Q1-2007Q4)
CONCLUSION

This dissertation is devoted to investigating the U.S. housing market from both theoretical and empirical perspectives. The core of my research lies in the interesting implications of macroeconomic facts, especially the causes and drivers of the recent housing bubble, which the applied/extended models can deliver. The housing good is not only a consumption substitute of the non-durable good, but also an investment asset whose quantity and price have cyclical properties. Hence, the theoretical study on housing is a connection of macroeconomic endogenous decisions and the asset market. The empirical study on housing can shed light on the business cycle.

Chapter 1 proposes a housing deep-habit model which is extended from Ravn, Grohe, and Uribe (2006) deep-habit framework to a two-sector dynamic general equilibrium model with nondurable and housing goods. Housing goods are appropriate to be incorporated into the deep-habit framework because they have remarkably heterogeneous characteristics. In this model, the market value share of housing production and residential investment share act as the linkage between the two sectors. The model implies that the change in the influential parameter of the single sector, such as the intratemporal elasticity of substitution among varieties of
housing goods, the level of housing goods’ deep habits, and the production share of capital in one sector, affect the steady-state markups and profits in both sectors. The interaction between nondurable and housing sectors reflects the important cross-sector roles of these influential factors in explaining markups.

Chapter 2 explores the seed of the housing market bust and the current economic crisis since 2007. The proposed nonlinear dynamic bi-factor model with Markov-switching components indicates the strong historical linkage between the housing cycle and the business cycle, that between the housing cycle and interest rates, and that between the business cycle and interest rates. However, we find their relationship with the interest rate changed remarkably around the 2001 recession and during its subsequent slow recovery primarily because interest rates were kept at the low level by the Fed which aimed to motivate the U.S. economy. The linkage between the business cycle and interest rates weakened, while that between the housing cycle and interest rates significantly strengthened since the 2001 recession. The missed linkage between the housing cycle and the business cycle since this recession triggered the current housing crisis and the economic recession.

Chapter 3 applies Kim, Morley and Nelson (KMN 2004) that incorporates people’s expectation into the housing asset market to investigate the dynamics of this
sector during 1963-2007. The empirical results suggest the significantly positive relationship between the U.S. housing market volatility and the expected housing asset returns, and they support the important role of people’s expectation on the demand side of the housing market if the volatility feedback effect is considered.

In addition, this chapter indicates three main features of the U.S. housing price in the post-1999 during which the recent housing boom and bust occur. First, if volatility feedback effect is considered, significant temporary Markov-switching in volatility and volatility-state-dependent housing asset return in the U.S. housing market are found. Second, the unrestricted volatility feedback is strong with the most significant effect in the post-1999 among all sub-periods. Third, the difference between high and low volatility is much larger in the post-1999 than the pre-1999.

The strong association between the U.S. housing market cycle and the business cycle is supported, and it is implied by the close relationship between housing volatility and returns in the proposed model. Noticeably, significant volatility feedback effect and the smoothed probability inferences indicate a remarkable uncertainty in the U.S. housing market during the post-1999 period---it corresponds to that in Chapter 2 which points out the uncertainty around the 2001 recession.

The housing market is discussed in the growing studies from various
perspectives. This dissertation is devoted to delivering the theoretical implication of housing asset pricing and the empirical investigation of housing cyclical properties. Hopefully they can motivate related researches which either investigate the housing market further, or connect the housing sector with other economic activities and financial markets.