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Implications of Homeownership for Endogenous Risk Aversion, Asset Pricing and Portfolio Composition

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Author
Liang, Xuan

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UNIVERSITY OF CALIFORNIA, SAN DIEGO

Implications of Homeownership for Endogenous Risk Aversion, Asset Pricing and Portfolio Composition

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy in Economics by Xuan Liang

Committee in charge:

Professor Marjorie Flavin, Chair
Professor Thomas Baranga
Professor James Hamilton
Professor Alexis Toda
Professor Rossen Valkanov

2015
The dissertation of Xuan Liang is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

Chair

University of California, San Diego

2015
DEDICATION

To

My Parents,

Qin Zhang
and
Weimin Liang
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Chapter 1, in part, is currently being prepared for submission for publication of the material. Flavin, Marjorie; Liang, Xuan. The dissertation author is one of the primary investigators and authors of this material.
VITA

2010  B. S. in Mathematics, University of Michigan, Ann Arbor
2010  B. S. in Economics, University of Michigan, Ann Arbor
2013  M. A. in Economics, University of California, San Diego
2015  Ph. D. in Economics, University of California, San Diego

PUBLICATIONS

ABSTRACT OF THE DISSERTATION

Implications of Homeownership for Endogenous Risk Aversion, Asset Pricing and Portfolio Composition

by

Xuan Liang

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Professor Marjorie Flavin, Chair

The dissertation studies the role of housing in asset pricing and household asset allocation. Housing is unique in the sense that it is both an asset and a consumption good. In addition, any adjustment in housing consumption will incur a non-convex adjustment cost. This makes housing adjustment infrequent. Due to these unique characteristics, the role of housing in a household portfolio is quite different from financial assets such as stocks and bonds.

The first chapter, “The Housing CCAPM with Adjustment Costs and Heterogeneous Agents” examines how the inclusion of housing consumption in the utility function can increase the volatility and countercyclicality of the stochastic discount factor and thus help explain a higher level of equity premium despite only
moderate curvature of the utility function. The keys to better performance of the model are (i) existence of the adjustment cost (ii) non-separability between housing goods and nondurable goods in the utility function and (iii) low substitutability between housing consumption and nondurable consumption. It is also shown that the housing CCAPM performs better than a standard CCAPM in explaining the variation of cross-sectional risk premia.

Chapter 2, “Implications of the Housing Market for Endogenous Risk Aversion” studies household portfolio choice in a partial equilibrium model with housing consumption, adjustment costs, and varying housing prices. It is shown that household relative risk aversion is dependent on their house value to wealth ratio. Therefore, by changing the household’s house value to wealth ratio, variation in house prices can affect household stock holdings through a change in household risk aversion. In addition, the model has two specific implications for households. The first is that volatile house price dynamics leads to more frequent moving. The second is that household moving leads to higher relative risk aversion. In general equilibrium, these effects would imply that volatile housing prices can lead to a higher moving frequency and thus result in a higher level of aggregate risk aversion, which would increase the price of risk in the risky asset markets. We provide empirical evidence that there is a high correlation between housing price volatility and the price of risk.

Chapter 3, “Implications of the Housing Model for Moving Frequency, Relative Risk Aversion and the Portfolio Share of Risky Assets” tests the implications of the household portfolio choice model developed in Chapter 2 using household level data from the Panel Study of Income Dynamics and finds that the empirical evidence is consistent with the model. Firstly, we use cross-sectional variation in state level house prices and household moving to study the relationship between the volatility of house prices and moving frequency. Secondly, we use household moving and portfolio data to study the effect of moving on risk aversion. In addition, Chapter 3 also studies the effect of becoming unemployed on household moving by solving a model with housing consumption, adjustment costs, and a stochastic labor income process. The result suggests that the overall effect of un-
employment is to reduce the frequency of moving. In addition, a sudden shift to an unemployed status can increase household risk aversion. Thus in general equilibrium, we would expect that a higher unemployment rate will increase economy wide risk aversion, which will in turn decrease the demand for stocks and increase the risk premium required. This provides a new channel (through the change in risk aversion) for the unemployment rate to affect asset prices.
Chapter 1

The Housing CCAPM with Adjustment Costs and Heterogeneous Agents

Abstract

We explicitly model housing consumption in a consumption based CAPM framework with heterogeneous agents. Due to non-convex adjustment costs associated with housing consumption, the adjustment of housing is infrequent. For most periods, the household maximizes over nondurable consumption conditional on their current level of housing consumption. When the intratemporal substitutability of the two goods is limited, we show that, theoretically, the stochastic discount factor derived from a housing CCAPM is more volatile and more countercyclical than a SDF from a standard version of the model (without housing). Empirically, we show that housing CCAPM performs better than a standard CCAPM in terms of both explaining level of equity premium with moderate level of curvature of the utility function and explaining more of the variation of cross-sectional risk premia.
1.1 Introduction

The goal of this paper is to test empirically whether modeling housing explicitly in a consumption based capital asset pricing model improves the performance of the model in terms of (1) better explaining the equity premium with moderate curvature of utility function and (2) better explaining cross-sectional differences in excess returns. We focus on these two points because the literature has shown that the standard CCAPM does poorly in terms of these two empirical implications. It is well known that the standard model would require an unreasonably high curvature of the utility function to explain the level of the equity premium observed in the data, and that the model has very limited power in explaining the cross-sectional variation in risk premia.

The problem with the standard CCAPM is that in order to use per capita consumption growth to explain the high excess returns observed in the U.S data, an implausibly high level of risk aversion of households is needed (Mehra and Prescott, 1985 [32]). Another way of stating the empirical problem is that the consumption growth rate observed in the data is too smooth and not sufficiently volatile, which implies low risk aversion under the standard model. Consequently, a high level of the risk premium, according to the standard model, only arises when risk aversion is implausibly high.

With a non-convex adjustment cost and non-separability between housing and nondurable consumption, the housing model introduces an additional state variable, the house size, which remains the same for substantial periods of time. Therefore, apart from the nondurable consumption growth factor in the standard CCAPM, the housing model introduces a new risk factor which is the difference between nondurable consumption growth and composite consumption growth.\(^1\) We show mathematically that if housing consumption and nondurable consumption are more like complements than like substitutes, the second risk factor will complement the movement of the first risk factor and thus make the stochastic discount factor more volatile without requiring a high level of risk aversion.

\(^1\)Composite good is defined in our model as a CES function over nondurable consumption and housing consumption. For a formal definition, please see section 1.2.
Apart from the housing model, there are mainly two types of models that have been developed in the literature to address the equity premium puzzle. One is the habit-persistence model (Abel, 1990 [1], Constantinides, 1990 [11] and Constantinides and Ferson, 1991 [18]). Similar to the housing model, the habit-persistence model introduces an additional state variable, which is interpreted as the habitual level of consumption. The period utility function depends on the difference between actual and habitual consumption. The idea is that utility today depends on how much today’s consumption is compared with habitual consumption. This can also magnify households’ dislike of a change in consumption given any level of risk aversion, since a given percentage change in consumption produces a much larger percentage change in habit-adjusted consumption than in consumption itself. In this way, small fluctuations in consumption growth can generate large variations in habit-adjusted consumption growth and hence explain sizable excess return on risky assets even for moderate values of the degree of risk aversion. However, empirical results from Dynan (2000) [13] shows that there is very little evidence of habit persistence at the household level. Furthermore, Flavin and Nakagawa (2008) [21] show that the parameter restrictions implied by the habit-persistence model are rejected decisively while the restrictions imposed by the housing model are not rejected. The other type of models uses Epstein-Zin preferences (Epstein and Zin, 1989 [16],1991 [17]), a specification of recursive utility. By introducing extra parameters, the utility specification is able to separate the elasticity of intertemporal substitution from risk aversion and thus potentially solve equity premium puzzle. However, Epstein-Zin preferences are less intuitive compared with the housing model, which assumes time-separability and imposes a simple aggregation over nondurable and housing consumption.

There has not been much research that explicitly introduces housing into a CCAPM framework. The most closely related paper is Piazzesi, Schneider and Tuzel (2008) [38]. There are three primary differences in the assumptions made by Piazzesi et al. (2008) [38] and our own work. First, Piazzesi et al. (2008) [38] assume housing consumption can be adjusted frictionlessly, while we assume there is non-convex adjustment cost associated with housing and thus, housing adjust-
ment is infrequent. In addition to the intuitive plausibility of the existence of a non-negligible adjustment cost on housing, it is easy to appeal to survey data to support the assumption. For example, among all households included in the Consumer Expenditure Survey (CEX) from 1980-2010, only 364 households moved during the years they were interviewed. This means that for the vast majority of households, their real housing consumption doesn’t change from quarter to quarter. Theoretically, during periods that households find it optimal not to incur the adjustment cost and thus keep housing fixed, housing consumption becomes a state variable and the household would then choose nondurable consumption conditional on their current level of housing consumption. In this context, the intratemporal first order condition that sets ratio of marginal utility of housing consumption and non-housing consumption equal to their relative price will not hold period by period for each household. Another major difference between our paper and theirs is that we explore the empirical implication of the model based on a different range for the parameter that governs intratemporal substitution between nondurable consumption and housing consumption. In fact, a primary objective of the paper is the estimation of the parameter governing intratemporal substitutability using data from the CEX. Finally, we do not assume a complete markets setting and therefore use a micro level data set, while they assume market completeness and use aggregate per capita data to estimate a representative agent version of the model.

Since we use a microlevel data set to both estimate and study the implication of the model, our paper is closely related to the literature on heterogeneous agents and asset pricing. The idea is that if the Euler equation holds for all households, then each SDF derived from household level consumption data will be a valid SDF. However, since the SDF is nonlinear in consumption, using aggregate consumption to construct a SDF is a misspecification. To obtain a good measure of the aggregate SDF, two aggregation approaches have been used in the literature. One is a simple average over all households SDFs proposed by Constantinides and Duffie (1996) [12]. The other is to take the average over marginal utilities proposed by Balduzzi and Yao (2007) [5]. In this paper, we study the implications based on
the first aggregation approach because we believe the marginal rate of substitution should be calculated at household level.

Another strand of literature that is closely related with our research is empirical testing of CCAPM. We follow Brav, Constantinides and Geczy (2002) [7] in testing the extent to which the standard model and the housing model are capable of explaining the equity premium. We find that the equity premium is consistent with housing model with heterogeneous agents, for plausible values of the parameters governing the intratemporal substitutability of the two goods and the curvature of the utility function with respect to the composite good.

We also estimate the extent to which the housing model is capable of explaining the cross-section of expected excess returns using Fama-MacBeth regressions. In specifications derived from unconditional Euler equations, we find that the housing CCAPM explains much more of the cross-sectional variation in risk premia than the standard CCAPM. In future research, we would like to investigate whether the explanatory power of Housing CCAPM increases when conditional moments are taken into account, as in Lettau and Ludvigson (2001) [27]. The intuition is that some portfolios are riskier and have higher excess returns not because of high unconditional correlation with consumption growth, but because of high correlation with consumption growth during times of high risk or risk aversion. Their study was based on standard CCAPM and used the log ratio of consumption to wealth as the conditioning variable. One advantage of the housing model is that it is able to generate time varying risk aversion, in contrast to the standard model.

Finally, as is well known, households’ limited participation in asset markets is an important issue that could cause the CCAPM to fail (Mankiw and Zeldes, 1991 [30], Vissing-Jorgensen, 2002 [42] and Vissing-Jorgensen and Attanasio, 2003 [43]). Therefore, we also take this into consideration when studying empirical implication of our model. In the empirical study of Brav, Constantinides and Geczy (2002) [7], some households are excluded from the sample if their asset holdings are below certain thresholds. In this paper, our criterion for excluding observations on households that are possibly constrained is based on the ratio of
financial assets to the level of consumption expenditure. The reason for this is we believe total asset holdings of a household are also related with household characteristics, such as family size, number of children, etc. However, variation in asset holdings due to these characteristics is not going to affect households’ participation in asset markets.

The remainder of the paper is organized as follows. Section 1.2.1 presents the basic framework. Section 1.2.2 discusses the properties of household stochastic discount factor and Section 1.2.3 defines the aggregate stochastic discount factor used for the empirical study. Section 1.3 discusses the estimation procedure used to obtain parameters of the utility function that are required for constructing the SDF series. Section 1.4.1 presents results on the empirical volatilities of SDFs constructed from the CEX. Sections 1.4.2 and 1.4.3 discuss explanatory power of the Housing CCAPM towards the equity premium on the market portfolio and the cross-section of risk premia. Conclusions are offered in section 1.5.

1.2 Model

1.2.1 General Equilibrium Setting

We consider a large number of households, indexed by $i = 1, ..., I$. Households are identical in terms of their preferences, but may differ in terms of the values of their state variables. Households can trade in a set of financial assets indexed by $j = 1, ..., J$. Trade in financial assets is frictionless, in the sense that trading is not subject to any costs to buy or sell, or short-selling constraints. In addition to income from financial assets, households receive a stochastic stream of labor income. Labor is assumed to be supplied inelastically, and we thus treat labor income as exogenous. Markets are incomplete in the sense that households cannot buy or sell contingent claims to their stochastic stream of labor income. Indeed, the only markets that exist are spot markets for the two consumption goods, housing and non-housing consumption, and the markets for financial assets.
As usual, the household maximizes expected lifetime utility:

\[ U = E_0 \sum_{t=0}^{\infty} \beta^t u_t \tag{1.1} \]

In addition to non-housing consumption, denoted \( C \), period utility depends on the consumption of housing services, denoted \( H \), in a CES utility specification:

\[ u(C, H) = \left( \frac{C^\alpha + \gamma H^\alpha}{1 - \rho} \right)^{\frac{1}{1 - \rho}}, \alpha \leq 1, \rho > 0, \gamma > 0 \tag{1.2} \]

The specification of period utility in equation (1.2) is sufficiently general to incorporate Cobb-Douglas utility as the limiting case as \( \alpha \) approaches zero, as well as the standard, one-good utility function.

Non-housing consumption (aka nondurable consumption), \( C \), is numeraire. Housing consumption, \( H \), is a physical measure of the quantity of housing. While there are many different physical attributes to housing as an argument of the utility function, we measure only a single, basic attribute: square feet. In essence, the utility specification in equation (1.2) replaces the standard power function of a single consumption good with a power function of a composite good:

\[ \text{Composite} \equiv (C^\alpha + \gamma H^\alpha)^{\frac{1}{\alpha}}. \tag{1.3} \]

As in the standard, one-good model, the volatility of the stochastic discount factor depends on \( \rho \), the parameter governing the curvature of the utility function with respect to the composite good. By not restricting attention to the Cobb-Douglas specification of the composite good, we introduce a second parameter, \( \alpha \), that governs the degree of intratemporal substitutability of the two goods. This intratemporal substitutability parameter, \( \alpha \), helps to determine the volatility of the stochastic discount factor.

Non-housing consumption is assumed frictionlessly adjustable. Changing the quantity of housing, however, incurs a non-convex adjustment cost. That is, in order to change the quantity of the consumption of housing services, the household must sell the old house, incurring a cost equal to a fraction, \( \lambda \), of the value of the house sold, and purchase a different house. The model pertains to renters as well as owner-occupiers as long as we assume that renters also face an adjustment cost.
that is not convex in the size of the adjustment when moving from one rental to another. While the adjustment costs faced by renters are presumably smaller than those faced by owner-occupiers, the model applies equally well to both types of households as long as each faces a non-convex adjustment cost.

In a completely frictionless setting (that is, if both goods are assumed to be costlessly adjustable), merely adding housing to the utility function as a distinct good does not in itself alter the implications of the model for asset pricing. If both goods are assumed to be costlessly adjustable, both the marginal utility of housing consumption and the marginal utility of non-housing consumption would satisfy intertemporal Euler equations. In addition, an intratemporal first order condition equating the marginal rate of substitution between the two goods to the ratio of prices would also hold. When we leave a completely frictionless environment and incorporate the adjustment cost on housing, the household’s optimal plan will no longer satisfy either the Euler equation for housing consumption or the intratemporal first order condition. Nevertheless, the assumption that non-housing consumption is costlessly adjustable implies that the Euler equation for non-housing consumption will hold:

\[
E_t \left[ \beta \left( \frac{C_{t+1}^\alpha + \gamma H_{t+1}^\alpha}{C_t^\alpha + \gamma H_t^\alpha} \right)^{\frac{1-\rho-\alpha}{\alpha}} \frac{C_{t+1}}{C_t} \right]^{\frac{\alpha-1}{\alpha}} R_{t+1}^f = 1 \tag{1.4}
\]

where \( R_{t+1}^f \) is the gross risk free rate. Therefore, the stochastic discount factor for household \( i \) can be written as

\[
M_{i,t+1} = \beta \left[ \frac{C_{i,t+1}^\alpha + \gamma H_{i,t+1}^\alpha}{C_{i,t}^\alpha + \gamma H_{i,t}^\alpha} \right]^{\frac{1-\rho-\alpha}{\alpha}} \left[ \frac{C_{i,t+1}}{C_{i,t}} \right]^{\frac{\alpha-1}{\alpha}} \tag{1.5}
\]

Taking the log of both sides gives:

\[
m_{i,t+1} = \ln \beta + (\alpha - 1) \ln \frac{C_{i,t+1}}{C_{i,t}} + (1 - \rho - \alpha) \ln \frac{\text{Composite}_{i,t+1}}{\text{Composite}_{i,t}} \tag{1.6}
\]

Rearranging, the log SDF can be expressed as:

\[
m_{i,t+1} = \ln \beta - \rho \ln \frac{C_{i,t+1}}{C_{i,t}} + (\alpha - [1 - \rho]) \left( \ln \frac{C_{i,t+1}}{C_{i,t}} - \ln \frac{\text{Composite}_{i,t+1}}{\text{Composite}_{i,t}} \right) \tag{1.7}
\]
In equation (1.7), note that the first two terms correspond exactly to the log SDF from a standard one-good model. Since the expression for the log SDF is derived from the Euler equation for non-housing consumption, equation (1.7) is equally valid when housing consumption is assumed frictionlessly adjustable or subject to adjustment costs. Assume, for the moment, that both goods are costlessly adjustable, and, further, that their relative price is constant. In this case, an optimizing household would choose quantities of housing consumption and non-housing consumption in fixed proportions with the consequence that non-housing consumption \( C \), housing consumption, \( H \) and the composite good would all move in lockstep. Under these assumptions, the growth rate of non-housing consumption and the growth rate of the composite good would exactly coincide, and the third term would drop out of equation (1.7). Thus even if the true utility specification were given by equation (1.2), and even if the parameters were consistent with nonseparability (i.e., \( \alpha \neq 1 - \rho \)), the standard one-good specification which omits housing (by setting \( \gamma = 0 \)) would generate exactly the same series for the stochastic discount factor because non-housing consumption acts as a perfect indicator for the composite good. Including housing consumption in the utility function will affect the volatility of the stochastic discount factor only if (1) the utility function is nonseparable in the two goods, and (2) the adjustment of housing consumption incurs a non-convex cost, which induces variation in the ratio of non-housing consumption to consumption of the composite good.

1.2.2 The Effect of Adjustment Costs on the Volatility of the Household SDF

In contrast to the fully frictionless case, in which non-housing consumption and composite consumption move in lockstep, consider the expression for the household SDF under the assumption of non-convex adjustment costs on housing consumption. Theoretical models of optimal consumption in the presence of adjustment costs, casual empiricism, and formal empiricism all indicate that if the adjustment cost is lumpy, or non-convex in the size of the adjustment, that the household will make infrequent, large adjustments in the quantity of housing but
in most periods make no adjustment at all. For example, Bajari, Chan, Krueger, and Miller (2010)\cite{Bajari2010} consider moves of primary residence by owner-occupiers in the PSID from 1980 to 1993. In a sample of 1931 households, they find that 58% never moved within the 14 year time period, and that among the 42% who did move, only a very small percentage moved more than once. Conditional on moving, they find that the magnitude of adjustment in housing consumption is large.

For most observations (that is, most households for a given time interval and most time intervals for a given household), the quantity of housing consumption will not change. For these observations $H_{i,t} = H_{i,t+1}$ and the growth rate of non-housing consumption will differ from the growth rate of the composite good in equation (1.7). Note that even when the expression in large curved brackets is nonzero due to adjustment costs, the third term still drops out if $\alpha = 1 - \rho$ (i.e., utility is separable). Whether the inclusion of housing in the utility function increases or decreases the volatility of the SDF depends on the relative magnitudes of $\alpha$ and $1 - \rho$. First, consider the case in which $\alpha > 1 - \rho$. Suppose that positive innovations to financial wealth or labor income in period $t+1$ cause the marginal value of wealth in $t+1$ to decline relative to period $t$. In the absence of adjustment costs on housing, the household would increase its consumption of both goods. However, for the bulk of households for whom it is not immediately worthwhile to incur the adjustment cost on housing, the consumption of housing remains constant and only non-housing consumption increases; the growth rate of non-housing consumption between $t$ and $t+1$ is positive. The growth rate of the composite good is also positive, although smaller than the growth rate of non-housing consumption alone. When $\alpha - [1 - \rho]$ is positive, the third term in equation (1.7) will be negatively correlated with the second term, and thus may reduce the volatility of the SDF. Conversely, if $\alpha < 1 - \rho$, the second and third terms are positively correlated with the result that the inclusion of housing increases the volatility of the SDF. For example, if $\rho$ takes on the relatively low value of unity (i.e., a log specification of the utility function), negative values of $\alpha$ would amplify volatility, while positive values of $\alpha$ would dampen the volatility of the SDF.

More formally, the variance of the log SDF of the housing model is the
\( \text{var}(m_{i,t+1}) = \rho^2 \text{var}\left( \frac{\ln C_{i,t+1}}{C_{i,t}} \right) \) (1.8)

\[
+ (\alpha - [1 - \rho])^2 \text{var}\left( \frac{\ln C_{i,t+1}}{C_{i,t}} - \frac{\ln \text{Composite}_{i,t+1}}{\text{Composite}_{i,t}} \right)
- 2\rho(\alpha - [1 - \rho]) \text{cov}\left( \frac{\ln C_{i,t+1}}{C_{i,t}}, \left( \frac{\ln C_{i,t+1}}{C_{i,t}} - \frac{\ln \text{Composite}_{i,t+1}}{\text{Composite}_{i,t}} \right) \right)
\]

Compared with the standard SDF, the variance of the housing SDF has two more terms (the second and the third terms in equation (1.8)). The second term is always positive, but it can be small in magnitude. The third term changes sign depending on the values of parameter \( \alpha \) and \( \rho \). When \( \alpha < 1 - \rho \), the third term is also positive and thus the total effect of housing (and adjustment costs) on the volatility of the household SDF is definitely positive. When \( \alpha > 1 - \rho \), the third term is negative. Although in this case, theoretically, the volatility of the housing SDF may still be larger than the volatility of the standard SDF due to the positive second term, this is not what we observe from the data. We will show in section 1.4.1 that, empirically, the second term is not significant in determining the volatility of housing SDF. It is the third term (the value of \( \alpha \) and \( \rho \)) that determines whether the volatility of SDF with housing (and adjustment costs) is larger or smaller than the standard SDF.

### 1.2.3 Aggregate SDF

Returning to the SDF of household \( i, M_{i,t+1} \), household optimization implies that household \( i \) will satisfy an Euler equation for each of the \( J \) assets. Thus the moment condition

\[
E_t[M_{i,t+1} R_{t+1}^j] = 1 \quad (1.9)
\]

holds for all \( i \) (households) and all \( j \) (financial assets); the marginal rate of substitution, \( M_{i,t+1} \), of any household could be used to test the implications of the model for risk premia. While one could, in principle, test the model with data on the SDF from a single household, data limitations preclude doing so in practice.
Because a given household is included in the CEX for only four quarters before being replaced, we obtain only a single observation on the SDF for a given household. However, equation (1.9) implies a corresponding moment condition for an aggregate SDF calculated as the average (across \( i \)) of the household level SDFs at a point in time. That is, equation (1.9) at the household level implies

\[
E_t[M_{t+1}R_{t+1}^j] = 1
\]

(1.10)

where \( M_{t+1} \equiv \frac{1}{T} \sum_{i=1}^{I_t} M_{i,t+1} \). Our approach consists of first estimating the parameters of the utility function, then, using the CEX, constructing the household level SDF for a cross section of households for a given time interval, and finally aggregating these observations on the SDF across households for a given time interval to obtain the aggregate pricing kernel, \( M_{t+1} \).

Under our assumptions, the model does not admit a representative agent interpretation. Even if we were willing to assume the existence of complete contingent claims markets through which households could insure against idiosyncratic labor income risk, the presence of the adjustment cost on housing rules out a representative agent interpretation. In the context of the standard one-good model (without housing), both theoretical work (Constantinides and Duffie (1996) [12]) and empirical work (Brav, Constantinides, and Geczy (2002) [7]) indicate that by assuming market incompleteness, and thus departing from a representative agent representation, both the volatility and the countercyclicality of the SDF are amplified. Housing (with the adjustment friction) adds another source of heterogeneity. For comparison to our primary results on the asset pricing implications of the model with heterogeneous agents, we also calculate, using the same data from the CEX, the SDF that would be obtained under a representative agent interpretation of the model (that is, under the assumption of complete markets and frictionless adjustment of housing). For the representative agent version of the model, we calculate the average consumption of the housing and non-housing good as

\[
C_t = \frac{1}{T} \sum_i^T C_{i,t} \quad \text{and} \quad H_t = \frac{1}{T} \sum_i^T H_{i,t}.
\]

With these values of aggregate per capita consumption (in the CEX), we then calculate the value of the SDF under the
assumption of a representative agent, \( M_{t+1}^{RA} \), as

\[
M_{t+1}^{RA} = \beta \left[ \frac{C_{t+1}^\alpha + \gamma H_{t+1}^\alpha}{C_t^\alpha} \right]^{\frac{1-\rho-\alpha}{\alpha}} \left[ \frac{C_{t+1}}{C_t} \right]^{\alpha-1}
\]  

(1.11)

Since SDF is nonlinear in consumption, \( M_{t+1}^{RA} \) does not coincide with \( M_{t+1} \). For the standard one-good model, Campbell (2003) [8] shows that under the assumption of log normally distributed nondurable consumption, the heterogeneous agent and representative agent log SDFs are related as follows:

\[
m_{t+1} = m_{t+1}^{RA} + \frac{\rho(\rho + 1)}{2} Var_{t+1}^* \Delta \ln C_{i,t+1}
\]  

(1.12)

where \( Var_{t+1}^* \Delta \ln C_{i,t+1} \) is the cross-sectional variance of household level consumption growth rate. Since \( \rho \) is nonnegative, equation (1.12) implies that the SDF derived from a heterogeneous agent model is more strongly countercyclical than the SDF implied by a representative agent model if the cross-sectional variance of consumption growth is negatively correlated with aggregate consumption growth.

While the correlation of the cross-sectional variance of consumption growth can be estimated, it seems likely that idiosyncratic risk is larger in economic downturns. For the two good model, simple expressions analogous to equation (1.12) cannot be derived without much more complicated assumptions on the joint distribution of non-housing consumption and housing consumption. In section 1.4.3, we compare the explanatory power of heterogeneous agent and representative agent models, with and without housing, for risk premia on 25 Fama-French portfolios.

1.3 Estimating the Parameters of the Utility Function

1.3.1 A Two Step Approach

In this section, we estimate the parameters of the nonseparable, two-good utility specification given in equation (1.2), as well as the one-good specification using household level data from the CEX. The estimated parameters will then
be used to calculate risk premia based on the heterogeneous agent version of the Housing CCAPM. Even before the household level and aggregate SDF is calculated, the estimated value of $\alpha$ relative to the estimate of $1 - \rho$ will reveal whether the inclusion of housing amplifies or dampens the volatility of the SDF.

Compared to the PSID, the CEX has both advantages and disadvantages. While the PSID has data on some components of consumption (food, utilities, some durable expenditures), it does not have data on any reasonably comprehensive concept of consumption. The CEX offers a comprehensive measure of non-housing consumption, but tracks households only for five consecutive quarters. Secondly, while the CEX has data on some aspects of housing consumption (e.g., number of rooms, number of baths and half baths, and whether the housing unit is a detached single family, multi-family, or mobile home), it does not provide data on a single continuous measure of housing consumption such as square feet. To address the second issue, we use the American Housing Survey to impute the respondent’s quantity of housing (measured in square feet). With a true panel data set, the parameters of the utility function can be obtained by GMM estimation of the Euler equation for non-housing consumption that is implied by the utility specification in equation (1.2). However, this straightforward approach is not feasible because the short time dimension of the CEX provides just four consecutive observations for each household.

Instead of estimating all of the parameters of the utility function simultaneously, we first estimate $\alpha$ and $\gamma$; that is, the parameters that determine the aggregation of the two goods into the composite good. In the absence of adjustment frictions on either of the goods, the intratemporal first order condition says that the household should set the marginal rate of substitution between the two goods equal to their relative price:

$$\frac{U_H(C,H)}{U_C(C,H)} = \gamma \left( \frac{H}{C} \right)^{\alpha-1} = P \quad (1.13)$$

where $U_H$ denotes the partial derivative of utility with respect to housing and $P$ is the relative price of housing. Conceptually, the relative price of housing ($P$) reflects the unit (per square foot) price of the flow of housing services, not the acquisition
price of a home. To construct a measure of $P$, we take the reported monthly rent paid by renters, or the monthly rental value reported by owner-occupiers, and divide by a measure of the square footage of the house or apartment. Since $P$ is based on the monthly rental rate (per square foot), non-housing consumption, $C$, is measured as the average monthly non-housing consumption expenditure in a quarter.

In an ideal world without adjustment costs or measurement error, equation (1.13) should fit without error, both in a cross-section, and over time. Since the data on both goods undoubtedly reflects a significant amount of measurement error, one interpretation of the regression residual is, of course, measurement error. When one of the goods is subject to an adjustment cost, however, the intratemporal first order condition (equation (1.13)) does not hold, even if consumption of the two goods is measured perfectly. Thus we add an error term to the first order condition, and interpret the resulting residuals as reflecting both measurement error and the departures from frictionless optimal consumption created by the adjustment cost on housing:

$$\frac{U_H(C,H)}{U_C(C,H)} = \gamma \left( \frac{H}{C} \right)^{\alpha - 1} = Pe^\epsilon$$

(1.14)

Taking the log of both sides of equation (1.14) and rearranging gives\(^2\):

$$\ln \frac{PH}{C} = -\ln \gamma + \frac{\alpha}{\alpha - 1} \ln P + \epsilon$$

(1.15)

In estimating equation (1.15), the dependent variables is the log of the budget share devoted to housing; the budget share is measured by taking the ratio of monthly rent (or rental value of owner-occupied homes) and dividing by monthly non-housing consumption expenditure.

Obtaining an estimate of $\rho$ requires estimation of the intertemporal first order condition, which is complicated by the short time dimension of the CEX. To do this, we follow Parker and Preston (2005) [37], who use the CEX to estimate the curvature of the utility function in the standard, one-good case. To address the issues created by the short panel dimension in the CEX, Parker and Preston (2005) [37] use a weaker moment condition restriction than the normal

\(^2\)Where $\epsilon = \frac{\epsilon}{\alpha - 1}$.
Euler equation. That is, instead of estimation based on the following moment conditions,

\[
E \left[ e^{X_{i,t+1}\delta} \left( \frac{C_{i,t+1}}{C_{i,t}} \right)^{-\rho} R^f_{t+1} - 1 \right] Z_{i,t} = 0 \tag{1.16}
\]

they use instead:

\[
E \left[ \frac{1}{I(t)} \sum_{i \in I_t} e^{X_{i,t+1}\delta} \left( \frac{C_{i,t+1}}{C_{i,t}} \right)^{-\rho} R^f_{t+1} - 1 \right] Z_{i,t} = 0 \tag{1.17}
\]

Equation (1.17) says that we would expect the average expectation errors across all households to be zero over time. It is a weaker constraint because if equation (1.16) is satisfied, then equation (1.17) will be satisfied, but not vice versa. This helps solve the problem of small number of observations of each household in CEX. 

\(X_{i,t+1}\) is a vector containing first differences in household characteristics that are likely to shift preferences, such as family size, number of children, etc. Since non-housing consumption exhibits seasonality, the vector \(X_{i,t+1}\) also includes monthly dummies as additional preference shift variables. \(Z_{i,t}\) is a vector of instruments, including all the variables in the preference shifters, together with real interest rate, lagged real interest rate, log of unemployment rate and age of the reference person of the household.

Adapting the approach of Parker and Preston (2005) [37] to our utility specification, the moment condition becomes:

\[
E \left[ \frac{1}{I(t)} \sum_{i \in I_t} e^{X_{i,t+1}\delta} \left( \frac{C_{i,t+1}^{\hat{\alpha}} + \hat{\gamma} H_{i,t+1}^{\hat{\alpha}}}{C_{i,t}^{\hat{\alpha}} + \hat{\gamma} H_{i,t}^{\hat{\alpha}}} \right)^{1-\hat{\alpha}^\rho} R^f_{t+1} - 1 \right] Z_{i,t} = 0 \tag{1.18}
\]

where \(\hat{\alpha}\) and \(\hat{\gamma}\) are first stage estimates.

To address the problem of measurement error in the data, we also follow Parker and Preston (2005) [37] in grouping households into cohorts by the birth year of the head of the household\(^3\). We first construct the term \(C_{i,t+1}/C_{i,t}\) and the term \((C_{i,t+1}^{\hat{\alpha}} + \hat{\gamma} H_{i,t+1}^{\hat{\alpha}})/(C_{i,t}^{\hat{\alpha}} + \hat{\gamma} H_{i,t}^{\hat{\alpha}})\) at the household level. Then the geometric

\(^3\)We keep all households that have a reference person at the age of 15 to 75 in 1981. Cohorts are five years apart.
means of both growth rates within a cohort and the arithmetic means of the preference shifters (X’s) within a cohort are calculated. Equation (1.18) is then estimated by GMM using the cohort level data.

1.3.2 Data

For the data on non-housing consumption, we start with the measure of total consumption expenditure in the CEX, and subtract expenditure on housing, health, and education. Therefore, the non-housing consumption variable includes total expenditure on food, alcoholic beverages, apparel, transportation, entertainment, personal care, reading material, tobacco and smoking supplies, miscellaneous expenditures and cash contributions. In the CEX, the maximum number of interviews for a given household is five and consumption data is only available in the 2nd to 5th interviews. A given household is interviewed at 3 month intervals, but the interview cycles are staggered across the year. Consumption reported in an interview reflects expenditures made during the previous three months. With the four consecutive observations on consumption, we could in principle construct three quarter-to-quarter consumption growth rates. In practice, though, we use at most two growth rates for a given household, measuring the consumption growth between interview 2 and 4 or between interview 3 and 5. For the risk free interest rate, we use the 6 month Treasury bill maturing in the middle month of period $t + 1$.

For some households, the Euler equation for non-housing consumption may fail to hold due to a binding borrowing constraint. We exclude households with total financial assets that are smaller than 6 months worth of the household’s non-housing expenditures in an attempt to eliminate borrowing constrained households from the sample.

To impute data on the household’s consumption of housing, we find variables descriptive of housing consumption that are common to both the CEX and the American Housing Survey (AHS). These variables are: number of rooms, num-

\begin{footnote}
\footnotesize
4In this way, we make $C_t$ and $C_{t+1}$ not contiguous. This is because, if $C_t$ and $C_{t+1}$ are contiguous, it will be hard to obtain a clear separation of information available at period $t$ and period $t + 1$.
\end{footnote}
ber of bathrooms, number of half bathrooms, type of housing (single detached house, apartment or mobile home) and whether the residence is in an urban or rural area. Since the AHS has data on the square footage of the residence, we then regress square feet of housing on the common set of variables and use the resulting estimates to impute square feet of housing for the households in the CEX. Table 1.1 reports the summary statistics of data in AHS.\(^5\)

In the AHS data, some households reported a different number of rooms or bathrooms in consecutive surveys even if the square footage of the home was reported as exactly the same in both years. While this could reflect remodeling activity, it seems more likely that it indicates misreporting. For this reason, we drop households that report constant square footage but different room composition across two consecutive surveys. Table 1.2 summarizes the results of the square footage regression based on the AHS. The reported coefficients are used to impute square feet of housing consumption of households in the CEX.

### 1.3.3 Results

The resulting estimates of the parameters of the utility function are presented in Table 1.3.\(^6\) For the standard one-good model, the estimated value of \(\rho\) is about 1.64, which is comparable to the value reported in Parker and Preston (2005) [37]. For the housing model, the estimate of \(\alpha\) is about -1.6, \(\rho\) is 1.86, and \(\gamma\) is about 0.08.

The estimates confirm that \(\alpha\) is smaller than 1 \(- \rho\), which is the key condition under which the housing model increases the volatility and countercyclicality of the SDF. Many papers that include housing as a second good in the utility function assume that the composite good is a Cobb-Douglas aggregate of housing consumption and non-housing consumption, which would imply that \(\alpha\) is equal to zero. Note that \(\alpha\) is sufficiently precisely estimated that the Cobb-Douglas specification can be decisively rejected.

\(^5\)The data is available from 1997 to 2009.
\(^6\)Table 1.4 lists the coefficients of the preference shifters (X’s).
1.4 Empirical Results

1.4.1 Volatility of SDFs

Using the parameters estimated in section 1.3, we construct the household level SDFs from the CEX data. Table 1.5 reports the volatility of the SDFs (measured in terms of standard deviation). If we compare column 2 and column 4 in Table 1.5, we find that for the standard model, in general, the SDF from a heterogeneous agents framework increases the volatility. Moreover, the difference between the two becomes larger as $\rho$ increases. This is consistent with equation (1.12) since we confirm, using the CEX, that the cross-sectional variance of log consumption growth is indeed negatively correlated with aggregate consumption.\footnote{According to Equation (1.12), for the one good model}

If we compare column 1 and column 3 for the housing model, we see that for most cases, the volatility of the heterogeneous agent SDF is larger than representative agent SDF and like the standard model, the difference gets larger as the curvature parameter increases.

If we compare column 1 with column 2 or column 3 with column 4, we see that when $\rho$ is 1 or 2, SDFs from the housing model have greater volatility than the SDFs from standard model for both the heterogeneous and representative agent versions of the model. On the other hand, if $\rho$ is 3 or 4, the volatility of the SDFs from the housing model are smaller. This is consistent with equation (1.7), which indicates that when $\alpha < 1 - \rho$, the third term from housing causes the SDF to be more countercyclical. Since the SDFs are constructed with the point estimate of -1.6 for $\alpha$, the condition that $\alpha < 1 - \rho$ is satisfied when $\rho$ is 1 or 2, but violated when $\rho$ is 3 or 4. Figure 1.1 is a plot of SDFs using aggregation over the SDFs of the heterogeneous agents.

\begin{align*}
\text{var}(m_{t+1}) &= \text{var}(m_{t+1}^{RA}) + \frac{\rho^2(\rho+1)^2}{4} \text{var}(Var_{t+1}^{RA}\Delta\ln C_{i,t+1}) + 2\text{cov}(m_{t+1}^{RA}, Var_{t+1}^{RA}\Delta\ln C_{i,t+1}) \\
&= \text{var}(m_{t+1}^{RA}) + \frac{\rho^2(\rho+1)^2}{4} \text{var}(Var_{t+1}^{RA}\Delta\ln C_{i,t+1}) - \rho^2(\rho+1)\text{cov}(\Delta\ln C_{i,t+1}, Var_{t+1}^{RA}\Delta\ln C_{i,t+1})
\end{align*}
1.4.2 Explaining the Equity Premium

We start by constructing the quarterly SDFs using non-housing consumption and the imputed measure of square footage of housing for households interviewed in the CEX in Jan, April, July and October. The risk free rate is calculated from the three month Treasury bill and the market return is measured by the return on the value weighted portfolio reported in CRSP. The data is quarterly, 1986-2010. The average (net) risk free rate and average (net) market return for this time interval are 1.06% and 2.45%, as reported in Table 1.6. Based on the observed average risk free rate, we use following equation to predict the expected risk premium. (Of course the series for $M_t$ will differ depending on whether the SDF is constructed according to the housing model or the standard model.)

$$E[R_m] = E[R_f](1 - cov(R_m, M_t))$$ (1.19)

The results are recorded in Table 1.6. As expected, the predicted market return from the standard model is lower than that from the housing model. While the inclusion of housing in the utility function goes in the direction of increasing the predicted risk premium on the market portfolio, the magnitude of the increase is very modest for the point estimate of $\alpha$ of $-1.6$. In the last two columns of Table 1.6, we report the predicted market risk premium for values of $\alpha$ that are more negative (and therefore reflect preferences in which there is less substitutability between the two goods). For a given value of $\rho$, decreasing the value of $\alpha$ from $-1.6$ to $-4.2$ approximately doubles the model’s prediction for the market risk premium.

From the Euler equations for the market portfolio and for the risk free asset, the model implies the restriction:

$$E[M_t(R_m^t - R_f^t)] = 0$$ (1.20)

where $R_m^t$ is the value weighted market return and $R_f^t$ is the risk free rate. Following Brav, Constantinides and Geczy (2002) [7], we construct the following statistic, denoted $u$, as a measure of the unexplained risk premium.

$$u = \frac{1}{T} \sum_{t=1}^{T} M_t(R_m^t - R_f^t)$$ (1.21)
In this section, we construct $u$ based on different values of parameters, keeping $\gamma$ fixed at 0.08 (the estimated value). Table 1.7 reports the value of the $u$ statistic for a range of values of the parameters $\alpha$ and $\rho$. The first column reports the value of the unexplained market risk premium for various values of $\rho$ in the context of the standard model. While the unexplained component of the premium falls as $\rho$ rises, the unexplained component of the risk premium does not change sign from positive to negative until $\rho$ reaches a value of 11. This means that, under the standard model, one would need a value of $\rho$ between 10 and 11 to set the unexplained premium equal to zero.

The table does not report the standard errors for the $u$ statistics. The standard errors are fairly large, and in general one cannot reject the standard model, with heterogeneous agents, based on the $u$ statistic for moderate values of $\rho$. While acknowledging that many of the positive values of the $u$ statistic in Table 1.7 are not statistically significant, we think that the values of the $u$ statistic in the first column are useful in demonstrating that, for given data on household level consumption of housing and non-housing goods, the predicted risk premium is fairly insensitive to variation in $\rho$. That is, “fixing” an equity premium puzzle by cranking up the value of $\rho$ requires a large increase in $\rho$. Based on estimation of the Euler equation using cohort data, we obtained estimates of $\rho$ of slightly under 2 (for both the one-good and two-good specifications). Consider the row in Table 1.7 corresponding to $\rho = 2$. The values of the unexplained premium for the housing model with $\alpha = -1$ and $\rho = 2$ coincides with value of the $u$ statistic under the one good model, because for these parameter values, we have $\alpha = 1 - \rho$ and the utility function is separable. As we move to the right along this row, for $\alpha = -2$ there is a modest decline in the value of the unexplained premium. As $\alpha$ decreases to $-3$ and $-4$, the unexplained premium falls fairly rapidly, and switches sign between $\alpha = -4$ and $\alpha = -5$. Note that while the value of the unexplained premium falls reliably as $\alpha$ becomes more negative, within a column for a constant value of $\alpha$, the value of the unexplained premium is fairly insensitive to the value of $\rho$.

Figure 1.2 provides plots of the SDF from the one-good model for various values of $\rho$; note the extent to which the volatility of the SDF changes with the
value of $\rho$. Figure 1.3 reports the results of a similar exercise for the housing model.

### 1.4.3 Explaining the Cross-Section of Risk Premia

Denoting the log of the stochastic discount factor ($M_t$) as $m_t$, as before, the first order log-linear approximation for $M_t$ can be written as:

$$
\frac{M_t}{E[M_t]} \approx 1 + m_t - E[m_t]
$$

(Subequation 1.22)

Substituting equation (1.22) into the unconditional Euler equation implies

$$
E[R^j_t - R^f_t] = -\frac{cov(M_t, R^j_t)}{E[M_t]} \approx -cov(m_t, R^j_t)
$$

(Subequation 1.23)

Consider first a representative agent model and let $\Delta lnC_t$ and $\Delta lnComposite_t$ denote the change in log per capita non-housing consumption and the change in log per capita composite good. Under a representative agent interpretation, $m_t$ is a linear function of $\Delta lnC_t$ in the standard model, and a linear function of both $\Delta lnC_t$ and $\Delta lnComposite_t$ in the housing model. Based on this, we can obtain specifications of risk premia for these two cases (equation (1.24) and (1.25)).

$$
E[R^j_t - R^f_t] = a_1 cov(\Delta lnC_t, R^j_t)
$$

(Subequation 1.24)

$$
E[R^j_t - R^f_t] = b_1 cov(\Delta lnC_t, R^j_t) + b_2 cov(\Delta lnComposite_t, R^j_t)
$$

(Subequation 1.25)

For the one-good model, assuming that non-housing consumption is distributed log normally, and allowing for heterogeneity imply that the covariance of the asset return with the cross-sectional variance of non-housing consumption also matters for risk premia\(^8\); in this case

$$
E[R^j_t - R^f_t] = c_1 cov(\Delta lnC_t, R^j_t) + c_2 cov(Var^*_t \Delta lnC_{i,t}, R^j_t)
$$

(Subequation 1.26)

Finally, for the housing model with heterogeneous agents, we posit a reduced form specification of risk premia in the cross-section that reflects a plausible (although

\(^8\)Equation (1.12) describes how the heterogeneous agent log SDF relates to the cross-sectional variance term.)
ad hoc) generalization of the standard model with heterogeneous agents and the housing model with representative agents:

\[ E[R^i_t - R^f_t] = d_1 \text{cov}(\Delta \ln C_t, R^i_t) + d_2 \text{cov}(\Delta \ln \text{Composite}_t, R^i_t) \]
\[ + d_3 \text{cov}(\text{Var}^* \Delta \ln C_{i,t}, R^i_t) + d_4 \text{cov}(\text{Var}^* \Delta \ln \text{Composite}_{i,t}, R^i_t) \] (1.27)

For each of the 96 quarterly observations in the 1986 to 2010 time interval, we calculate the cross-sectional variance of household level non-housing consumption growth rates and the cross-sectional variance of household level growth rates in the composite good. In addition to these cross-sectional variance variables, we also calculate the growth rate of the non-housing consumption, \( \Delta \ln C_t \), and the growth rate of the composite good, \( \Delta \ln \text{Composite} \), evaluated at the per capita values of the two goods. We then calculate the covariance of each of these four consumption variables with the return to a portfolio, \( R^i_t \). The set of portfolios consists of 25 Fama-French portfolios constructed based on size and book-to-market ratio. The cross-section specification in equation (1.27) is then estimated by regressing the excess return to a portfolio on the set of four covariance variables. The results are reported in Table 1.8.

According to the one-good, representative agent model, risk premia should be explained by the covariance of the growth rate of per capita non-housing consumption with the excess return. However, this covariance explains only 5% of the cross-sectional variation in risk premia. If we stick with the one-good model, but move to a heterogeneous agent interpretation of it, the cross-sectional variance of household consumption growth rates comes into play and the model explains 15% of the cross-sectional variation in risk premia. In the two-good model with heterogeneity, the percentage of the cross-sectional variation in risk premia explained by the model rises to 49%.

1.5 Conclusion

In this paper, we show that empirical evidence from CEX supports the following three assumptions. (1) Housing consumption and nondurable consumption are nonseparable. (2) Housing consumption and nondurable consumption are
complements (with cross derivative being positive). (3) Housing adjustment is infrequent due to significant adjustment cost. Based on these three empirical findings, we compare behavior of the stochastic discount factors from the standard, one-good model and the housing model. Theoretically, the SDF from the housing model is more volatile and countercyclical. Empirically, SDF from housing model has more explanatory power for both high equity premium and cross-sectional variation in asset returns. The power of housing model comes from the interaction between the two parameters that govern intratemporal substitution and intertemporal substitution. Although the value of intratemporal substitution needed to explain all excess return is more negative than the point estimate obtained using CEX, the value is within the reasonable range.
### Table 1.1: Summary Statistics from the American Housing Survey

**Northeast:**

<table>
<thead>
<tr>
<th></th>
<th>Urban</th>
<th>Nonurban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average square feet</td>
<td>1214</td>
<td>1528</td>
</tr>
<tr>
<td>Average number of rooms</td>
<td>4.75</td>
<td>5.42</td>
</tr>
<tr>
<td>Average number of baths</td>
<td>1.18</td>
<td>1.39</td>
</tr>
<tr>
<td>Average number of half baths</td>
<td>0.23</td>
<td>0.29</td>
</tr>
</tbody>
</table>

**Midwest:**
- Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas.

<table>
<thead>
<tr>
<th></th>
<th>Urban</th>
<th>Nonurban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average square feet</td>
<td>1264</td>
<td>1376</td>
</tr>
<tr>
<td>Average number of rooms</td>
<td>4.85</td>
<td>5.06</td>
</tr>
<tr>
<td>Average number of baths</td>
<td>1.26</td>
<td>1.35</td>
</tr>
<tr>
<td>Average number of half baths</td>
<td>0.23</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Data Source: American Housing Survey (1997-2009)
Table 1.1: Summary Statistics from the American Housing Survey (Cont.)

South:
Delaware, Maryland, District of Columbia, Virginia
West Virginia, North Carolina, South Carolina, Georgia
Florida, Kentucky, Tennessee, Alabama, Mississippi
Arkansas, Louisiana, Oklahoma, Texas

<table>
<thead>
<tr>
<th></th>
<th>Urban</th>
<th>Nonurban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average square feet</td>
<td>1319</td>
<td>1422</td>
</tr>
<tr>
<td>Average number of rooms</td>
<td>4.92</td>
<td>5.20</td>
</tr>
<tr>
<td>Average number of baths</td>
<td>1.52</td>
<td>1.61</td>
</tr>
<tr>
<td>Average number of half baths</td>
<td>0.16</td>
<td>0.15</td>
</tr>
</tbody>
</table>

West:
Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona
Utah, Nevada, Washington, Oregon, California, Alaska, Hawaii

<table>
<thead>
<tr>
<th></th>
<th>Urban</th>
<th>Nonurban</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average square feet</td>
<td>1149</td>
<td>1389</td>
</tr>
<tr>
<td>Average number of rooms</td>
<td>4.59</td>
<td>5.10</td>
</tr>
<tr>
<td>Average number of baths</td>
<td>1.42</td>
<td>1.58</td>
</tr>
<tr>
<td>Average number of half baths</td>
<td>0.14</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Data Source: American Housing Survey (1997-2009)
Table 1.2: Coefficients for Imputation of Housing Consumption

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Room</td>
<td>215.761</td>
</tr>
<tr>
<td></td>
<td>(5.233)</td>
</tr>
<tr>
<td>Bath</td>
<td>303.246</td>
</tr>
<tr>
<td></td>
<td>(10.740)</td>
</tr>
<tr>
<td>Half bath</td>
<td>225.769</td>
</tr>
<tr>
<td></td>
<td>(13.187)</td>
</tr>
<tr>
<td>Single family attached (dummy)</td>
<td>327.067</td>
</tr>
<tr>
<td></td>
<td>(11.989)</td>
</tr>
<tr>
<td>Apartment (dummy)</td>
<td>130.285</td>
</tr>
<tr>
<td></td>
<td>(12.147)</td>
</tr>
<tr>
<td>Urban (dummy)</td>
<td>-102.569</td>
</tr>
<tr>
<td></td>
<td>(11.491)</td>
</tr>
<tr>
<td>Urban Northeast(dummy)</td>
<td>93.909</td>
</tr>
<tr>
<td></td>
<td>(15.336)</td>
</tr>
<tr>
<td>Urban Midwest(dummy)</td>
<td>75.330</td>
</tr>
<tr>
<td></td>
<td>(11.970)</td>
</tr>
<tr>
<td>Urban South(dummy)</td>
<td>52.994</td>
</tr>
<tr>
<td></td>
<td>(10.365)</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>11428</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.647</td>
</tr>
</tbody>
</table>

Data Source: American Housing Survey (1997-2009)
Table 1.3: Estimation of the Parameters of the Utility Function

<table>
<thead>
<tr>
<th></th>
<th>Standard Model</th>
<th>Housing Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\rho$</td>
<td>1.64</td>
<td>1.86</td>
</tr>
<tr>
<td></td>
<td>(0.285)</td>
<td>(0.276)</td>
</tr>
<tr>
<td>$\alpha$</td>
<td></td>
<td>-1.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(0.0164)</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0012)</td>
<td></td>
</tr>
</tbody>
</table>

Data Source: Consumer Expenditure Survey (1980-2010)

Table 1.4: Coefficients of the Preference Shifters

<table>
<thead>
<tr>
<th>Variables</th>
<th>Housing Model</th>
<th>Standard Model</th>
<th>Parker and Preston Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implied $\beta$</td>
<td>0.99</td>
<td>1</td>
<td>N/A</td>
</tr>
<tr>
<td>Implied $ln\beta$</td>
<td>-0.0112</td>
<td>0.00004</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>(0.0078)</td>
<td>(0.0064)</td>
<td></td>
</tr>
<tr>
<td>Change in Family Size</td>
<td>0.2027</td>
<td>0.1787</td>
<td>1.355</td>
</tr>
<tr>
<td></td>
<td>(0.0445)</td>
<td>(0.0375)</td>
<td>(0.25)</td>
</tr>
<tr>
<td>Change in Number of Children</td>
<td>-0.1071</td>
<td>-0.0805</td>
<td>-0.405</td>
</tr>
<tr>
<td></td>
<td>(0.0487)</td>
<td>(0.0386)</td>
<td>(0.085)</td>
</tr>
</tbody>
</table>

Data Source: Consumer Expenditure Survey (1980-2010)
### Table 1.5: Standard Deviation of SDFs

<table>
<thead>
<tr>
<th>$\rho$</th>
<th>$M^H_{t+1}$</th>
<th>$M^S_{t+1}$</th>
<th>$M^{RA,H}_{t+1}$</th>
<th>$M^{RA,S}_{t+1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.0533</td>
<td>0.028</td>
<td>0.0726</td>
<td>0.0297</td>
</tr>
<tr>
<td>2</td>
<td>0.0757</td>
<td>0.0615</td>
<td>0.0751</td>
<td>0.0595</td>
</tr>
<tr>
<td>3</td>
<td>0.1008</td>
<td>0.1147</td>
<td>0.0792</td>
<td>0.0893</td>
</tr>
<tr>
<td>4</td>
<td>0.1285</td>
<td>0.1857</td>
<td>0.0849</td>
<td>0.1194</td>
</tr>
</tbody>
</table>

Notes: $\alpha$ is -1.6 and $\gamma$ is 0.08  
Data Source: Consumer Expenditure Survey (1980-2010)

### Table 1.6: Average Return vs Predicted Return

<table>
<thead>
<tr>
<th>$R^f$</th>
<th>$R^m$</th>
<th>$R^m$ w/ one-good</th>
<th>$R^m$ w/ Housing</th>
<th>$R^m$ w/ Housing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.06%</td>
<td>2.45%</td>
<td>1.16 %</td>
<td>1.22%</td>
<td>1.57%</td>
</tr>
</tbody>
</table>

$\rho = 1.64$  $\rho = 1.86$  $\rho = 1.86$  $\rho = 1.86$  $\alpha = -1.6$  $\alpha = -3$  $\alpha = -4.2$
Table 1.7: Value of the $u$ Statistic for the Unexplained Risk Premium

<table>
<thead>
<tr>
<th>$\rho$</th>
<th>Without</th>
<th>With $\alpha = -1$</th>
<th>With $\alpha = -2$</th>
<th>With $\alpha = -3$</th>
<th>With $\alpha = -4$</th>
<th>With $\alpha = -5$</th>
<th>With $\alpha = -6$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.403</td>
<td>1.362</td>
<td>1.262</td>
<td>0.972</td>
<td>0.425</td>
<td>-0.298</td>
<td>-1.086</td>
</tr>
<tr>
<td>1</td>
<td>1.354</td>
<td>1.326</td>
<td>1.219</td>
<td>0.925</td>
<td>0.403</td>
<td>-0.268</td>
<td>-0.999</td>
</tr>
<tr>
<td>2</td>
<td>1.297</td>
<td>1.297</td>
<td>1.120</td>
<td>0.919</td>
<td>0.429</td>
<td>-0.199</td>
<td>-0.884</td>
</tr>
<tr>
<td>3</td>
<td>1.220</td>
<td>1.220</td>
<td>0.974</td>
<td>0.516</td>
<td>-0.081</td>
<td>-0.740</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1.112</td>
<td>1.118</td>
<td>0.693</td>
<td>0.105</td>
<td>-0.553</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>0.998</td>
<td>0.998</td>
<td>0.402</td>
<td>-0.289</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0.869</td>
<td>0.869</td>
<td>0.110</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>0.728</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>0.567</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>0.373</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0.132</td>
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<td></td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>11</td>
<td>-0.171</td>
<td></td>
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<td>12</td>
<td>-0.558</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Data Source: Consumer Expenditure Survey (1980-2010)
Table 1.8: Fama-MacBeth Regressions

<table>
<thead>
<tr>
<th>cov</th>
<th>cov</th>
<th>cov</th>
<th>cov</th>
</tr>
</thead>
<tbody>
<tr>
<td>$(\Delta \ln C_{t, R}^i, R_t^i)$</td>
<td>$(\Delta \ln C_{t, e}, R_t^j)$</td>
<td>$(\Delta \ln \text{Composite}_{t, R}^i)$</td>
<td>$(\Delta \ln \text{Composite}_{t, e}, R_t^j)$</td>
</tr>
<tr>
<td>$R^2$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14.3641</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(8.6091)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13.1479</td>
<td>-9.7577</td>
<td>0.15</td>
<td></td>
</tr>
<tr>
<td>(7.5970)</td>
<td>(20.6809)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.5584</td>
<td>4.4389</td>
<td>0.34</td>
<td></td>
</tr>
<tr>
<td>(21.7761)</td>
<td>(15.8589)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25.5335</td>
<td>58.6549</td>
<td>-15.0412</td>
<td>-95.6128</td>
</tr>
<tr>
<td>(18.3006)</td>
<td>(35.8669)</td>
<td>(10.1835)</td>
<td>(58.2469)</td>
</tr>
</tbody>
</table>


Figure 1.1: SDFs Using Heterogeneous Agents Aggregation
Figure 1.2: SDF for the Standard (one-good) Model

Figure 1.3: SDF for the Housing Model
1.8 Acknowledgement

Chapter 1, in part, is currently being prepared for submission for publication of the material. Flavin, Marjorie; Liang, Xuan. The dissertation author is one of the primary investigators and authors of this material.
Chapter 2

Implications of the Housing Market for Endogenous Risk Aversion

Abstract

This paper studies the dynamics of relative risk aversion in a model with housing consumption, adjustment costs, and varying housing prices. Due to non-convex adjustment costs associated with housing consumption, relative risk aversion depends on both the housing price and the housing to wealth ratio of a household and thus will vary overtime. This is in contrast to a standard model without housing consumption, in which a constant curvature utility specification implies constant relative risk aversion. By solving the model numerically using value function iteration, we are able to quantify the relationship between relative risk aversion and the state variables that determine relative risk aversion: the ratio of home value to wealth, and the relative price of housing. In general, changing housing consumption (household moving) increases the household relative risk aversion. Further, moving is observed more frequently when house prices vary. We also find that the effect of housing prices on relative risk aversion depends on the household housing to wealth ratio. Using a self-reported measure of risk aversion from the Health and Retirement Survey, we empirically confirm the effect of moving on
household relative risk aversion. Using GARCH models, we also find macroeconomic evidence that house price volatility is positively correlated with the price of risk, which is viewed as a proxy for the aggregate level of risk aversion.
2.1 Introduction

The aim of this paper is to study the dynamics of relative risk aversion of homeowners in a model with housing consumption, adjustment costs, and varying housing prices. Relative risk aversion in this model is endogenous and can change with the household consumption and asset holdings. This is in contrast to the standard model without housing and adjustment costs, in which a constant curvature utility specification implies constant relative risk aversion. Variation in relative risk aversion in this model comes from two sources. One is the non-convex adjustment cost associated with housing and the other is the varying relative price of housing.

The reason that we want to study the variation of relative risk aversion is that we believe it is a key to characterize household risk preferences and thus their demand for risky assets. When relative risk aversion is high, households will demand relatively smaller amount of risky assets. Conversely, if relative risk aversion is low, demand for risky assets will be high. We know that in reality, the return and price of risky asset, such as stocks, depend crucially on the demand for risky assets. Therefore, the variation in relative risk aversions arising from changes in housing prices and housing consumption, can generate a link from the housing market to the equity market.

There has been a rising interest in studying household asset allocation problems in the presence of housing, but papers assume an exogenous level of risk aversion. Flavin and Yamashita (2002) [22] use a mean variance efficiency framework to study the asset allocation of households given different levels of housing consumption. They show that housing imposes a constraint on the household’s portfolio optimization and thus can lead to different financial assets holdings even though households have ex ante identical preferences. Cocco (2005) [10] endogenizes housing choice in a life-cycle model and finds that investment in housing reduces the benefits of equity market participation and house price risk would crowd out stock holdings. Yao and Zhang (2004) [46] also study the effects of housing on portfolio allocation in a life-cycle framework, but they allow households to acquire housing services either by renting or owning. They find that households choose different
portfolio allocations depending on whether they own a house or rent housing services. When owning a house, households substitute home equity for risky stocks, but the stock to bond ratio is higher in their liquid portfolios. More recently, Fischer and Stamos (2013) [20] study life-cycle portfolio allocation with housing market cycles. They find that in a good state, homeownership rates rise and households invest a larger share of their net wealth in housing.

In comparison, the literature of endogenous risk aversion is limited. The seminal work of Grossman and Laroque (1990) [24] introduces the idea of (S,s) inventory models (Arrow and Harris, 1951 [2]) to durable goods consumption. It has shown that due to non-convex adjustment costs, consumption of a durable good is not a continuous function of wealth and there exists an upper bound and a lower bound for the ratio of the durable good value to wealth. That is, only when the ratio is too large, will household downsize their durable good consumption, or only when the ratio is too small, will the household upgrade their durable good consumption. When the ratio lies in between the two bounds, the household maintains the current level of durable good consumption in order to avoid the adjustment cost. There have been empirical studies on the boundaries and inaction region of durable goods consumption, mainly for automobiles (Attanasio, 2000 [3] and Eberly, 1994 [14]).

Flavin and Nakagawa (2008) [21] generalize the model of Grossman and Laroque (1990) [24] by adding nondurable consumption to the framework and having housing consumption as the durable good consumption. It shows that in order to minimize adjustment costs, most households will not change their housing consumptions for substantial periods of time, during which, they simply maximize over nondurable consumption conditional on their housing consumption. In a framework with constant relative price of housing, it has been shown that there exists an upper bound and a lower bound for the housing value to wealth ratio. If the household hits either bound, it will reoptimize its housing consumption; we refer to the reoptimized housing to wealth ratio as the return point. So the return point characterizes the optimal housing to wealth ratio of a household when it chooses a new level of housing. In this case, the current housing consumption of
a household becomes a state variable. This is because, in each period, household has to decide whether they would like to change their housing consumption and thereby incur the adjustment cost. The introduction of this state variable has implications on household relative risk aversion. Relative risk aversion is defined to be the curvature of the value function with respect to wealth. If the value function depends on housing consumption, then for each level of housing consumption, we could potentially obtain a different level of relative risk aversion. It has been shown that relative risk aversion is the highest in the neighborhood of the return point, and the lowest in the neighborhood of either bound. Therefore, even with a constant relative price of housing, the adjustment cost model implies nonconstant risk aversion. More specifically, as wealth levels change due to consumption and investment activities, household housing to wealth ratios can change, which causes a change in their relative risk aversion.

The focus of this paper, however, is to obtain the dynamics of relative risk aversion in a context of varying housing prices. To simplify the problem, we characterize housing prices as a three state Markov chain. Since current housing price will influence the household consumption and asset holdings in each period, the housing price becomes another state variable, and thus potentially influences relative risk aversion. Solving the model using value function iteration, we can compute relative risk aversion for each price state. Furthermore, we are able to analyze the changes in household relative risk aversion directly caused by a house price change, which has not been studied before. Although Fillat, Stefano and Vergaraa-Alert (2014) [19] also include a housing price dynamics in their framework, their numerical results are obtained by solving the problem for each price level, instead of solving the model as a whole. Therefore, they do not account for the connection between different house price states and thus do not provide insights on the change of risk aversion due to instant house price changes. Another difference between Fillat, Stefano and Vergaraa-Alert (2014) [19] and this paper is that they assume Cobb-Douglas aggregation between housing and nondurable consumption, which indicates constant share between the two goods. In comparison, we assume the two goods have smaller substitutability, which is consistent
with the empirical results from section 1.3.3.

Here are a few main findings of the paper. Firstly, the numerical results suggest that changing housing consumption (household moving) increases the household relative risk aversion. This is true whether housing price is constant or is varying. Secondly, when house prices vary, moving is observed more frequently. Since moving is associated with a higher relative risk aversion, more frequent moving of households could imply a higher aggregate relative risk aversion in the economy. Empirically, we confirm the effect of moving on household relative risk aversion using a self-reported measure of risk aversion from the Health and Retirement Survey. Also, we find some empirical evidence that house price volatility is positively correlated with the price of risk, which is viewed as a proxy for the aggregate level of risk aversion.

The rest of the paper is organized as follows. Section 2.2 describes the model and its calibration. Section 2.3 describes the computational methods used to solve the model. Section 2.4 discusses the numerical results on relative risk aversion obtained by solving the model using value function iteration. Section 2.5 discusses the model implications and provides both microeconomic and macroeconomic empirical evidence. Section 2.6 concludes.

2.2 Model

The household maximizes expected lifetime utility:

$$U = E_0 \sum_{t=0}^{\infty} \beta^t u(C_t, H_t)$$ (2.1)

Period utility has the following specification, which is a CRRA utility function over a composite good.

$$u(C, H) = \frac{(C^\alpha + \gamma H^\alpha)^{1-\frac{\alpha}{\rho}}}{1-\rho}, \alpha \leq 1, \rho > 0, \gamma > 0$$

$$Composite \equiv (C^\alpha + \gamma H^\alpha)^{\frac{1}{2}}$$

$C_t$ is nondurable consumption, which can be adjusted costlessly. $H_t$ is housing consumption; its adjustment will incur a non-convex adjustment cost, which is
proportional to the value of household’s current house. This period utility function is general enough to incorporate many cases. Firstly, if $\alpha$ is equal to $1 - \rho$, the period utility function becomes separable in the housing good and nondurable good. All the asset pricing implications of the model would be the same as the one-good model under this condition. Therefore, we would assume that $\alpha$ is not equal to $1 - \rho$. We also have two other assumptions on the values of the parameters. $\alpha$ in the period utility function governs the intratemporal substitution between the two goods. When $\alpha$ approaches negative infinity, the aggregation between the housing and non-housing goods becomes Leontief, which indicates that there is zero substitution between the two goods. $\alpha$ equals one would indicate perfect substitutability. When $\alpha$ equals zero, we have Cobb-Douglas aggregation. There are many papers that incorporate housing into the utility function start with Cobb-Douglas aggregation, which indicates constant budget share between housing and non-housing consumption. However, we would think people who stay in areas such as San Francisco and New York, where relative price of housing is high, would have a larger share of their income paid to housing. This would suggest $\alpha < 0$. Furthermore, based on the estimation results of Flavin and Nakagawa (2008) [21], we assume $\alpha < 1 - \rho$.

The household’s maximization problem can be described using the following value functions.

$$ V(W_t, P_t, H_{t-1}) = \max \left\{ V^c(W_t, P_t, H_{t-1}), V^{nc}(W_t, P_t, H_{t-1}) \right\} $$

(2.2)

where $V^c$ and $V^{nc}$ represent the value functions associated with changing and not changing housing consumption. So in each period, household firstly calculates the best value for changing house and the best value for not changing house. Then they choose the maximum of the two.

More specifically, $V^{nc}$ is defined in equation (2.3). $P_t$ is the relative price of housing. $a_{t+1}$ is the risky asset holding till period $t + 1$. $b_{t+1}$ is the risk free bond held, which is defined to be positive. $b_{t+1}^m$ is the mortgage held. At the beginning of period $t$, households know their $W_t$, which is the net wealth or the resources available for households. They also know the new relative price of housing they face and the house size they had from last period. Since at the beginning of each
period, these three variables are known to households and are useful for households to make subsequent decisions, these three variables are the state variables. $W_t$ is equal to the sum of the values of all the assets households hold at the beginning of each period: the value of the house, the accumulated value of risky asset, the value of bond, subtracting the value of mortgage. Households need to choose the amount of bond holding, mortgage holding, the risky asset holding, the new house size as well as the nondurable consumption. Since we assume household is not changing their house size, we have $H_t$ and $H_{t-1}$ equal. Also, we assume that households can only borrow against their house, up to 80% of the house value.

$$V^{nc}(W_t, P_t, H_{t-1}) = \max_{C_t, H_t, a_{t+1}, b_{m_{t+1}}, b_{t_{t+1}}} u(C_t, H_t) + \beta E_t V(W_{t+1}, P_{t+1}, H_t)$$ (2.3)

s.t $C_t + a_{t+1} + b_{t+1} - b_{m_{t+1}} + P_t H_t \leq W_t$

$$W_t = P_t H_{t-1} + a_t (1 + r^a_t) + b_t (1 + r_f) - b_{m_t} (1 + r_m)$$

$$H_t = H_{t-1}$$

$$b_{m_{t+1}} \leq 0.8 P_t H_t$$

$$a_{t+1} \geq 0, b_{t+1} \geq 0, b_{m_{t+1}} \geq 0$$

$$V^c(W_t, P_t, H_{t-1}) = \max_{C_t, H_t, a_{t+1}, b_{m_{t+1}}, b_{t_{t+1}}} u(C_t, H_t) + \beta E_t V(W_{t+1}, P_{t+1}, H_t)$$ (2.4)

s.t $C_t + a_{t+1} + b_{t+1} - b_{m_{t+1}} + P_t H_t + \lambda P_t H_{t-1} \leq W_t$

$$W_t = P_t H_{t-1} + a_t (1 + r^a_t) + b_t (1 + r_f) - b_{m_t} (1 + r_m)$$

$$b_{m_{t+1}} \leq 0.8 P_t H_t$$

$$a_{t+1} \geq 0, b_{t+1} \geq 0, b_{m_{t+1}} \geq 0$$

There are two main differences between the $V^c$ and $V^{nc}$ problems. Firstly, for the $V^c$ problem, there is no constraint ($H_t = H_{t-1}$) on the house size. Secondly, when household is changing their house, they have to firstly sell the house, pay an adjustment cost equal to a proportion of the house value, represented by the term $\lambda P_t H_{t-1}$ in the budget constraint.

Since it is not possible to obtain an analytical solution to the value function, the problem becomes computational. For computation, $\rho$, the curvature parameter,
is set to be 3. \(\alpha\), the parameter that governs the intratemporal substitutability between nondurable consumption and housing consumption, is set to be -5.\(^1\) Risk free rate is 1%. The risky asset return is normally distributed with an expectation of 8% and a standard deviation of 20%. The mortgage rate is 3%. The discount factor is set to be 0.9896 on an annual basis.

To focus on illustrating the changes of relative risk aversions in response to varying housing prices, we choose the housing price process to be a three state Markov chain with the transition matrix specified below. Since housing consumption \(H_t\) is defined to be the quantity of housing measured in square feet, the housing price is in units of dollars per square foot. The price at the middle state, \(P_m\), is set to be 100. The price at low state, \(P_l\), is 90 and the price at high state, \(P_h\), is 110. The transition probabilities are chosen so that in most periods, the housing price will stay in the middle state at 100. There are small probabilities that price will go up or down. When price is high, it is equally likely for it to stay in high state or go to medium state (normal state). There is only a small probability for the housing market to collapse suddenly. When price is low, however, the recovery is slow since there is no possibility for the price to go from the low to the high state.

\[
\begin{pmatrix}
P_l & P_m & P_h \\
0.25 & 0.75 & 0 \\
0.05 & 0.85 & 0.1 \\
0.1 & 0.45 & 0.45 \\
\end{pmatrix}
\]

From computations, we are able to obtain the value functions, from which we can infer relative risk aversions using equation (2.5). We believe relative risk aversion is defined as the curvature of the value function with respect to wealth. This is because relative risk aversion should reflect how tolerant households are about gambles of their wealth. This definition is also used in the paper of Swanson (2012) [40] and Swanson (2013) [41]. In a standard CRRA utility function, the curvature of the utility function, \(\rho\) is the curvature of the value function and thus is equal to RRA. However, in our model, both \(P_l\) and \(H_{t-1}\) enter the value function

\(^1\)According to Flavin and Nakagawa (2008) [21], a reasonable \(\alpha\) would be between 0 and -7.
and thus influence the curvature. Therefore, RRA in our model will vary according to different $P_t$ and $H_{t-1}$.

$$RRA \equiv -\frac{\partial^2 V(W_t, P_t, H_{t-1})}{\partial W_t^2} W_t$$

(2.5)

### 2.3 Computational Methods

To make the model more tractable, the state variable $H_{t-1}$ and the choice variable $H_t$, which represent the previous and the new housing consumption respectively, are replaced with $H_{t-1}^{pt} = \frac{P_t H_{t-1}}{W_t}$ and $H_t^{pt} = \frac{P_t H_t}{W_t}$, which represent the proportion of wealth allocated to housing. It should be noted that the actual maximization problem, formulated this way, is the same as the one in section 2.2. The advantage of formulating the problem this way is that it makes the grids of $H_t$ vary for households with different wealth levels. This is more efficient for computation, since we only need to search for the best house for a household within a range according to their wealth level. Correspondingly, the other choice variables are also reformulated as the proportions of wealth allocated to consumption or assets, which are denoted as the variables with an overhead bar. Therefore, the problem used for computation is the following:

$$V\left(W_t, P_t, H_t^{pt}\right) = \max \left\{ V^c\left(W_t, P_t, H_t^{pt}\right), V^{nc}\left(W_t, P_t, H_t^{pt}\right) \right\}$$

(2.6)

where

$$V^{nc}\left(W_t, P_t, H_t^{pt}\right) = \max_{\tilde{C}_t, H_t^{pt}, \tilde{a}_{t+1}, \tilde{b}_{t+1}, \tilde{b}_{t+1}} u(C_t, H_t) + \beta E_t V\left(W_{t+1}, P_{t+1}, H_{t+1}^{pt}\right)$$

(2.7)

s.t. $\tilde{C}_t + \tilde{a}_{t+1} + \tilde{b}_{t+1} - \tilde{b}_{t+1}^{m} + H_t^{pt} \leq 1$

$$1 = H_t^{pt} + \tilde{a}_t (1 + r_a) + \tilde{b}_t (1 + r_f) - \tilde{b}_t^{m} (1 + r_m)$$

$$H_t = H_{t-1}$$

$$\tilde{b}_{t+1}^m \leq 0.8 H_t^{pt}$$

$$\tilde{a}_{t+1} \geq 0, \tilde{b}_{t+1} \geq 0, \tilde{b}_{t+1}^m \geq 0$$
\[ V^c(W_t, P_t, H_{t-1}^{pt}) = \max_{C_t, H_t, a_{t+1}, b_{t+1}, \bar{b}_{t+1}} u(C_t, H_t) + \beta E_t V\left(W_{t+1}, P_{t+1}, H_{t+1}^{pt+1}\right) \]

\[ (2.8) \]

\[ s.t \ C_t + a_{t+1} + b_{t+1} - H_{t-1}^{pt} + \lambda H_{t-1}^{pt} \leq 1 \]

\[ 1 = H_{t-1}^{pt} + a_t(1 + r_t^a) + b_t(1 + r_f) - b_{t+1}^m(1 + r_m) \]

\[ \bar{b}_{t+1}^m \leq 0.8 H_t^{pt} \]

\[ \bar{a}_{t+1} \geq 0, \bar{b}_{t+1} \geq 0, \bar{b}_{t+1}^m \geq 0 \]

Value function iteration is used to solve the model. The following illustrates the procedure:

(i) Set an initial value for the value function: \( V_0 = 0 \),
(ii) Solve equation (2.7) by plugging in \( V = V_0 \) and obtain \( V_{1}^{nc} \),
(iii) Solve equation (2.8) by plugging in \( V = V_0 \) and obtain \( V_{1}^c \),
(iv) Obtain \( V_1 \) by setting \( V_1 = \max\{V_{1}^{nc}, V_{1}^c\} \),
(v) Repeat step (ii): Solve equation (2.7) by plugging in \( V = V_1 \) and obtain \( V_{2}^{nc} \),
(vi) Repeat step (iii): Solve equation (2.8) by plugging in \( V = V_1 \) and obtain \( V_{2}^c \),
(vii) Repeat step (iv): Obtain \( V_2 \) by setting \( V_2 = \max\{V_{2}^{nc}, V_{2}^c\} \),

\[ \vdots \]

The procedure continues until the obtained value function is converging such that \( \|V_t - V_{t-1} < \varepsilon \| \), where \( \varepsilon \) is a very small preset number.\(^2\) Grid search is used for each maximization. It is confirmed that the choices made by the household are not constrained by the bounds of the grid points. After obtaining the final value function, we calculate risk aversions according to equation (2.5).

### 2.4 Numerical Results

For the numerical exercises, there are three main cases. The first one is when the utility function is separable in the two goods or there is no adjustment

\(^2\)\( \varepsilon \) is set to be \( 10^{-6} \).
cost associated with housing consumption, the value function depends only on wealth \((W_t)\). In that case, relative risk aversion is constant and equal to the curvature parameter \(\rho\). The second case is when there is an adjustment cost on housing and the relative price of housing is constant, value function depends on both housing consumption \((H_{t-1})\) and wealth \((W_t)\). In this case, the relative risk aversion depends on the housing to wealth ratio \(\frac{PH_{t-1}}{W_t}\). The third, which is also the focus of this paper is when there is both an adjustment cost on housing and uncertainty in housing prices, the value function depends on housing price \((P_t)\), housing consumption \((H_{t-1})\) and wealth \((W_t)\). Then relative risk aversion depends not only on the housing to wealth ratio \(\frac{PH_{t-1}}{W_t}\) but also the housing price \((P_t)\).

In order to compare the case of a varying housing price to the case of a constant housing price, we start by solving case 1 and case 2. Figure 2.1 illustrates how relative risk aversion changes across different housing to wealth ratios when the assumed housing price is constant at 100. The horizontal axis is the housing to wealth ratio. The horizontal line is the benchmark for the case with no adjustment cost, and the relative risk aversion is equal to the curvature parameter of the utility function, which is 3.

When there is an adjustment cost, relative risk aversion varies with the housing to wealth ratio of the household. The relevant range for the housing to wealth ratios is from 0.2 to 1.8, suggesting 0.2 is the lower bound and 1.8 is the upper bound. If a household has a housing to wealth ratio equal to or smaller than 0.2, it will upgrade its house. If it has a housing to wealth ratio equal to or greater than 1.8, it will downsize its house. When the household changes the house size, it chooses an optimal housing to wealth ratio at 1.2. This ratio is larger than the optimal housing to wealth ratio of 1 in the case of no adjustment cost. This is understandable, because given that there is an adjustment cost to upgrade and an expectation to accumulate wealth over time, when having a chance to upgrade, the household will choose a house of a size larger than their immediate need, so that they don’t have to upgrade in the near future.

As for the change in RRA, the first observation is that magnitude of vari-
ation in RRA is significant. It can be as low as 1.5 and as high as almost 5. The second observation is that RRA is lower in the region closer to the bounds and higher in the region closer to the return point. To understand the intuition behind this, we first take a look at the normal dynamics of RRA. Assuming the household has just changed their house and is around the return point, although RRA can go left or right according to the specific realizations of the returns of the risky asset, the general trend should be that RRA gradually drifts to the left due to a positive expected growth rate of wealth and thus decreasing housing to wealth ratio.

Knowing the above, we can provide the following intuition. The household will be more risk averse around the return point because when households are around the return point, they have a housing to wealth ratio that they are satisfied with and thus do not want to change away from their current situation. Therefore, they hold less risky assets because risky assets would increase uncertainty of their wealth. This preference would correspond to a higher RRA. On the other hand, if households are near the bounds, they are not satisfied with their current housing to wealth ratio and they would hope to stay in that area relatively shorter than the more satisfactory areas. Therefore, they would hope to increase wealth relatively faster by investing more in risky assets, which have higher expected returns. In these areas, households are still risk averse. However, in order to have higher expected wealth growth, they are willing to accept the higher risk, which indicates lower relative risk aversion.

The reason that we may observe the highest RRA region to the right of the return point is the following. Due to adjustment cost, when households adjust, they have already purchased a larger house than they should have. If at that time, they are hit by bad luck and realize losses from risky assets, they can become highly risk averse and extremely careful in order to prevent future losses that will make it really hard for them to maintain their current house.

To better understand the dynamics, we provide simulation results in Figure 2.2. There are four graphs: household risky asset holding, house size, dynamics of net wealth and corresponding RRA. The red line illustrates the case of no adjustment cost and the blue line illustrates the case with adjustment cost. Both
simulations are dependent on the same return sequence for the risky asset. We see that before upgrading, when house size is relatively small compared with their net wealth, the household holds more risky asset and thus accumulates wealth faster than the frictionless case. When wealth accumulates enough, they purchase a house that is larger than the current optimal (the optimal under the frictionless case). After the change in house size, the risky asset holding decreases and the trend of net wealth converges to the frictionless case.

In fact, for both cases, with or without adjustment cost, we would expect the general trend of wealth to be similar. However, due to adjustment costs, households would manage their asset allocations and thus their wealth accumulation according to their housing to wealth ratio, so that for some periods (when they are near the bounds), they increase wealth faster by accepting higher risk, while in other periods (when they are near the return point), they increase wealth slowly by accepting lower risk.

So far, the relative price of housing is kept at 100. To look at the effect of price levels on RRA, we also solve the model with a relative price at 90 and 110 respectively. Figure 2.3 compares the three cases. We see that the three curves are very similar in terms of shapes and the bounds. This suggests that the effect of housing price levels on RRA, if price is kept constant, is not that significant.

After understanding the dynamics of RRA in a setting of constant housing prices, we then solve the model with the housing price process as a three state Markov chain (as specified in section 2.2).

We first compare the medium price RRA curve from the model of varying housing prices with the RRA curve from the constant price model\(^4\). We see from Figure 2.4 that both the upper and lower bounds are more to the right for the case with varying prices. This suggests that households are more likely to hold relatively higher proportion of housing when housing price is varying. This is not too hard to understand considering the price process specified in the model. From the transition matrix, we see that at the medium price, the upside risk is twice as large as the downside risk and therefore making housing a good investment at the

\(^4\)The price is set to be 100.
medium price.

After comparing the two cases, we then look at how relative risk aversion would vary according to different housing prices. The RRA curves shown in Figure 2.5 have already reflected household concerns on the housing price uncertainty. If the realized price doesn’t change, the relative risk aversion would move along each curve. If there is a change in price, RRA jumps from one curve to the other.⁵

From Figure 2.5, we see that although the general shapes of the RRA curves are similar for different prices, there are significant differences in the upper and lower bounds as well as return points for different prices. The return points are approximately 1.5 for low price, 1.2 for medium price, and 0.9 for high price respectively. The lower bound for the low price is 0.6 and the upper bound is 2.4. While the lower bound for medium price is 0.4 and upper bound is 2. For the high price, the bounds are the lowest, which is 0.2 for lower bound and 1.6 for upper bound. This means the housing to wealth ratio that triggers house resizing would be different across prices.

We see that the lower bound for the low price is the highest. This suggests that when housing price is low, household is willing to upgrade their house relatively earlier. They don’t need to wait long and accumulate that much wealth before upgrading. Since we have seen from Figure 2.3 that the effect of price level, if price is kept constant at different levels, doesn’t generate that much difference for the bounds, we believe the difference of lower bounds is caused by the dynamics of the house price. In other words, it is due to the possibility of appreciation of the house at the low price. Similarly, the upper bound of the high price is relatively lower, which suggests that when price is high, household is more likely to downgrade their house. This can be due to the possibility of depreciation at the high price.

From Figure 2.5, we see the relevant range of housing to wealth is from 0.2 to 2.4. To make sure the relevant housing to wealth ratios predicted by the model are largely in line with the data, we look at the empirical cross-sectional distribution of the housing to wealth ratio of households from the Panel Study of Income Dynamics

⁵The jump is not vertical because if housing price changes, the housing to wealth ratio will change too.
(PSID). Figure 2.6 shows that although the distributions changed modestly across the years, about 82% household housing to wealth ratios were between 0.2 to 2.4 and thus consistent with the model’s prediction. According to our assumption, the largest possible housing to wealth ratio allowed by the model is 5, that is when a household takes the maximum mortgage proportion at 80% of the house value and holds no other assets. In reality, we might observe a long tail of housing to wealth ratio as shown in Figure 2.4. This is because for many young households, they may take much higher mortgage and don’t possess many other assets. For example, a 90% mortgage would indicate a housing to wealth ratio of 10 and a 95% mortgage can indicate a ratio of 20.

To see the dynamics of RRA due to the change of housing prices, we start from each state of the housing price and see how the RRA curve changes. Figure 2.7 shows how relative risk aversion would change if the price goes from the medium state to the high state or from medium state to low state. When the price changes, there are two effects. One is the price effect (shifting between price lines) and the other is the housing to wealth ratio effect (moving along the same price line). Therefore, to find the corresponding RRA of a household after a price change, we first need to calculate the housing value and the level of wealth under the new price, from which we obtain the new housing to wealth ratio. Then, we use the new housing to wealth ratio to locate the new RRA from RRA curve for the new price. If the new housing to wealth ratio hits the upper or lower bound of the new price, we know the change in housing price has triggered an adjustment in housing consumption. In this case, the new RRA corresponds to the return point under the new price.⁶

When the price suddenly goes down, the households with lower housing to wealth ratios will have the biggest changes in RRA. These are the households who are close to the lower bound and thus are almost ready to upgrade their houses at the medium price. A sudden decrease in house price makes them hit the lower bound, giving them incentive to upgrade right away. Similarly, when price suddenly goes up, the households with higher housing to wealth ratios will have

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⁶In Figure 2.7 (as well as Figure 2.8 and 2.9), the horizontal axis only indicates the housing to wealth ratio of the household before the price change.
the biggest changes in RRA. Those are the households who are close to the upper bound before the price change and thus almost ready to downsize their houses at the medium price. A sudden increase in the house price triggers their downsizing right away.

Similar patterns are observed if we start from high price and see what happens to RRA when price suddenly goes down to medium or low, as shown in Figure 2.8. Again, the biggest changes are observed for households who are around the lower bound and thus can take advantage of the lower prices and upgrade their houses earlier.

Finally, if we start from low price, the only possibility is to go to the medium price. The result is shown in Figure 2.9. Similar to the case of going from medium price to high price, households who start with housing to wealth ratios close to the upper bound have a big increase in their RRA, since they will hit the bound due to the price increase and downsize their houses right away.

From these three graphs, we can conclude that the main effect of varying housing prices is that it makes households hit bounds more often and thus make them move more frequently than in the case of a constant house price. In addition, we see that, for households that don’t hit bounds due to price changes, there can still be changes in their RRA, although the changes may be less significant.

Figure 2.10 shows simulation results for the cases with constant and varying housing prices (both with adjustment cost). Simulations are based on the same return sequence of the risky asset. The main observation is that when price is varying, it is more likely for households to hit bounds and resize their house. The circled prices (in the graph of the housing price) are the house prices that instantly trigger housing adjustment. We see that the first adjustment (in the case of varying housing prices) is triggered by a sudden increase in house price from 100 to 110 in period 8.7 In comparison, if the price is always constant, the household will downsize their house much later (in period 14). The second adjustment is triggered by a sudden drop in housing price. The household takes advantage of the price drop and upgrades their housing. For the last adjustment, it is also due

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7In the graph of the housing price in Figure 2.10, state 1 corresponds to a price of 90, state 2 corresponds to 100, and state 3 corresponds to 110.
to a sudden increase of the housing price.

Another observation from Figure 2.10 is that on average, RRA in the case of varying housing prices is higher than RRA in the case with a constant price. Consequently, the higher RRA (due to varying housing prices) will result in a lower risky asset holding and thus slower accumulation of wealth. This contributes to the difference in the wealth level between the two cases in Figure 2.10. In addition, the larger adjustment cost paid due to more frequent moving (in the case of varying housing prices) also contributes to the wealth difference.

2.5 Model Implications

2.5.1 Microeconomic Implications

From the numerical results in section 2.4, we see that one of the main implications of the model is that RRA increases when households move. It will be interesting to see whether we can find support for this implication of the model from the data. In principle, it is very hard to observe one’s RRA directly. One good data source is the Health and Retirement Survey (HRS), where there are survey questions that directly ask people about their attitudes toward risk. Thus, we will be able to see whether their risk preferences change after moving.

In the survey, respondents are asked to choose between pairs of jobs where one guarantees current family income and the other offers a chance to increase income but also carries the risk of loss of income. If respondent says he/she would take the risk, the same scenario but with riskier odds is presented. If he/she would not take the risk, the same scenario with less risky odds is asked. Here are the questions:

1. Respondent would take a job with even chances of doubling income or cutting it in half.
2. Respondent would take a job with even chances of doubling income or cutting it by a third.
3. Respondent would take a job with even chances of doubling income or cutting it by 20%.
4. Respondent would take or stay in the job that guaranteed current income rather than take any of the above alternatives.

From these questions, we can come up with a rough measure of the implied relative risk aversion for households in each category. For this calculation, assume a simple value function of the form

\[ V(W) = \frac{W^{1-\rho}}{1-\rho} \]  

We set initial wealth level \( W_0 = 0.5W^h \), where \( W^h \) is the human wealth. Then if household accepts 1 (least risk averse), it implies that

\[ V(W_0 + W^h) \leq 0.5V(W_0 + 2W^h) + 0.5V(W_0 + 0.5W^h) \]  

This would imply \( \rho \leq 1.5 \). Using this method, we can obtain a range for \( \rho \) for each category and the results are listed in Table 2.1. We can see that the implied range of RRA from the Health and Retirement Survey is generally in line with the range predicted by the model, which is from 1.5 to 5.

The data on risk aversion is available every two years from 1998 to 2006. We only have three inter-year changes from 1998-2000, 2000-2002 and 2004-2006. We lose observations for 2002-2004 because there are no respondents who were asked the questions both in 2002 and 2004. Table 2.2 shows the summary of the changes in risk aversion observed in the data. We notice from the table that it is common for respondents to change their reported level of risk aversion. Besides, we can also observe large changes of risk aversion, such as from 1 to 4 or from 4 to 1. Table 2.3 is a more detailed summary.

We are interested in whether change of housing consumption, which we interpret as a move to the return point, is associated with a change in self-reported risk aversion. From the theory and the computational results presented in previous sections, we would expect change of housing consumption to lead to an increase in reported relative risk aversion. As seen in Figure 2.1, when households are about to move, they should be around either the lower or upper bound, where RRAs are low. After a change in housing consumption, the household housing to wealth ratio changes to middle area, where RRA is high.
To see the effect of the household moving on RRA, a probit model is used, where the dependent variable is an indicator of whether respondent reports a higher risk aversion compared to the last interview. The independent variable of interest is an indicator of whether a household moved to a different house since the last interview period. We also control for other factors such as a change of wealth, change in the number of people living in the household, change in the number of children, age and education of the respondent. The specification is as follows

\[
D^*_{it} = \beta_0 + \beta_1 I\{i \text{ Moved between } t-1 \text{ and } t\} + X'_{it}\Gamma + u_{it}
\]

\[
P(D_{it} = 1) = P(D^*_{it} > 0) = \Phi(\beta_0 + \beta_1 I\{i \text{ Moved between } t-1 \text{ and } t\} + X'_{it}\Gamma)
\]

where \(D^*_{it}\) is a latent variable and can be interpreted as the change in risk aversion and \(D_{it} = 1\) is the case that we observe a reported higher level of risk aversion. The result is listed in Table 2.4.

We see that our main variable of interest, the indicator variable for moving, is statistically significant at the 10% level and has a positive effect on reporting a higher risk aversion. This is consistent with our model’s prediction. To better interpret our regression result, we calculate the average partial effect of moving on reporting higher risk aversion according to the following equation

\[
\frac{1}{n} \sum_{i=1}^{n} \{\Phi(\hat{\beta}_0 + \hat{\beta}_1 + X'_{it}\hat{\Gamma}) - \Phi(\hat{\beta}_0 + X'_{it}\hat{\Gamma})\}
\]

where the first term captures the average predicted probability of reporting a higher risk aversion conditional on the household moving, which is calculated to be 80%. The second term captures the average predicted probability of reporting a higher risk aversion conditional on the household not moving, which is 65%. Thus the average partial effect is found to be about 15%.

The variables Report 1 and Report 2 listed in Table 2.4 are dummy variables. Report 1 is equal to 1 if respondent’s reported level of risk aversion in the

\footnote{All respondents (home owners) are included in the data set except respondents who reported 4 (the most risk averse) in the first interview. This is because there is no possibility for those households to report a higher level of risk aversion in the second interview. The dependent variable is 1 for those reporting a higher risk aversion in the subsequent interview and equals 0 for those reporting the same or a lower risk aversion.}
first period is 1 and Report 2 is equal to 1 if respondent’s reported level of risk aversion in the first period is 2. As expected, the positive and statistically significant coefficients of Report 1 and Report 2 confirm that the lower the starting risk aversion of a respondent, the more likely it is that he/she would subsequently report a higher risk aversion. The other two variables that are statistically significant are Respondent’s age and Respondent’s education. We see that age has a positive effect while education has a negative effect. This suggests that older people are likely to become more risk averse. This may be related with their deteriorating health status. Intuitively, older people are more likely to face new health problems that require more stable income and thus they will have less ability to bear financial risk compared with before. As for the observation that better educated people are less likely to report a higher risk aversion, one interpretation is that better educated people tend to understand these questions better and thus are more consistent with their answers. Finally, we find that none of the change of household net wealth, change of respondent’s income or change of number of people or children are statistically significant.

As seen from the above, Table 2.4 provides us with empirical evidence on the increase of RRA for movers. From the numerical results in section 2.4, we know that the model also has implications for the change in RRA for non-movers. Based on the same results shown in Figure 2.7, Figure 2.11 is an explicit illustration of the change in RRA for non-movers due to price changes. We see that the change in RRA, both its direction and magnitude, depends on the housing to wealth ratio. The absolute change can be as large as 2.2 and as small as 0.2. This can give us some ideas on why we observe so many changes in risk preferences in Table 2.2, even for non-movers. If we believe the changes are not simply due to reported errors and random inconsistency of households, Figure 2.11 suggests that change of house prices can certainly be one factor.

2.5.2 Macroeconomic Implications

As we see from section 2.4, another numerical result is that stochastic housing price process will make households hit the upper and lower bounds more often
than a model with constant housing prices. This would indicate that when housing prices are volatile, a higher proportion of households will hit the bounds and therefore increase their RRA. Then, in theory, we should observe a higher level of the weighted average RRA in the economy. Thus, the model suggests a potential link between housing volatility and the economy wide RRA. In practice, it would be very hard, if not impossible, to measure the average RRA in the economy. Therefore, we use price of risk in the stock market as a proxy measure. The positive link between risk aversion and price of risk should be intuitive. When the average RRA is high in the market, we would expect investors to require a higher risk premium to hold any risky assets and thus there should be a higher price of risk. Formally, Lintner (1970) [28] has shown that the market price of risk is the market’s risk aversion. Therefore, in the following empirical exercise, we are interested in finding out whether housing price volatility is positively correlated with the market price of risk.

To obtain the price of risk, we follow Engle, Lilien, and Robins (1987) [15] to construct a GARCH-M model for the stock market returns. The basic insight is that risk-averse agents will require compensation for holding a risky asset. Given that the riskiness of an asset can be measured by the variance of returns, the risk premium will be an increasing function of the conditional variance of returns. They express this idea by writing the excess return from holding a risky asset as the following:

\[
\begin{align*}
  y_t &= \mu_t + \epsilon_t \\
  \mu_t &= \beta + \delta h_t \\
  h_t &= \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \gamma_1 h_{t-1} \\
  \epsilon_t &= \nu_t \sqrt{h_t}
\end{align*}
\]  

(2.13)

where \( y_t \) is the excess return from holding a risky asset, for which we use the excess return of S&P 500 value weighted portfolio. To be consistent with the housing data used later, the return is quarterly, from 1975 Q2 to 2013 Q4. \( \mu_t \) is interpreted as the risk premium necessary to induce the risk averse agent to hold the risky asset and \( \epsilon_t \) is the unforecastable shock to the excess return.
Equations (2.13) imply that the expected excess return from holding the risky asset must be equal to the risk premium and it is assumed that the risk premium is an increasing function of the conditional variance of \( \epsilon_t \); in other words, the greater the conditional variance of returns, the greater the compensation necessary to induce the agent to hold the risky asset. Equations (2.14) display the estimation result.

\[
y_t = -0.0096 + 4.8431h_t + \epsilon_t
\]

\[
h_t = 0.0012 + 0.1909\epsilon_{t-1}^2 + 0.6178h_{t-1}
\]

The coefficient of the volatility term is marginally significant. The ARCH term is also marginally significant, while the GARCH term is statistically significant. Figure 2.12 is a picture of the fitted risk premium versus the realized excess returns.

With the results from equation (2.14), we construct the price of risk from the stock market as the ratio of the fitted risk premium (also the fitted excess return) to the fitted conditional standard deviation, as written in equation (2.15).

\[
\text{price of risk} = \frac{\hat{\mu}_t}{\sqrt{\hat{h}_t}}
\]

The housing price data used is the quarterly House Price Index (HPI) from Federal Housing Finance Agency from 1975 Q2 to 2013 Q4. To construct housing price volatility, we use a ARMA(5,2)\(^9\) with GARCH(1,1) model for the growth of housing price and predict the conditional variance from the model. ARMA(5,2) is selected by the AIC criterion and only after controlling for these lags, the autocorrelation function and the partial autocorrelation function of the error terms have no more obvious patterns.

\[
y_t = 0.0059 + 1.1927y_{t-1} - 1.1814y_{t-2} + 0.7767y_{t-3} - 0.3472y_{t-4} + 0.2882y_{t-5} + \epsilon_t - 0.7041\epsilon_{t-1} + 0.6953\epsilon_{t-2}
\]

\[
h_t = 6.38 \times 10^{-6} + 0.4337\epsilon_{t-1}^2 + 0.5514h_{t-1}
\]

\(^9\)It is confirmed that there are no remaining patterns for both the standardized errors and the squared standardized errors.
Equations (2.16) display the estimation result. Most of the coefficients are statistically significant. Figure 2.13 shows the fitted HPI growth rate and the actual HPI growth rate.

We are interested in whether housing volatility is correlated with the market price of risk. Figure 2.14 illustrates the dynamics of both price of risk and housing volatility. The correlation of the two series is 0.23 for the whole period and is about 0.4 for the period after 2008. This provides some empirical evidence that there exists a correlation between housing market and stock market due to the change of RRA. In particular, more volatile housing price process can result in an increase in the average RRA. Higher RRA requires a higher risk premium given any level of risk. Therefore, we can expect a higher level of excess return in the stock market.

2.6 Conclusion

To conclude, this paper studies the implications of housing consumption on relative risk aversion. Both the numerical results of the model and empirical results using data from the Health and Retirement Survey show that the change of housing consumption (moving) is associated with an increase in relative risk aversion. The effect of housing prices on relative risk aversion depends on household housing to wealth ratio. Another important implication of the model is that a volatile housing price process will make households move more often and thus increase the aggregate risk aversion in the economy. Therefore, the model implies a positive link between the housing price volatility and the price of risk. Using excess return of S&P 500 value weighted portfolio and the House Price Index from the Federal Housing Finance Agency, we do find empirical evidence that housing volatility is positively correlated with the price of risk, especially in certain time periods like 2008-2014.
## 2.7 Tables

**Table 2.1: Implied Relative Risk Aversion**

<table>
<thead>
<tr>
<th>Category</th>
<th>Implied Values for $\rho$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$\rho \leq 1.5$</td>
</tr>
<tr>
<td>2</td>
<td>$1.5 &lt; \rho \leq 3$</td>
</tr>
<tr>
<td>3</td>
<td>$3 &lt; \rho \leq 5.5$</td>
</tr>
<tr>
<td>4</td>
<td>$5.5 &lt; \rho$</td>
</tr>
</tbody>
</table>

**Table 2.2: Summary of Changes in Risk Preference Categories from HRS**

<table>
<thead>
<tr>
<th>Change</th>
<th>Number of Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower</td>
<td></td>
</tr>
<tr>
<td>-3</td>
<td>118</td>
</tr>
<tr>
<td>-2</td>
<td>175</td>
</tr>
<tr>
<td>-1</td>
<td>365</td>
</tr>
<tr>
<td>No Change</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>1497</td>
</tr>
<tr>
<td>Higher</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>400</td>
</tr>
<tr>
<td>2</td>
<td>183</td>
</tr>
<tr>
<td>3</td>
<td>140</td>
</tr>
<tr>
<td>Total Number of Observations</td>
<td>2878</td>
</tr>
</tbody>
</table>
Table 2.3: Detailed Changes of Risk Preference Categories from HRS

<table>
<thead>
<tr>
<th>Up Change</th>
<th>Number of Observations</th>
<th>Down Change</th>
<th>Number of Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 2</td>
<td>55</td>
<td>4 to 3</td>
<td>248</td>
</tr>
<tr>
<td>1 to 3</td>
<td>55</td>
<td>4 to 2</td>
<td>129</td>
</tr>
<tr>
<td>1 to 4</td>
<td>140</td>
<td>4 to 1</td>
<td>118</td>
</tr>
<tr>
<td>2 to 3</td>
<td>54</td>
<td>3 to 2</td>
<td>71</td>
</tr>
<tr>
<td>2 to 4</td>
<td>128</td>
<td>3 to 1</td>
<td>46</td>
</tr>
<tr>
<td>3 to 4</td>
<td>291</td>
<td>2 to 1</td>
<td>46</td>
</tr>
<tr>
<td>Variables</td>
<td>Pr(Increase Risk Aversion)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------------------------------</td>
<td>-----------------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$I_{\text{Moved}}$</td>
<td><strong>0.2264</strong>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.1210)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change of Wealth</td>
<td>0.0113</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0541)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change of Respondent’s Income</td>
<td>-0.1805</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.1453)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change of Number of People</td>
<td>-0.0245</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0468)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Change of Number of Children</td>
<td>-0.0132</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0597)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respondent’s Gender(Female)</td>
<td>0.1132</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0769)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respondent’s Age</td>
<td><strong>0.0183</strong>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0069)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Respondent’s Education</td>
<td><strong>-0.0541</strong>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0151)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reported 1 last interview (least risk averse)</td>
<td><strong>0.4223</strong>**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0888)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reported 2 last interview (2\textsuperscript{nd} least risk averse)</td>
<td><strong>0.3607</strong>**</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0969)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Observations</td>
<td>1172</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pseudo $R^2$</td>
<td>0.036</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
2.8 Figures

Figure 2.1: Relative Risk Aversion for Different Housing to Wealth Ratios

Figure 2.2: Simulation Result: With and Without Adjustment Cost
Figure 2.3: Relative Risk Aversion Given Different Constant Housing Prices

Figure 2.4: Relative Risk Aversion Comparison
Figure 2.5: Relative Risk Aversion Given Varying Housing Prices

Figure 2.6: Housing to Wealth Ratio Distribution
Figure 2.7: Dynamics of Relative Risk Aversion (from Medium Price)

Figure 2.8: Dynamics of Relative Risk Aversion (from High Price)
Figure 2.9: Dynamics of Relative Risk Aversion (from Low Price)

Figure 2.10: Simulation Result: With and Without House Price Changes
Figure 2.11: Change of Relative Risk Aversion (from Medium Price)

Figure 2.12: Predicted Risk Premium vs Realized Excess Return
Figure 2.13: Growth Rate of HPI from Federal Housing Finance Agency

Figure 2.14: Price of Risk and Housing Volatility
Chapter 3

Implications of the Housing Model for Moving Frequency, Relative Risk Aversion and the Portfolio Share of Risky Assets

Abstract

This paper tests the implications of a model with housing consumption, adjustment costs, and varying housing prices. Firstly, we use cross-sectional variation in state level housing dynamics and homeowners’ moving frequency to study the relationship between the volatility of house prices and moving frequency. The results lend support to the first implication of the model that volatile house prices lead to more frequent moving. Secondly, we use household moving and stock holding data to study the effect of moving on relative risk aversion (RRA). The results lend support to the second implication of the model that household moving is associated with higher RRA. Finally, we study the effect of unemployment on household moving by solving a model with housing consumption, adjustment costs and a stochastic labor income process. The results suggest that the overall effect of higher unemployment is to reduce the frequency of moving. Furthermore, a sudden shift to an unemployed status can increase household RRA without triggering a
move. This provides a new channel (through the change in risk aversion) for the unemployment rate to affect asset prices.
3.1 Introduction

The aim of this chapter is to test the two main implications of the model developed in Chapter 2, that is a model with housing consumption, adjustment costs, and varying housing prices, using data from the Panel Study of Income Dynamics (PSID). The first implication is that volatile house price dynamics leads to more frequent moving. The second implication is that household moving is associated with higher relative risk aversion (RRA).

We observe from the data in the PSID that there is cross-sectional variation in homeowners’ moving frequency at state level. It is also the case that there is cross-sectional variation in house price dynamics across states. Therefore, the question of interest is whether the variation in house price dynamics contributes to the variation in moving frequency in different states. What we find is that the higher the historical volatility of the house price growth rate in a given state, the higher is the frequency of moving in that state. This result lends support to our model.

Although the second implication has been tested in Chapter 2 using data from the Health and Retirement Survey (HRS), both the data and methodology utilized here are different. From the HRS, we infer household RRA from their choices over theoretical gambles. In the PSID, we can directly observe household stock holdings and thus can use that as an indicator for RRA. We find that for households who moved due to endogenous reasons (mainly consumption related), moving is associated with a lower proportion of assets allocated to stocks.

We also find that at the state level, the unemployment rate is also related to homeowners’ moving propensity. To further understand the effect of unemployment on moving, we solve a model with housing consumption, adjustment costs and a stochastic labor income process. The main finding is that unemployment can trigger a move to a smaller home while lowering the chances of a move to a larger house. Since trading up is more common considering normal wealth accumulation, the effect of unemployment on the frequency of moving to a larger house dominates its effect on trading down. Therefore, the overall effect of higher unemployment is to reduce moving frequency. We also find a sudden shift to unemployment status
can increase the RRA of a household without triggering a move. This provides a new channel (through the change in risk aversion) for the unemployment rate to affect asset prices.

The rest of the paper is organized as follows. Section 3.2.1 provides a summary on household moving in the PSID. Section 3.2.2 studies the effect of house price volatility on homeowners’ moving frequency across states. Section 3.3 studies the effect of moving on household stock holdings. Section 3.4 studies the effect of unemployment on moving in a model with a stochastic labor income process. Section 3.5 concludes.

3.2 Household Moving in PSID

3.2.1 Frequency of Moving and Reasons for Moving

From the model, we see that when we have a varying (as opposed to constant) housing price, households hit bounds more often, which leads to more frequent moving. It would be interesting to see whether there is any evidence supporting this using household level data. To be consistent with the model, we are mainly interested in the moves of homeowners. In the PSID, there are about 8000 households for each interview year from 1975 to 2011. There are three possible housing states: owning, renting, and living in free housing. Free housing is rare and accounts for less than 3% of all the households. The main occurrence of free housing is when housing is part of compensation, such as for servants, housekeepers, nurses, etc. Figure 3.1 is a plot of the proportion of homeowners (out of all households in each interview year) across years. The proportion of homeowners peaked around 2003 and then fell afterwards.

What we are interested in is homeowners’ likelihood of moving. To look at that, we need to exclude new homeowners (renters who become homeowners). On average, there are around 7% of households who become new homeowners in a given year and the peak is around 2000. Figure 3.2 is a plot of the proportion of new homeowners in each interview year. After excluding new homeowners, we focus on moves by existing homeowners. Figure 3.3 is a plot of the fraction of
homeowners who move in a given period. We see that before 2000, the average frequency of moving is around 5%. Around 2007, the proportion reaches more than 10%. There can be both endogenous and exogenous reasons for moving. We define “endogenous moving” as moves that are endogenous with respect to wealth dynamics and thus are moves predicted by the model. “Exogenous moving” can be due to other events, such as a new job, eviction, retiring, etc. The PSID asks households about their reasons for moving. Households identify their motive for moving as one of the following.

(1) Purposive productive reasons: to take another job; transfer; stopped going to school.
(2) To get nearer to work.
(3) Purposive consumptive reasons – expansion of housing: more space; more rent; better place.
(4) Purposive consumptive reasons – contraction of housing: less space; less rent.
(5) Purposive consumptive reasons – other house-related: want to own home; got married.
(6) Purposive consumptive reasons – neighborhood-related: better neighborhood; go to school.
(7) Response to outside events (involuntary reasons).
(8) Ambiguous or mixed reasons: to save money; all my old neighbors moved away.

Motives (1) and (2) are related to work and categorized as productive reasons. They are considered as exogenous. (7) is obviously exogenous. Endogenous reasons are (3) to (6), which are consumption related. Figure 3.4 is a plot of the proportion of households that moved for different reasons. We see that consumption motive is the largest category and it increases the most (almost doubles from 4% to 8%) around 2007. Figure 3.6 is a plot of detailed consumptive (endogenous) reasons. We see that expansion is the largest category and getting married the second.

3.2.2 House Price Volatility and Moving Frequency

Figure 3.5 is the quarterly growth rate of the House Price Index (HPI) from the Federal Housing Finance Agency starting in 1975. We see that the periods of
surge of household endogenous moving shown in Figure 3.4 seem to be associated with relatively more volatile house price dynamics as shown in Figure 3.5. This is consistent with the model’s prediction that when house prices are more volatile, it is more likely for households to hit bounds, which will trigger changes in housing consumption.

To further explore the relationship between house price volatility and moving frequency, we use cross-sectional variation in states’ house price growth rates and the cross-sectional variation in states’ moving frequencies from the PSID. There is significant variation in moving frequencies across states. Table 3.1 records the average proportion of homeowners and the average fraction of homeowners who move in each state. The moving frequency is sorted from low to high.

The volatility of the house price process in each state is measured by the historical standard deviation of the growth rate of the House Price Index. To look at the effect of house price volatility on moving frequency, we run a regression of the fraction of homeowners who move due to consumption related reasons (endogenous moving) on the volatility of the growth rate of the house price. Other variables included are the level of the House Price Index, the mean growth rate of the house price, states’ annual unemployment rates, states’ personal income per capita and states’ proportion of homeowners. We also control for year fixed effects. The specification is the following.

\[
PM_{it} = \beta_0 + \beta_1 HGV_i + \beta_2 MHGR_i + \beta_3 HPI_{it} + \beta_4 UNEMPLOY_{it} + \beta_5 PI_{it} + \text{Year Effects} + \epsilon_{it} \tag{3.1}
\]

where \(PM_{it}\) is the proportion of households who move in state \(i\) in period \(t\); \(HGV_i\) is the standard deviation of the house price growth rate in state \(i\) during the period from 1975-2011; \(MHGR_i\) is the mean house price growth rate in state \(i\) during that period. \(HPI_{it}\), \(UNEMPLOY_{it}\) and \(PI_{it}\) are the house price index, unemployment rate and personal income per capita in state \(i\) and period \(t\).

From the first column of Table 3.2, we see that house price growth rate volatility has a positive and statistically significant effect on frequency of moving
in different states. In the regression, the frequency of moving, proportion of homeowners, house price growth rate volatility, and mean house price growth rate are all measured in units of percentage points. That is, a value of 1 for these four variables would mean 1 percentage point. Therefore, the results suggest that a 1 percentage point increase in the standard deviation of the house price growth rate on an annual basis can increase the frequency of moving by about 0.6%. If we compare the state of California to the state of Kansas, with house price growth rate volatility of 10.4% and 3.4% respectively, this would suggest that holding all other factors constant, we would expect the frequency of moving in California to be higher by about 4.3%.

One observation is that, at the state level, there is a high correlation, about 0.6, between the mean house price growth rate and the standard deviation. In other words, empirically, we find that the higher the mean of the house price growth rate, the more volatile are prices. We see in the column 4 of the Table 3.2 that if we don’t control for the volatility of the house price growth rate, we would get a statistically significant positive effect of the mean house price growth rate. However, if we control for volatility, as in the first column, the sign of the coefficient of mean house price growth rate becomes negative, although not statistically significant. This suggests that when holding the volatility constant, higher growth rate reduces the frequency of moving. To understand that, we can compare two cases, one with a constant positive house price growth rate, and the other with a growth rate of zero. For the case of zero growth rate, we know that the house price is constant and thus the house value does not change. Then we would expect household housing to wealth ratio \( \frac{PH}{W} \) to go down gradually as wealth accumulates, until the lower bound of the housing to wealth ratio is hit. In comparison, when we have a positive house price growth rate, household housing to wealth ratio \( \frac{PH}{W} \) will go down slower due to increasing house value. Thus, it will take longer for households to hit lower bound. This means there will be less frequent moving on average.

The coefficient on the unemployment rate is also negative and statistically significant, suggesting that a higher unemployment rate decreases the frequency of
moving. We know that there are essentially two types of moving for endogenous reasons, trading up and trading down. Intuitively, unemployment will decrease the rate of wealth accumulation, which decreases the probability of trading up. It may also lead to wealth decumulation and thus increase the probability of trading down. However, in general, trading up is much more common than trading down. This is what we observe from the data in the PSID. From 1975 to 2011, we observe 435 households trading up in total, while only 106 households trading down. This is also consistent with the model’s prediction, since we would expect a larger proportion of households to be on the left side of the return point due to the positive trend of wealth accumulation. Therefore, although unemployment has opposite effects on trading up and trading down, considering that an increase in house size is far more common than a decrease, the negative effects of unemployment on trading up dominate the positive effects on downsizing. Then, the total effect of unemployment rate on the frequency of moving should be negative. To confirm this, we look at household level moves.

\[
P(I_{it} = 1) = \Phi(\beta_0 + \beta_1 I_{BecomeUnemployed, it} + \beta_2 I_{BecomeRetired, it} + \beta_3 ADULTC_{it} + \beta_4 CHILDRENC_{it} + \beta_5 WEALTHC_{it})
\]

We run three probit regressions. The dependent variables are indicator variables of household moving, increasing house size and decreasing house size. The variable of interest is the indicator variable \(I_{BecomeUnemployed, it}\). It is equal to 1 if the head of household \(i\) was employed in period \(t - 1\), but was unemployed in period \(t\). Similarly, \(I_{BecomeRetired, it}\) is equal to 1 if the head of household \(i\) was employed in period \(t - 1\), but was retired in period \(t\). \(ADULTC_{it}\) is the change of number of adults in the household \(i\) from period \(t - 1\) to \(t\). \(CHILDRENC_{it}\) is the change of number of children (under 18) living in the household from period \(t - 1\) to \(t\). Finally, \(WEALTHC_{it}\) is the change of family wealth.

We see from the second column of Table 3.3 that becoming unemployed has a statistically significant positive effect on the probability of downsizing. In comparison, the third column shows that becoming unemployed has a statistically significant negative effect on probability of trading up. When we combine both directions, we see from first column that the effect of becoming unemployed is
negative, although not statistically significant. We also observe that the effect of becoming retired is very similar to that of becoming unemployed. In addition, a change in the number of children is statistically significant in all three regressions. We see that increasing the number of children living in the household significantly increases the probability of moving to a larger house, while decreasing probability of downsizing. All in all, the results from Table 3.3 confirm our understanding of why unemployment could have a negative impact on moving frequency in regression (3.1).

Finally, we might also expect the proportion of homeowners to have an effect on the frequency of moving. If it is easier for households to become homeowners in some states, it may be also easier for households to sell and purchase a new house in one state due to some characteristics of the housing markets, such as taxation or administrative procedures, etc. From Table 3.2, we see that although the sign of proportion of homeowners is positive, it is not statistically significant.

### 3.3 The Effects of Moving on Household Stock Holding

In this section, we are primarily interested in testing the hypothesis that household moves are associated with a lower share of risky assets (equities) in the portfolio. According to the model, households are more risk averse at the return point or right after they move. They are less risk averse near the bounds or right before they move. Intuitively, we would expect more risky asset holding when risk aversion is low and less risky asset holding when risk aversion is high. Therefore, the model implies that households will hold a smaller portfolio share in stocks just after moving.

Although the PSID is considered as a long panel data, the relevant variables, related to detailed wealth information of households, are only available from 1999 to 2011 every other year. There are seven categories of asset values that are recorded in the PSID apart from the primary residence value: the value of business or farm, the value in checking or savings account, the value of bond funds or cash value in
insurance, the value of other real estate (other than the primary residence), the value of stocks, the value of annuity or IRA and the value of vehicles. The total asset value is computed as the sum of these assets.

We look at the proportion share of stock holdings held by households (relative to the total asset value) and use it as an indicator of risk aversion. To be consistent with the model, we are only interested in homeowners’ stock holdings. Due to the problem of limited participation, we only include households who ever reported positive stock values and thus are considered as stock market participants. Table 3.4 is a summary of the stock holdings of homeowners in the PSID.

One thing to notice from Table 3.4 is that the participation rate seems to decline over this period, from more than 31% in 1999 to 21% in 2011. The percentiles of stock holdings for the participants, however, seem to be relatively stable. The lowest 10th percentile is around 2%. 25th percentile is around 8%, 50th percentile around 25%, 75th percentile around 50% and 90th percentile around 72%.

Furthermore, we only include moves for which households reported an endogenous motive and exclude those that are due to exogenous reasons, such as work or other outside events. This is because for those exogenous reasons, it is very likely that households were not close to bounds before they moved and thus a move was not significantly changing their housing to wealth ratio. Therefore, we don’t expect moves of these households to be associated with higher RRA and lower stock holdings.

The specification for the pooled regression is:

\[ SH_{it} = \beta_0 + \beta_1 I_{moved, it} + \beta_2 HV_{it} + \beta_3 WHE_{it} + \beta_4 FS_{it} + \beta_5 AGEH_{it} + \beta_6 EDUC_{it} + \beta_7 I_{retired, it} + \beta_8 I_{unemployed, it} + \beta_9 I_{student, it} + \beta_{10} I_{disabled, it} + \text{Year Fixed Effects} + \epsilon_{it} \]  

\[ (3.3) \]

\( SH_{it} \) is the proportion of stock holding (relative to the total asset value) of the household \( i \) in period \( t \). It can be considered as an indicator of the household risk aversion. \( I_{moved, it} \) is an indicator of whether household \( i \) moved between period \( t - 1 \) and \( t \). \( HV \) stands for the value of the current house, \( WHE \) is the amount of net wealth including home equity. \( FS \) is the family size, \( AGEH \) is the age
of the household head and $EDUCH$ is the years of education completed by the household head. The rest of the indicators specify the head’s employment status. The baseline category is that the head is working. We also include year fixed effects and the baseline interview year is 1999.

The regression results are reported in Table 3.5. The unit of the dependent variable is percentage point. This means, if the dependent variable increases by 1, this corresponds to a 1% increase in proportion of stock holding. We see that the coefficient of the variable of interest, the indicator of moving or not, is negative and statistically significant. This is consistent with our model’s prediction, which says that risk aversion will be high after moving and thus will lead to lower stock holdings. More specifically, the result indicates that on average, moving is associated with a 3.5% lower share of stocks in financial wealth. The effect of wealth level on proportion of stock holding is far from significant. This is consistent with the theory that the wealth level alone is not affecting risk aversion.

Family size has a negative statistically significant effect on stock holding. This means the larger the family size, the smaller the proportion of assets allocated to stocks. Intuitively, we would think larger families face larger financial burden and thus need higher financial safety, which would lead to higher risk aversion and lower stock holding. Both age and education of the head have positive statistically significant effects on stock holding. The older the head, the higher proportion of assets are allocated to stocks. Also, the more education the head finished, the higher proportion of assets are allocated to stocks. In general, higher educated people have better knowledge about the financial market and should feel more confident about investing in stocks directly.

The baseline employment status is employed. So we see from Table 3.5 that the retired group has a much larger stock holding, 6.5% higher, than the working group. As for the year fixed effects, the baseline year is 1999. The lowest stock holding proportion is observed in 2009, which is 5.2% lower than 1999.
3.4 How Becoming Unemployed Triggers Moving - A Model

The results from section 3.2.2 suggest that unemployment can affect moving frequency. In the original model, we abstract from labor income. In this section, we solve the model with a Markov process for labor income, so that we can study the effect of unemployment on the frequency of moving and on risk aversion. As before, the household maximizes the expected lifetime utility.

\[ U = E_0 \sum_{t=0}^{\infty} \beta^t u(C_t, H_t) \]  \hspace{1cm} (3.4)

Period utility has the following specification, which is sufficiently general to incorporate Cobb-Douglas utility as the limiting case as \( \alpha \) approaches zero, as well as the standard, one-good utility function.

\[ u(C, H) = \left( \frac{C^\alpha + \gamma H^\alpha}{1 - \rho} \right)^{1/\alpha}, \alpha \leq 1, \rho > 0, \gamma > 0 \]  \hspace{1cm} (3.5)

\( C_t \) is nondurable consumption, which can be adjusted costlessly. \( H_t \) is housing consumption; its adjustment will incur a non-convex adjustment cost, which is proportional to the value of household’s current house. In each period, the household allocates wealth among the housing asset, a risk free bond and risky assets. Households can only borrow against their houses up to 80% of the house value. The mortgage rate is slightly higher than the risk free rate. Both the return on the risky asset and the current labor income level are realized at the beginning of the period.

The household’s maximization problem can be described using the following value functions.

\[ V(W_t, I_t, H_{t-1}) = \max \left\{ V^c(W_t, I_t, H_{t-1}), V^{nc}(W_t, I_t, H_{t-1}) \right\} \]  \hspace{1cm} (3.6)

where \( V^c \) and \( V^{nc} \) represent the value functions associated with changing and not
changing housing consumption. More specifically, they are defined as follows.

\[
V^{nc}(W_t, I_t, H_{t-1}) = \max_{C_t, H_t, a_{t+1}, b_{t+1}^m, b_{t+1}} u(C_t, H_t) + \beta E_t V(W_{t+1}, I_{t+1}, H_{t}) \tag{3.7}
\]

\[
s.t \quad C_t + a_{t+1} + b_{t+1} - b_{t+1}^m + PH_t \leq W_t
\]

\[
W_t = \lambda PH_{t-1} + a_t(1 + r_a^t) + b_t(1 + r_f^t) + I_{t-1} - b_{t-1}^m (1 + r_m^t)
\]

\[
H_t = H_{t-1}
\]

\[
0.8PH_t \leq b_{t+1}^m \leq 0
\]

\[
a_{t+1} \geq 0, b_{t+1} \geq 0, b_{t+1}^m \geq 0
\]

\[
V^c(W_t, I_t, H_{t-1}) = \max_{C_t, H_t, a_{t+1}, b_{t+1}^m, b_{t+1}} u(C_t, H_t) + \beta E_t V(W_{t+1}, I_{t+1}, H_{t}) \tag{3.8}
\]

\[
s.t \quad C_t + a_{t+1} + b_{t+1} - b_{t+1}^m + PH_t + \lambda PH_{t-1} \leq W_t
\]

\[
W_t = \lambda PH_{t-1} + a_t(1 + r_a^t) + b_t(1 + r_f^t) + I_{t-1} - b_{t-1}^m (1 + r_m^t)
\]

\[
0.8PH_t \leq b_{t+1}^m \leq 0
\]

\[
a_{t+1} \geq 0, b_{t+1} \geq 0, b_{t+1}^m \geq 0
\]

\(W_t\) is the wealth of the household at the beginning of period \(t\). \(I_t\) is the labor income that the household will earn during period \(t\). \(H_{t-1}\) is the size of the house held by the household during period \(t - 1\). \(P\) is the relative price of housing. Since housing consumption \(H_t\) is defined to be the quantity of housing measured in square feet, the house price \(P\) is in units of dollars per square foot and is assumed to be constant at 100. \(a_{t+1}\) is the risky asset holding till period \(t + 1\). \(b_{t+1}\) is the amount of risk free bond held, which is restricted to be nonnegative. \(b_{t+1}^m\) is the mortgage held. The curvature parameter \(\rho\) is set to be 3. \(\alpha\), the parameter that governs the intratemporal substitutability between nondurable consumption and housing consumption, is set to be -5.\(^2\) The risk free rate is 1%. The risky asset return is normally distributed with a mean of 8% and standard deviation of 20%. The mortgage rate is 3%. The discount factor is set to be 0.9896 on an annual basis.

\(^2\)According to Flavin and Nakagawa (2008) [21], a reasonable \(\alpha\) would be between 0 and -7.
For illustration, we set the low income level (representing the unemployed state) to be 5000 and the high income level (representing the employed state) to be 20000. The non-zero labor income for the unemployed state is an analogy to the unemployment benefits households could get in case of unemployment. The transition matrix is set so that the probability of losing a job for the employed is very small, only 4% a year. To pin down the probability of finding a job for the unemployed, we resort to data in the PSID. From 1999 to 2011, we find that about 40% of respondents who reported “temporarily unemployed” or “unemployed but looking for jobs” remained unemployed till their subsequent interviews. If we let $p$ represents the probability of getting employed within a year, then the probability of staying unemployed after a year is $1 - p$. Since interviews were two years apart, then for the unemployed, the probability of remaining unemployed till the subsequent interview is $(1 - p)^2$. From the data, we know $(1 - p)^2 = 40\%$. This implies $p$ is approximately 40%. Then, the transition matrix for the income process is:

$$
\begin{pmatrix}
I_t & I_h \\
0.6 & 0.4 \\
0.04 & 0.96
\end{pmatrix}
$$

As before, we solve the model using value function iterations. Figure 3.7 summarizes the results. The first observation is that the lower and upper bounds, as well as the optimal return point are all smaller for the unemployed state. The lower bound for the unemployed state is 1.75, while the lower bound for the employed state is 2.25. The upper bound for the unemployed state is 4, while the upper bound for the employed state is 4.5. The optimal return points are around 3.5 and 4 respectively for the two states. This suggests that, on average, employed households will have houses of higher value relative to their net wealth.

Figure 3.7 also tells us what would happen if there is a change in employment status. Since the labor income level doesn’t instantly change the wealth of the household or its house value, the household housing to wealth ratio remains the same at the time of the change in employment status. Therefore, a change from employed to unemployed would make household jump vertically between the two RRA curves.
If income decreases, there are two possible outcomes depending on the current value of the household housing to wealth ratio. If the current housing to wealth ratio is above the upper bound of the unemployed state at 4, the lowering of labor income would trigger downsizing. This is consistent with the empirical evidence from section 3.2.2 that becoming unemployed increases the probability of trading down.

On the other hand, if the current housing to wealth ratio is smaller than 4, no moving will be triggered by a decrease in the labor income level. Furthermore, for households with a low housing to wealth ratio, who are almost ready to trade up, a sudden decrease in the labor income moves them further away from that event, because the lower bound for the new labor income state is now smaller. For example, if the housing to wealth ratio is currently around 2.5, a small increase in wealth could lead to trading up since the lower bound for the high labor income state is 2.25. However, if labor income level decreases, it will take much longer for households to reach the lower bound of 1.75. This corresponds to our empirical finding from section 3.2.2 that becoming unemployed decreases the probability of trading up.

On average, households are more likely to be on the left side of the return point given the normal dynamics of household’s wealth\textsuperscript{3}. This means the second outcome (decreasing the probability of trading up) discussed above is more common among households. Therefore, we would expect the effect of becoming unemployed on reducing the probability of upsizing to dominate. This is what we observe from both the state level regressions and the household level regressions in section 3.2.2.

The model also suggests that RRA will increase when a household becomes unemployed. As Figure 3.7 shows, if the current housing to wealth ratio is greater than 4, downsizing is triggered and thus the household moves to the optimal return point for the unemployed state, which has a RRA of around 7, higher than the RRA before downsizing. If the current housing to wealth ratio is smaller than 4 and downsizing is not triggered, we see that the change in RRA is even larger in

\textsuperscript{3}After a moving, households start from the return point. We would expect for most households, wealth would gradually accumulate and thus housing to wealth ratio should gradually drift to the left of the return point.
magnitude, ranging from 1 to 4 depending on the household housing to wealth ratio.

Therefore, from this model, we can get an implication for RRA at the household level: that is, becoming unemployed can increase household level RRA. Based on this, we can think about the general equilibrium effect. If more people become unemployed or if we have a higher unemployment rate, there will be an increase in the aggregate level RRA. The higher aggregate RRA can decrease the demand for risky assets and thus lower their prices. This generates a link between unemployment rate and risky asset prices: the higher the unemployment rate, the higher the aggregate RRA, and the lower are risky asset prices. This is the relationship we can normally observe in the data, but the most common explanation of this relationship is that if unemployment rate goes up, household labor income goes down. A lower labor income may force households to sell assets in order to smooth their consumption. The selling of the assets lowers their prices. This channel doesn’t take RRA into account; indeed the standard model assumes constant RRA. Our model, on the other hand, explains the effect of unemployment on asset prices through a change in RRA. Since the increase in RRA can immediately lower the demand for risky assets, the effect through our channel is instantaneous.

3.5 Conclusion

This paper tests the implications of a model with housing consumption, adjustment costs, and varying housing prices. Firstly, we use cross-sectional variation in state level house price dynamics and homeowners’ moving frequencies to study the relationship between house price volatility and moving frequency. The results lend support to the first implication of the model that volatile housing prices lead to more frequent moving. Secondly, we use household moving and stock holding data to study the effect of moving on RRA. The results lend support to the second implication of the model that household moving is associated with higher RRA. Finally, we also study the effect of becoming unemployed on household moving by solving the model with housing consumption, adjustment costs
and a stochastic labor income process. The result suggests that the overall effect of becoming unemployed is to reduce moving frequency. Furthermore, a sudden shift to an unemployed status increases the household RRA even if it does not trigger a move. This provides a new channel (through the change in risk aversion) for the unemployment rate to affect asset prices.
3.6 Tables

<table>
<thead>
<tr>
<th>State</th>
<th>Proportion of Homeowners</th>
<th>Moving Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC</td>
<td>0.2396</td>
<td>0.0129</td>
</tr>
<tr>
<td>PA</td>
<td>0.5447</td>
<td>0.0311</td>
</tr>
<tr>
<td>WY</td>
<td>0.5807</td>
<td>0.035</td>
</tr>
<tr>
<td>MS</td>
<td>0.5645</td>
<td>0.0382</td>
</tr>
<tr>
<td>NY</td>
<td>0.4543</td>
<td>0.0388</td>
</tr>
<tr>
<td>MD</td>
<td>0.3933</td>
<td>0.0409</td>
</tr>
<tr>
<td>MI</td>
<td>0.5538</td>
<td>0.0424</td>
</tr>
<tr>
<td>NJ</td>
<td>0.5681</td>
<td>0.0448</td>
</tr>
<tr>
<td>RI</td>
<td>0.6135</td>
<td>0.0451</td>
</tr>
<tr>
<td>LA</td>
<td>0.4280</td>
<td>0.0452</td>
</tr>
<tr>
<td>NC</td>
<td>0.5605</td>
<td>0.0452</td>
</tr>
<tr>
<td>IL</td>
<td>0.4825</td>
<td>0.0459</td>
</tr>
<tr>
<td>MA</td>
<td>0.6317</td>
<td>0.0469</td>
</tr>
<tr>
<td>SC</td>
<td>0.5565</td>
<td>0.0475</td>
</tr>
<tr>
<td>NM</td>
<td>0.6463</td>
<td>0.0494</td>
</tr>
<tr>
<td>ME</td>
<td>0.6691</td>
<td>0.0499</td>
</tr>
<tr>
<td>NE</td>
<td>0.6657</td>
<td>0.0500</td>
</tr>
<tr>
<td>CT</td>
<td>0.6437</td>
<td>0.0503</td>
</tr>
<tr>
<td>IN</td>
<td>0.5577</td>
<td>0.0506</td>
</tr>
<tr>
<td>KY</td>
<td>0.6727</td>
<td>0.0515</td>
</tr>
<tr>
<td>OH</td>
<td>0.5731</td>
<td>0.0516</td>
</tr>
<tr>
<td>IA</td>
<td>0.7024</td>
<td>0.0521</td>
</tr>
<tr>
<td>TX</td>
<td>0.4944</td>
<td>0.0522</td>
</tr>
<tr>
<td>WV</td>
<td>0.7565</td>
<td>0.0527</td>
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</table>
Table 3.1: Variation in Homeownership and Moving Frequency (Cont.)

<table>
<thead>
<tr>
<th>State</th>
<th>Proportion of Homeowners</th>
<th>Moving Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>CA</td>
<td>0.4504</td>
<td>0.0527</td>
</tr>
<tr>
<td>VA</td>
<td>0.5663</td>
<td>0.0546</td>
</tr>
<tr>
<td>WI</td>
<td>0.6314</td>
<td>0.0549</td>
</tr>
<tr>
<td>MO</td>
<td>0.5752</td>
<td>0.0588</td>
</tr>
<tr>
<td>UT</td>
<td>0.6857</td>
<td>0.0591</td>
</tr>
<tr>
<td>GA</td>
<td>0.4285</td>
<td>0.0594</td>
</tr>
<tr>
<td>TN</td>
<td>0.6292</td>
<td>0.0607</td>
</tr>
<tr>
<td>SD</td>
<td>0.7332</td>
<td>0.0609</td>
</tr>
<tr>
<td>AR</td>
<td>0.6195</td>
<td>0.0613</td>
</tr>
<tr>
<td>HI</td>
<td>0.4297</td>
<td>0.0615</td>
</tr>
<tr>
<td>FL</td>
<td>0.5973</td>
<td>0.0618</td>
</tr>
<tr>
<td>MN</td>
<td>0.7309</td>
<td>0.0646</td>
</tr>
<tr>
<td>WA</td>
<td>0.6748</td>
<td>0.0662</td>
</tr>
<tr>
<td>ND</td>
<td>0.8138</td>
<td>0.0692</td>
</tr>
<tr>
<td>AL</td>
<td>0.5882</td>
<td>0.0719</td>
</tr>
<tr>
<td>OR</td>
<td>0.5886</td>
<td>0.0726</td>
</tr>
<tr>
<td>AZ</td>
<td>0.6467</td>
<td>0.0731</td>
</tr>
<tr>
<td>VT</td>
<td>0.7172</td>
<td>0.0745</td>
</tr>
<tr>
<td>DE</td>
<td>0.5866</td>
<td>0.0757</td>
</tr>
<tr>
<td>CO</td>
<td>0.6192</td>
<td>0.0794</td>
</tr>
<tr>
<td>ID</td>
<td>0.5248</td>
<td>0.0812</td>
</tr>
<tr>
<td>KS</td>
<td>0.5147</td>
<td>0.0884</td>
</tr>
<tr>
<td>OK</td>
<td>0.5794</td>
<td>0.0921</td>
</tr>
<tr>
<td>AK</td>
<td>0.6222</td>
<td>0.1083</td>
</tr>
<tr>
<td>NH</td>
<td>0.6592</td>
<td>0.1083</td>
</tr>
<tr>
<td>NV</td>
<td>0.5757</td>
<td>0.1134</td>
</tr>
<tr>
<td>MT</td>
<td>0.6344</td>
<td>0.2063</td>
</tr>
</tbody>
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Table 3.2: Effects of Housing Volatility on Moving Frequency

<table>
<thead>
<tr>
<th></th>
<th>Estimate 1</th>
<th>Estimate 2</th>
<th>Estimate 3</th>
<th>Estimate 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housing Growth Rate</td>
<td>0.6283***</td>
<td>0.6085***</td>
<td>0.5368***</td>
<td></td>
</tr>
<tr>
<td>Rate Volatility</td>
<td>(0.1351)</td>
<td>(0.1434)</td>
<td>(0.1020)</td>
<td></td>
</tr>
<tr>
<td>Mean Housing Growth Rate</td>
<td>-0.3638</td>
<td>-0.3159</td>
<td>0.7114***</td>
<td></td>
</tr>
<tr>
<td>Growth Rate</td>
<td>(0.2901)</td>
<td>(0.2977)</td>
<td>(0.2208)</td>
<td></td>
</tr>
<tr>
<td>HPI</td>
<td>0.0002</td>
<td>-0.0008</td>
<td>-0.0015</td>
<td>-0.0034</td>
</tr>
<tr>
<td></td>
<td>(0.0031)</td>
<td>(0.0033)</td>
<td>(0.0029)</td>
<td>(0.0029)</td>
</tr>
<tr>
<td>Unemployment Rate</td>
<td>-0.5437***</td>
<td>-0.4906***</td>
<td>-0.5439***</td>
<td>-0.5129***</td>
</tr>
<tr>
<td></td>
<td>(0.1194)</td>
<td>(0.1398)</td>
<td>(0.1188)</td>
<td>(0.1194)</td>
</tr>
<tr>
<td>PI Per Capita</td>
<td>-0.2333***</td>
<td>-0.2125***</td>
<td>-0.2376***</td>
<td>-0.1635***</td>
</tr>
<tr>
<td></td>
<td>(0.0684)</td>
<td>(0.0756)</td>
<td>(0.0674)</td>
<td>(0.0631)</td>
</tr>
<tr>
<td>Proportion of</td>
<td>0.0338</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Homeowners</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.0299)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.139</td>
<td>0.143</td>
<td>0.1377</td>
<td>0.1132</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>1108</td>
<td>1108</td>
<td>1108</td>
<td>1108</td>
</tr>
</tbody>
</table>
### Table 3.3: Whether Becoming Unemployed Triggers Moving (Probit)

<table>
<thead>
<tr>
<th></th>
<th>Total Moving</th>
<th>Down</th>
<th>Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Become Unemployed</td>
<td>-0.0177</td>
<td>0.2687*</td>
<td>-0.4434***</td>
</tr>
<tr>
<td></td>
<td>(0.0671)</td>
<td>(0.1563)</td>
<td>(0.1453)</td>
</tr>
<tr>
<td>Become Retired</td>
<td>-0.2226***</td>
<td>0.2234</td>
<td>-0.3470**</td>
</tr>
<tr>
<td></td>
<td>(0.0748)</td>
<td>(0.1678)</td>
<td>(0.1385)</td>
</tr>
<tr>
<td>Change of Number of Children</td>
<td>0.2293***</td>
<td>-0.1582***</td>
<td>0.3771***</td>
</tr>
<tr>
<td></td>
<td>(0.0263)</td>
<td>(0.0434)</td>
<td>(0.0376)</td>
</tr>
<tr>
<td>Change of Number of Adults</td>
<td>-0.0154</td>
<td>-0.0276</td>
<td>0.0631***</td>
</tr>
<tr>
<td></td>
<td>(0.0114)</td>
<td>(0.0225)</td>
<td>(0.0223)</td>
</tr>
<tr>
<td>Change of Net Wealth</td>
<td>-2.23e-09</td>
<td>-3.96e-09</td>
<td>1.40e-08</td>
</tr>
<tr>
<td></td>
<td>(1.18e-08)</td>
<td>(1.02e-08)</td>
<td>(1.09e-08)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.0104</td>
<td>0.0049</td>
<td>0.0062</td>
</tr>
<tr>
<td>Number of Observations</td>
<td>18401</td>
<td>18401</td>
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</table>
Table 3.4: Summary of Stock Holdings of Homeowners

<table>
<thead>
<tr>
<th></th>
<th>1999</th>
<th>2001</th>
<th>2003</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participation%</td>
<td>0.312</td>
<td>0.310</td>
<td>0.297</td>
<td>0.281</td>
</tr>
<tr>
<td>10&lt;sup&gt;th&lt;/sup&gt; Percentile</td>
<td>2.439</td>
<td>2.028</td>
<td>2.071</td>
<td>2.381</td>
</tr>
<tr>
<td>25&lt;sup&gt;th&lt;/sup&gt; Percentile</td>
<td>9.091</td>
<td>7.742</td>
<td>7.407</td>
<td>8.427</td>
</tr>
<tr>
<td>50&lt;sup&gt;th&lt;/sup&gt; Percentile</td>
<td>26.094</td>
<td>24.931</td>
<td>24.561</td>
<td>24.368</td>
</tr>
<tr>
<td>75&lt;sup&gt;th&lt;/sup&gt; Percentile</td>
<td>51.282</td>
<td>48.780</td>
<td>45.801</td>
<td>49.079</td>
</tr>
<tr>
<td>90&lt;sup&gt;th&lt;/sup&gt; Percentile</td>
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<td>10&lt;sup&gt;th&lt;/sup&gt; Percentile</td>
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Table 3.5: Stock Holdings and Moving

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<th>$I_{retired}$</th>
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$R^2$ 0.0376
Adjusted $R^2$ 0.0351
3.7 Figures

Figure 3.1: Proportion of Homeowners
Figure 3.2: Proportion of New Homeowners

Figure 3.3: Moving Frequency for Homeowners
Figure 3.4: Reasons for Moving (Homeowners)

Figure 3.5: House Price Growth Rate
Figure 3.6: Detailed Reasons for Endogenous Moving (Homeowners)

Figure 3.7: Relative Risk Aversion Conditional on Employment States
Bibliography


