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Essays on Housing and Macroeconomics

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Essays on Housing and Macroeconomics

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This dissertation studies households' housing decision in the presence of income risks, and its implication on within-cohort income/consumption inequality and the nature of income risks facing households. It is composed of three chapters. The first chapter presents evidence from Panel Study of Income Dynamics (PSID) and Consumer Expenditure Survey (PSID) that housing consumption and housing investment are negatively affected by income risks. Within a household portfolio choice model, the negative effect can be attributed to the illiquidity of housing investment and the positive correlation between house price and income. The second chapter provides empirical evidence that the secular rise of income and consumption inequalities in the United States is age-dependent. It is more significant among younger households. With this feature, biasedness arises from the traditional methodology of decomposing inequality into age effect, year effect and cohort effect. A simple but effective remedy for the problem is proposed. The third chapter of the dissertation studies the age-profile of within-cohort income/consumption inequality, using the methodology proposed in the second chapter. It documents

the age-profile of housing consumption inequality which is almost flat. This stands in contrast to the well-documented fact that within-cohort nonhousing consumption inequality rises with age, which has been argued to be evidence for persistent, uninsurable income shocks to households. This argument is challenged by the finding that housing consumption inequality has a flat age-profile. Within the framework of standard lifecycle model, the coexistence of rising nonhousing consumption inequality and flat housing consumption inequality constitutes a puzzle. A potential resolution lies in the negative effect of income uncertainty on housing decision which diminishes with age, as shown in the first chapter of the dissertation.

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Chapter 1

Housing Decisions under Uncertain Income

How does households' income uncertainty affect their housing decisions? Answer to this question bears on the cyclical fluctuations of housing market, the lifetime consumption inequality, and the cross sectional differences in households' portfolio compositions. Using data from the Panel Study of Income Dynamics and Consumer Expenditure Survey, this paper documents a significant negative effect of income uncertainty on the rate of homeownership, on the value of owned house, on the share of home equity in total wealth, and on the housing-nonhousing consumption ratio. The theoretical part of the paper uses a household portfolio choice model to shed light into the rationale behind the empirical observations. It identifies two factors that lead to these negative effects: housing transaction costs and the positive correlation between housing price and income. The role of borrowing constraints is also examined. In the renter-to-owner switch, borrowing constraints impose MORE hindrance for households with relatively stable income.

1.1 Introduction

The effect of household level income uncertainty on stock investment has received much attention in the past decades. For many U.S. households, housing is their single most important asset. In spite of that, there exist only limited studies on the link between income uncertainty and housing investment. This paper studies such a link in a compresensive manner by examining the effects of income uncertainty on homeownership rate, on the value of owned house, on the share of home equity in total wealth, and on housing-nonhousing consumption ratio.

The portfolio choice literature generally suggests that income uncertainty should reduce a household's demand for risky assets [1] and illiquid assets[2]. This leads to the conjecture that housing demand should decrease with the degree of income uncertainty, although a residential house differs fundamentally from the other financial assets – it is both an asset and a consumption good. On the other hand, the literature of precautionary saving establishes both empirically and theoretically that households with greater income uncertainty hold more total wealth[3]. In light of this, and given the fact that residential houses are the most important component of wealth for most of

[1] e.g.,Kimball (1993), Guiso et al. (1996), Viceira (2001).

[2] See Faig and Shum (2002).

[3] For example, Carroll and Samwick (1997) considers three measures of wealth – very liquid assets, non-housing non-business wealth, and total net wealth. Equity in the primary residence is included in the total net worth, while public traded stock is included in the very liquid assets. For each of the three measures, wealth increases unequivocally with the degree of income uncertainty

the US households, one might conjecture that housing demand should increase with the degree of income uncertainty.

This paper turns to data for a verdict. Relying on data from Panel Study of Income Dynamics (PSID) and Consumer Expenditure Survey (CEX), the paper empirically examines the effect of income uncertainty on housing demand on both the extensive margin (housing tenure choice) and the intensive margin (value of owner-occupied house, housing-nonhousing consumption ratio and share of home equity in total wealth). On the extensive margin, my results confirm the previous empirical finding that households with greater income uncertainty have a lower probability of owning houses. On the intensive margin, the negative relationship between income uncertainty and housing demand also exists. Specifically, among homeowners, those with greater income uncertainty tend to own houses of smaller value and invest less share of total wealth in home equity. These effects are significant even after controlling for the mortgage rates which may be higher for homeowners with greater income uncertainty. Furthermore, the paper studies the consumption demand of housing by investigating the housing-nonhousing consumption ratio, and finds that income uncertainty again has negative impacts. Another important empirical finding is that these effects are age-dependent. They are typically stronger for young households.

One potential explanation of these empirical observations is that illiquidity and risk exposure considerations outweigh the precautionary motives in housing decisions. It is also possible that the empirical observations are caused by the dual role of residential houses and the resulting distortion in the household's optimization behavior as demonstrated in Henderson and Ioannides (1983). The theoretical part of the paper endeavors to understand the effects and relative importance of these factors in a lifecycle model. It begins with a version of the model in which borrowing constraints, housing transaction costs and house price risks are absent. In this case, the paper shows that housing investment motives impose no constraint on housing consumption demand, therefore housing consumption inherits all the properties of nonhousing consumption. In particular, households with greater income uncertainty consume less housing in the early stage of life due to precautionary motives. This leads to the lower share of housing in total wealth. In other words, the role of housing as a consumption good coupled with precautionary motives can qualitatively generate the negative relationship between income uncertainty and the share of housing in total wealth, without introducing any market friction and house price uncertainty.

When housing transaction costs are introduced into the model, the expected user cost of an owned house increases with the degree of income uncertainty, which causes a negative impact of income uncertainty on the housing-nonhousing consumption ratio. The transaction costs also strengthen the negative impact of income uncertainty on housing share in total wealth.

The effect of house price risks depends heavily on the correlation between house prices and income. If the correlation is high, housing demand is greatly discouraged by income uncertainty on both the extensive and intensive margins. When the correlation is assumed to be zero, house price risks have little power in explaining the empirical observations[4]. House price risks also encourage households with greater income uncertainty to invest more in housing early on to hedge against future housing cost risk, as illustrated in Han (2008).

Borrowing constraints and downpayment requirements impose more hindrance for households with relatively stable income to switch from renters to owners, because these households are subject to a greater extent to the conflict between housing consumption incentives and investment incentives. Consequently, absent house price risks, households with greater income uncertainty have a HIGHER probability of owning. When income and house prices are assumed to be positively correlated, borrowing constraints become less binding. Once the effect of borrowing constraints is dominated by the risk-avoidance considerations, the negative relationship between income uncertainty and homeownership rates emerges. It is also found that borrowing constraints carries little effect on the relation between income uncertainty and the intensive margin housing demand.

There exist a few papers that examine the effect of income uncertainty on housing demand. The negative effect on homeownership is found in multiple studies. Haurin (1991) reports evidence from U.S. data and Diaz-Serrano

[4]This is not an reiteration of the findings in Davidoff (2006) which holds income uncertainty constant and proves that households whose income exhibits higher correlation with housing prices own relatively little housing. In contrast, this paper assumes the same correlation but different degrees of income uncertainty for the households.

(2005) has similar findings for Spain and Germany. Robst et al. (1999) employs three measures of income uncertainty, one of which is similar to that in my paper. With each of these measures, income uncertainty lowers the probability of homeownership. On the intensive margin, Haurin and Gill (1987) studies a sample of military personnel families and find that income uncertainty reduces housing consumption. They assume that spouses' income is more uncertain than that of military personnel, and approximate income risk with the share of spouse income in total. The work therefore suffers from both sample selection and measurement problems. Haurin (1991) measures income uncertainty by the coefficient of variation of income across time and finds the impact of income uncertainty on housing demand to be insignificant. Since even deterministic component of lifetime income can exhibit a high coefficient of variation, the measurement problem could seriously bias the test. Shore and Sinai (Forthcoming) shows that housing transaction costs may cause housing demand to increase with the degree of income uncertainty. This result is based on the assumption that housing is a consumption good only, ignoring the its role as an asset.

My paper is closely related to the literature that studies portfolio choice in the presence of housing. Henderson and Ioannides (1983) demonstrates the potential distortion of households' investment behavior when the housing consumption demand exceeds the housing investment demand. This theoretical framework is completed in Fu (1995) which points out that a conflict between the two types of housing demand arises in the presence of borrowing constraints. Brueckner (1997) and Flavin and Yamashita (2002) show that the housing investment constraint introduced by Henderson and Ioannides (1983) significantly alters the mean-variance frontier of a household's wealth portfolio. Cocco (2004) and Yao and Zhang (2005) numerically solve lifecycle models in which the holding of housing, riskfree bond and risky assets are endogenously determined. Both works find that housing investment crowds out stock holdings. On the empirical side, Ioannides (1989) finds evidence from the 1983 Survey of Consumer Finances that the illiquidity of housing has a strong negative effect on the equity-value ratio and the relative share of housing equity in total wealth. Cocco (2004) and Yao and Zhang (2005) also provide data evidence to support their numerical results.

Another related literature studies income uncertainty, borrowing constraints, precautionary saving, and portfolio choice. Deaton (1991) and Carroll (1992) propose the buffer stock theory of saving in which households hold wealth primarily to insulate consumption from income shocks. Bertaut and Haliassos (1997) studies long-run precautionary motives for life-cycle wealth accumulation and portfolios, and concludes that income uncertainty raises the demand for riskfree assets at any level of wealth. A number of other papers contains discussions on the link between income uncertainty and portfolio choice, examples are Kimball (1993), Duffie and Zariphopoulou (1982), Koo (1998), Elmendorf and Kimball (2000), Viceira (2001), Gomes and Michaelides (2005) and Polkovnichenko (2007). In a computational model, Heaton and Lucas (2005) finds that the saving level is sensitive to income risks, while the choice of bond versus stock is not. Heaton and Lucas (2000) shows evidence that entrepreneurial income risk significantly discourages stock holdings. Paxson (1990) and He and Pages (1993) study optimal portfolio choice in the presence of labor income risks and borrowing constraints.

This paper shows the housing transaction costs are critical in understanding housing decision under uncertain income. This relates the paper to the literature on irreversible investment under uncertainty. In a continuous-time infinite horizon model, Grossman and Laroque (1990) analytically obtains the optimal decision rule for the consumption good which is durable and costly to adjust. The optimal decision follows the (s, S) rule with the inaction regions defined by the ratio of durable good over total wealth. Damgaard et al. (2004) extends the analysis to the situation in which nondurable good is also an argument in the utility function. In the presence of housing transaction costs, my paper shows the households adjust their housing stock infrequently, largely in response to the income shocks, rather than to the deterministic changes in income.

To the best of my knowledge, this is the first paper that employs proper measures of income uncertainty and documents its negative effects on housing demand on the intensive margin. Housing demand is measured not only as the value of the owner-occupied house, but also (i) as the share of home equity in total wealth, highlighting the investment demand of housing, and (ii) as the ratio of house value over nonhousing consumption, highlighting the consumption demand of housing. In addition, the paper documents the age-dependency of the effect of income uncertainty. On the theoretical side, my paper sheds light into the potential channels through which income uncertainty affect housing decisions. It illustrates the roles played by the dual-purpose of housing, housing transaction costs, house price risks and borrowing constrains.

The negative effect of income uncertainty on housing demand implies an indirect positive effect of income uncertainty on the demand for nonhousing risky assets. Specifically, a household with great income uncertainty chooses a relatively conservative housing position, which in turn prompts more investment in other risky assets such as stocks[5]. This should partially offset the direct negative effect as theorized in articles such as Koo (1998) and Elmendorf and Kimball (2000). Therefore any quantitative model that explains the little stockholding of the majority of households via labor income risks but ignores housing[6] is subject to reassessment.

This paper also provides a new perspective in studying the cyclical fluctuation of the housing market. Bloom et al. (2008) finds evidence that recessions are associated with a dramatically higher volatility and uncertainty of sales, earnings and output of firms. It is also well-known that job-separation probability rises during recessions. Given the close link between income uncertainty and housing decision, it is evident that the fall of housing demand in recessions are caused not only by the reduced income level, but also by the increased income uncertainty. Estimation and inferences of the cyclical

[5]See Flavin and Yamashita (2002), Cocco (2004) and Yao and Zhang (2005).

[6]e.g., Viceira (2001)

properties of housing demand could be misleading if the impact of income uncertainty is ignored.

1.2 Empirical Investigation

Given the purpose of this paper, household level income uncertainty is necessary for the empirical analysis. Generally the estimates can be obtained from two sources. The first one is the survey questions regarding the expected variability of future income. For example, Guiso et al. (1996) uses the Bank of Italy Survey of Household Income and Wealth which asks respondents to attribute probability weights to given intervals of nominal income increase one year ahead. Estimates from this source is subjective by nature. The second sources is the panel data such as PSID. Since panel data track households for years, a time series of income is available for each households. One can remove the predictable component from the time series and measure the variability of the residues. The problem lies in how to extract the predictable component of income for each household. In this paper I adopt the method used by Carroll and Samwick (1997) and Robst et al. (1999). Even though the negative effect of income uncertainty on housing tenure choice has been documented in some existing papers, the novelty here is that income uncertainty is decomposed into transitory and permanent components. Nevertheless the major empirical contribution of the my paper is one the intensive margin.

1.2.1 Data

The paper draws upon two data sets for empirical inference: the Panel Study of Income Dynamics (PSID) and Consumer Expenditure Survey (CEX). The data appendix gives details on sample selection and variable definitions.

I extract the following variables from 1984-1997 family file, freely available at the data center of PSID website[7]: total family income, housing status (renter or owner), value of owned house and a rich set of demographics, including age, race, sex, years of schooling, occupation, industry, marital status of househeads, number of children, spouse's years of schooling (if married), as well as region and location of households. Prior to 1997 PSID data were collected annually, and biannually after that. I choose 1997 as the ending year because it is not clear how to adjust for this shift for the purpose of studying income uncertainty. I use the Wealth Supplement Files (1984) to draw information on total wealth, home equity, whether owning business and whether owning stock. I obtain current interest rate on mortgage loan from the 1996 wave of survey[8]. For each household I estimate its degree of income uncertainty based on its realized income during 1984-1997. I assume that a household rationally predicts the degree of uncertainty of its future income, and makes decisions on housing and other financial wealth accordingly.

A major drawback of the PSID data is its lack of detailed information on consumption expenditure. Therefore I turn to CEX for housing-nonhousing

[7] http://psidonline.isr.umich.edu/data/

[8] No mortgage rate information is available from PSID prior to 1996

consumption ratio. CEX carries high quality information on consumption expenditure, house value and demographics. However CEX is not a panel, thus it is impossible to evaluate the degree of income uncertainty for individual households within CEX. I transport the measure of income risk obtained from PSID to CEX using the two-sample two-stage least square (TS2SLS) technique[9]. The TS2SLS is readily implementable in this case because PSID and CEX can be regarded as two samples independently drawn from the same population. In addition both surveys contain rich information on demographics. Classifications of occupation and industry are slightly different between the two samples. Appendix A.1 provides details on how the occupation and industry types are re-grouped so that they are comparable between the two samples.

1.2.2 Measuring Income Uncertainty from PSID Data

To obtain the predictable component of income, I run the following regression on the pooled data of the N individual households's 1984-1997 time series.

$$y_{i,t} = Z_{i,t}\beta + u_{i,t}$$

where $y_{i,t}$ is the logarithm of income for household i at time t and $Z_{i,t}$ is the set of demographics that households use to predict their future income paths. Included in the Z are age, age-squared, race, dummies of marital status, education, occupation, industry of employment of househeads and the interaction of

[9] See Angrist et al. (1999) and Inoue and Solon (2008).

age with these dummies. In view of the ever-increasing importance of spouses' contribution to family income, Z also includes dummies of spouse's educational attainment. It's recognized that owning stock or business may have huge impact on the degree of income uncertainty, which is again taken care of by dummies.

Household i has a time series of residue income $\{u_{i,t}\}_{t=1984}^{1997}$. This is not observed by the household at t=1984, but is used by the econometricians to infer the degree of income uncertainty for this particular household. In the simplest case, one can assume that the $u_{i,t}$'s are iid and that $\hat{\sigma}_{u,i}^2$, the sample variance of $\{u_{i,t}\}_{t=1984}^{1997}$, is an unbiased estimator the true variance $\sigma_{u,i}^2$. Even if the residuals are serially correlated, $\hat{\sigma}_{u,i}^2$ is still a valid measure of income uncertainty. To see this, let $u_{i,t} = \rho u_{i,t-1} + \xi_{i,t}$, where ρ measures the persistence of the random shock ξ_t, then $\sigma_{u,i}^2 = \frac{\sigma_{\xi,i}^2}{1-\rho^2}$. In this case $\hat{\sigma}_{u,i}^2$ is merely a rescaled version of $\hat{\sigma}_{\xi,i}^2$, the estimate of variance of iid random shock ξ. It is also possible to allow for more general specification of the structure of residual income. Carroll and Samwick (1997) assumes the residual income to be the sum of permanent income plus transitory shock.

$$u_{i,t} = p_{i,t} + \epsilon_{i,t} \tag{1.1}$$

while the permanent income is assumed to follow a random walk.

$$p_{i,t} = p_{i,t-1} + \eta_{i,t} \tag{1.2}$$

Both the transitory shock and persistent shock are assumed to follow normal distributions, and the degree of income uncertainty is measured by the variances of the shocks, $\sigma^2_{\eta,i}$ and $\sigma^2_{\epsilon,i}$. This specification is appealing for several reasons. Various pieces of evidence show that income shocks do have a very persistent, near random walk component[10]. Also when implemented in a computational model, this structure can greatly reduce the computational task because all the state variables can be normalized by the permanent income, reducing the problem by one dimension. More details on this point is given in Appendix A.3. Technical details about estimating $\sigma^2_{\eta,i}$ and $\sigma^2_{\epsilon,i}$ are omitted in this paper, since I follow strictly the methodology in Carroll and Samwick (1997). In the subsection below, I examine and report the effects on housing decisions of $\hat{\sigma}^2_{\eta,i}$ and $\hat{\sigma}^2_{\epsilon,i}$, the estimates of $\sigma^2_{\eta,i}$ and $\sigma^2_{\epsilon,i}$. The effects of $\sigma^2_{u,i}$ on housing decision are also tested, with the same qualitative results, only more significant than the situation where $\sigma^2_{u,i}$ is decomposed into $\sigma^2_{\eta,i}$ and $\sigma^2_{\epsilon,i}$.

Extracting the predictable component of income by using income equation involves a strong assumption, that the individual-specific growth rate of income is completely explained by observable personal characteristics. It also assumes that changes in demographics, such as marital status, are predictable. Although this is a commonly used methodology, there might still be concerns regarding these assumptions. For robustness, I employ another way of extracting the predictable component of income, Hodrick-Prescott Filtering. Put simply, for each household, the time series of realized incomes is detrended by a smooth curve, which is assumed to be predictable. This is a widely used way

[10]See MaCurdy (1982), and Abowd and Card (1989). Guvenen (2007) provides a good review of competing views on this issue in the literature.

to recover aggregate shocks in the business cycle literature. Reassuringly, the empirical results from this methodology are qualitatively the same as those from using the income equation approach.

1.2.3 Empirical Results

The goal is to evaluate the effects of income uncertainty on the housing decision after controlling for a set of determinants, such as income level, wealth stock, age, marital status, number of children, region, location and mortgage rate. I run a probit model to test the role of income uncertainty on housing tenure choice, and report the results in Table 1.2[11]. The variance of both the permanent and transitory shocks exert negative effects on the probability of owning residential houses, which confirms the previous findings. Such negative effects of income uncertainty on tenure choice are age dependent, generally diminishes with age until the househead reaches middle age, then become more pronounced with age afterward. This point is clearer in panel (1) of Figure 1.1, where the partial effects of income uncertainty are plot against age, based on the coefficients on income uncertainty, interaction of income uncertainty and age, and interaction of income uncertainty and age-squared. In column (2) and (3) of Table 1.2, I include dummies for stock owner and business owner. Owning business reduces the probability of homeownership by 0.75% on average, a small but statistically significant effect which increases

[11]Robst et. al. (1999) also tests a probit model based on PSID data, but income uncertainty is not decomposed. My sample yields very similar results as theirs when income uncertainty is not decomposed.

with age, as is evident in column (4).

One might conjecture that the income uncertainty effects on tenure choice are caused by credit constraint. PSID 1996 wave of survey asked respondents whether they had an application for a loan on the current property turned down since January 1991. Of the households in my sample, only 0.38% answered yes[12]. So credit constraint should have very limited influence in this case. Diaz-Serrano (2005) uses Italian data and has similar results. Presumably households with greater income uncertainty choose not to own or become an owner later, either to avoid huge transaction cost or to reduce the variability in income and wealth.

I study housing decision on the intensive margin along three dimensions: (1) house value; (2)home equity share in total wealth; (3) housing-nonhousing consumption ratio. Notice that only the subsample of homeowners are used hereafter. Housing consumption is assumed to be a fixed fraction of house value and housing-nonhousing consumption is simply measured by the ratio of house value on annual nonhousing expenditure.

The logarithm of the house value is regressed on $\hat{\sigma}^2_{\eta,i}$ and $\hat{\sigma}^2_{\epsilon,i}$, logarithm of income and total wealth, mortgage rate, age, age^2, race, sex, marital status, number of children, years of schooling, occupation and industry of the main job, region, location, dummy for stock owner and dummy for business

[12]About 50% answered inapplicable because (1) no morgtage on home, (2)not a homeowner,(3) got a mortgage prior to 1991.

owner[13]. If a spouse is present, his/her years of schooling is also included. The results are reported in column 1-3 of Table 1.3. Mortgage rate has a negative effect on house value, but the coefficient is measured imprecisely. Intuitively, if mortgage lenders have information about the riskiness of the borrowers' income, they should price the it and vary the rate accordingly. Lenders usually check the credit history and income level of borrowers, but the major US mortgage guarantors, Fannie Mae and Freddie Mac (both are in trouble as I write the paper) do not question the variance of borrower's incomes. The tiny effect of mortgage rate here seems to be evidence that degree of income risk at individual level does not effectively enter the calculation of mortgage rate.

All the other coefficients look very reasonable. Most importantly, both $\hat{\sigma}^2_{\eta,i}$ and $\hat{\sigma}^2_{\epsilon,i}$ have significant, negative effects on house value. Not surprisingly, the impact of variance of permanent shocks is much stronger than transitory shocks. To grasp a rough idea of how big these effects are, suppose a household has a house valued at $\$150,000$. Roughly speaking an everything-else-equal household whose $\sigma^2_{\eta,i}$ is higher by 0.01 would own a house that worths about \$3000 less; while an everything-else-equal household whose $\sigma^2_{\epsilon,i}$ is higher by 0.01 would own a house that worths about \$700 less. Owning stock or business also reduces house value by a minor amount, this may reflect the consideration of

[13]Recall that $\hat{\sigma}^2_{\eta,i}$ and $\hat{\sigma}^2_{\epsilon,i}$ are estimated from 14 observations since household i is observed from 1984 to 1997. Concern arises that bias might be introduced by error-in-variables problem. Instruments should fix the problem in theory, but in practice it is not clear what instrumental variables should be used. In the robustness checks I use education, occupation and industry of househead, education of spouse (if present) and their interaction with age of head as instruments. The results are qualitatively very similar and available upon request.

portfolio choice. In other words, aside from portfolio consideration, income uncertainty still have sizable impact on house value.

To understand how the negative effects of income uncertainty depend on age, I include in the regression the interaction of $\hat{\sigma}^2_{\eta,i}$ and $\hat{\sigma}^2_{\epsilon,i}$ with age and age^2 and report the results in column 4-6 of Table 1.3. The age-dependency is clear from the coefficients of these interaction terms, and is illustrated in panel (3) and (4) of Figure 1.1. The intuition is, as young households accumulate financial assets over time, they become less vulnerable to income shocks. Consequently income uncertainty exerts diminishing impacts on housing decision until the households reach middle-age (around 50). After that, households have short life horizon and user cost calculation becomes increasingly important in housing decision. Any housing transaction cost entailed by large income shocks is amortized over shorter period of time, therefore income uncertainty is translated into expected user cost at enhanced strength.

The effects of income uncertainty on home equity share in total wealth is analyzed in a similar fashion. The results are presented in Table 1.4. Again, both $\hat{\sigma}^2_{\eta,i}$ and $\hat{\sigma}^2_{\epsilon,i}$ affect home equity share significantly and negatively, after controlling for income, wealth, mortgage rate and demographics. Inclusion of stock dummy reduce the equity share, reflecting the substitution effect as in Yao and Zhang (2005). Owning business not only decreases the equity share, but also reduces the partial effects of income uncertainty on equity share. This is consistent with Heaton and Lucas (2000), who find that entrepreneurial risk plays an important role in household portfolio choice. Column 3-6 of Table 1.4

and panel (5) and (6) of Figure 1.1 present a similar pattern of age-dependence of the negative effects of income uncertainty.

Analyzing the impact of income uncertainty on the housing-nonhousing ratio involves two data sets. Household level income uncertainty is measured in PSID, but PSID does not have sufficient information on nonhousing consumption. CEX has high quality consumption expenditure data, but it tracks a household for at most five quarters, which makes the measurement of income risk virtually impossible. To deal with the problem, I take two steps. First I compare the housing-nonhousing consumption ration between groups that are know to be exposed to different degrees of income uncertainty. Household headed by individuals who do not have any college education, on average, face much higher income risk than those who have. From CEX data, I extract the lifecycle profiles of the housing-nonhousing consumption ratio for both education groups, using synthetic panel construction technique. Figure 1.2 plots the result. Clearly the low income uncertainty group exhibits a higher ratio, but the gap diminishes with age. I also construct the lifecycle profile for two occupation groups, managerial and professional versus laborers and operators, with the former known to have less exposure to income risks. Figure 1.3 again displays a higher ratio for low income uncertainty groups.

Since the housing-nonhousing consumption ratio has more determinants than degree of income uncertainty, I use two-sample two-stage least square regression to controll for the potential determinants. Specifically the measures of income uncertainty, $\hat{\sigma}^2_{\eta,i}$ and $\hat{\sigma}^2_{\epsilon,i}$ are predicted by the key variables used in aforementioned regressions, with education, occupation and industry and their interaction with age serving as instruments. This is the first stage regression in PSID. The regression coefficients are transported to CEX to predict $\sigma^2_{\eta,i}$ and $\sigma^2_{\epsilon,i}$ for households in CEX sample. The predicted $\sigma^2_{\eta,i}$ and $\sigma^2_{\epsilon,i}$ are then used in the second stage regression, which is carried out in CEX. Results of the second stage are reported in Table 1.5. The calculation of t-statistics is based on Inoue and Solon (2008). The negative effects of income uncertainty on housing-nonhousing consumption ration are still quite significant. Interactions with age and age^2 yields imprecise measures of the partial effects. Panel (7) and (8) of Figure 1.1 illustrates that the negative effects generally diminishes with age.

1.3 Theory

It is clear from the data that the stronger precautionary needs of households with greater income uncertainty are not met by increased housing investments. One potential reason is the illiquidity of housing investment which makes housing an inferior precautionary asset. Another reason could the riskiness of house prices. In face of uncertain income, households with greater income uncertainty should prefer safer assets to reduce the overall risk exposure. This risk avoidance effect should be even stronger if house prices are positively correlated with income[14]. In the presence of borrowing constraints,

[14]Davidoff (2006) finds that a one standard deviation increase in covariance between income and home prices is associated with a decrease of approximately $7500 in the value

households are less cushioned against bad income shocks. This may further reduce the attractiveness of housing investment, particularly for those with high income uncertainty. On the other hand, borrowing constraints render substantial saving in the form of housing at a time when less saving is preferred. This leads to the conflict between the housing consumption motives and investment motives, the extent of which is greater for households with relatively stable income. This section analyzes the significance and relative importance of the foregoing considerations in a household lifetime optimization model. It first lays out the general model that incorporates housing adjustment costs, house price risks, and borrowing constraints. Next, various variants of the model are computed to highlight the roles played by the potential determinants of the data observations.

1.3.1 General Model

A household enters the labor market with zero asset, and stays on the labor market for 40 years before retirement. After retirement, it lives another 20 years before death. When on the labor market, the household receives stochastic income. Let $y_{i,t}$ denote the logarithm of income for household i with t years of age, the income process before retirement is specified below.

$$y_{i,t} = p_{i,t} + \epsilon_{i,t} \tag{1.3}$$

$$p_{i,t} = G_t + p_{i,t-1} + \eta_{i,t} \tag{1.4}$$

---

of owner occupied house.

where G_t is the deterministic income that captures the hump-shaped lifetime income profile; $\epsilon_{i,t}$ and $\eta_{i,t}$ are random income shocks, with the former being transitory and the latter permanent. $p_{i,t}$ is the permanent income with the initial value $p_{i,0} = 0$.

After retirement, a household receives fixed income that equals $\pi e^{p_{i,40}}$, where π is the income replacement ratio, and $p_{_{i,40}}$ is the permanent income of household i before retirement.

Households are differentiated into types based on the variances of transitory and permanent income shocks. Each type has a unit measure of households. The effect of income uncertainty on housing decisions is assessed by comparing among types the average lifetime profiles of the housing demand. The deterministic income profile $\{G_t\}_{t=1}^{40}$ is assumed to be the same across households, to ensure that the between-type differences are not caused by the difference in income levels or the timing of income flows over the lifecycle.

The permanent shocks $\eta_{i,t}$ follow a normal distribution with mean μ_η and variance σ_η^2. I assume $\mu_\eta = -\frac{\sigma_\eta^2}{2}$ to ensure that higher variance types do not have greater mean values of income[15]. Similarly, the transitory shocks follow a normal distribution with mean $-\frac{\sigma_\epsilon^2}{2}$ and variance σ_ϵ^2. Notice that the distributions of income shocks are type-specific, but the realizations of shocks are household-specific. In the text that follows, the subscript i in income and income shocks are omitted for simplicity. The subscript t is also omitted

[15]Recall that the actual income, e^{y_t} follows a lognormal distribution with mean $e^{\mu+\frac{\sigma^2}{2}}$.

whenever this causes no confusion.

A household acquires housing services through either renting or owning. Renters own no housing stock while owners consume all the housing stocks they own[16]. The stochastic process for house price Q_t is modeled in a standard way.

$$Q_t = Q_{t-1}(1 + \mu_h)R_{h,t} \tag{1.5}$$

This is to say the logarithm of house prices follow a random walk with drift. μ_h is the deterministic growth rate of house price and $R_{h,t}$ is the stochastic component which is assume to be lognormal, with mean zero and variance σ_ξ^2.

The rent of a house with stock H and price Q is ωHQ. Thus rents and house prices move perfectly together[17].

A household maximizes the lifetime utility by choosing nonhousing consumption (C), housing stock (H), and riskfree asset (A) which accrues at an annual rate of r. In the beginning of each period, a renter decides whether to become an owner given the state vector (y, A, Q). The value function of a renter of age t is

$$v_t(y, A, Q) = max\{v_t^{rent}(y, A, Q), v_t^{own}(y, A, Q)\} \tag{1.6}$$

where $v_t^{rent}(y, A, Q)$ is the value function of the renter if he decides to keep renting, and $v_t^{own}(y, A, Q)$ is the value function if he decides to become an

[16]This strengthens the assumptions in Henderson and Ioannides (1983).

[17]If the rent-income correlation differs from correlation between house prices and income, some of the results regarding housing tenure choices in this paper may be affected. Ortalo-Magne and Rady (2002) discusses the effect of rent-income correlation on housing tenure choice.

owner. In that case, he needs to pay down d percent of the house value, and the remaining is financed through mortgage with annual mortgage rate r_m. As a buyer, he also pays ϕ fraction of the house value as the transaction cost.

The optimization problem of an owner has one more state variable – housing stock (H). In the beginning of each period, a homeowner decides whether to sell the house and become a renter. If he keeps owning, he also chooses whether to adjust the current housing stock by selling the existing house and buying another one. Let $w_t(y, A, Q, H)$ denote the value function of a homeowner, then

$$w_t(y, A, Q, H) = max\{w_t^{rent}, w_t^{move}, w_t^{stay}\} \tag{1.7}$$

where w_t^{rent}, w_t^{move} and w_t^{stay} are the value functions if the owner chooses to rent, to move, and to stay, respectively. Each of these functions depends on the state vector (y, a, Q, H). An owner also spends δ fraction of the house value as the "maintenance cost" which corresponds to property tax, fee charged by homeowner's association, maintenance costs and others in the real world. If an owner decides to sell his house, he pays the selling cost which is λ times the house value.

Now I am ready to define v_t^{rent} v_t^{own} for renters and w_t^{rent}, w_t^{move}, w_t^{stay} for owners recursively. Let $u(C, S)$ be the momentary utility function, where S stands for housing services that come either from renting or owning. Equation (1.8) to (1.13) lay out the recursive formulation of the value functions.

The value function of a renter who chooses to keep renting:

$$v_t^{rent}(y, A, Q) = max_{A',S} u(C, S) + \beta E_t[v_{t+1}(y', A', Q')] \tag{1.8}$$

$$\text{s.t. } A' = y + (1 + r)A - \omega QS - C$$
$$A' \geq 0$$

The value function of a renter who choose to become an owner:

$$v_t^{own}(y, A, Q) = max_{A',H'} u(C, S) + \beta E_t[w_{t+1}(y', A', Q', H')] \tag{1.9}$$

s.t. S=H'

$$A' = y + (1 + r)A - (\phi + \delta)QH' - C$$
$$A' \geq -(1 - d)QH'$$

The value function of an owner who chooses to become a renter:

$$w_t^{rent}(y, A, Q, H) = max_{A',S} u(C, S) + \beta E_t[v_{t+1}(y', A', Q')] \tag{1.10}$$

$$\text{s.t. } A' = y + (1 + r)A + (1 - \lambda)QH - \omega QS - C$$
$$A' \geq 0$$

The value function of an owner who chooses to adjust the housing stock:

$$w_t^{move}(y, A, Q, H) = max_{A',H'} u(C, S) + \beta E_t[w_{t+1}(y', A', Q', H')] \tag{1.11}$$

$$\text{s.t. } S = H'$$
$$A' = y + (1 + r)A + (1 - \lambda)QH - (\phi + \delta)QH' - C$$
$$A' \geq -(1 - d)QH'$$

The value function of an owner who chooses not to adjust the housing stock:

$$w_t^{stay}(y, A, Q, H) = max_{A'} u(C, S) + \beta E_t[w_{t+1}(y', A', Q', H')] \qquad (1.12)$$

s.t. s=H=H'

$$A' = y + (1 + r)A - \delta QH - C$$

$$A' \geq -(1 - d)QH'$$

In period T, the last period of life, the household's future value V_{T+1} depends on the bequest wealth W_{T+1}. Following Yao and Zhang (2005), I assume the following bequest value.

$$V_{T+1}(W_{T+1}) = L^{\gamma} \frac{[W_{T+1}(\theta/\omega Q_{T+1})^{\theta}(1 - \theta)^{1-\theta}]^{1-\gamma}}{1 - \gamma} \qquad (1.13)$$

This is the solution to the static optimization problem of beneficiaries. L governs the strength of bequest motives. The bequest wealth is the value of house plus the riskfree bond: $W_{T+1} = H_T Q_{T+1} + (1 + r)A_T$.

Since the model does not have an analytical solution, it is solved numerically. In the computational exercises that follow, the utility function takes the following form:

$$u(C_t, H_t) = \frac{C_t^{1-\theta} H_t^{\theta}}{1 - \gamma}$$

The Cobb-Douglas preference is chosen over the more general constant elasticity of substitution preference for computational reasons[18]. The utility function

[18] See Appendix A.3 for details.

exhibits constant relative risk aversion, and the coefficient γ determines the degree of risk aversion. It is also clear from the recursive formulation above that the elasticity of intertemporal substitution is assumed to be $\frac{1}{\gamma}$ in the model.

Table 1.1 presents the parameter values used in model computation. The principle here for model calibration is to use the standard values for the parameters whenever possible. For most of the parameters, similar values have been used in Cocco (2004), Yao and Zhang (2005), Li and Yao (2006), Yang (2008) and other papers. Yao and Zhang (2005) sets $\mu = 0$ based on the empirical findings by Goetzmann and Spiegel (2000). The correlation between income shocks and house price shocks are assumed to be 0.2. This is considered to be moderate but high enough to generates the negative effect of income uncertainty on homeownership rate. The proportional rental price of house (ω) is assumed to be 6%, which is slightly higher than owner's user cost. When house price is fixed, owner's user cost is the sum of interest rate ($r = 0.02$), maintenance cost ($\delta = 0.03$) and the amortized value of transaction costs ($\lambda = 0.06$ and $\phi = 0.02$).

The deterministic income profile, $\{G_t\}_{t=1}^{40}$, is estimated from the PSID sample used in the empirical study in this paper. It is the average profile for all the households in the sample, hence the same for each household. In the quantitative results that follow, the between-type difference is only attributable to the ex-ante difference in the degree of income uncertainty.

Table 1.1: Parameter Values

Parameter	Symbol	value
Discount factor	β	0.96
Coefficient of relative risk aversion	γ	4
Housing share in utility	θ	0.15
Bequest strength	L	4
Income replacement ratio	π	0.6
Mean growth rate of house price	μ	0.
Standard deviation of house price	σ_ξ	0.1
Riskfree bond rate	r	0.02
Mortgage rate	r_m	0.02
Downpayment requirement	d	0.1
Closing cost	ϕ	0.02
Selling cost	λ	0.06
Maintenance cost	δ	0.03
House rental price	ω	0.06
Correlation between shocks to house price and permanent income	$\rho_{\xi,\eta}$	0.2
Correlation between shocks to house price and transitory income	$\rho_{\xi,\epsilon}$	0.2

1.3.2 The Baseline Model

The baseline version of the model assumes a frictionless world in which borrowing constraints and housing transaction costs do not exist. House price is normalized to one and dropped out of the state space.

Define housing-nonhousing consumption ratio as $\frac{H_t}{C_t}$. It is easy to show that in the baseline model, housing-nonhousing consumption ratio is independent of the degree of income uncertainty. This result holds under less restrictive assumptions, which is presented in the theorem that follows. Proof of the theorem is given in appendix A.2.

Theorem 1.3.1. *The housing-nonhousing consumption ratio is independent of the degree of income uncertainty if the following conditions hold.*

- *there exists no borrowing constraints and transaction costs of assets.*

- *the stochastic component of the growth rate of house price can be replicated by a portfolio comprised of human capital (represented by the stochastic income) and financial assets held by the household.*

- *the preference over housing and nonhousing consumptions is homogeneous.*

An important implication arise from the theorem: the dual roles of owner-occupied house, as formalized in Henderson and Ioannides (1983), is disentangled under the aforementioned assumptions. For investment purpose, housing is perfectly substituted by the replicating portfolio. Therefore a household needs only to consider the consumption demand when choosing the housing stock. This results in a housing consumption path with the identical shape as that of the nonhousing consumption which is steeper for household with greater income uncertainty.

Households with greater income uncertainty consume less housing when young, but save more for precautionary purposes. This leads to a lower housing shares in total wealth. Figure 1.4 demonstrates the lifecycle profile of housing consumption, housing-nonhousing consumption ratio, holding of risk-free asset and housing share in total wealth for different types of households. The upper-left panel displays the steeper profile of housing value for households with greater income uncertainty, illustrating the insight that housing consumption demand is not restricted by the investment demand. In the upper-right panel, households with greater income uncertainty save more for precautionary purpose. The lower-left panel illustrate the constant housing-nonhousing consumption ratio when house price is fixed. It should be noted that if house price has a deterministic trend, this ratio will not be constant, but will remain independent of the degree of income uncertainty. The lower-right panel shows the lower housing share in total wealth for households with greater income uncertainty, which can be envisioned as the combined result of the upper panels.

One valuable insight is gained from the baseline model: the observation that households with low income uncertainty have larger share of housing in total wealth and more housing stock may have nothing to do with house price uncertainty and market frictions such as borrowing constraints and transactions costs. It can at least partially be explained by the differences in precautionary motives and consumption demands among different types of households. In the computational exercises that follow, these results in the baseline model serve as a benchmark for testing the roles played by illiquidity of housing, house price uncertainty and borrowing constraints.

1.3.3 Illiquidity and price uncertainty

Transaction costs induce an inaction region in the housing decision rule. In a continuous-time infinite horizon setup, using Cobb-Doglous preference over durable and nondurable goods, Damgaard et al. (2004) proves that the boundaries of inaction regions are defined by the ratio of total wealth over the value of durables. Such a nice property is not available in the finite horizon model in the present paper. It is not even clear how the boundaries depend on the degree of income uncertainty. Under the premise of insensitivity of the boundaries to degree of income uncertainty, households with greater income uncertainty should demand less housing due to higher expected user cost. The user cost as a proportion of the value of a house that is kept for τ years is $r + \psi + \bar{\lambda} + \bar{\phi}$. The amortized selling cost ($\bar{\lambda}$) and buying cost ($\bar{\phi}$) are from the following two equations,

$$\bar{\lambda} + \frac{\bar{\lambda}}{1+r} + \frac{\bar{\lambda}}{(1+r)^2} + ... + \frac{\bar{\lambda}}{(1+r)^{\tau-1}} = \frac{\lambda}{(1+r)^{\tau}}$$
$$\bar{\phi} + \frac{\bar{\phi}}{1+r} + \frac{\bar{\phi}}{(1+r)^2} + ... + \frac{\bar{\phi}}{(1+r)^{\tau-1}} = \phi$$

Solving the two equations yields:

$$\bar{\lambda} = \frac{r}{(1+r)^{\tau+1} - 1}\lambda$$
$$\bar{\phi} = \frac{1 - 1/(1+r)}{1 - 1/(1+r)^{\tau+1}}\phi$$

Both $\bar{\lambda}$ and $\bar{\phi}$ decreases with τ. Intuitively, the longer a house is kept, the less is the annual amortization of the transaction costs. If different types of households have similar inaction regions regarding housing decisions, those with higher income uncertainty are more likely to be knocked out of the boundaries. This is confirmed quantitatively. Figure 1.6 plots the fractions of movers and stayers for three types of households. The upper panels are generated from the version of the model in which house price is fixed. Households with greater income uncertainty clearly move more frequently than those with relatively stable income. Furthermore, no household moves after retirement, since income shocks no longer occur. The lower panels are generated in the presence of risky house prices. It delivers the same message as in the upper panels, except that some households move even after retirement due to house prices shocks.

Households with greater income uncertainty move more frequently, resulting in a lower value of τ and higher user cost in expectation. User cost of owned house is essentially the price of housing services, thus higher user cost shall lead to lower housing-nonhousing consumption ratio and housing share in total wealth. Figure 1.5 shows the quantitative results for the case of illiquid housing and fixed house price. Compared with Figure 1.4, the most notable changes occur to the housing-nonhousing consumption ratio in the lower-left panel. The ratio now increases with age, which is consistent with evidence from various data sources[19]. More importantly, the model replicates the negative effect of income uncertainty on housing-nonhousing consumption ratio, which confirms the above user cost argument. Transaction costs also strengthen the negative effect of income uncertainty on housing share in total wealth. This point is clear in Figure 1.7. On the left panel of Figure 1.7, the

[19]Figure 1.2 and Figure 1.3 in this paper relies on data from the Consumer Expenditure Survey. Yang (2008) combines the Consumer Expenditure Survey and Survey of Consumer Finance by constructing synthetic cohorts.

housing share in total wealth[20] is plotted against degree of income uncertainty. The two lines on the top originate from the model without housing transaction costs ; while the bottom lines from the model with transaction costs. The bottom lines are steeper, indicating more sensitivity of the housing share in total wealth to income uncertainty. The right panel of Figure 1.7 plots house values against degrees of income uncertainty. In the presence of housing transaction cost, house value, averaged over the time before retirement, decreases with income uncertainty.

Next, I consider a model in which house price is uncertain, but transaction costs are absent. Results are displayed in Figure 1.8. Compared with results from the baseline model, house price uncertainty makes little difference as far as the effects of income uncertainty on housing decisions are concerned. Housing-nonhousing consumption varies little with the degree of income uncertainty. The correspondence between income uncertainty and house value is plotted in the right panel of Figure 1.7. The two lines on the top indicate that house value does not decrease with the degree of income uncertainty when housing transaction costs are absent. Notably, the starred line, which represented house values when house price is risky, lies above the circled line which represents house values when house price is fixed. This is because households choose more housing investment to hedge against the uncertain future house prices. Han (2008) provides an clear argument on this point. Including

[20] This statistics is obtained by taking the average of housing shares in total wealth of those before retirement. Same method is used for the house value in the right panel.

both transaction costs and house price uncertainty yields results that indicate slightly stronger impacts of income uncertainty on housing decisions, as shown in Figure 1.7.

In reality, house prices move together with income at the aggregate level. Cocco (2004) estimates the correlation between house price and the aggregate component of household income uncertainty to be more than 53%. In light of this, the zero correlation assumption seems unrealistic. there I set the both $\rho_{\xi,\eta}$ and $\rho_{\xi,\epsilon}$ to 0.2, 0.3 and 0.4, and redo the previous exercise. Figure 1.9 displays the impacts of income uncertainty on housing decisions under these parameterizations, in the presence of transaction costs. The effects of the comovement between income and house price are quite significant. When both $\rho_{\xi,\eta}$ and $\rho_{\xi,\epsilon}$ equal 0.4, average housing stock drops by about 80% if σ_η and σ_ϵ are increased from 0.08 to 0.2. Intuitively, if house price tends to decline at a time when it has to be liquidated due to bad income shocks, a rational household should reduce housing investment and keeps more saving in riskfree bonds.

Overall, absent borrowing constraints, house price risks play a very limited role in the negative relation between income uncertainty and housing demand, unless house prices comove significantly with income. A natural question is: why do the households care a lot about income uncertainty in making housing decisions, but less about house price uncertainty? This has to do with the user cost of owing a house. With housing investment being illiquid, higher income uncertainty means higher expected user cost, or equivalently, means higher price of the housing servics. On the other hand house price uncertainty imposes little effect on the user cost.

1.3.4 Borrowing constraints

I follow the common assumption that (1) no borrowing is allowed except mortgage debt and (2) house purchase entails an upfront downpayment. Hence the borrowing constraints have a weak form in which collateral borrowing is allowed. The roles played by the borrowing constraints are best understood from the viewpoint of the tension between the housing consumption motives and housing investment motives, as demonstrated in Henderson and Ioannides (1983) and Fu (1995). For young households, retirement is decades away, so they need limited saving only for precautionary purpose. Therefore acquiring housing service from owning entails over-saving. When borrowing is allowed, households can balance out the over-saving by hold negative financial assets. With borrowing constraints imposed, the conflict between housing consumption motives and investment motives rises. Households with greater income uncertainty have stronger precautionary motives, hence suffer less from the over-saving and have a high probability of owning, especially when young.

The computational results show that such a conflict indeed causes higher homeownership rate for households with greater income uncertainty, provided that house prices are uncorrelated with income. This is shown in Figure 1.10. The upper panel is generated from the model without house price risks, and the lower panel with house price risks, but house price is assumed to be uncorrelated with income. The squared lines plots the increase of homeownership rate with the degree of income uncertainty. In contrast, absent borrowing constraints, homeownership rate exhibit little change in response to income uncertainty, which is shown by the starred lines.

It should be noted that borrowing constraints do not increase homeownership rate, but lower homeownership rate to greater extent for households with more stable income, causing the homeownership rate to increase with income uncertainty. When house prices and income are assumed to be positively correlated, the correspondence between income uncertainty and homeownership rate is no longer monotone, because risk-avoidance consideration begins to gain strength. When both $\rho_{\xi,\eta}$ and $\rho_{\xi,\epsilon}$ reach 20%, homeownership rate decreases monotonically with income uncertainty. Furthermore, in this case the correspondence between homeownership rate and income uncertainty is virtually the same as in the absence of borrowing constraints. This indicates the home buyers are little bound by borrowing constraints, but choose not to borrow to reduce the risk exposure. The upper panels of Figure 1.11 plot the profiles of riskfree asset holding and homeownership rate for the case of fixed house price. households with greater income uncertainty accumulate more asset and become homeowners earlier. In the lower panels, both $\rho_{\xi,\eta}$ and $\rho_{\xi,\epsilon}$ equal 20%. Households with higer income uncertainty still accumulate more assets, but switch to owner later than those with lower income uncertainty.

My results are consistent with those in Diaz-Serrano (2005). Using Italian data, Diaz-Serrano (2005) finds that borrowing constraints exerts a significant negative effect on the probability of homeownership, but the negative relationship between income uncertainty and homeownership is driven by households' risk aversion.

Another interesting question regarding borrowing constrains is: do the borrowing constraints help explain the negative effect of income uncertainty on housing decisions on the intensive margin? To answer this question, I set the correlation between both $\rho_{\xi,\eta}$ and $\rho_{\xi,\epsilon}$ to 20%, and compare the quantitative results from the model with borrowing constraint to those from the model without borrowing constraint. I find little difference, which again shows that households are little bound by the borrowing constraints when risk-avoidance consideration dominates housing decisions.

1.3.5 Quantitative results from the general version of model

Figure 1.13 displays housing decisions under uncertain in the fully-specified model, the version with borrowing constraints, housing transaction costs and house price uncertainty. The negative effects of income uncertainty on housing demand are replicated on both the extensive margin and intensive margin. Such negative effects are age-dependent with young households being more sensitive to income uncertainty, consistent with empirical findings. In data, the negative effects tend to regain strength when households get close to retirement, which the model fails to generate.

Empirical analysis reveals a much stronger effect on housing decisions of permanent income shocks relative to transitory shocks. This is intuitive because with 40 years of working life, the realization of transitory shocks have a very good chance to be average out to the expected value. The computational results replicates this data observation. In figure 1.14, the squares depict the correspondence between income uncertainty and housing demand when both permanent and transitory shocks are present. The 'x's' depict the correspondence between σ_η and housing demand, with $\sigma_\epsilon = 0.13$. The correspondence is only slightly different from those represented by stars. On the other hand, the effect of transitory shocks on housing demand is very minor. This is shown by the circles, with σ_η fixed at the level of 0.13.

1.4 Robustness

The computational results presented in the previous section generally do not change qualitatively with reasonable changes in parameter values. Examples include changing γ between 2 to 5, changing downpayment requirement from 10% to 20%, and changing the selling cost of houses to from 6% to 8% of the house values. The exception is ω, the rental price of houses. As discussed in the calibration, owning is generally more advantageous financially[21], hence it is reasonable to set ω at a level that is slightly higher than owner's user cost. When ω is raised from 0.06 to 0.062, the computational results show a higher homeownership rate for households with greater income uncertainty. If ω=0.08, a positive correlation between income uncertainty and homeown-

[21]Henderson and Ioannides (1983) show that externality associated with renting makes owning more attractive. In the US, homeowners also enjoy income tax advantages.

ership rate appears even if both $\rho_{\xi,\eta}$ and $\rho_{\xi,\eta}$ equal 50%. The relationship between income uncertainty and homeownership rate is the result of the tension between two mechanisms. (i) The conflict between housing consumption and investment demand leads to a positive relationship. (ii) The comovement between income and house prices leads to negative relationship. The sensitivity of homeownership rate to ω shows that the second mechanism dominates the first one only weakly.

Thus far I have assumed free refinancing[22] and the same interest rate for mortgage debt and riskfree bond. In reality these assumptions do not hold. Home buyers typically pay off their mortgage debt according to a mortgage payment schedule which is costly to change via refinancing. These arrangements make housing investment more irreversible. They also intensify the conflict between housing consumption demand and investment demand, because costly refinancing implies more stringent borrowing constraints. With these considerations in mind, I solve a model in which home buyers are required to pay off the mortgage debt in 15 years, mortgage rate is assumed to be 4%, and refinancing cost is 0.5% of the house value. Appendix A.3 provides the details on model computation. This computational exercise reveals: (i) The results in the previous section still hold qualitatively; (ii) The relationship between income uncertainty and homeownership rate becomes even more sensitive to the rental price of houses ω.

[22]Here I am equating refinancing with loans backed by home equity. Hurst and Stafford (2004) provides evidence that refinancing is an important means of consumption smoothing for PSID respondents.

1.5 Concluding Remarks for Chapter I

This paper studies the effect of income uncertainty on housing demand. It uses four variables to measure housing demand: homeownership rate, value of owner-occupied house, share of home equity in total wealth and housing-nonhousing consumption ratio. The paper presents empirical evidence that all these variables are negatively affected by income uncertainty.

To understand the rationale behind the empirical observations. The paper uses a lifecycle model to examine the roles played by housing transaction costs, house price risks, and borrowing constraints. Housing transaction costs are critical in explaining the data facts because it leads to higher expected cost for households with greater income uncertainty. A positive correlation between house price and income means housing is a poor precautionary asset, which leads to the significant decrease of housing demand with income uncertainty. Borrowing constraints discourage housing demand of households with greater income uncertainty to a LESS extent, because they suffer less from the conflict between the consumption and investment demand of housing relative to those with more stable income.

These findings necessitate a reassessment of a class of portfolio choice models that abstracts from housing but uses income uncertainty to explain the reluctance of households to hold stocks in spite of the high equity premium. Since income uncertainty depresses housing investment, and the depressed housing investment leads to more investment in other risky assets, this class of models overstates the impact of income uncertainty on portfolio choice.

Therefore a profitable direction of future research is to evaluate the impact of income uncertainty on portfolio choice in the presence of housing.

Findings in this paper also provide a channel to resolve the lifetime consumption inequality puzzle. Chapter 3 of this dissertation uses data from Consumer Expenditure Survey and documents an almost flat lifetime profile of housing consumption inequality. This is puzzling because a standard lifecycle model predicts that within-cohort housing consumption inequality should rise with age of the cohort due to the persistent idiosyncratic income shocks. Since the negative effect of income uncertainty on housing demand diminishes with age, the housing consumption gap between households with greater income uncertainty and those with less income uncertainty is high when they are young, then decreases with age. This generates a tendency for within-cohort housing consumption inequality to decrease over lifetime, which can potentially counteract the increasing tendency caused by the arrival of persistent income shocks.

Another direction of future research is to incorporate the negative effect of income uncertainty on housing demand into the study of cyclical fluctuations in the housing market. Storesletten et al. (2004) shows the dramatic increase of household level income uncertainty during recessions, which further reduces housing demand during recessions. This channel may potentially explain the excessive volatility of residential investment and house trading volume observed in the data.

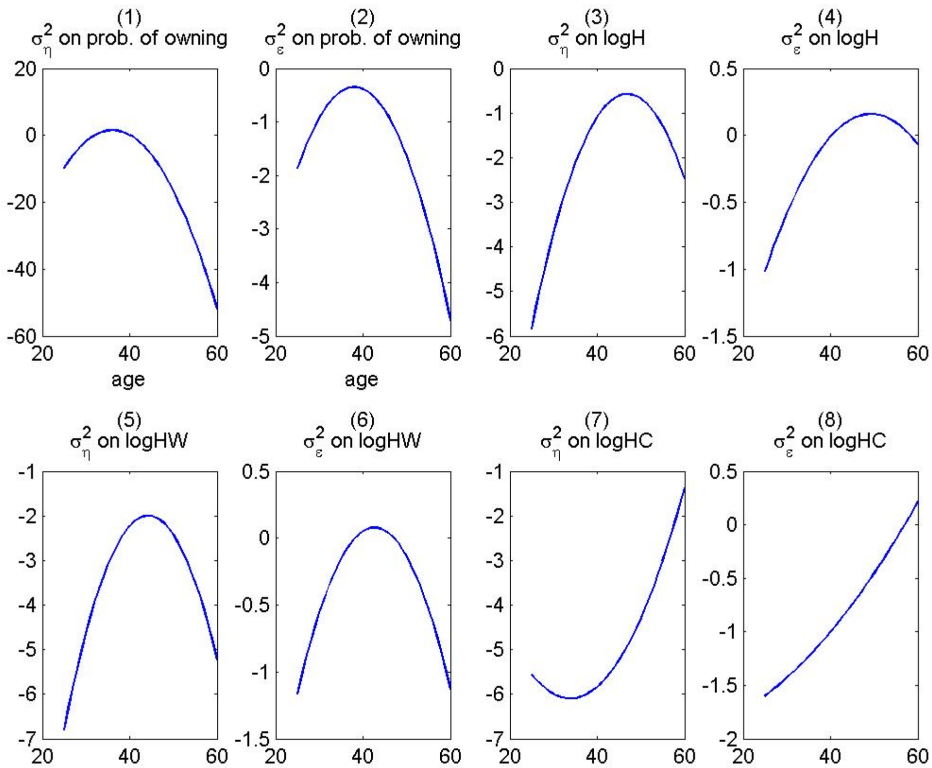

Figure 1.1: The effects of income uncertainty by age.

Table 1.2: Effects of Income Uncertainty on Tenure Choice

	(1)	(2)	(3)	(4)
Constant	-8.900	-10.185	-10.495	-11.548
	(2.65)	(2.84)	(2.93)	(3.11)
Var. of permanent shock	-94.781	-92.138	-94.183	-119.229
	(1.54)	(1.51)	(1.56)	(1.78)
Var. of permanent shock * Age	5.281	5.111	5.382	6.702
	(1.45)	(1.42)	(1.49)	(1.71)
Var. of permanent shock * Age^2	-0.075	-0.072	-0.077	-0.093
	(1.41)	(1.37)	(1.45)	(1.64)
Var. of transitory shock	-9.639	-7.854	-7.984	-13.346
	(0.73)	(0.59)	(0.66)	(0.91)
Var. of transitory shock * Age	0.462	0.364	0.421	0.684
	(0.62)	(0.49)	(0.60)	(0.83)
Var. of transitory shock * Age^2	-0.006	-0.004	-0.005	-0.009
	(0.55)	(0.43)	(0.55)	(0.74)
Total wealth	0.191	0.348	0.305	0.425
	(0.45)	(0.77)	(0.67)	(0.91)
Predictable income	0.725	0.731	0.798	0.803
	(12.75)	(12.76)	(13.08)	(12.98)
Black	-0.018	-0.020	-0.076	-0.047
	(0.11)	(0.12)	(0.44)	(0.27)
Female head	-0.101	-0.118	-0.160	-0.126
	(0.23)	(0.27)	(0.36)	(0.28)
Having chileren	0.626	0.603	0.621	0.610
	(3.27)	(3.12)	(3.19)	(3.10)
Married	0.272	0.276	0.304	0.304
	(2.06)	(2.09)	(2.28)	(2.27)
Owning stock		-0.148	-0.162	-0.151
		(1.01)	(1.10)	(1.02)
Owning business			-0.754	6.967
			(3.94)	(1.35)
Owning business * Age				-0.408
				(1.39)
Owning business * Age^2				0.005
				(1.25)

Probit Regressions of housing status (1 for owner, 0 for renter) on income risk, income wealth and demographics. In parenthesis are t-statistics. The effects of region and location are not reported.

Table 1.3: Effects of Income Uncertainty on House Value

	Without Age Interaction			With Age Interaction		
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	3.274	2.994	2.668	2.432	1.991	1.591
	(2.40)	(2.00)	-1.795	(1.91)	(1.46)	(1.17)
Variance of permanent shock	-2.545	-2.544	-2.307	-25.992	-25.691	-24.733
	(3.35)	(3.35)	-3.054	(1.56)	(1.54)	(1.50)
Variance of permanent shock * Age				1.081	1.072	1.031
				(1.28)	(1.27)	(1.23)
Variance of permanent shock * Age^2				-0.012	-0.012	-0.011
				(1.13)	(1.13)	(1.08)
Variance of transitory shock	-0.474	-0.472	-0.359	-5.894	-5.725	-4.692
	(2.83)	(2.82)	(2.13)	(1.65)	(1.60)	(1.32)
Variance of transitory shock * Age				0.253	0.245	0.197
				(1.40)	(1.35)	(1.10)
Variance of transitory shock * Age^2				-0.003	-0.003	-0.002
				(1.25)	(1.21)	(0.95)
Mortgage rate	-0.003	-0.003	-0.002	0.000	-0.001	0.000
	(0.20)	(0.22)	(0.17)	(0.01)	(0.06)	(0.00)
Total wealth	0.295	0.295	0.318	0.303	0.303	0.326
	(15.35)	(15.35)	(15.95)	(16.09)	(16.12)	(16.69)
Predictable income	0.039	0.079	0.097	0.266	0.323	0.338
	(0.20)	(0.37)	(0.46)	(1.67)	(1.88)	(1.99)
Age	0.046	0.044	0.039			
	(2.28)	(2.17)	(1.91)			
Age^2	-0.001	-0.001	0.000			
	(2.05)	(1.96)	(1.67)			
Black	-0.144	-0.143	(0.15)	-0.115	-0.117	-0.119
	(2.57)	(2.56)	(2.63)	(2.11)	(2.14)	(2.21)
Female head	0.02	0.035	0.030	0.099	0.115	0.113
	(0.19)	(0.28)	(0.24)	(0.86)	(0.99)	(0.97)
One child	0.06	0.063	0.062	0.083	0.087	0.084
	(1.22)	(1.26)	(1.25)	(1.72)	(1.79)	(1.74)
Two children	-0.037	-0.034	-0.032	-0.018	-0.015	-0.016
	(0.76)	(0.71)	(0.66)	(0.41)	(0.34)	(0.36)
Three children	0.018	0.020	0.020	0.048	0.048	0.044
	(0.28)	(0.30)	(0.31)	(0.77)	(0.78)	(0.72)
Four children	0.105	0.107	0.100	0.149	0.148	0.137
	(0.98)	(0.99)	(0.94)	(1.41)	(1.41)	(1.31)
Five or more children	0.337	0.341	0.343	0.365	0.370	0.367
	(1.59)	(1.60)	(1.63)	(1.73)	(1.75)	(1.75)
Married	-0.053	-0.057	-0.053	-0.075	-0.081	-0.075
	(0.35)	(0.38)	(0.35)	(0.50)	(0.54)	(0.50)
Owning stock		-0.019	-0.025		-0.037	-0.042
		(0.45)	(0.59)		(0.89)	(1.02)
Owning business			-0.192			-0.193
			(3.89)			(3.92)

Results of regressing logH on income uncertainty and demographic variables.

Table 1.4: Effects of Income Uncertainty on Home Equity Ratio

	Without Age Interaction			With Age Interaction		
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	4.247	1.954	0.380	2.766	0.669	-1.645
	(2.15)	(0.90)	(0.18)	(1.53)	(0.35)	(0.88)
Var. of permanent shock	-3.444	-3.413	-2.533	-32.010	-30.550	-27.429
	(3.02)	(3.01)	(2.33)	(1.25)	(1.20)	(1.13)
Var. of permanent shock * Age				1.334	1.292	1.150
				(1.03)	(1.01)	(0.94)
Var. of permanent shock * Age^2				-0.015	-0.015	-0.013
				(0.95)	(0.95)	(0.85)
Var. of transitory shock	-0.949	-0.924	-0.515	-11.034	-10.222	-7.189
	(3.84)	(3.75)	(2.15)	(2.06)	(1.92)	(1.41)
Var. of transitory shock * Age				0.522	0.486	0.341
				(1.94)	(1.81)	(1.33)
Var. of transitory shock * Age^2				-0.007	-0.006	-0.004
				(1.96)	(1.86)	(1.33)
Mortgage rate	0.019	0.017	0.015	0.023	0.019	0.018
	(1.01)	(0.88)	(0.85)	(1.19)	(1.00)	(1.02)
Predictable income	-0.001	-0.001	-0.001	-0.721	-0.445	-0.163
	(2.16)	(1.79)	(1.36)	(3.41)	(1.92)	(0.73)
Age	-1.099	-0.762	-0.567			
	(4.04)	(2.52)	(1.96)			
Age^2	0.069	0.056	0.045			
	(2.32)	(1.89)	(1.60)			
Black	-0.064	-0.060	-0.095	-0.026	-0.032	-0.058
	(0.78)	(0.74)	(1.22)	(0.32)	(0.40)	(0.76)
Female head	-0.161	-0.062	-0.042	-0.053	0.026	0.092
	(0.90)	(0.34)	(0.24)	(0.31)	(0.16)	(0.57)
One child	0.072	0.094	0.085	0.098	0.115	0.102
	(1.00)	(1.29)	(1.22)	(1.37)	(1.62)	(1.50)
Two children	0.027	0.046	0.057	0.048	0.063	0.063
	(0.39)	(0.66)	(0.85)	(0.72)	(0.95)	(0.99)
Three children	0.054	0.066	0.067	0.088	0.090	0.082
	(0.56)	(0.69)	(0.73)	(0.97)	(1.00)	(0.94)
Four children	0.156	0.171	0.155	0.209	0.210	0.189
	(0.98)	(1.08)	(1.03)	(1.35)	(1.36)	(1.28)
Five or more children	0.313	0.341	0.308	0.342	0.364	0.316
	(1.01)	(1.11)	(1.05)	(1.11)	(1.19)	(1.08)
Married	0.209	0.179	0.212	0.196	0.167	0.203
	(0.95)	(0.81)	(1.01)	(0.89)	(0.76)	(0.97)
Owning stock		-0.153	-0.160		-0.171	-0.182
		(2.50)	(2.73)		(2.84)	(3.17)
Owning business			-0.581			-0.568
			(8.85)			(8.66)

Results of regressing logHW on income uncertainty and demographic variables..

Table 1.5: Effects of Income Uncertainty on Housing-nonhousing Consumption Ratio

	Without age interaction	With age interaction
Constant	1.710	1.567
	(5.41)	(16.40)
Var. of permanent shock	-12.986	1.793
	(2.80)	(0.05)
Var. of permanent shock * Age		-0.4667
		(0.30)
Var. of permanent shock * Age^2		0.007
		(0.45)
Var. of transitory shock	-1.111	-1.995
	(1.52)	(0.52)
Var. of transitory shock * Age		0.001
		(0.00)
Var. of transitory shock * Age^2		0.001
		(0.32)
Mortgage rate	-0.028	0.011
	(0.95)	(1.09)
Total wealth	3.856E-07	2.635E-07
	(1.42)	(1.66)
Predictable income	-3.494E-07	-1.959E-06
	(0.11)	(1.15)
Age	0.001	
	(0.09)	
Age^2	-0.0001	
	(0.37)	
Black	0.235	0.182
	(3.27)	(2.90)
Female head	-0.011	-0.004
	(0.16)	(0.07)
One child	(0.10)	-0.160
	(1.61)	(2.99)
Two children	-0.110	-0.161
	-1.737	(2.92)
Three children	-0.127	-0.210
	(1.61)	(3.06)
Four children	-0.120	-0.263
	(0.97)	(2.32)
Five or more children	-0.498	-0.467
	(3.44)	(3.70)
Married	-0.152	-0.166
	(2.19)	(2.71)

Results of regressing logHC on income uncertainty and demographic variables. TS2SLS technique is used. The first stage regression is done in PSID, and the second stage done in CEX.

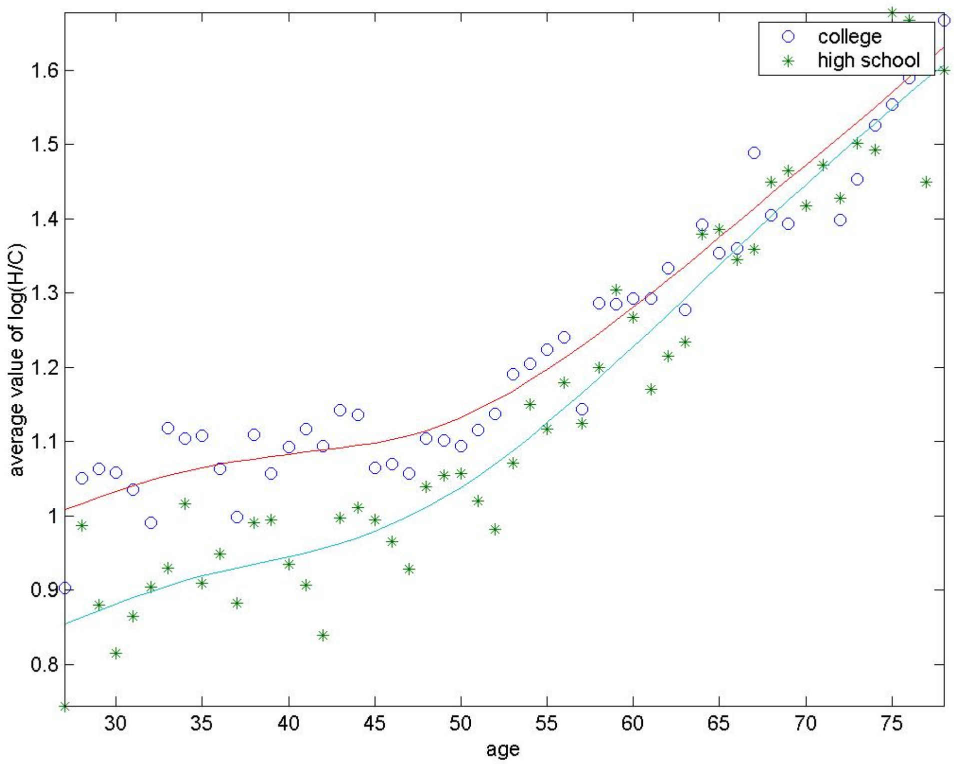

Figure 1.2: Housing-nonhousing ration by education.

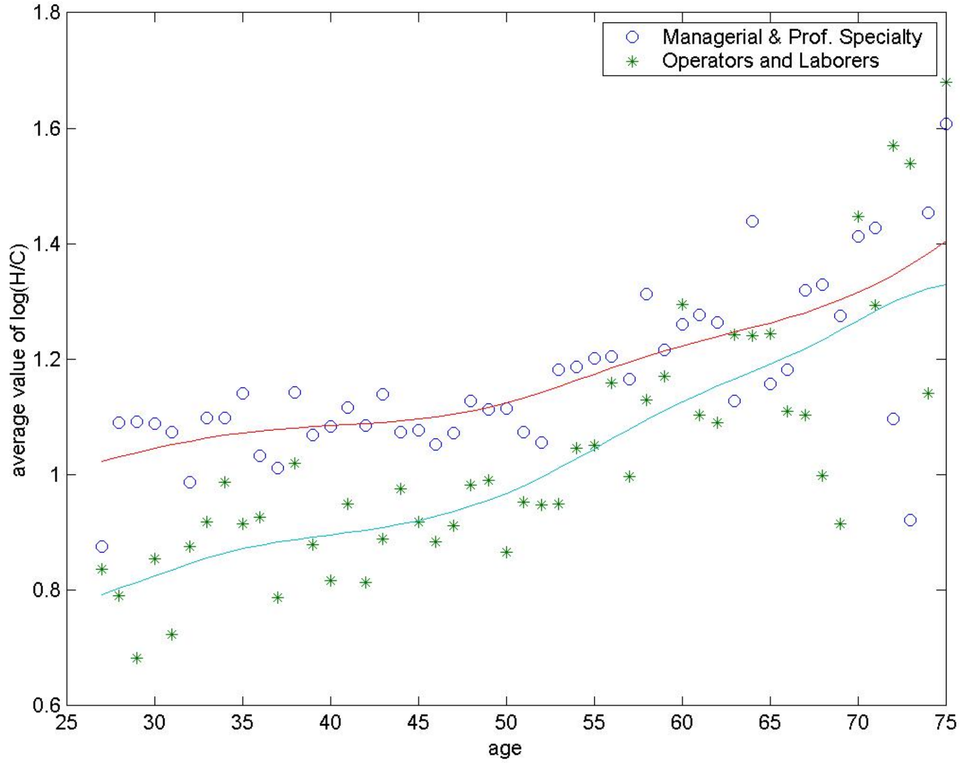

Figure 1.3: Housing-nonhousing ration by occupation.

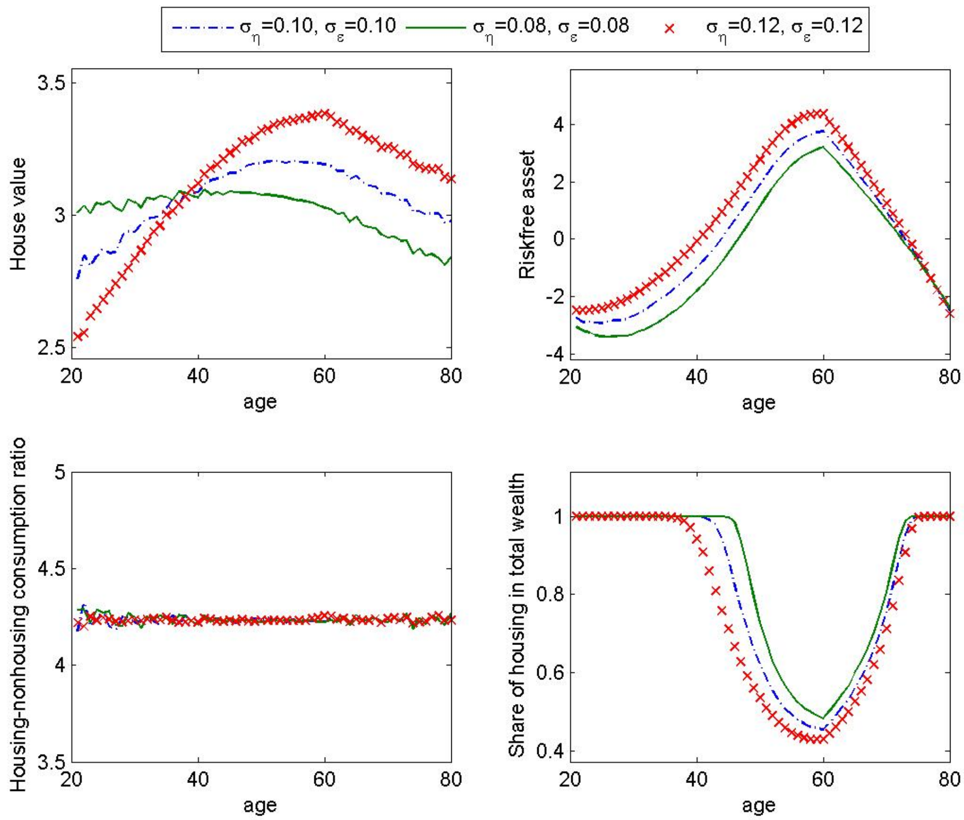

Figure 1.4: Housing decisions in the baseline model in which borrowing constraints and housing transaction costs are absent. House price is fixed at 1.

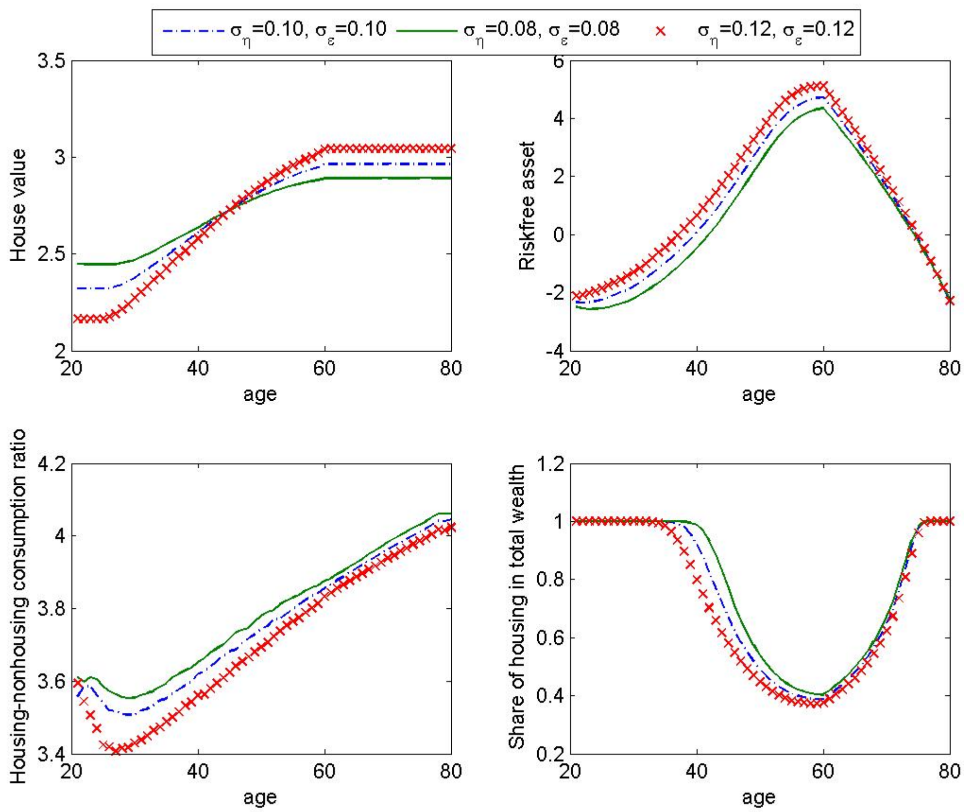

Figure 1.5: Housing decisions in the presence of transaction costs. House price is fixed at 1.

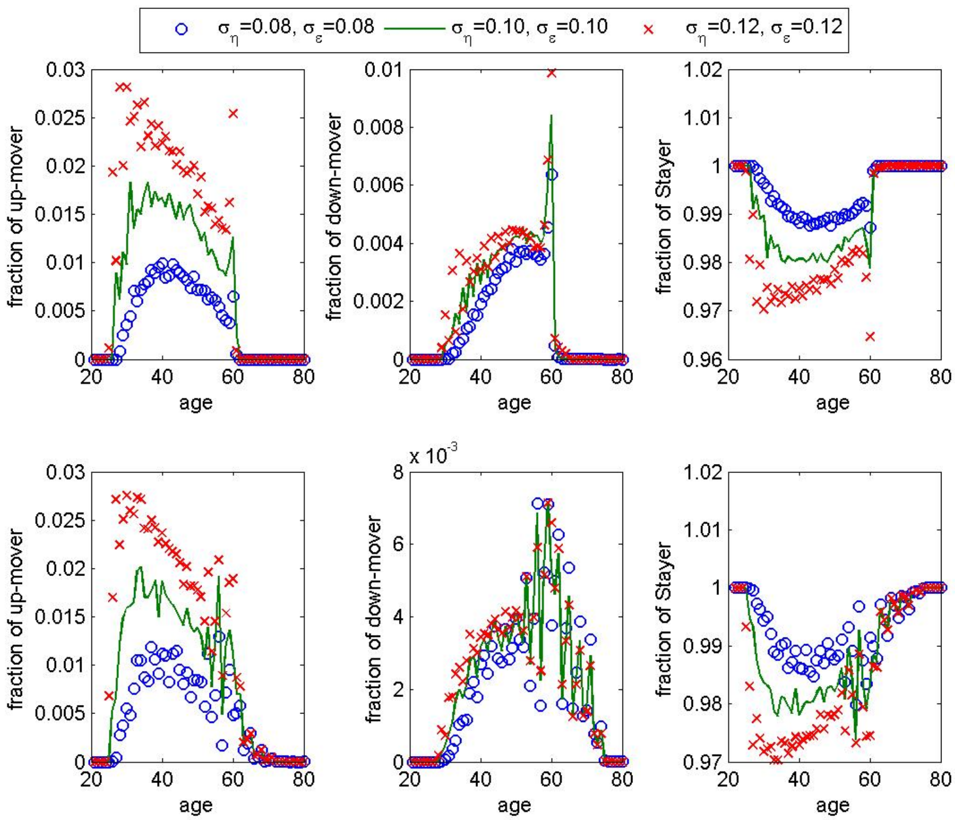

Figure 1.6: Fractions of movers and stayers. The upper panels are generated in the absence of house price risks; while the bottom panels with house price risks.

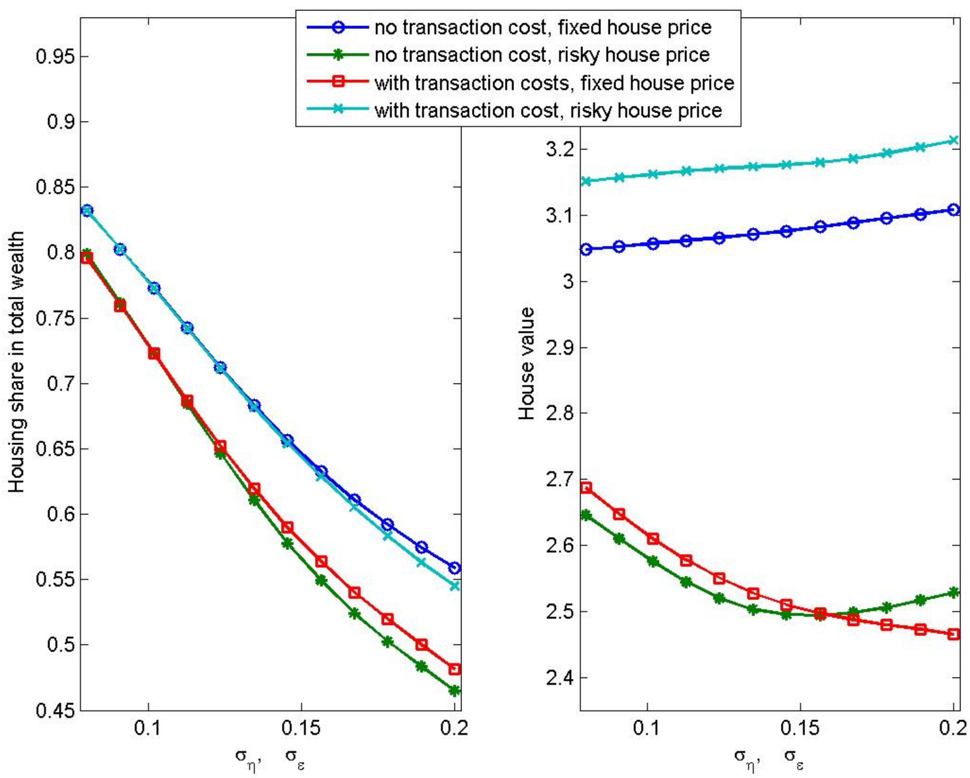

Figure 1.7: A comparison of housing decisions among four cases.

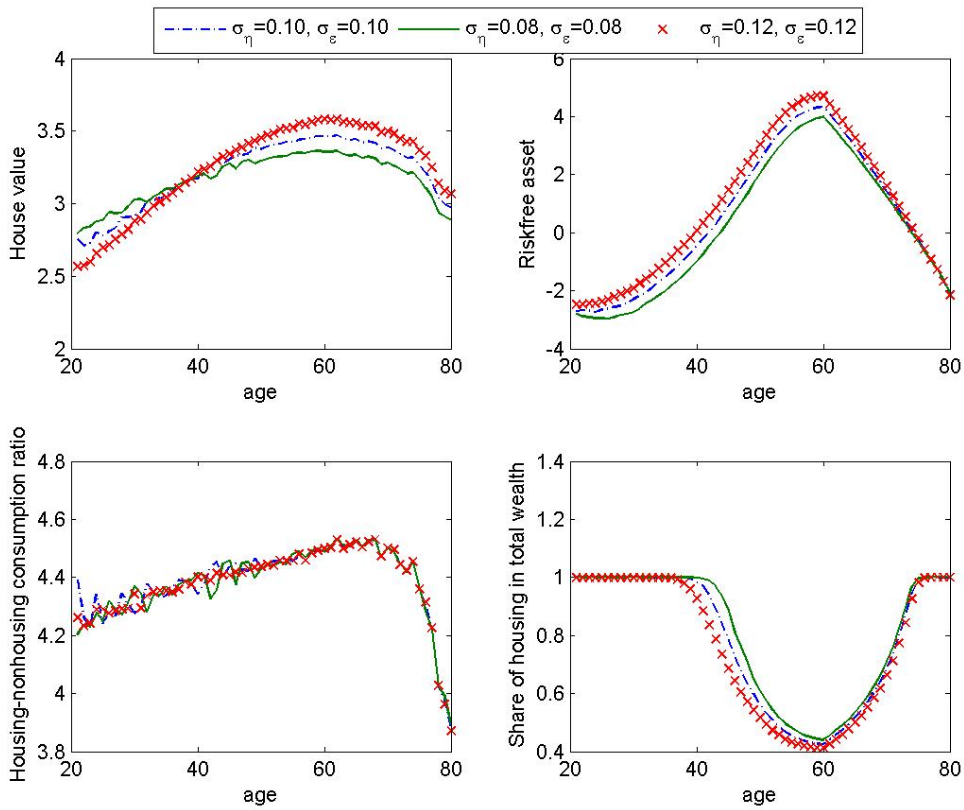

Figure 1.8: Housing decisions when house price is risky and transaction costs are absent.

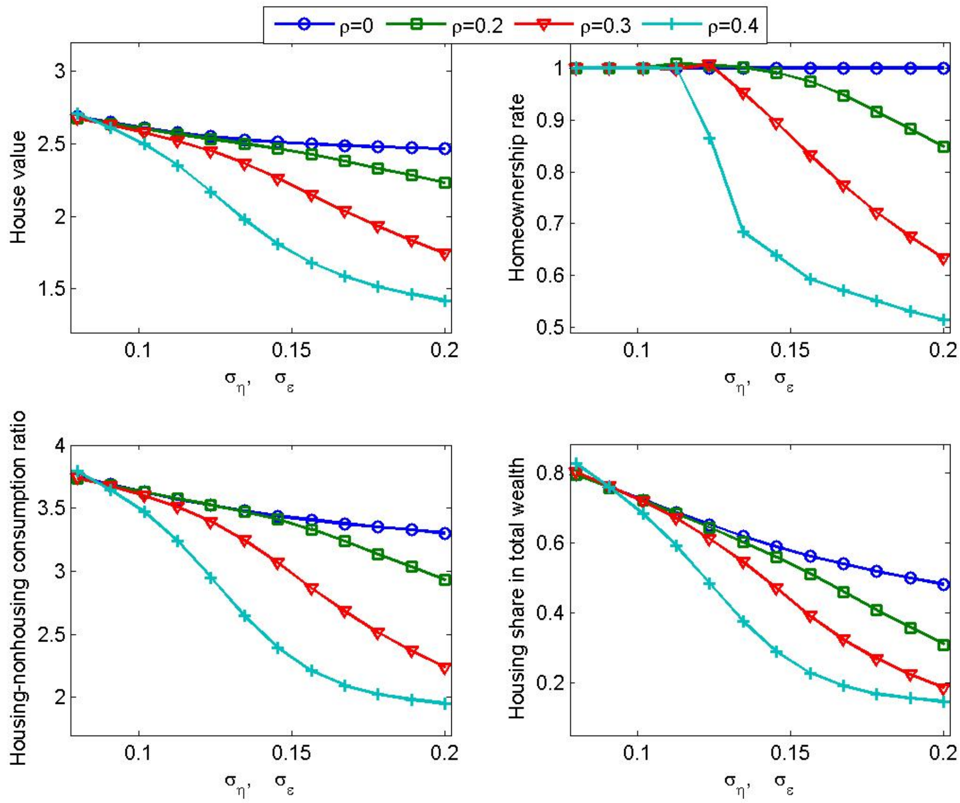

Figure 1.9: Impacts of income uncertainty under different correlation coefficients between income and house price (ρ).

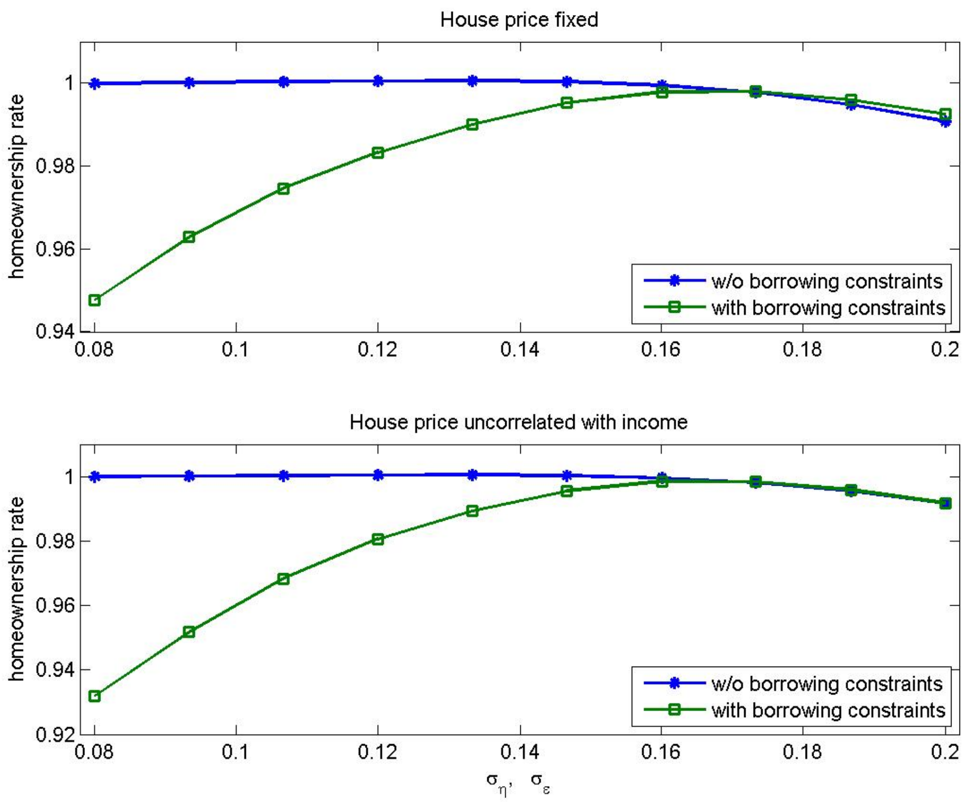

Figure 1.10: Homeownership rate as a function of standard deviations of income shocks. The upper panel is for the situation without house price uncertainty, the lower panel assumes house prices are uncertain but uncorrelated with income.

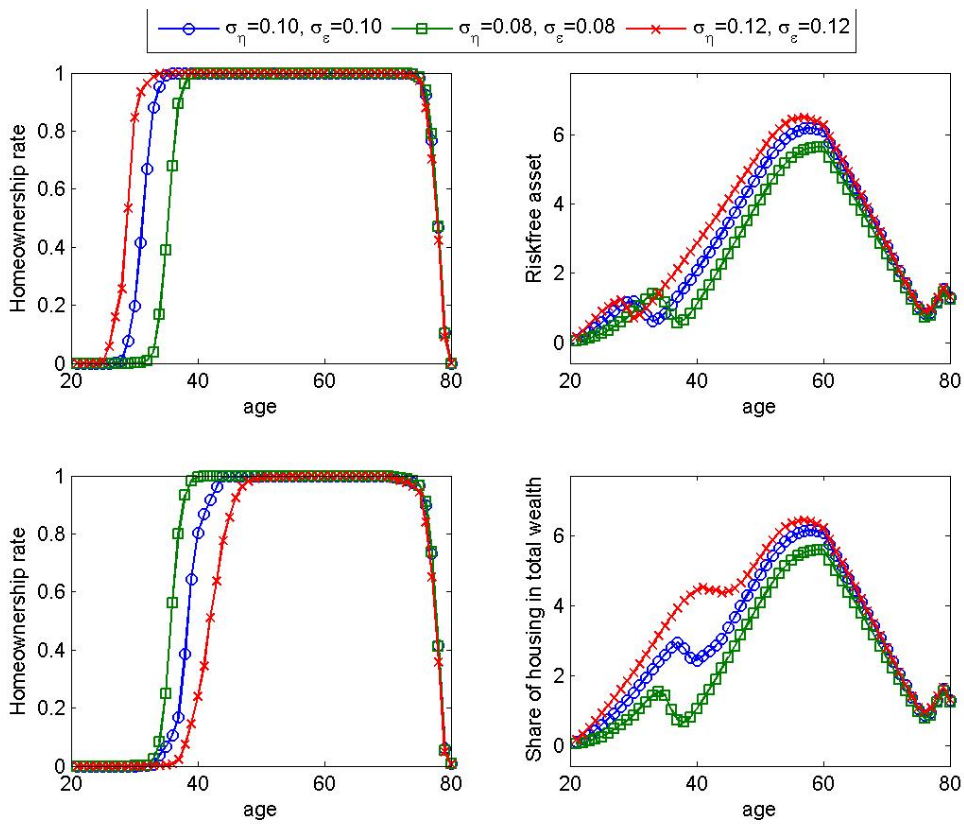

Figure 1.11: Homeownership rate and riskfree asset. The upper panels are for the situation without house price uncertainty, the lower panel assumes risky house price that is correlated with income.

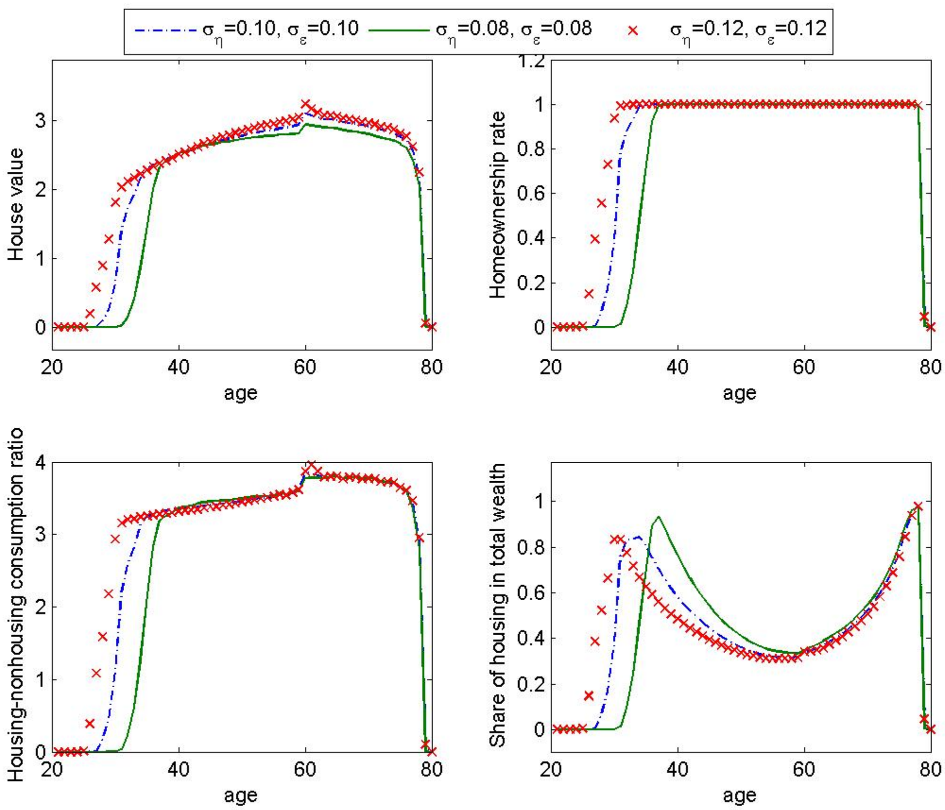

Figure 1.12: Housing decisions when transaction costs are absent and downpayment is required.

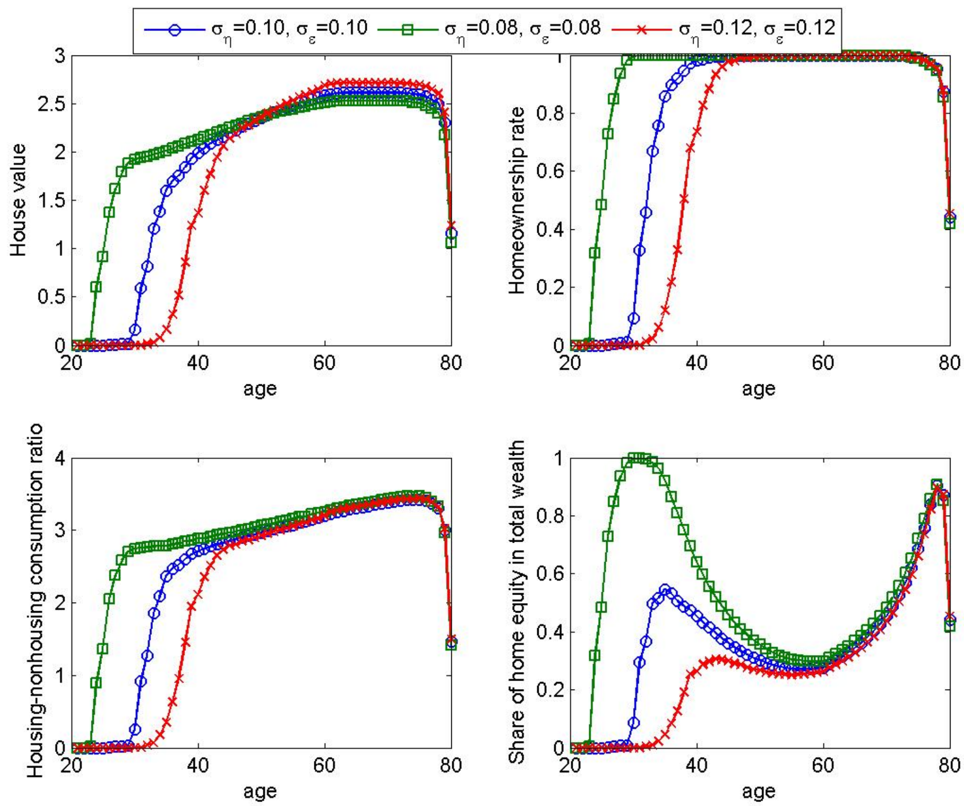

Figure 1.13: Housing decisions in the fully-specified model.

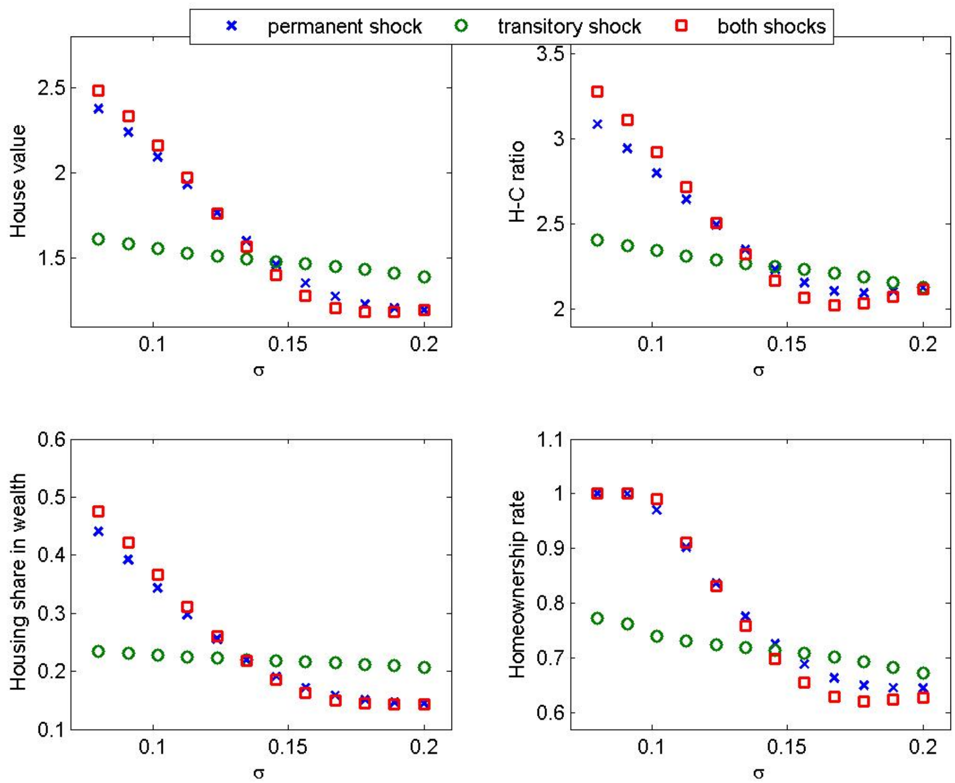

Figure 1.14: Magnitudes of the effect of permanent and transitory income shocks.

Chapter 2

Another Look at Income and Consumption Inequality

An exploration of PSID data reveals that the increase of income inequality and housing consumption inequality over the past decades is more significant among younger households. Such age-biasedness has important implications. I first discuss briefly the implication on identifying the sources of growing inequality. Then I concentrate on its implication on the extraction of age-profile of within cohort income/consumption inequality. I find that one either overstates or understates the rise of inequality with age when the usual dummy regression methodology is employed, due to the existence of age-dependent year effect. A simple solution is then proposed.

2.1 Introduction

In the vast literature of rising income and consumption inequality since the 1970's, only limited attention has been paid to how the rises depends on age [1]. In this paper I measure inequality with the variance of logarithm of

[1]For example, it is known that young, poor-educated workers have been severely worse off since 1970's

interested variables. From PSID data[2], I find the rise of family income inequality, househead's income inequality, and housing consumption[3] inequality are significantly higher among younger households. If one uses the term "year effects" to describe the changes to the cross sectional distribution of income and consumption, then year effects are generally stronger on younger households. This indicates an increasing heterogeneity among agents which is revealed in the first few year after they enter the labor market, consistent with the estimation by Heathcote et al. (2005). For nonhousing consumption inequality (from CEX 1981-2003), the age-dependency of year effects is minor, indicating sizable consumption smoothing over lifecycle and/or good predictions about the secular rise in income inequality.

The age-dependency of year effects turns out to have important bearings on how to extract lifecycle profile of inequality from micro data. The rise of income and consumption inequality over lifetime is known to be significant, implying large, persistent and uninsurable idiosyncratic income shocks[4]. The steepness of lifetime income and consumption profiles are used to determine the size and persistence of such shocks, and the completeness of the insurance market. therefore it is critical to understand how reliable the methodologies used to extract the profile are. The most widely used methodology to obtain lifecycle profile from repeated cross sections of data is the dummy regression introduced in Deaton and Paxson (1994). The variances of logarithm of inter-

[2]see Appendix B1 for data description
[3]See Appendix B1 for the definition
[4]e.g., Storesletten et al. (2004)

ested variables are decomposed into age effects, year effects and cohort effect. Since cohort is perfectly identified by the difference between year and age, one cannot estimate both year effects and cohort effects without further normalization. In practice one either controlls for year effect or cohort effect. Heathcote et al. (2005) show that age profiles resulting from controlling for cohort effects can be significantly steeper than those from controlling for year effects. The secular rise of inequality over the past decades is well-documented, while cohort effects are found to be negligible. Therefore Heathcote et al. (2005) suggest the control of year effects rather than cohort effects.

The implicit assumption under these dummy regression schemes is age-independence of year effects. In this paper I show that controlling for year effects while ignoring its age-dependency introduces biased age profile. In particular, if year effects are stronger on younger agents, then the rise of inequality with age is understated. On the other hand, if year effects are generally stronger among older agents, the rise of inequality with age is overstated. This does not mean that controlling for cohort effect is a better alternative – it will always overstate the rise in the presence of strong year effect. Simply adding interactive terms of year dummies and age, year dummies and age-squared turns out to work quite well in identifying the true lifecycle profiles of income/consumption inequality.

2.2 Age-dependent Year Effect

Throughout the paper, I use income and housing consumption data from PSID and nonhousing consumption data from CEX. Variable definitions and sample selection criteria are stated in the Appendix. The stronger year effects among younger agents is evident in Figure 2.1 which plots variance of logarithm of family income by age for survey year 1968, 1972, 1976, 1980, 1985 and 1990. For example, comparing income inequality between survey year 1968 and 1990, a huge difference exists between those who aged 30, while only a mild difference between those aged 60.

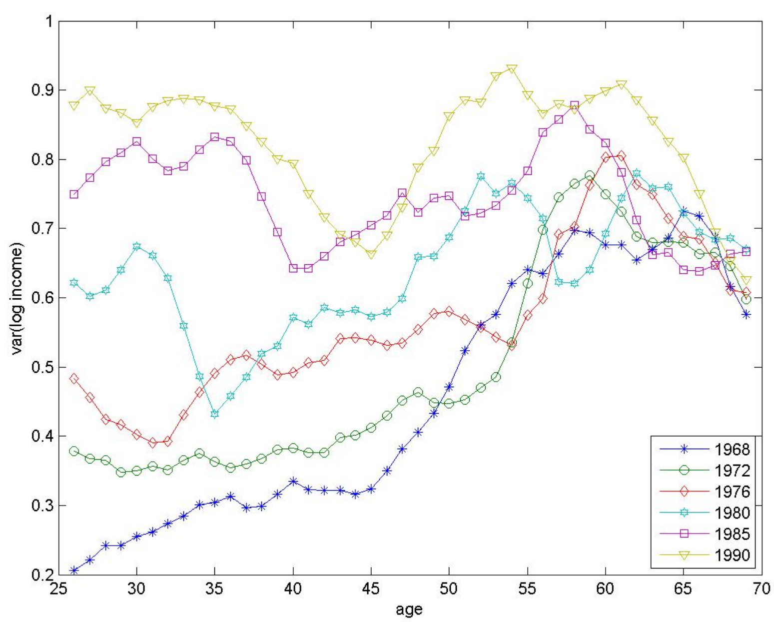

Figure 2.1: Variance of logarithm of family income by age for year 1968, 1972, 1976, 1980, 1985 and 1990

To understand the data better, let $x_{h,t}$ be the variance of logarithm of income/consumption for agents with age h at year t. I assume age effects and year effects are additive, i.e.,

$$x_{h,t} = x_{h-1,t-1} + A_h + Y_{h,t} \tag{2.1}$$

Notice A_h is the increment of variance when the agents grow from age h to $h-1$; while $Y_{h,t}$ is the increment in year t for agents aged h. The current interest is to obtain $Y_{h,t}$ to see how year effect depends on age. I use a quadratic function to approximate age-dependent year effect: $Y_{h,t} = b_{0,t} + b_{1,t} * h + b_{2,t} * h^2$. The following regression recovers $b_{0,t}$, $b_{1,t}$ and $b_{2,t}$:

$$x_{h,t} = \alpha_t + D_{age}\psi + D_{yr}\beta + D_{yr}h\gamma + D_{yr}h^2\delta \tag{2.2}$$

In equation 2.2, D_{age} and D_{yr} are age and year dummies. Notices the initial year, t_0, and initial age, h_0, do not have dummies. $D_{yr}h$ ($D_{yr}h^2$) denote the interaction terms of year dummies and age (age-squared). The set of coefficients, $\{\beta_t, \gamma_t, \delta_t\}_{t=0,1,2...}$ describes the difference in year effects between year t and year t_0. The increment in inequality in year t is given by:

$$Y_{h,t} = \beta_t - \beta_{t-1} + (\gamma_t - \gamma_{t-1})h + (\delta_t - \delta_{t-1})h^2 \tag{2.3}$$

i.e., $b_{0,t} = \beta_t - \beta_{t-1}$, $b_{1,t} = \gamma_t - \gamma_{t-1}$ and $b_{2,t} = \delta_t - \delta_{t-1}$. I run equation 2.2 for four variables: family income 1968-1997 from PSID, househead income 1968-1993 from PSID, nonhousing consumption 1981-2002 from CEX and housing consumption 1968-1997 from PSID. The estimated $\{\beta_t, \gamma_t, \delta_t\}_{t=0,1,2...}$ for each variable are presented in Table 2.1 and Table 2.2. Figure 2.2 plots the age-dependency of year effects. The upper panels depict age-dependency of year effect on family income and househead's income, where the stronger year effect on younger agents are clear. Similar pattern for housing consumption inequality, the lower-right panel. The lower-left panel shows a somewhat different picture: year effects are strongest when agents are around 40. In addition, the scale of variation with age is much smaller than for the other three variables.

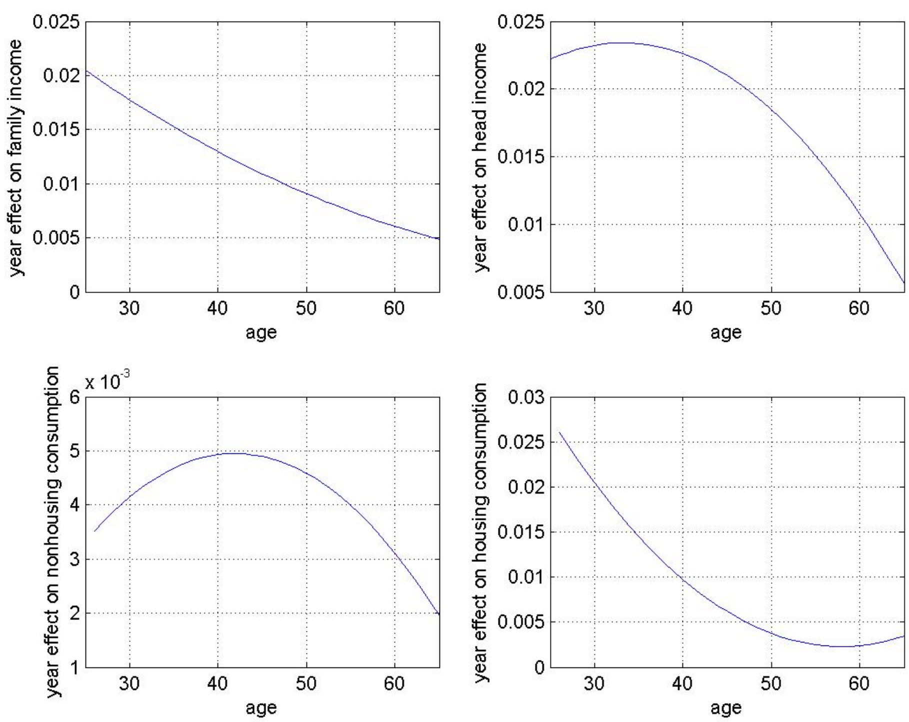

Figure 2.2: Age-dependency of year effects of family income (upper-left), househead's income (upper-right), nonhousing consumption (lower-left) and housing consumption (lower-right). Age-dependent year effect is approximated by a second-order polynomial of age, with the coefficients estimated using equation 2.2.

2.3 Age Profile of Inequality

2.3.1 Sources of Biasedness

Heathcote et al. (2005) find that age profiles of inequality are steeper when cohort effects are controlled for than when year effects are controlled for. In the presence of positive year effects this is generally true. The reason is clear from the following example.

I simulate artificial data with given age effects and age-dependent year effects. Specifically, the artificial data have 10 cross sections, say from year 1981 to 1990. In each cross section there are 20 data points, representing inequality for groups aged 31-50. In the initial year (year 1981), inequality goes from 0.05 to 1 for agents aged 31 to 50, respectively. In terms of equation (1), I set $A_h = 0.05$ and $Y_{h,t} = 0.2 - log(h - h_0)/15$. Hence year effects are 0.2 for 30-year olds, then decrease logarithmically with age.

The artificial data is depicted in figure 2.3. The upper-left panel is a scatter plot of simulated data. In the upper-right panel, data points of the same year are connected into lines, forming a year-effect view. In a dummy regression controlling for year effects, these lines are shifted and averaged. The thick starred line is exactly the age-profile using such a regression. If year effects were not age-dependent, the regression coefficients on age should yield unbiased estimates of age effects. However, as is evident in the year-effect view picture, controlling for year effects generates an almost flat age profile, quite different from the actual one fed into the simulation. It is straightforward to image that in case of stronger year effects on older agents, year-effect view would overstate the rise of inequality. In the lower-left panel, data points are connected by cohorts, constituting a cohort-effect view. The thick starred line is the age-profile of inequality when cohort dummies, rather than year dummies, are included in the regression. Basically it is the average of these cohort lines after being shifted, which greatly exaggerate the upward trend of the age-profile due to the positive year effects.

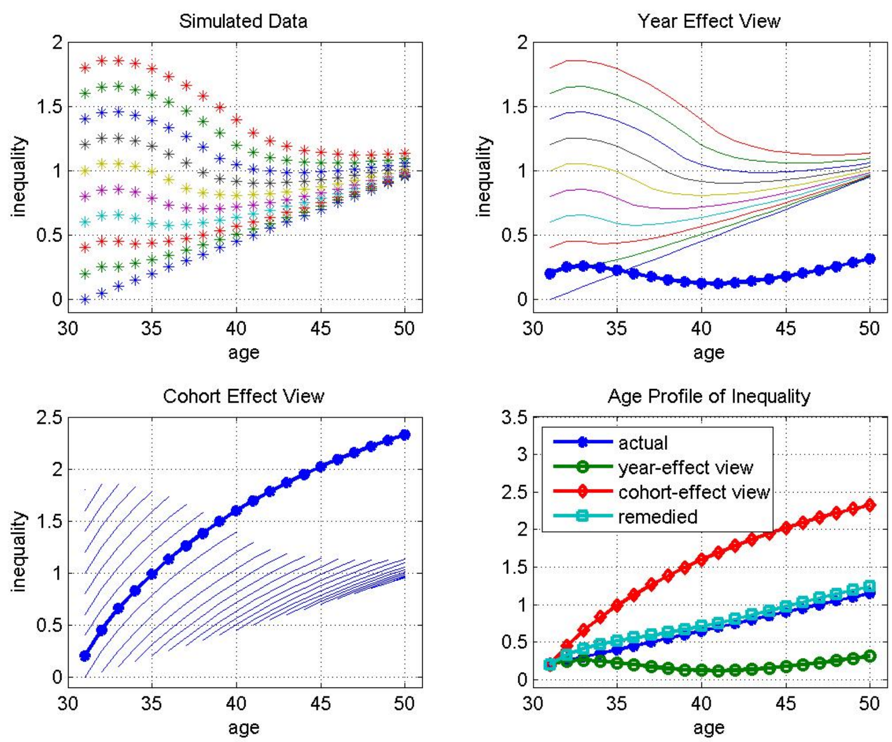

Figure 2.3: The upper-left panel depicts simulated data by age. In the upper-right panel data points are connected by years, with the thick line representing age-profile from the year-effect view. In the lower-left panel data points are connected by cohorts, with the thick line representing age-profile from the cohort-effect view. The lower-right panel is a comparison of age profiles from these views and from the remedied regression with the actual one fed into the simulation. Inequality of age 31 is normalized to 0.2.

2.3.2 A Simple Remedy

Up to now it is clear that adding interaction terms would at least partially remedy the bias introduced by age-dependent year effects. The lower-right panel of Figure 2.3 shows the effectiveness: the "actual" line depicts the actual age profile fed into the simulated, while the "remedied" line depicts the age-dummy coefficients from running equation 2.2. For comparison, estimates from year-effect view and cohort-effect view are also presented in the panel.

Next, I apply the same remedy to real income and consumption data. Figure 2.4 show the results. In the figure, I use circled line for the age profile of inequality obtained after controlling for cohort effect, starred line for profile after controlling for year effect, and diamond-ed line for the remedied profile. Age profile of nonhousing consumption inequality from the year-effect view (i.e., year effects are controlled for) is only slightly different from the remedied line. This is not surprising given figure (2), where the age-dependency of year effects on nonhousing consumption inequality is almost negligible. For family income, househead income and housing consumption, it is clear that the rise of inequality is overstated by the cohort-effect view, understated by the year-effect view, while the remedied lines sit in the middle.

It is worth noticing that the regression scheme employed here assumes non-changing age profile. In reality age profile may change as a result of structural changes of the economy. The most obvious example is housing consumption. Using dummy regression with age-dependent year effects controlled

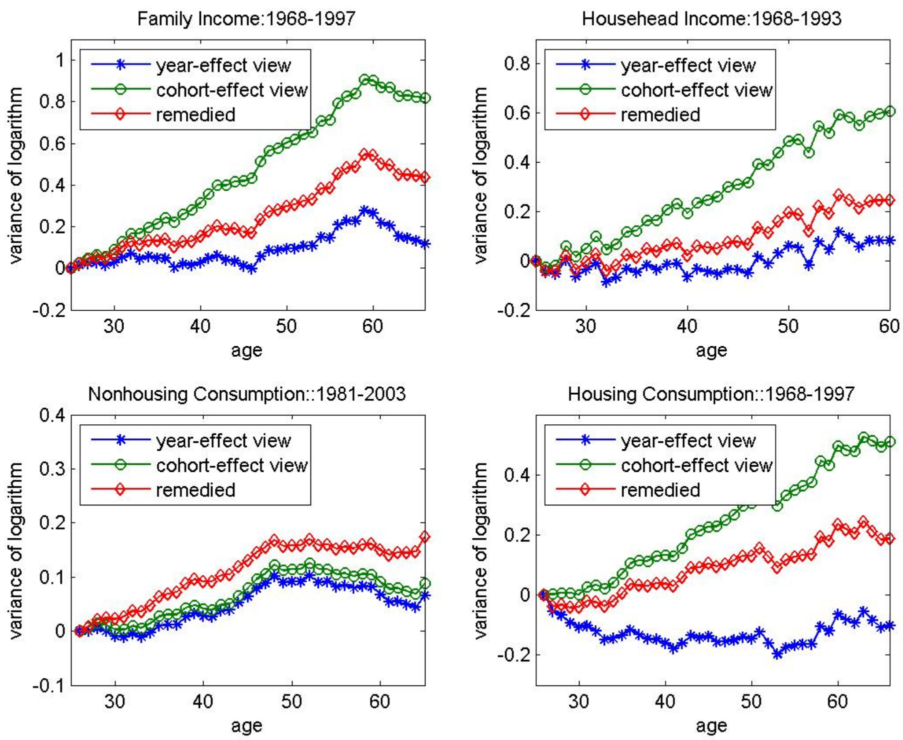

Figure 2.4: Age profiles of income/consumption inequality. The profiles are coefficients of age dummies with age effects of 25-year-olds normalized to zero. Cohort-effect view is obtain by controlling for cohort effects using cohort dummies. Year-effect view is obtained by controlling for year effects. The "remedied" lines represent the age profile obtained by running equation 2.2

for, it appears that housing consumption inequality rises with age during 1968-1980, but not so during during 1981-1997. This is depicted in figure 2.5;

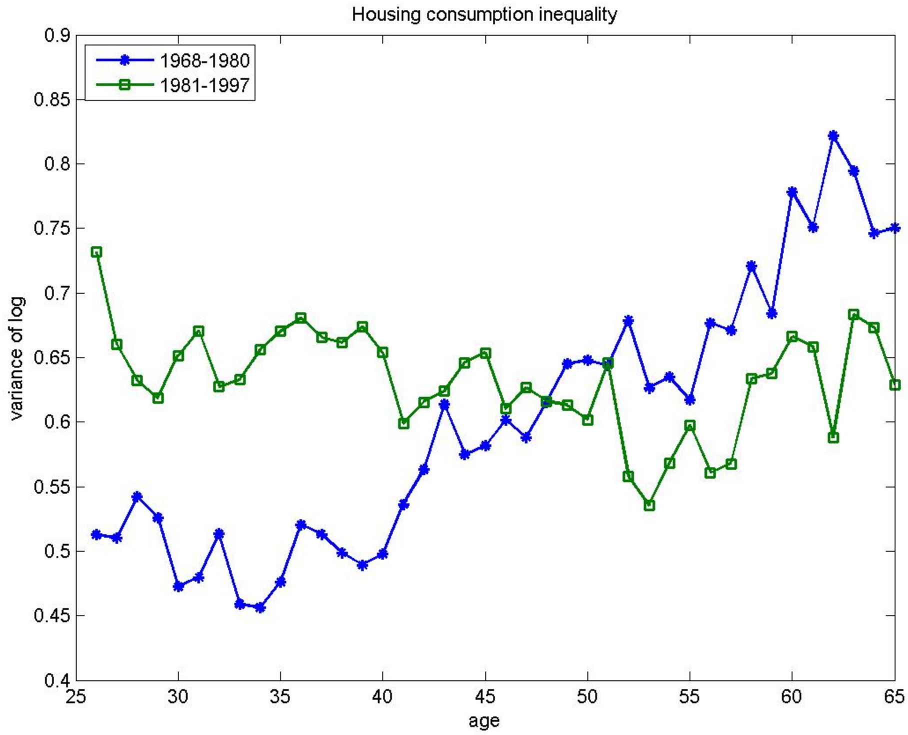

Figure 2.5: Housing consumption inequality from different years of data, obtained by running equation 2.2. The different profiles points to structural changes occurred to the economy.

2.4 Concluding Remarks for Chapter II

In this paper I have shown: (1), the year effects of rising income and consumption inequality are age-dependent. (2), controlling for year effects but ignoring its age-dependency greatly understates the rise of inequality over a cohort's lifetime (except for nonhousing consumption), controlling for cohort effects while ignoring year effects totally overstates the rise. When age-dependent year effects is taken into account, the lifetime profiles of inequality is closer to the truth, which is steeper than in Heathcote et al. (2005), but flatter than Deaton and Paxson (1994) and Storesletten et al. (2004). Consequently, the current understanding regarding the size and persistence of idiosyncratic shocks, the effectiveness of insurance market and the degree of ex ante income heterogeneity may need to be reassessed.

	Family Income				Househead's Income			
year	$D_{yr} * age$	t-stat	$D_{yr} * age^2$	t-stat	D_{yr}	t-stat	$D_{yr} * age^2$	t-stat
1969	-0.0021	-0.22	0.00005	0.24	-0.01063	-0.67	0.00031	0.80
1970	-0.00297	-0.30	0.00008	0.40	0.01905	1.19	-0.00057	-1.48
1971	-0.01299	-1.33	0.00029	1.37	-0.01748	-1.10	0.00044	1.14
1972	-0.00992	-1.02	0.00018	0.86	-0.0273	-1.71	0.00064	1.67
1973	-0.01166	-1.20	0.0002	0.96	-0.02688	-1.68	0.00063	1.63
1974	-0.00586	-0.60	0.0001	0.49	-0.01207	-0.76	0.0003	0.77
1975	-0.00364	-0.37	-0.00002	-0.08	-0.00275	-0.17	-0.00004	-0.10
1976	-0.00511	-0.52	0.00001	0.03	-0.00813	-0.51	-0.00002	-0.06
1977	-0.00421	-0.43	-0.00003	-0.13	0.00307	0.19	-0.00015	-0.38
1978	-0.00681	-0.70	0.00005	0.25	-0.0085	-0.53	0.00015	0.40
1979	-0.01241	-1.28	0.00017	0.80	-0.00854	-0.54	0.0002	0.51
1980	-0.01149	-1.18	0.00011	0.54	-0.01212	-0.76	0.00024	0.61
1981	-0.0148	-1.52	0.00018	0.88	-0.03702	-2.32	0.0009	2.34
1982	-0.02185	-2.24	0.00027	1.27	-0.033	-2.07	0.00073	1.89
1983	-0.01787	-1.84	0.00014	0.66	-0.01618	-1.01	0.00023	0.59
1984	-0.01413	-1.45	0.00003	0.13	0.01131	0.71	-0.00059	-1.53
1985	-0.01522	-1.56	0.00005	0.25	0.00356	0.22	-0.00031	-0.80
1986	-0.00728	-0.75	-0.00013	-0.62	0.00306	0.19	-0.00025	-0.64
1987	-0.0131	-1.35	-0.00001	-0.05	0.00383	0.24	-0.00038	-0.98
1988	-0.00706	-0.73	-0.00014	-0.65	0.0003	0.02	-0.00018	-0.48
1989	-0.0066	-0.68	-0.00012	-0.56	0.00735	0.46	-0.00026	-0.67
1990	-0.01442	-1.48	0.00002	0.09	0.00978	0.61	-0.0004	-1.04
1991	-0.01785	-1.83	0.00012	0.58	-0.00416	-0.26	-0.00002	-0.05
1992	-0.00688	-0.71	-0.0001	-0.47	-0.02045	-1.28	0.00038	0.98
1993	0.00072	0.07	-0.00025	-1.18	0.00733	0.46	-0.00044	-1.15
1994	0.00255	0.26	-0.00029	-1.38				
1995	-0.00058	-0.06	-0.0002	-0.96				
1996	0.00287	0.29	-0.00033	-1.57				
1997	-0.01646	-1.69	0.00013	0.62				

Table 2.1: regression coefficients of interaction terms: family income and househead income

Nonhousing Consumption					Housing Consumption				
year	$D_{yr} * age$	t-stat	$D_{yr} * age^2$	t-stat	year	D_{yr}	t-stat	$D_{yr} * age^2$	t-stat
1981	0.00024	0.20	-0.00003	-1.25	1969	0.00144	0.14	-0.00006	-0.24
1982	-0.00168	-1.36	-0.00001	-0.36	1970	-0.01229	-1.18	0.00023	0.99
1983	-0.00024	-0.19	0	0.02	1971	-0.01322	-1.27	0.00028	1.25
1984	0.0019	1.54	-0.00003	-1.06	1972	-0.02137	-2.06	0.00045	1.99
1985	0.00068	0.55	-0.00002	-0.61	1973	-0.0195	-1.88	0.00046	2.03
1986	0.00034	0.27	-0.00002	-0.76	1974	-0.02109	-2.03	0.0004	1.77
1987	0.00173	1.40	-0.00004	-1.63	1975	-0.01919	-1.85	0.00032	1.41
1988	0.00056	0.45	-0.00004	-1.63	1976	-0.02513	-2.42	0.00045	1.99
1989	0.00697	5.64	-0.00019	-6.94	1977	-0.02724	-2.63	0.00049	2.16
1990	0.00351	2.84	-0.00008	-2.90	1978	-0.01877	-1.81	0.00029	1.27
1991	0.00177	1.43	-0.00008	-2.85	1979	-0.01988	-1.92	0.00038	1.66
1992	0.00367	2.98	-0.00013	-4.80	1980	-0.01707	-1.65	0.00027	1.18
1993	0.0047	3.80	-0.0001	-3.83	1981	-0.01949	-1.88	0.00032	1.38
1994	-0.00218	-1.77	0.00003	1.20	1982	-0.02585	-2.49	0.0004	1.76
1995	0.00109	0.88	-0.00004	-1.50	1983	-0.03044	-2.93	0.00051	2.22
1996	0.00625	5.06	-0.00016	-5.90	1984	-0.03072	-2.96	0.00051	2.23
1997	0.00283	2.29	-0.0001	-3.57	1985	-0.01429	-1.38	0.00013	0.59
1998	0.00316	2.56	-0.0001	-3.75	1986	-0.00802	-0.77	-0.00001	-0.03
1999	0.00501	4.06	-0.00015	-5.47	1987	-0.01313	-1.27	0.00011	0.47
2000	0.00634	5.14	-0.00017	-6.38	1988	0.00112	0.11	-0.00024	-1.07
2001	0.008	6.48	-0.00022	-7.96	1989	0.0041	0.39	-0.00023	-0.99
2002	0.00394	3.19	-0.00012	-4.56	1990	-0.01364	-1.31	0.00014	0.60
					1991	-0.02574	-2.48	0.00038	1.66
					1992	-0.01905	-1.84	0.00024	1.05
					1993	-0.03036	-2.93	0.00051	2.25
					1994	-0.01611	-1.55	0.00016	0.70
					1995	-0.01922	-1.85	0.00018	0.80
					1996	-0.01805	-1.74	0.00018	0.79
					1997	-0.04317	-4.16	0.00068	2.97

Table 2.2: regression coefficients of interaction terms: nonhousing consumption and housing consumption

Chapter 3

Uninsurable Income Risks and Lifetime Consumption Inequality – A Puzzle

Using data form Consumer Expenditure Survey (CEX 1980-2004) and Panel Study of Income Dynamics (PSID 1981-1997), I document the following features concerning within cohort housing consumption inequality over lifetime: (i), housing consumption inequality is higher than nonhousing consumption inequality when the cohort is young: (ii), housing consumption inequality exhibits an almost flat lifetime profile. These findings cast doubt on the argument that households receive persistent uninsurable income shocks over lifetime, but are consistent with the view that the majority of income uncertainty is resolved before households enter the labor market. On the other hand, rising nonhousing consumption inequality is at odds with the latter view, but consistent with the former. On the theoretical side, I examine the lifetime profile of housing consumption inequality using a usual Bewley-type model featuring housing transaction costs. This standard incomplete market model is not able to generate the empirical features, hence a puzzle.

3.1 Introduction

Idiosyncratic income risks have been at the heart of economics research premised on market incompleteness. Consumption data are useful for inferring the size and persistence of income shocks, because from income data alone econometricians are unable to distinguish random shocks from predictable variations. It is a well-documented fact that given a cohort of households, the within cohort nonhousing consumption inequality rises significantly with age. This has been viewed as evidence for the persistent uninsurable income shocks households receive over their working lives[1]. As Robert E. Lucas (2003) states: "The fanning out over time of the earnings and consumption distributions within a cohort [that Angus Deaton and Christina Paxson (1994) document] is striking evidence of a sizable, uninsurable random walk component in earnings."

This paper takes housing consumption of homeowners into consideration. If persistent idiosyncratic income shocks are indeed the driving force behind the rising nonhousing consumption inequality, one would expect to see also a rising housing consumption inequality over lifetime. From CEX 1980-2004 and PSID 1981-1997, however, the profile of homeowners' housing consumption inequality is almost flat, casting doubt on the "persistent idiosyncratic shocks" argument. On the other hand, one might regard the initially highly, but non-rising housing consumption inequality as evidence that sub-

[1]see Deaton and Paxson (1994), Storesletten et al. (2004)

stantial part of lifetime income inequality is known when the cohort enters the labor market[2]. However this reasoning makes rising nonhousing inequality difficult to understand. Thus we are faced with a puzzle when attempting to understand the underlying income process from the lifetime profiles of both housing and nonhousing consumption consumption inequality.

The level of inequality also bears on income risks over lifetime. It is known that nonhousing consumption inequality is less than income inequality at every age, which has been argued to be the result of some insurance arrangement such as social security system. I show that from the data housing consumption inequality is significantly greater than nonhousing consumption inequality when the cohort is at young age. This again is consistent with the assumption that much of the lifetime income dispersion is known at early stage of cohort's life. These findings makes it necessary to reassess the effectiveness of existing insurance against income risks. Previous studies have used the gap between income inequality and nonhousing consumption inequality only to infer the effectiveness of insurance arrangements.

One might resort to housing transaction costs for an explanation. The substantial housing transaction costs lead the households to adjust housing infrequently. In the limit, households do not move once they become homeowners, then their housing consumption inequality should exhibit a flat profile. Apparently many homeowners move at least a few times in their lives. The

[2]Keane and Wolpin (1997) concludes 90% of lifetime earning uncertainty is resolved before individuals enter the labor market

question is whether such infrequent move leads to the near flat housing consumption inequality in the presence of persistent idiosyncratic income shocks. To answer this question, I solve a lifetime utility maximization model in which housing is a durable consumption good. From the model, the higher is the adjustment cost, the less sharp is the rising of housing consumption inequality. Nevertheless, even in the presence of very high adjustment costs, lifetime housing consumption inequality still exhibits a rising profile, rather than a flat one.

Another question the model tries to answer is whether ex ante heterogeneity in lifetime income level can explain the relative large housing consumption inequality at young age. To answer that, I reduce the variance of income shocks and introduce heterogeneity in income level which is known ex ante. As a result, consumption inequality becomes higher at young age, but rise less sharply. However, The model fails to produce a greater housing consumption inequality at young age. Therefore, the level of consumption inequality is as puzzling as the age-profile of consumption inequality.

Arguably one can make quite reliable inference concerning income risks based on observations of housing decisions. A household makes a thorough evaluation of its income risks when making housing decisions, because homeownership involves huge amount of downpayment, and sizable periodical mortgage payments. According to the 2001 Survey of Consumer Finance, about 55% of a homeowner's total asset rests in owned house. Appendix C1 is taken from the website of Survey of Consumer Finance, it shows that about 80% of the household level borrowing is for the purpose of purchasing and improving residential property. In other words, housing consumption is of crucial importance when it come to such issues as risk sharing, consumption smoothing, self-insurance and borrowing constraints. It is intriguing that the combination of housing and nonhousing consumption inequalities paints a puzzling picture regarding the important question: "To what extent households are exposed to persistent idiosyncratic income shocks."

To resolve the puzzle it is necessary to introduce some heterogeneity to the households. For example the heterogeneity in the degree of income uncertainty. Toward the end, the paper provides some intuition why this has the potential to generate both the rising nonhousing consumption inequality and flat housing consumption inequality.

3.2 Housing Consumption Inequality in the Data

This paper uses two data sets to study the lifetime profile of housing consumption inequality: Consumer Expenditure Survey (CEX) 1980-2004 and Panel Study of Income Dynamics (PSID) 1981-1997. CEX 1980-2004 is taken from Fabrizio Perri's website http://www.fperri.net/research_data.htm. This is the same data as used in Krueger and Perri (2006). PSID 1981-1997 is obtained from the data center of PSID website http://simba.isr.umich.edu. Details about data description and sample selection is provided in Appendix A1.

For CEX 1980-2004, I follow Deaton and Paxson (1994) and construct synthetic panel from repeated cross sections. Only homeowners are considered and housing consumption is measured by the reported house value. I use variance of logarithm of consumption to measure inequality, as is usually done in the literature. For each combination of age and year, one measurement of housing consumption inequality is available which is the result of age effect, year effect and cohort effect. Following Deaton and Paxson (1994), I use dummy regression to recover age effect. It is impossible to control for both year effect and cohort effect due to the perfect multicollinearity among the three. Heathcote et al. (2005) show that cohort effect is less significant than year effect, and suggest the control of year effect. Chapter 2 of this dissertation demonstrates the age-dependency of year effect from PSID and proposes the inclusion of age-year interaction in the regression. Following that methodology, in this paper I isolate the age effect by controlling for year effect and include the age-year interaction in the dummy regression[3].

Figure 3.1 displays the lifetime profiles of housing and nonhousing consumption inequality based on CEX 1980-2004.

It is evident from figure 3.1 that nonhousing consumption inequality rises with age, but housing consumption inequality does not. Housing consumption inequality appears to be much higher, partly because housing con-

[3]Housing consumption inequality exhibits a rising profile if the dummy regression controls for cohort effect only as in Deaton and Paxson (1994). Heathcote et al. (2005) has shown this approach overstates the rising trend. On the other hand, housing consumption inequality decreases with age if I follow Heathcote et al. (2005) and control for year effect only.

sumption has a larger mean value than nonhousing consumption[4]. For comparison purpose, it is better to consider the coefficient of variation. For each year of data in CEX, for households in the specific age group, I take the coefficient of variation of the logarithm of income/consumption. Then I average over the survey years. The mean and standard deviation of these coefficient of variation are presented in table 3.1. From the table, housing consumption inequality is greater than that of nonhousing consumption before middle age, but lower than income inequality. The initially high housing consumption inequality makes it necessary to reassess the effectiveness of insurance against income shocks. Previous researches observe that income inequality is significantly greater than then nonhousing consumption inequality, and concludes this is because part of the income shocks are insured away through various insurance arrangements. While the aforementioned empirical findings does not dispute this conclusion, it does imply the insurance arrangements are not as effective as we thought.

Given the well-known fact that homeownership rate in the US increases with age, using the synthetic panel to obtain housing consumption inequality has a potential sampling problem. For example, the cohort of homeowners aged 32 in 1982 wave of CEX may not represent the same population as the cohort aged 21 in 1981 wave of CEX, because new homeowners entered the cohort. I call this a reverse sample attribution problem. To overcome the reverse sample attrition problem, I turn to PSID 1981-1997. Following Storesletten et

[4]Recall that housing consumption is measured by the reported value of owned house

Table 3.1: Coefficient of variation of income/consumption inequality by age from CEX 1980-2003. In parentheses are standard errors.

	Coefficient of Variation		
age	nonhousing	housing	income
25-35	0.059	0.067	0.075
	(0.004)	(0.010)	(0.011)
35-45	0.063	0.066	0.085
	(0.005)	(0.010)	(0.012)
45-55	0.071	0.065	0.100
	(0.007)	(0.011)	(0.026)
55-65	0.069	0.066	0.116
	(0.006)	(0.011)	(0.022)
65-75	0.071	0.064	0.167
	(0.006)	(0.011)	(0.029)

al. (2004), I trace a cohort for 5 consecutive years. For each year, housing consumption inequality is again measured by the variance of logarithm of reported house value. Now each observation of variance of logarithm is associated with an age and a survey year. These observations are then pooled together to form the basis of dummy regression as proposed in chapter 2. The stars in figure 3.2 show the results. Clearly, the flat housing consumption inequality profile is also obtained. However if I use PSID 1968-1980, housing consumption inequality increases slightly, which is shown by the squares in figure 3.2. Therefore, after 1980s, based on both PSID and CEX, housing consumption inequality has an almost flat age-profile. But before 1980s, based on PSID[5], housing consumption inequality rises with age. This suggests some structural

[5]No annual CEX data available before 1980s

changes in the labor market and/or housing market between the two sample periods.

To further address the reverse sampling attrition problem, I compare the cross sectional housing consumption inequality between new and old homeowners of similar ages. Using PSID 1981-1997, for each wave of survey, I define old homeowners as those who have been owners for at least 5 years, and new owners as those who became owner after the preceding wave. If the new owners have less dispersed housing consumption, then the flat age-profile of housing consumption inequality should at least partly caused by the reverse sample attrition problem. Table 3.2 shows the opposite. Housing consumption inequality is greater among new owners for various age groups. One possible reason is housing transaction costs which cause inaction regions of housing adjustment – Households do not adjust housing stocks unless they are knocked out of the inaction regions in the state space. For the fraction of old homeowners within the inaction region, inequality in realized income is not translated into housing consumption inequality. Therefore the overall housing consumption inequality is greater among new homeowners (first-time buyers) who are not in any inaction regions.

The aforementioned reasoning illustrates the importance of housing transaction costs which causes inaction regions and lumpy housing adjustments. The inaction regions stop income inequality from being translated into housing consumption inequality. The lumpiness in housing adjustment may make housing consumption inequality overreact to income inequality at certain

Table 3.2: Within cohort housing consumption inequality for new and old homeowners in PSID 1981-1997. In parentheses are standard errors.

	variance of logarithms of house value	
age	new owners	old owners
30-35	1.02	0.90
	(0.55)	(0.21)
35-40	1.16	0.89
	(0.75)	(0.19)
40-45	1.19	0.88
	(0.86)	(0.19)
45-50	1.17	0.89
	(0.86)	(0.18)
50-55	1.12	0.90
	(0.82)	(0.20)
55-60	1.12	0.90
	(0.81)	(0.20)
60-65	1.11	0.90
	(0.81)	(0.20)

states. The lumpiness is also likely to cause the great housing consumption inequality at the cohort's young age. One of the purposes of the next section is to examine the role of transaction costs in the Bewley-type model.

The dummy regression method, although widely used to recover age effect, potentially has the problem of misspecification. To ensure this does not give rise to bias that leads to the observed flat age-profile of housing consumption inequality, I adopt a more primitive method. For data in each year of survey, I take variance of logarithm for households at different ages to obtain the age profile, then take the mean of the age profiles from different survey years. This simple method does not attempt to isolate year effect and cohort effects, but assume these effects are averaged out when I take the mean of age profiles. The results are shown in figure 3.3. The upper-left panel shows results for the subsample in which house heads have no college education. The upper-right panel are from the subsample in which heads have at least some college education. The lower-left panel are from the full sample in CEX. In each panel, the rising nonhousing consumption inequality and flat housing consumption inequality is quite clear. The lower right panel is the result from PSID 1981-1997. It shows that housing consumption inequality is not rising, but fall slightly before age 40.

3.3 Housing Consumption Inequality in a Bewley-type Model

In this section I solve a model in which a household receives stochastic income and maximizes the lifetime utility by choosing the appropriate amount of housing and nonhousing consumption. Self-insurance is allowed: households can smooth their consumption by trading riskfree bonds and housing. The purpose of this exercise is to (i), examine the age-profiles of housing and nonhousing consumption inequality in a Bewley-type model. (ii), understand how housing transaction costs affect these profiles. (iii), understand how the ex ante heterogeneity in income level (known to the households, commonly referred to as the 'fixed effect') shapes the level and age-profile of income inequality.

3.3.1 the Income process

The same as in chapter I.

3.3.2 the Preference

The same as in chapter I.

3.3.3 Household's Lifetime Optimization Problem

The same as in chapter I.

3.4 Model Results

In the simplest version of the model, housing transaction is costless and borrowing constraints do not exist. In this case it can be shown that housing-nonhousing consumption ratio depends on interest rates and preference parameters. In other words, if interest rate does not vary, then the model should generate the same age-profiles for both housing and nonhousing consumption inequality. Appendix A2 proves this property under more general assumptions.

Calibration of the model is similar to that in chapter 1, with parameter values shown in table 3.3 I solve the model computationally and show the results graphically. In the current version of the model, I assume extremely high rental price of house. As a result, all the households are homeowners. Housing consumption is measured by the value of owned house, as is done in the empirical part of the paper.

Table 3.3: Parameter Values

Parameter	Symbol	value
Discount factor	β	0.96
Coefficient of relative risk aversion	γ	4
Housing share in utility	θ	0.2
Bequest strength	L	4
Income replacement ratio	π	0.6
Riskfree bond rate	r	0.02
Mortgage rate	r_m	0.02
Downpayment requirement	d	0.2
Closing cost	ϕ	0.02
Selling cost	λ	0.06
Maintenance cost	δ	0.03

First, I assume away the 'fixed effect': all the households have the same predictable income. The results are presented in figure 3.4 and figure 3.5. From these figures, both housing consumption inequality and nonhousing consumption inequality rise with age in the model. This is not surprising, since persistent random income shocks are fed into the model, which causes the fanning out of income of households within the cohort. This is translated into housing consumption inequality because the difference in income is not predictable. Another noteworthy feature is that inequality of the two types of consumption are about the same when housing adjustment cost is absent. These results are clearly at odds with empirical observations.

The question is whether transaction costs of housing help explain this disparity. I present the housing consumption inequality profiles under different transaction costs in figure 3.4, where 'high transaction costs' means $\phi = 0.05$ and $\lambda = 0.1$, while 'moderate transaction costs' takes parameter value from table 3.3 ($\phi = 0.02$ and $\lambda = 0.6$) The figures show that transaction cost reduces housing consumption inequality considerably: the profile becomes less steep as the transaction costs increases. Nevertheless, even with extremely high housing transaction costs, housing consumption inequality still exhibit a rising age-profile. Therefore transaction costs can at most explain part of the puzzle.

An examination of nonhousing consumption inequality under difference level of transaction costs (figure 3.5) reveals equally interesting patterns. With high transaction costs, nonhousing consumption inequality is greater and the age-profile is steeper. In other words, with higher housing transaction costs, more of the dispersion in income is reflected in dispersion in nonhousing consumption, and less is reflected in housing consumption inequality. This again warns us about the potential bias if we use the gap between income inequality and nonhousing consumption inequality to assess the size of income shocks and the effectiveness of insurance arrangement.

Next, I incorporate the 'fixed effect' into the model by assuming a non-degenerated distribution for income levels. For the deterministic component of income, I assume households are heterogeneous in their initial levels, but have the same income growth rate. A normal distribution is assumed for the logarithm of initial income level, with mean μ_{y_0} and variance $\sigma^2_{y_0}$. In simulation, I set $\mu_{y_0} = 0$ and $\sigma^2_{y_0} = 0.25$, and truncate the tails that are 3 standard deviations from the mean. The results are shown in figure 3.6 and figure 3.7. It is evident that the puzzles persist. The introduction of fixed effect raises the initial consumption inequality. But it does not generate housing consumption inequality that is higher than nonhousing consumption inequality, nor the flat age-profile. It is interesting to note that even though the initial income is assumed to be very dispersed, the initial consumption inequality is not raised significantly. The reason is that household have precautionary motives and much of the fixed effect is reflected in the difference in the stocks of saving, rather than in consumption.

3.5 Potential Resolution of the Puzzle

It is evident by now that a Bewley-type model predicts the rise of housing consumption inequality over lifetime, contrary to what is seen in the data. On the other hand, suppose that income shocks are not persistent, and the within cohort income dispersion is caused by factor known to households, then housing consumption inequality should be flat. But then nonhousing consumption inequality should also be flat, contrary to what is in the data again.

Heterogeneity in dimensions other than income level and realization of income shocks seem necessary to resolve the puzzle. One potential is the heterogeneity in the degree of income uncertainty facing households. Chapter 1 of the dissertation shows that income uncertainty has a negative effect on the demand for owner-occupied housing. Further the negative effect diminishes with age. As a results, housing consumption inequality between households with difference income uncertainty should decrease with age. This decreasing tendency may counteract the increasing tendency resulting from different realization of income shocks, leading to a flat profile of housing consumption inequality.

Chapter 1 of the dissertation provides numerical results regarding the effects of income risks on housing decisions. In a two-period model, one can prove the negative correlation between income uncertainty and housing-nonhousing consumption ratio. This is given in the following proposition which is proved in Appendix C3.

Proposition: *Given the constant elasticity of substitution preference over C and H, if housing adjustment cost is proportional to selling price, then housing-nonhousing consumption ratio increases with the uncertainty associated with future income in a two period model.*

3.6 Concluding Remarks for Chapter III

From the data, lifetime profile of within-cohort housing consumption is flat, while nonhousing consumption inequality rises significantly with age. Before age 45, housing consumption inequality is larger than nonhousing consumption inequality. A income process with persistent idiosyncratic shocks should cause housing consumption inequality to rise with age. While the assumption that much of the income uncertainty is known when households enter the labor market is consistent the flat profile, it is at odds with the rising nonhousing consumption inequality. Therefore a puzzle arise when one attempts to infer the structure of income risks from consumption. Within the framework of a Bewley-type model, the puzzle persists even if housing transaction costs and heterogeneity in income levels are included. Heterogeneity in income growth rate and in degree of income uncertainty are promising candidates in resolving the puzzle.

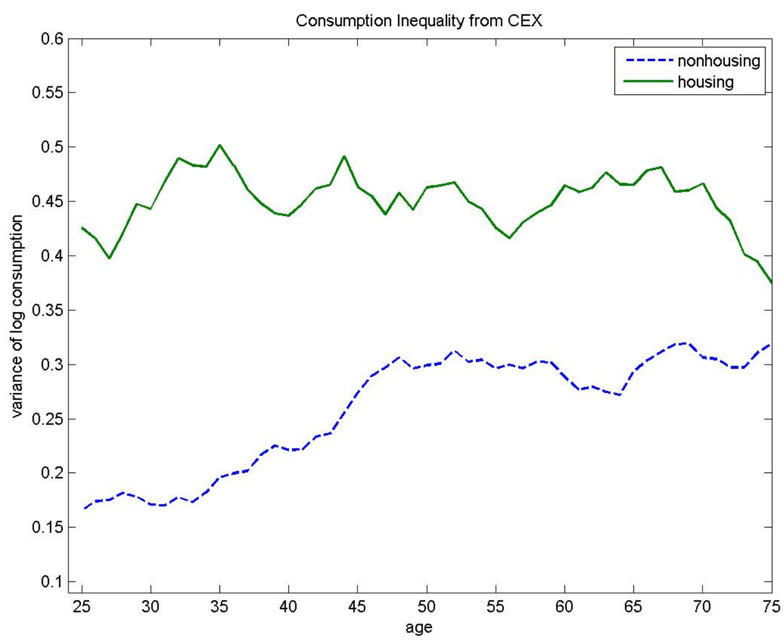

Figure 3.1: Housing Consumption Inequality and nonhousing consumption inequality from CEX 1980-2003. Inequality is measured by the variance of logarithm of consumption. Data points in the figure are results of dummy regression, rescaled to match the overall average value.

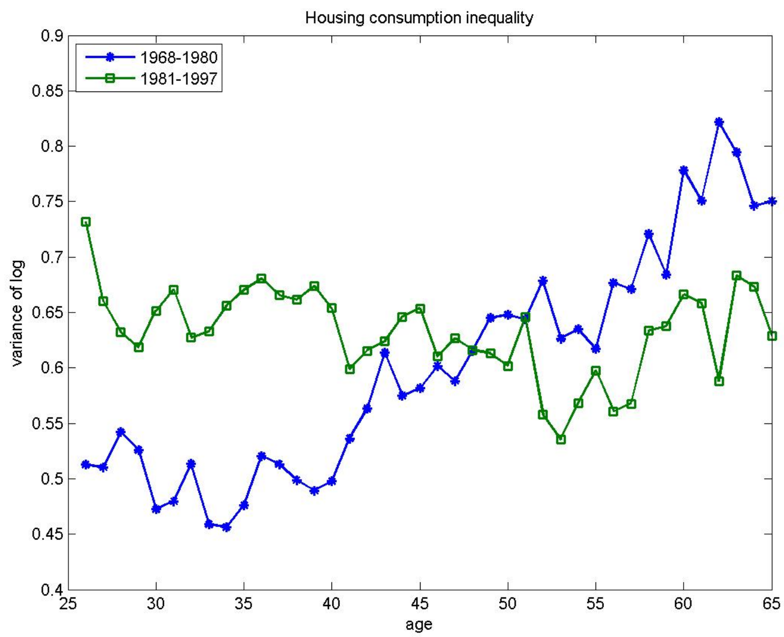

Figure 3.2: Housing consumption Inequality and income inequality from PSID 1981-1997. Inequality is measured by variance of logarithm of reported house values. Data points in the figure are results of dummy regression, rescaled to match the overall average value.

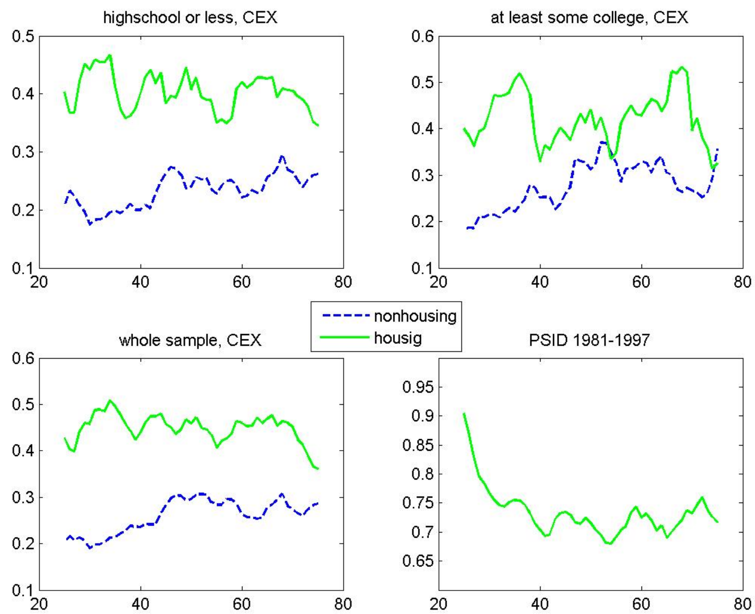

Figure 3.3: Income/consumption inequality from CEX 1980-2003 and PSID 1981-1997. The upper panels are from subsamples by educational attainment. No dummy regression is used. For any particular age and survey year, inequality is measured by variance of logarithm. Averaging over the survey years produces the plotted data points.

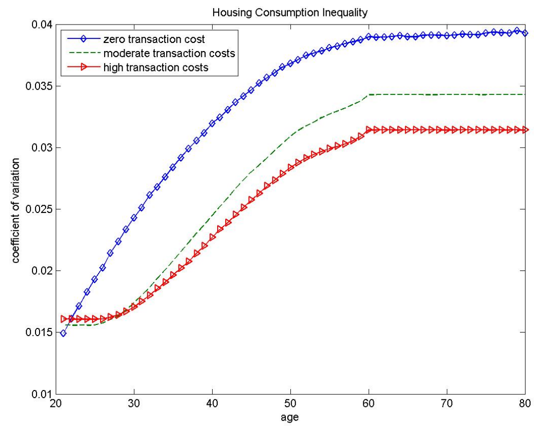

Figure 3.4: Model results: "Moderate transaction costs" means 2% of house value for buying and 6% for selling. "High transaction costs" means 5% of house value for buying and 10% for selling. Transaction costs reduce the upward trend of housing consumption Inequality profile. But the rising profile persists even in the presence of high transaction costs.

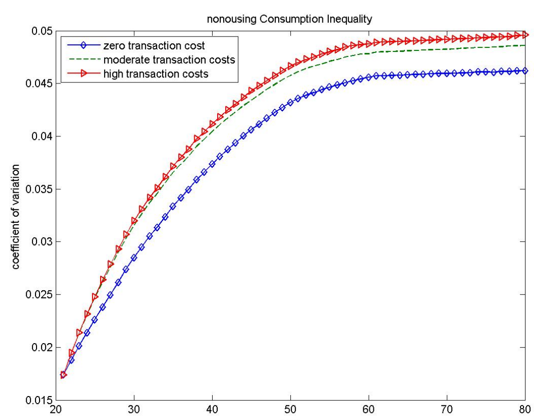

Figure 3.5: Model results: "Moderate transaction costs" means 2% of house value for buying and 6% for selling. "High transaction costs" means 5% of house value for buying and 10% for selling. Compared with the case of zero transaction costs, nonhousing consumption inequality rises more sharply when housing transactions are costly.

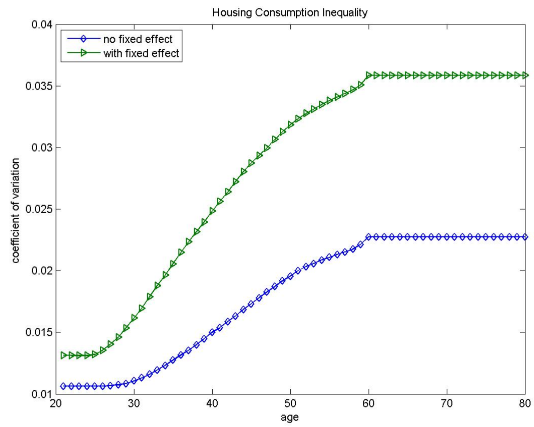

Figure 3.6: Model results: With fixed effects (heterogeneity in income levels), housing consumption inequality is of larger scale, but still displays rising age-profile.

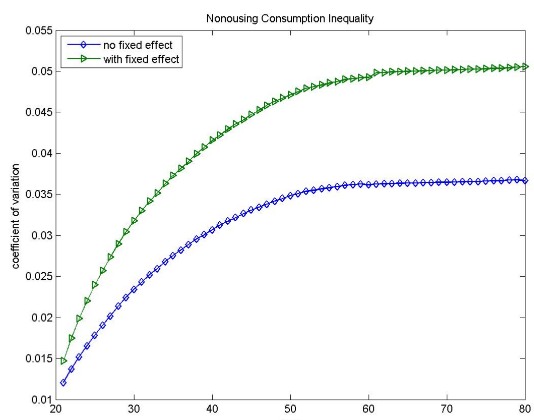

Figure 3.7: Model results: With fixed effects (heterogeneity in income levels), nonhousing consumption inequality is of larger scale.

Appendices

Appendix A

A.1 Data Appendix

Income and consumption data used in the paper are from the Panel Study of Income Dynamics (PSID). Since Survey of Economic Opportunity subsample includes low-income families only, it does not represent the general population, and is excluded in this study.

From the family files of PSID surveys 1984-1997, I take the total family income (variable V11022, V12371, V13623,V14670, V16144, V17533,V18875, V20175, V21481, V23322 ER12079) of 1066 households. Total family income is defined as the sum of total taxable income and transfers of all family members. Information on a household's total wealth, house value, home equity value, whether owning stock and whether owning business are obtained from Wealth Supplement Files for year 1984 and year 1994. PSID interviewers started to ask about interest rates on mortgage loans since 1996. This study uses the mortgage rate on the first loan (asked in survey year 1996) in the empirical analysis. A household is included in the sample if all of the following selection criteria are satisfied: (1) The househead should age between 20-60 in 1984 and live in urban area and (2) It should have non-zero income in each year from 1984-1997. (3) It should report valid information on househead's marital status, number of children, occupation and industry of employment, and region of residence from 1984-1993 (not available for the other years). (4) It should have valid code for location of residence in 1985-1993 (not available for the other years). (5) In 1984 survey, it should have valid information on age, sex, race, years of schooling of househead, and years of schooling of the spouse if present. (6) If it is an homeowner, it should report valid information on mortgage rate in 1996.

Consumer Expenditure Survey data are available from NBER website[1]. In the family files, total expenditure is defined as the sum of expenditures on food, tobacco, alcohol, nightclub; nonfood, clothing, personal care, household operations, business service, life insurance, transportation, recreation, education, charity, medical expenditure and housing service. My measure of non-housing consumption is the total expenditure minus housing service which is the actual or imputed rent paid by the household. I exclude in the sample the households that (1) are not homeowners, (2) reported head age that is less than 20, (3) reported zero nonhousing consumption, (4) lived rural area, (5) do not report valid information on age, sex, race, years of schooling, and head's occupation and industry of employment.

Definitions of occupations and industries are slightly different in PSID and CEX. To reconcile the two samples, I define six categories of occupation and nine categories of industry. The table below lists the corresponding PSID and CEX codes.

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[1] http://www.nber.org/data/ces_cbo.html.

Occupation Category	PSID 3-digit (H-E) code	CEX occupation code
Not working or retired	0	09, 10
Professional, and managerial workers	1-195, 201-245	01
Technical and administrative workers	260-285, 301-395,401-600	02, 05
Operator,fabricator and laborers	601-695-701-715,740-785	06
Farmer, farm manager and worker	801-802, 821-824	04
Service workers	901-965, 980-984	03
Industry Category	PSID 3-digit (H-E) code	CEX industry code
Agriculture, forestry, fisheries and mining	17-28, 47-57	01
Construction	67-77	02
Manufacturing	107-398	03
Public Utilities	407-479	04
Whole and retail trade	507-698	05
Finance, insurance and real estate	707-718	06
Business, personal and recreational services	727-759, 769-798, 807-809	08
Professional services	828-897	07
Public administration	907-937	09

A.2 Proof of the Theorem

A household solves the following problem

$$\max_{C_t,H_t,A_t} \mathrm{u}(\mathrm{C}_t, H_t) + \beta E_t[V(W_{t+1})]$$

$$\text{s.t.}$$

$$C_t = (1+\mu_p)\tilde{R}_{p,t}A_{t-1} - A_t + Q_t H_{t-1} - Q_t(1+\psi)H_t$$

$$W_{t+1} = (1+\mu_p)\tilde{R}_{p,t+1}A_t + Q_{t+1}H_t$$

where A_t is the value of a portfolio of nonhousing financial assets and the stochastic labor income (human capital). $1+\mu_p$ is its mean return and $\tilde{R}_{p,t}$ is the stochastic component of the portfolio return. W_{t+1} is the total wealth in the beginning of period t+1. As in the main text, Q_t is the house price and H_t is the housing stock. The expectation E_t integrates the value function, $V(W_{t+1})$, over the probability space Ω.

In a frictionless world the value function is differentiable and it is easy to derive the following first order conditions.

$$(1+\psi)Q_t\frac{\partial u(C_t,H_t)}{\partial C_t}=\frac{\partial u(C_t,H_t)}{\partial H_t}+\beta E_t[Q_{t+1}\frac{dV(W_{t+1})}{dW_{t+1}}] \tag{A.2.1}$$

$$\frac{\partial u(C_t,H_t)}{\partial C_t}=(1+\mu_p)\beta E_t[\tilde{R}_{p,t+1}\frac{dV(W_{t+1})}{dW_{t+1}}] \tag{A.2.2}$$

Divide both sides of (A.2.1) by Q_t and recall $\frac{Q_{t+1}}{Q_t}=(1+\mu_h)R_{h,t}$, then

$$(1+\psi)\frac{\partial u(C_t,H_t)}{\partial C_t}=\frac{1}{Q_t}\frac{\partial u(C_t,H_t)}{\partial H_t}+\beta(1+\mu_h)E_t[R_{h,t}\frac{dV(W_{t+1})}{dW_{t+1}}] \tag{A.2.3}$$

By assumption (2), $R_{h,t}$ can be replicated, say by A_t for ease of exposition. In other words, $\tilde{R}_{p,t}(\omega)=R_{h,t}(\omega)$, $\forall\omega\in\Omega$. Therefore (A.2.3) can be rewritten as

$$(1+\psi)\frac{\partial u(C_t,H_t)}{\partial C_t}=\frac{1}{Q_t}\frac{\partial u(C_t,H_t)}{\partial H_t}+\beta(1+\mu_h)E_t[\tilde{R}_{h,t}\frac{dV(W_{t+1})}{dW_{t+1}}] \tag{A.2.4}$$

Combining (A.2.2) and (A.2.4) and rearranging terms yields

$$(1-\psi-\frac{1+\mu_h}{1+\mu_p})\frac{\partial u(C_t,H_t)}{\partial C_t}=\frac{1}{Q_t}\frac{\partial u(C_t,H_t)}{\partial H_t} \tag{A.2.5}$$

By assumption (3), let $u(C_t,H_t)=[(1-\theta)C_t^{\alpha}+\theta H_t^{\alpha}]^{\alpha_1}$, then from (A.2.5),

$$\frac{H_t}{C_t}=\left\{1/[Q_t(1-\psi-\frac{1+\mu_h}{1+\mu_p})\frac{1-\theta}{\theta}]\right\}^{1/(1-\alpha)} \tag{A.2.6}$$

Note that the expectation operator does not appear in the (A.2.6). The housing-nonhousing consumption is independent of degree of income uncertainty.

For investment purpose, housing is an redundant asset under assumption (1) and (2). But households own houses due to the consumption demand. In the case of fixed house price, the "stochastic" component of house price is replicated by riskfree bond. Hence the housing-nonhousing consumption ratio is also independent of income uncertainty.

A.3 Model Computation

First, I show that the model can simplified by rescaling. Let $P_t = e^{p_t}$ and $Y_t = e^{y_t}$, from equation (3), (4) and (5), one can get

$$\frac{P_t}{P_{t-1}} = e^{G_t \eta_t} \tag{A.3.1}$$

$$\frac{Y_t}{P_t} = e^{\epsilon_t} \tag{A.3.2}$$

$$\frac{Q_t}{Q_{t-1}} = (1 + \mu_h) R_{h,t} \tag{A.3.3}$$

Consider the value of an owner in the last period of life who decides to adjust the housing stock.

$$w_t(y_T, A_{T-1}, Q_T, H_{T-1}) = max_{A_T, H_T} u(C_T, H_T) + \beta E_T V_T(W_{T+1}] \tag{A.3.4}$$

s.t.

$$Y_T = \pi P_T$$

$$C_T = (1+r)A_{T-1} + (1-\lambda)H_{T-1}Q_T - A_T - (1+\phi)H_T Q_T$$
$$W_{T+1} = (1+r)A_T + (1-\lambda)H_T Q_{T+1}$$

Define $a_T = \frac{A_T}{p_T}$, $h_T = \frac{H_T Q_T}{p_T}$ and $c_T = \frac{C_T}{p_T}$. Dividing both sides of (A.3.4) by $(P_T/Q_T^{\theta})^{1-\gamma}$ yields

$$\frac{w_t(y_T, A_{T-1}, Q_T, H_{T-1})}{(P_T/Q_T^{\theta})^{1-\gamma}} = max_{a_T,h_T} u(c_T, h_T) + \beta E_T[v_T(w_{T+1})] \tag{A.3.5}$$

where

$$v_T(w_{T+1}) = \frac{V_T(W_{T+1})}{(P_T/Q_T^{\theta})^{1-\gamma}} = L^{\gamma} \frac{[w_{T+1}(\theta/\omega)^{\theta}(1-\theta)^{1-\theta}]^{1-\gamma}}{1-\gamma}$$

and

$$w_{T+1} = (1+r)a_T + (1-\lambda)h_t(1+\mu_h)R_{h,T+1}$$

Dividing both sides of the budget constraints by P_T yields

$$x_T = \pi$$
$$c_T = (1+r)a_{T-1}\frac{p_{T-1}}{p_T} + (1-\lambda)h_{T-1}\frac{Q_T p_{T-1}}{Q_{T-1}p_T} - a_T - (1+\phi)h_T$$
$$w_{T+1} = (1+r)a_T + (1-\lambda)h_t(1+\mu_h)R_{h,T+1}$$

where $x_T = Y_T/P_T$. Note that the new budget constraints can be further simplified by substituting (A.3.1) and (A.3.3) in.

Therefore the last period problem is rewritten as equation (A.3.5) and the new budget constraints. It turns out that the value function in each period can be normalized by $(P_t/Q_t^{\theta})^{1-\gamma}$; and the budget constraint in each period can be normalized by P_t. Thus the whole optimization problem can be normalized, and P_t, Q_t are dropped out of the state space. This greatly reduces the computational load of the problem.

The Cobb-Douglas preference is needed for such a simplification, since the equality

$$\frac{u(C_t,H_t)}{(P_t/Q_t^\theta)^{1-\gamma}} = u(c_t,h_t)$$

does not hold for more general constant elasticity of substitution preference. Also, the random walk specification of y_t and Q_t leads to (A.3.1) and (A.3.3), which is also necessary for the simplification.

I approximate both riskfree bond and housing asset by 150 equally-spaced grid points. Realization of income and house price shocks are approximated by two states using Gaussian quadrature (Tauchen and Hussey (1991)). In the model with costly refinancing, it is necessary to keep track of years to maturity of the mortgage loan. If house prices are fixed, mortgage balance can be calculated from years to maturity. In case of risky house prices, I use two states to approximate the ratio of current house price to the purchase price to infer mortgage balance. In case of 15-year mortgage, the state variables of the model are represented by a high-dimensional grid of $150 \times 150 \times 15 \times 2 \times 2 \times 2$. Given the high-dimensionality of the problem, it is hardly feasible to solve it on a personal computer. The numerical solutions in the paper are obtained by running Fortran-MPI programs on a cluster.

For each type of households, in each state, policy functions for bond holding, housing stock, nonhousing consumption are solved by grid search. For homeowners, there is an additional policy function that states whether they should refinance. To obtain the lifecycle profile of housing stock, home equity share, housing-nonhousing consumption ratio and homeownership rate for a particular type, I compute the measure of households on each grid point, then integrate the policy functions over these grid points. In the first period, all the households start with zero housing stock and riskfree bond, hence the measure is initially distributed based on the realizations of income shocks and house prices shocks. As the policy functions link each grid point in the first period to a grid point in the next period, it brings these measure to the next period and the periods that follows.

The computational results are more intuitive if they are on the original scale. For that purpose, I compute the weighted average level of permanent income on each grid point, and multiple the policy function with that.

Appendix B

B.1 Data Appendix

Income data used in the paper are from PSID with SEO subsample excluded. Househead's income (1968-1994) is the sum of the actual amounts of labor part of farm income and business income, bonuses, overtime, commissions, professional practice, labor part of income from roomers and boarders or business income reported by household head. Family income 1968-1997 includes the sum of taxable income of each family member, plus transfers. Housing consumption is assumed to be a fixed fraction of house value (the service flows) reported by 1968-1997 PSID survey reponsdents. With the fixed fraction, variance of logarithm of housevalue is the same as the variance of logarithm of service flow. Ages attached to family income and house values are assumed to be househead's ages.

For each variable from PSID, I exclude observation that: (1), has less than 3 years of positive values; (2), within any three years, there is value that's more than 20 times or less than 1/20 of the adjacent value(s). This is a very broad sample selection criteria. Consequently in most of the age-year cells, there are more than 100 observation.

(CEX) consumption data is from Krueger and Perri (2006), publicly available at Perri's website. Included in the nonhousing consumption measure are: nondurable good expenditure, services from vehicles, other vehicle expenses, expenditure on equipments and entertainments.

With the variance of logarithms as inequality measure, Inflation does not matter as long as I assume survey respondents in different regions are subject to the same price variations over years.

Appendix C

C.1 Purpose of Borrowing

Debt of all families, distributed by purpose of debt. Percentage

Purpose of debt	1989	1992	1995	1998	2001	2004
Primary residence Purchase	64.0	67.2	70.3	67.9	70.9	70.2
Primary residence Improvement	2.5	2.5	2.0	2.1	2.0	1.9
Other residential property	8.8	10.8	8.2	7.8	6.5	9.5
Investments excluding real estate	3.9	1.8	1.0	3.3	2.8	2.2
Vehicles	10.6	7.0	7.6	7.6	7.8	6.7
Goods and services	6.1	5.6	5.7	6.3	5.8	6.0
Education	2.4	2.8	2.7	3.5	3.1	3.0
Unclassifiable loans against pension accounts	0.1	0.1	0.2	+	+	+
Other	1.6	2.1	2.2	1.5	1.1	0.6
Total	100	100	100	100	100	100

Note: + Less than 0.05 percent.

(Source: 1989-2004 Survey of Consumer Finance)

C.2 Housing Transaction Costs in CEX data

Smith et al. (1988) estimate the transaction cost of changing houses to be approximately $8 - 10\%$. This estimate comprises transaction costs associated with search, legal costs, costs of readjusting home furnishings to a new house, and a psychic cost from disruption.

To justify the assumption that transaction cost is a fix proportion of house sold/purchased, I look into the Consumer Expenditure Survey data. The survey asks questions about the cost associated with buying/selling of houses. I collect transactions occurred in a given year, divide transactions into buying and selling, and regress reported transaction cost on house value, house value squared and a constant. The findings are: (i), the overall fit for selling regression is much better than buying regression. (ii), in selling cost regression, coefficient on house price squared is not significant, hence proportional cost is a pretty good approximation. (iii), from both the intercept term and linear term, adjustment cost of selling is much higher than buying.

C.3 Proof of the Proposition

First I prove it in the two-period setting Value of the last period

$$v_T(A,H,y) = \max\{v_T^a(A,H,y), v_T^{na}(A,H,y)\}$$
$$v_T^a(A,H,y) = \max_{H'} u(y + A + (1-\lambda)H - H' + \tfrac{1-\lambda}{1+r}H', H')$$
$$v_T^{na}(A,H,y) = u(y + A + \tfrac{1-\lambda}{1+r}H, H)$$

By the Envelope condition

$\partial v_T^a(A,H,y)/\partial A = u_c(C_a, H_a)$;

$\partial v_T^a(A,H,y)/\partial H = (1-\lambda)\ u_c(C_a, H_a)$

$\partial v_T^{na}(A,H,y)/\partial A = u_c(C_{na}, H_{na})$;

$\partial v_T^{na}(A,H,y)/\partial H = \frac{1-\lambda}{1+r} u_c(C_{na}, H_{na}) + u_h(C_{na}, H_{na})$

Here C and H are both subscripted to emphasize that consumptions are different in the two cases.

Now second to last period optimization problem is

$\max_{A',H'}\ u(C,H') + \beta E\ v_T(A',H',y')$

s.t. $\quad C = y + A - \frac{A'}{1+r} - dH$

$\quad dH = H' - (1-\cos t)H\ , \qquad if\ adjust$

$\quad dH = 0;\ H' = H, \qquad if\ not\ adjust$

Notice that the expectation is taken with respect to y'. Let Ω be the domain of y', and partition Ω into

Ω_a and Ω_{na}, When $y \in \Omega_a$, it is optimal to adjust housing. When $y \in \Omega_{na}$, it is optimal not to adjust.

Let $P_a = P(\ y \in \Omega_a)$,and $P_{na} = P(\ y \in \Omega_{na})$, we can rewrite the optimization problem as follows

$\max_{A',H'}\ u(C,H') + \beta P_a E_a\ v_T^a(A',H',y') + \beta P_{na} E_{na}\ v_T^{na}(A',H',y')$

where E_a and E_{na} are the expectation condition on y' falling in Ω_a and Ω_{na} respectively.

Now $v_T^a(A',H',y')$ and $v_T^{na}(A',H',y')$ are differentiable. The first order conditions are

$u_c(C,H) = \beta(1+r)\{\ P_a E_a \frac{\partial v_T^a}{\partial A} + P_{na} E_{na} \frac{\partial v_T^{na}}{\partial A}\ \} = \beta(1+r)\{\ P_a E_a u_c(C'_a, H'_a) + P_{na} E_{na} u_c(C'_{na}, H'_{na})\ \}$

Hence, $P_a E_a u_c(C'_a, H'_a) + P_{na} E_{na} u_c(C'_{na}, H'_{na}) = \frac{u_c(C,H)}{\beta(1+r)}$

$u_c(C,H) = u_H(C,H) + \beta\{\ P_a E_a \frac{\partial v_T^a}{\partial H} + P_{na} E_{na} \frac{\partial v_T^{na}}{\partial H}\ \}$

$= u_H(C,H) + \beta P_a E_a[\ (1-\lambda)\ u_c(C'_a, H'_a)] + \beta P_{na} E_{na}[\frac{1-\lambda}{1+r} u_c(C'_{na}, H'_{na}) + u_H(C'_{na}, H'_{na})]$

$= u_H(C,H) + \beta(1-\lambda)\{\ P_a E_a u_c(C'_a, H'_a) + P_{na} E_{na} u_c(C'_{na}, H'_{na})\ \} + \beta P_{na} E_{na}[\ u_H(C'_{na}, H'_{na}) - \frac{r(1-\lambda)}{1+r} u_c(C'_{na}, H'_{na})]$

$= u_H(C,H) + \beta(1-\lambda)\frac{u_c(C,H)}{\beta(1+r)} + \beta P_{na} E_{na}[\ u_H(C'_{na}, H'_{na}) - \frac{r(1-\lambda)}{1+r} u_c(C'_{na}, H'_{na})]$

Remember H'_{na} is next period's housing stock given that no adjustment is to be made, so $H'_{na} = H$. In addition, due to

consumption smoothing, when $H'_{na} = H$, $C'_{na} \approx C$. Therefore:

$u_c(C,H) \approx u_H(C,H) + \frac{1-\lambda}{1+r} u_c(C,H) + \beta P_{na}\{\ u_H(C,H) - \frac{r(1-\lambda)}{1+r} u_c(C,H)\}$

This implies:

$\frac{u_c(C,H)}{u_H(C,H)} \approx \frac{1+\beta P_{na}}{(\lambda+r)/(1+r) + r(1-\lambda)/(1+r)\beta P_{na}}$

Define $f(Q) = \frac{1+Q}{A+BQ}$, it is easy to show $f'(Q) > 0$ as long as $A > B$

Clearly $(\lambda + r)/(1+r) > r(1-\lambda)/(1+r)$, so $\frac{u_c(C,H)}{u_H(C,H)}$ increases with P_{na}, Given our preference, $\frac{u_c(C,H)}{u_H(C,H)} = \frac{1}{a}(\frac{H}{C})^{1-\theta}$

So $\frac{H}{C} \approx [\frac{a(1+\beta P_{na})}{(\lambda+r)/(1+r) + r(1-\lambda)/(1+r)\beta P_{na}}]^{1/(1-\theta)}$, where the right hand side increases with P_{na}.

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