ABSTRACT

Title of dissertation: MORTGAGE CONTRACTS AND THE DEFINITION OF AND DEMAND FOR HOUSING WEALTH

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Owner-occupied housing plays a central role in the portfolios of many households. Recent work has explored the connection between a household’s position in home equity and the demand for risky assets in the £nancial portfolio. This dissertation examines the role of the mortgage contract on the de£nition of and demand for housing wealth.

This £rst chapter develops a detailed partial equilibrium model of housing wealth’s role over the life-cycle to explore (1) housing’s dual role as a consumption and investment good; (2) the signi£cance of the mortgage contract being in nominal and not real terms; and (3) the tax bene£ts associated with owner-occupied housing. The household’s dynamic stochastic programming problem is solved using parallel processing. The results show that the “over-investment” in housing is not just a function of consumption demand but also can be driven by the bene£ts inherent in the mortgage contract. It also shows that the nominal mortgage contract results in the non-neutrality of perfectly expected in¤ation. Finally, the paper documents the effect of preferential tax treatment on housing demand.

This paper develops an alternative measure of the return on housing that incorporates the consumption stream and the required mortgage payments associated with owner-occupied housing. This measure is then used to demonstrate how the total return on housing varies with anticipated holding length, terms of the mortgage contract, and borrower income level. Data from the Panel Study of Income Dynamics and the Survey of Consumer Fiance are used to explore the empirical relationship between property, mortgage, and borrower characteristics and the total return on housing, the probability of negative total return, and the demand for risky assets.

MORTGAGE CONTRACTS AND THE DEFINITION OF AND DEMAND FOR HOUSING WEALTH

by

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This dissertation is dedicated to Wesley Webster Nichols, my father.

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Housing Wealth and Mortgage Contracts

1.1 Introduction.

This paper develops a detailed model of housing wealth's role over the life-cycle. Three key issues are explored: (1) housing's dual role as a consumption and investment good; (2) the signi£cance of the mortgage contract being in nominal and not real terms; and (3) the tax bene£ts associated with owner-occupied housing. The paper then demonstrates how each of these unique aspects of housing wealth affect consumption, savings, housing demand, and portfolio allocation over the life-cycle. This paper takes an initial step toward integrating a realistic model of housing wealth into the larger literature of life-cycle wealth accumulation and asset pricing.

1.1.1 The Importance of Housing Wealth

Housing wealth is a vitally important but understudied component of household wealth. The single most signi£cant asset for many households in the United States is the equity held in their home. Flavin and Yamashita (2002) used the Panel Study of Income Dynamics to show that among homeowner households with a head between 18 and 30 years old, 67.8% of their portfolio is in their home. In the same article the authors documented how a household's exposure to risk through their housing wealth could impact the portfolio allocation of their £nancial wealth. Fernández-Villaverde and Krueger (2001) document how housing could be used as collateral to relax lending constraints. These papers, among others, demonstrate that to understand the accumulation and composition of household wealth, one must £rst understand housing wealth.

The inclusion in a model of a simple consumption good, even one that is durable, or a simple investment good, even one with signi£cant transaction costs, is relatively straight forward. Housing's unique dual role as a consumption and an investment good makes it a far more interesting challenge to model. This unique aspect of housing is the £rst addressed in this paper. In general, the demand for a pure consumption good is simply determined by the marginal utility that it generates. On the other hand, the demand for an investment good is simply determined by its riskiness and correlation with the total portfolio. The demand for a composite good that acts as both an investment and consumption good and provides both utility and returns on investment is more complicated to determine. Therefore, it is necessary to explore the interaction between the consumption and investment motive for the good. The question becomes even more complex when the market for the good in question contains many frictions. The two most signi£cant frictions in the housing market are the use of mortgage contracts and the tax treatment of housing.

The second aspect of housing wealth addressed in this paper is that the mortgage balance and payments are set to nominal and not real values. The mortgage payment is not adjusted to re¤ect changes in the underlying cost of housing. Homeowners with existing mortgages see the real value of their mortgage balance and payment decline during periods of high in¤ation. This could have a direct impact on the behavior of households even if the in¤ation was perfectly anticipated.

The £nal aspect of housing wealth addressed is the three main ways owner-occupied housing bene£ts from preferental tax treatment: (1) the implicit rental from owner-occupied housing is not taxed as regular income, (2) the capital gains from housing is not taxed, and (3) mortgage interest is tax-deductable. The tax-free implicit rent is perhaps the most signi£cant tax bene£t associated with owner-occupied housing. Speci£cally, the homeowner is not taxed on the implicit rent generated by the housing. An investor who purchases and then rents a home must pay taxes on the rental income generated. However, a household that purchases and then occupies the same home directly consumes the stream of housing services, but pays no tax on the economic value of this stream of housing services. Naturally, if this stream of implicit income was taxed, it would be taxed net of mortgage interest, property taxes, and other owner costs. The implicit rent is equivalent to an untaxed dividend from a traditional £nancial asset. Models that do not address these aspect of housing may be signi£cantly understating one of the key advantages of housing as an investment good.

These unique aspects of housing wealth are not merely interesting, they can also have a profound effect on household behavior. It is impossible to develop a realistic model of housing wealth without explicitly addressing these issues. A traditional model of £nancial assets cannot explain the portion of housing demand driven by the desire to consume housing services. Likewise, a traditional model of durable consumption goods cannot explain the portion of housing demand driven by investment motives. A model that has real instead of nominal mortgage contracts is overstating the costs of the mortgage. The tax-free status of the implicit rent is perhaps the single biggest tax advantage housing has over other £nancial assets. Given the importance of these issues, it is vital to explicitly include them in a model of housing wealth.

1.1.2 Challenges of Modeling Housing Wealth

The two approaches to modeling housing wealth's role in the life-cycle each have advantages and disadvantages. The £rst approach is to develop an abstract model that captures only a few of the most important aspects of housing as an investment good. Papers such as Martin (2001) and Fernández-Villaverde and Krueger (2001) follow this approach. This type of model's advantages are that many can be solved analytically, or embedded in a general equilibrium framework and solved numerically. The primary disadvantage is the relatively narrow scope of such a model. The second approach is to sacri£ce simplicity for a more complicated partial equilibrium model that can be solved numerically using stochastic dynamic programming. Examples of this approach include Li and Yao (2004) and Hu (2002). Its advantage is that as a more complex model it presents a more realistic picture of the role of housing wealth over the life-cycle. The downside is an upper limit on the model's complexity level, beyond which the solution times are no longer tractable. Parallel processing can extend this upper limit in a grid-cluster or super-computer environment. The greater complexity of the model requires great care in presenting the results and currently precludes the option of embedding the model in a general equilibrium framework.

Both of the approaches described above are important and legitimate. Many of the questions the more detailed partial equilibrium models can address are outside the scope of the general equilibrium models. By explicitly including so many different aspects of housing wealth simultaneously, the partial equilibrium model is extraordinarily ¤exible. For example, by incorporating a few simple changes to the mortgage balance transition rule, the model can be used to simulate the effects of alternate mortgage contracts on housing demand and portfolio allocation. The same is true for changes in the tax treatment of housing or the success of alternative preferences in explaining the role of housing wealth of the life-cycle. The detailed partial equilibrium model in this paper provides important insight into how to develop an more abstract general equilibrium model that can still capture the complexities associated with modeling housing wealth.

1.1.3 A Detailed Partial Equilibrium Model of Housing Wealth

Housing wealth plays an important role, both as a signi£cant component of a household's portfolio and through its indirect effects on the demand for other types of investment assets. Housing wealth is also very different from other types of £nancial assets, calling for a different modeling approach. The model developed in this paper is used to demonstrate the importance of three unique aspects of housing wealth: (1) the dual role as a consumption and investment good; (2) the signi£cance of the mortgage contract being in nominal and not real terms; and (3) the tax bene£ts associated with owner-occupied housing. The paper shows how each of these unique aspects of housing wealth has profound effects on the demand for housing and the composition of household portfolios.

The model's design allows households to choose their current consumption, their savings, their savings allocated to risky assets, which type of housing to occupy, and whether to re£nance their mortgages. The housing tenure choice includes a rental unit, a small home, and a large home. Households may increase the sizes of their mortgage balances through the use of a cash-out re£nance. Renters choose the size of the rental unit so that the intra-period marginal utility of housing is equal to the marginal utility of non-durable consumption. The size of the large and small homes are £xed in terms of the number of housing units they represent. Households face uncertainty in the returns on risky assets and housing, the probability of survival, and a transitory shock to income; which is otherwise a deterministic function of age. The model includes moving, maintenance, and transaction costs. Both the option to and the costs of defaulting on a mortgage are also included in the model. The model is solved given the terms of a traditional 30-year £xed rate mortgage contract. The values of non-structural parameters, such as returns on different types of assets, the survival probability, mortgage terms, and income process, are taken from historical data.

The model's solution is then used to demonstrate the importance of each of the three unique aspects of housing wealth being examined. Two different versions of the model are solved differentiating the demands for housing as either an investment good or a consumption good. In the £rst version housing is treated as only an investment good and there exists a perfect rental market. Households may always rent the appropriate number of housing units such that the intra-period marginal utility of renting a house is equal to the marginal utility of all other consumption. Housing merely represents an unusual investment good that must be purchased using a traditional mortgage contract but generates no direct utility. The second version of the model treats housing as only a consumption good. The downpayment and the mortgage payments by the household are sunk costs and are not recouped when the home is sold. Instead households walk away from home sales with no gain or loss from the transaction. The paper demonstrates the signi£cance of the other two unique aspects of housing wealth in a similar way. To explore the effects of the nominal mortgage contract to additional versions of the model are solve, one version where the mortgage contract is in real and not nominal terms and another version with a historically high rate of in¤ation and a nominal mortgage contract. Finally, versions of the model are solved where each of the three major tax bene£ts of owner-occupied housing are removed: (1) the implicit rental from owner-occupied housing is taxed as regular income, (2) the capital gains from housing is taxed, and (3) mortgage interest is no longer tax-deductable.

1.2 Literature Review.

Many of the existing papers on the role of housing wealth tended to focus on different factors behind housing demand in isolation. Often housing was treated as either an investment good or as a consumption good. Often the models that explicitly captured housing's dual role did not include mortgage £nancing, or at most included only an abstract version of the mortgage contract. One of the innovations of this paper is to model housing as both an investment good and consumption good. The other key innovation is to explicitly model the mortgage contract. An important aspect of this paper, shared by several of the papers discussed below, is to model the portfolio allocation problem not just between one risky asset (stocks) and one risk-free asset (government bonds) but the portfolio allocation across three different assets, two risky (stocks and owner-occupied housing) and one risk-free asset (government bonds).

In several papers that explored in detail the role of housing wealth the actual decision of when and how much housing to consume was not endogenous. Fratantoni (1997) solved a £nite-horizon model with exogenous housing consumption and showed that introducing housing in the model reduced the share of risky assets held by households. The author extended the model in Fratantoni (2001) to show that the commitment to make future mortgage payments resulted in a lower level of equity holdings. In Fernández-Villaverde and Krueger (2001) the authors observed that young consumers have portfolios with little liquid assets but a signi£cant amount invested in durables. Fernández-Villaverde and Krueger hypothesized that young consumers can only borrow against future income by using their durable assets as collateral for loans. They then developed a structural life-cycle model with endogenous borrowing constraints and interest rates. Each of these papers explored an important aspect of housing wealth. However, by making the actual demand for housing exogenous they are unable to explore what exactly drives the demand for housing wealth. In this paper housing demand is endogenous and it is possible to determine how some of the unique aspects of housing wealth can drive the demand for housing.

Cocco (2000) developed a model with endogenous tenure choice to explore the effect of labor income, interest rate, and house price risk on both housing choices and investor welfare. Cocco utilized an abstract version of the mortgage contract where the level of mortgage debt adjusts in each period so that the loan-to-house value ratio remains £xed. Cocco's automatically-re£nancing mortgage precludes the opportunity to pay down or pay off a mortgage, two very common strategies among households. The more realistic mortgage model in this paper makes both of these strategies available to households.

Martin (2001) argued that consumers have an inaction region in the purchase of durable goods caused by transaction costs. Martin then argued that the inaction region in durable goods induces variation in the consumption of non-durable goods. Martin's model is a general equilibrium model and includes only a risk-free £nancial asset. It does not address the interaction between housing investment and the household's portfolio allocation problem. Martin also models the mortgage used to purchase a house as simply a negative position in the risk free bonds. In Martin, the inability of a single household to hold both a mortgage and a £nancial asset prevents any discussion of household level portfolio allocation, one of the key topics of this paper.

Hu (2002) developed a model very similar to the one in this paper where housing is endogenous. Hu solved a £nite-horizon model that allowed for households to hold a risk-free asset, a risky asset, or risky owner-occupied housing. Of the papers discussed here, Hu has the most detailed and realistic treatment of the mortgage contract. Hu's model re¤ects the composite nature of home equity and includes both the current value of the house and the current balance of the mortgage. Hu also allows for the mortgage payment to be £xed at the time of purchase. This model differs from Hu's by £xing the nominal mortgage payment while in¤ation reduces the real value of the mortgage payment. Additionally, Hu does not allow cash-out re£nancing, a signi£cant aspect of this model.

Li and Yao (2004) explored the housing and mortgage decisions of a household over the life-cycle. As this paper does, they utilized stochastic dynamic programming and parallel processing to solve an extremely detailed model. Many of their results were broadly consistent with this paper. However, this paper differs signi£cantly from Li and Yao in the treatment of the mortgage contract. Li and Yao made two key assumptions when modeling the mortgage contract in order to make their model tractable. First, they assumed that mortgages are amortized over the remainder of the household's life. Secondly, they assumed that the mortgage payment is indexed to the current value of the house. These simpli£cations allowed them to introduce permanent income shocks; which are absent from this paper. The cost of this simpli£cation was to ignore the ability of a household to lock in its mortgage payments at a constant nominal value. The result from Li and Yao's approach was that mortgage payments were signi£cantly lower, understating the cost of housing, and mortgage payments ¤uctuated with the value of the home, providing a form of insurance.

The dynamic stochastic optimizing framework adopted for the houshold for this paper is based on Rust and Phelan (1996). Rust and Phelan set up and solve a dynamic programming problem of labor supply with incomplete markets, Social Security, and Medicare. The dynamic programming problem in their paper is solved by discretizing the continuous state spaces and then using backward recursion to solve for the optimal value of the continuous choice variable at each point on the state space grid. The detailed rules governing the Social Security and Medicare application processes and bene£ts are imbedded in the income transition matrix. The model in this paper has a similar structure, but instead imbeds the detailed characteristics of the mortgage market contract in the income transition matrix.

All of these papers represent important work on interesting aspects of housing wealth. However, none of these papers attempts to develop a model that addresses all the unique characteristics of housing wealth. The key issue in modeling housing wealth is the treatment of the mortgage contract. More than any other single issue, it is mortgage £nancing that complicates realistically modeling housing wealth. The main contribution of this paper is to include an unprecedentedly detailed model of the mortgage contract.

1.3 A Partial Equilibrium Model of Housing Wealth with Mortgage Contracts.

This section describes the structure of the £nite-horizon life-cycle model of a household's savings, investment, and housing decisions. The structure of the model described here was chosen to highlight the effects of mortgage contracts on the evolution of housing wealth. In order to keep the model focused and tractable aspects such as endogenous labor supply an margin account for risky asset are excluded. The section concludes with a discussion of the method used to solve the household's optimization problem. The structure of the model is actually quite straight forward, with most of the complexities embedded in the wealth transition rules. Households receive utility from the consumption of both a non-durable good and the stock of housing that they own. Each period in the model represents a single year. Table B.1 in Appendix B provides a listing of the model parameters and their de£nitions.

Their optimization problem is to maximize their lifetime utility, de£ned as:

$$E\sum_{t=20}^{80}\beta^t\rho_t U(c_t,h(i_t))+\beta^t(1-\rho_t)(\theta_A U_B(A_t)+\theta_H U_B(H_t)-\theta_D U_B(D_t)) \quad c_t>0,\forall t \tag{1.1}$$

$$U(c_t,i_t)=\frac{(c_t^{1-\phi}h(i_t)^{\phi})^{1-\lambda}}{1-\lambda} \tag{1.2}$$

$$U_B(b)=\frac{b^{1-\lambda}}{1-\lambda} \tag{1.3}$$

where,

- c_t represents the consumption of non-durables;
- $h(i_t)$ represents the number of units of housing services consumed, given the housing tenure choice in period t (note that while the number of units of housing services consumed varies with tenure choice

the utility gained from a unit of services does not vary);

- A_t, H_t, and D_t are respectively the value of the £nancial assets, home, and mortgage debt left as bequests;
- β represents the discount rate;
- ρ_t is the survival probability;
- ϕ represents the measure of preference between of housing and consumption;
- λ represents a measure of risk aversion; and,
- θ_A, θ_H, and θ_M represent bequest parameters.

A household lives at most 80 years. It faces uncertainty about its survival, temporary income shocks, and the rate of return on both housing and risky assets. In addition to the stochastic elements for income and the rate of return on risky assets, the households may experience an additional shock. A small probability exists that the household will experience unemployment in one period, reducing income to zero. Also, a small independent probability exists of a stock market crash where the household will lose 100% of its investment in the risky £nancial asset. The probability of a stock market crash is in addition to the regular standard deviation associated with the stochastic rate of return on risky assets. Households also are not allowed to consume negative amounts of non-durable goods. The price of the consumption good is set equal to unity and the rental price of housing is set equal to a constant ratio of the underlying price of the housing unit. The in¤ation rate is constant and known.

1.3.1 Consumption of Housing

While consumption of the non-durable good in the model is continuous, the choices for housing consumption are partially discrete. The model has three different alternatives for housing: a rental unit, a small home, and a large home, represented by the corresponding symbols i_r, i_s, and i_l. The number of housing units available to rent is continuous while the number of housing units provided by a small or large home is £xed. Renter households are able to choose the number of housing units that equalizes their intra-period marginal utility from housing to their intra-period marginal utility from non-durable consumption.

$$\frac{\delta U(c_t, h(i_t))}{\delta c_t} = \frac{\delta U(c_t, h(i_t))}{\delta h(i_t)} \tag{1.4}$$

Optimal rental units may now be de£ned as a function of consumption,

$$h(i_r) = (\phi/(1-\phi))c_t \tag{1.5}$$

Many other factors in the model are conditional on current housing tenure, including rent or mortgage payments, maintenance costs, level of utility derived from housing, and the rate of appreciation in home value. The size of a small home is set equal to that of a median priced home, while the size of a large home is set to be twice that of a median priced home.

1.3.2 Accumulation of Financial Wealth and the Income Process

A household is "born" at age 20 with zero £nancial and housing wealth. It starts off as a renter with no savings. In each period it receives a draw from an age-dependent income process. The model contains no permanent income shock, only transitory shocks. In retirement, pension income is set to 60% of the deterministic portion of age 65 income. Pension income is still subject to transitory shocks, representing uncertainty regarding medical costs. Households can store their wealth in two different classes of assets, £nancial and real. The household's £nancial assets are held in a portfolio of risk free and risky assets. The household can, at no cost, rebalance its £nancial portfolio between risk free and risky assets every period. Households with zero wealth face a binding liquidity constraint for £nancial assets in that they cannot borrow against their future income. Households also cannot purchase leveraged portfolios, where they borrow at the risk free rate to invest more in the risky asset. In addition to moving to one of the three types of housing, $\{i_r, i_s, i_l\}$, the household can also decide to stay in its current home, $\{i_{t+1} = i_t\}$. Households may also either add to their mortgage balance through a cash-out re£nance or reduce their mortgage balance through a pre-payment re£nance.

The transition rule for the level of £nancial wealth is de£ned as:

$$
\begin{aligned}
A_{t+1} = {} & (1+(1-\gamma)(\alpha_t \widetilde{r_{s_t}} + (1-\alpha_t)r))(A_t - c_t - X_t(i_t,\kappa_t) + \\
& G_t(i_t,i_{t+1},\kappa_t) + Z_t(\kappa_t,\kappa_{t+1})) + (1-\gamma)\widetilde{e_{t+1}} + \gamma I_t(i_t,\kappa_t) \\
& s.t. \quad A_{t+1} \geq 0 \ \& \ 0 \leq \alpha_t \leq 1
\end{aligned}
\tag{1.6}
$$

where,

- A_t is the level of £nancial assets in period t;
- A_{t+1} is a random variable that depends on the stochastic rate of return on risky assets ($\widetilde{r_{s_t}}$) in period t and the realizations of earning ($\widetilde{e_{t+1}}$) in period $t+1$;
- α_t is the share invested in risky assets in time t;
- r is the deterministic rate of return on risk-free assets;
- $X_t(i_t,\kappa_t)$ (equation (C.7)) is the housing costs incurred in period t for a household currently choosing tenure type i_t with a mortgage κ_t years old;
- $I_t(i_t,\kappa_t)$ (equation (1.15)) is the mortgage interest paid;
- $G_t(i_t,i_{t+1},\kappa_t)$ (equation (1.16)) is the net gain for a household choosing i_t this period and i_{t+1} next period;
- $Z_t(\kappa_t,\kappa_{t+1})$ (equation (1.17)) is the net gain from cash-out re£nancing; and
- γ is the tax rate on income and capital gains (note that both income and capital gains have the same tax rate and taxes on capital gains are paid immediately).

The net gain from a home sale is tax-free and the mortgage interest paid is deducted from taxable income. Both the housing expenses and the amount of the mortgage interest deduction are functions of the current housing choice and age of mortgage. Re£nancing is modeled as a choice to lengthen the remaining number of years on the mortgage, or inversely, to shorten the current age of the mortgage. The model only allows cash-out re£nancing and does not allow prepayments. The age of a mortgage for a rental unit or a mortgage that has been paid off is zero. Households receive their wages at the same time they realize the returns on their investment from the previous period. As a result, the state variable A_t represents all available cash on hand, consisting of previous £nancial wealth and current income.

The income process is de£ned as a deterministic function of age plus a transitory shock, as shown below in log form:

$$\log(e_t) = \psi_0 + \psi_1 t + \psi_2 t^2 + \varepsilon_e \tag{1.7}$$

$$\varepsilon_e \sim N(0, \sigma_e)$$

The real rate of return on risky assets is a random variable with the distribution:

$$r_{S_t} \sim N(\eta_s, \sigma_s^2) \tag{1.8}$$

where η_s is the expected real rate of return on the risky asset and σ_s^2 is the variance.

1.3.3 Price of Housing

In addition to the portfolio of £nancial assets, households can also store their wealth in real assets by purchasing a house. It is only through the purchase of a house, and the acquisition of a mortgage loan, that households can borrow against their future income. The use of durable goods as collateral is in the same spirit as Fernández-Villaverde and Krueger (2001). The only mortgage contract available to the household in this model requires a 20% down payment; has a term of 30 years; and requires mortgage payments based on a £xed interest rate and the size of the original mortgage. The mortgage balance and the mortgage payment are both in nominal terms while the rest of the model is in real terms. Households selling their home are also required to pay a transaction cost equal to 10% of the value of the home that they are purchasing. This represents realtors' fees, credit checks, and other expenses associated with the purchase.

The real price of housing has a positive trend over time. The purchase price of either a small or large home increases non-stochastically by the average market price increase in each period. The value of homes that have already been purchased changes according to a stochastic process, with the expected increase equal to the non-stochastic market price increase. A household that has had a series of excellent draws in home price appreciation will own a home worth relatively more than a comparable home on the market. A household that has had a series of poor draws in home price appreciation will own a home worth relatively less than a comparable home on the market.

The price per housing unit is the same across all types of housing. Large homes cost more than small homes because they provide more units of housing for the homeowner to consume. Renters may choose as small or as large a home to rent as they wish. Their rent is proportional to the current market value of their chosen home. As the value of housing units change, so do their rental rates. The value of owner-occupied units evolves stochastically while the value of newly purchased and rental units are set equal to the current deterministic market price. The market price of a housing unit is the number of housing units, $h(i_t)$, multiplied by the current market price of a housing unit, $(1+\eta_h)^t P_0$. The value of an owner-occupied unit is the value of the unit from the previous period, H_t, multiplied by the realized rate of appreciation for that unit in that period, $(1+\widetilde{r_h})$. The price of owner-occupied housing is allowed to evolve differently from the market price of housing in order to capture the idiosyncratic aspect of housing returns. The formulas for the market price of home type i_t ($P_t(i_t)$) and the housing wealth (H_{t+1}) transition rule are:

$$P_t(i_t) = (1+\eta_h)^t P_0 h(i_t) \tag{1.9}$$

$$H_{t+1} = \begin{cases} H_t(1+\widetilde{r_h}), & i_{t+1} = i_t \\ P_t(i_t), & i_{t+1} \in i_s, i_l \\ 0, & i_{t+1} = i_r \end{cases} \tag{1.10}$$

$$r_h \sim N(\eta_h, \sigma_h^2) \tag{1.11}$$

where P_0 is the price of a single unit of housing in period 0; $\widetilde{r_h}$ is the realized rate of appreciation on housing in period t; η_h is the expected rate of appreciation on housing; and σ_h^2 is the variance of the house price growth. Note that home prices are in real terms, the increase in the market price of housing is note due to general in¤ation, but a real increase in the value of the house with time.

1.3.4 The Mortgage

A signi£cant source of the complexity in the model is the need to include the age of the mortgage in the state space. In the model this adds a discrete state variable with thirty-one discrete values, resulting in over 1.7 million points in the £nal state space. The computational techniques used to solve a problem of this scope are discussed brie¤y at the end of this section. The reason for including the age of the mortgage in the state space is the nature of the 30-year self amortizing mortgage. First, the actual equity households hold in their home is the difference between the value of the home minus the remaining balance on the outstanding mortgage. To accurately track the value of the household's home equity, it is necessary to track both the value of the home and the mortgage balance independently. The nature of the mortgage contract further complicates what would be a logical solution, the addition of a third continuous state variable for mortgage debt. The principal paid on a self amortizing mortgage is not constant over the life of the mortgage. Initial payments are almost completely composed of interest, with very little principal being paid. The £nal payments on a 30-year mortgage on the other hand are almost completely principal, with very little interest being paid. Therefore, the transition rule for mortgage debt is a function of the age of the mortgage. The fact that the mortgage balance and mortgage payment are in nominal terms provides an additional motivation for including the age of the mortgage in the state space. The real values of the mortgage balance and payment decline steadily over the life of the mortgage due to in¤ation.

The mortgage payment is based on the home price when purchased, and only changes when the household re£nances the mortgage or sells the house. A cash-out re£nance increases the number of years left on the mortgage. The formula for the real value of a mortgage payment at time t after κ_t years on a house of type i_t is:

$$M_t(i_t,\kappa_t) = \pi(1-\mu)P_{t-\kappa_t}[(1-(1+\pi)^{-\kappa_t})(1+\nu)^{\kappa_t}]^{-1} \qquad (1.12)$$

where π is the nominal mortgage interest rate; ν is the in¤ation rate; and μ is the required down payment.

The cost of housing services also re¤ects the maintenance costs paid by homeowners. As a result, the formula for the real cost of housing services is:

$$X_t(i_t, \kappa_t) = \begin{cases} M_t(i_t, \kappa_t) + \delta H_t, & i_t \in i_s, i_l \\ \\ 0.06 P_t(i_r), & i_t = i_r \end{cases} \tag{1.13}$$

where δ is the percent of current home value required in maintenance costs. Rent is equal to 6% of the current market value of the unit being rented and renters pay none of the maintenance costs for the property.

The present value of the household's home equity is the current value of the house minus the amount of the outstanding mortgage balance. While the value of the house increases or decreases according to the stochastic return on housing, the outstanding mortgage balance is a monotonically declining function of the age of the mortgage. The formula for the real value of the mortgage balance at time t after κ_t years on a house of type i_t is:

$$D_t(i_t, \kappa_t) = \begin{cases} M_t(i_t, \kappa_t) \frac{1-(1-\pi)^{\kappa_t - 30}}{\pi}, & i_t \in i_s, i_l \ \ \& \ \ \kappa_t \leq 30 \\ \\ 0, & (i_t \in i_s, i_l \ \ \& \ \ \kappa_t > 30) \quad \text{or} \quad (i_t = i_r) \end{cases} \tag{1.14}$$

The formulas for the mortgage payment is used to calculate the amount of mortgage interest paid for tax purposes. The values must be adjusted back from the real terms since this deduction is in nominal terms. The formula for the mortgage interest deduction is:

$$I_t(i_t, \kappa_t) = \pi M_t(i_t, \kappa_t)(1 - (1+\pi)^{\kappa_t - 30})(1+\nu)^{\kappa_t} \tag{1.15}$$

1.3.5 Gains from Sale or Re£nancing

The net gain after paying transaction costs and down payments for a household choosing next period's tenure $i_{t+1} \in \{i_r, i_s, i_l\}$ is given by:

$$G_t(i_t, i_{t+1}, \kappa_t) = \begin{cases} H_t - D_t(i_t, \kappa_t) - \mu P_t(i_{t+1}) - \tau H_t - \chi, & i_{t+1} \neq i_t \\ 0, & i_{t+1} = i_t \end{cases} \tag{1.16}$$

where τ is the transaction cost; μ is the downpayment rate; and χ is a £xed moving cost paid regardless of which type of housing is being purchased. When the household chooses not to move, $i_{t+1} = i_t$, it has zero net gain.

The net gain after choosing to re£nance a mortgage is de£ned as the sum of the difference between the mortgage balances before and after the re£nance and a fee for the transaction. Interest rates are constant in this model, so there is never any incentive to re£nance at a lower interest rate. The only bene£t of re£nancing is to extract home equity in order to invest in £nancial assets or smooth consumption. When no re£nance occurs $\kappa_{t+1} = \kappa_t + 1$ and the net gain is zero.

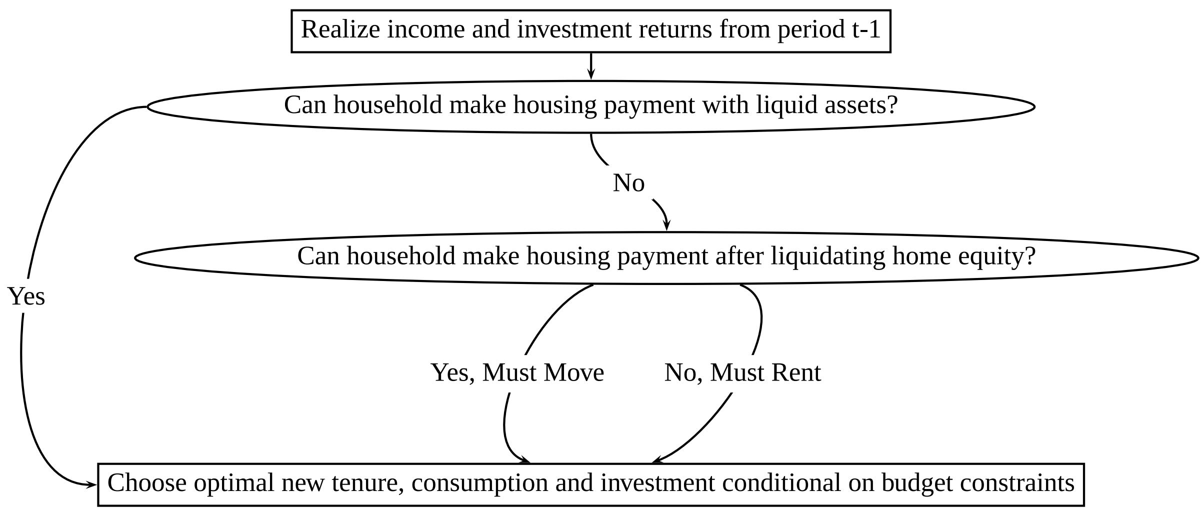
$$Z_t(\kappa_t, \kappa_{t+1}) = \begin{cases} (1-\zeta)D_t(i_t, \kappa_{t+1}) - D_t(i_t, \kappa_t), & \kappa_{t+1} \neq \kappa_t + 1 \\ 0, & \kappa_{t+1} = \kappa_t + 1 \end{cases} \tag{1.17}$$

where ζ represent the transaction costs associated with re£nancing. When there is a cash-out re£nance the household is increasing the number of years left on the mortgage, $\kappa_{t+1} < \kappa_t + 1$ and $Z_t(\kappa_t, \kappa_{t+1}) > 0$. Only households who choose not to move in a given period may choose to re£nance.

The effect of steadily increasing home prices provides another argument for the inclusion of the age of the mortgage as a state variable. Due to the steady increase in home prices, the initial mortgage on a given home today would be signi£cantly greater than the mortgage on a similar home twenty years ago. The current mortgage payments on these two similar homes would re¤ect this, with the mortgage payment for the home with the twenty-year old mortgage being signi£cantly less than the payment for the home with the new mortgage. The implication is that there might be some economic value to the ability to lock-in the recurring housing expense at a £xed level while the market price of housing ¤uctuates. This allows the model to capture the role of housing as a hedge against variability in rents, as argued by Sinai and Souleles (2003).

1.3.6 Default Penalties

Figure 1.1: Timing of Decisions



The model also contains a default penalty. In any period the household must be able to cover its housing expenses, including the rent or mortgage and maintenance costs. If it fails to do so, it must move the next period into rental housing, forfeiting all its home equity and all its £nancial equity above some small nominal amount. Households that can cover their expenses by selling their current house and extracting their home equity are allowed to do so. Households that can afford the associated transaction costs may also avoid defaulting through a cash out re£nance. The advantage of this for the household is the ability to keep its housing equity. Current consumption is also constrained to equal that same small nominal amount. The £rst constraint, shown in equation (2.8), affects those households that are forced to move but can avoid defaulting and the second constraint affects those households that default. The restriction that A_{t+1} may not be negative, combined with the de£nitions of $X_t(i_t, \kappa_t)$, $Z_t(\kappa_t, \kappa_{t+1})$, and $G_t(i_t, i_{t+1}, \kappa_t)$, along with the budget constraint, create an upper bound on possible levels of non-durable consumption, and also rule out some possible choices of housing tenure. If the household cannot afford the down payment for a large home without incurring negative wealth, it is not allowed to move to such a home. The ¤ow chart above shows how the default penalties affect the household's decisions.

1.3.7 Optimization Problem and Value Functions

The household's optimization problem is to choose variables $c_t, \alpha_t, i_{t+1}, \kappa_{t+1}$ given a series of state variables $t, \kappa_t, i_t, A_t, H_t$ to optimize equation (2.2) given equations (2.4) (1.16). The household only has one choice of mortgage contract, with a £xed downpayment rate. The choice variable κ_{t+1} capture the ability of a household to cash-out home equity by re£nancing, and therefore reduce the effective age of the mortgage as described above.

The value function of the household is the maximum utility, subject to the default constraints of the value functions for the households that choose next period tenure type $i_{t+1} \in \{i_r, i_s, i_l, i_t\}$:

$$(A_t - X_t(i_t,\kappa_t) < 0) \;\; \& \;\; (A_t - X_t(i_t,\kappa_t) + \max_{i_{t+1},\kappa_{t+1}} (G_t(i_t,i_{t+1}) + Z_t(\kappa_t,\kappa_{t+1}))) > 0) \Rightarrow \tag{1.18}$$
$$V_t(i_t, A_t, H_t, \kappa_t) = \max_{i_{t+1} \neq i_t or \kappa_{t+1} \neq \kappa_t + 1, c_t, \alpha_t} V_t^{i_{t+1}}(i_{t+1}, A_t, H_t, \kappa_t)$$

$$(A_t - X_t(i_t,\kappa_t) < 0) \;\; \& \;\; (A_t - X_t(i_t,\kappa_t) + \max_{i_{t+1},\kappa_{t+1}} (G_t(i_t,i_{t+1}) + Z_t(\kappa_t,\kappa_{t+1}))) > 0) \Rightarrow \tag{1.19}$$
$$V_t(i_t, A_t, H_t, \kappa_t) = U(\omega, h(i_t)) + \beta\rho_t V_t(i_r, \omega, 0, 0) + \beta(1-\rho_t)\theta_A U_B(\omega)$$

$$(A_t - X_t(i_t,\kappa_t) > 0) \Rightarrow \tag{1.20}$$
$$V_t(i_t, A_t, H_t, \kappa_t) = \max_{i_{t+1} \in \{i_r, i_s, i_l\}, c_t, \alpha_t, \kappa_{t+1}} V_t^{i_{t+1}}(i_m, A_t, H_t, \kappa_t)$$

where ω is the amount of consumption and wealth protected in default from creditors. Equation (2.8) is the value function when the households recurring housing expenses, $X_t(i_t,\kappa_t)$, are greater than their available liquid assets, A_t, but if their net equity after selling or re£nancing their home is positive, $(A_t -$

$X_t(i_t,\kappa_t)+\max_{i_{t+1},\kappa_{t+1}}(G_t(i_t,i_{t+1})+Z_t(\kappa_t,\kappa_{t+1})))$. Faced with this constraint, the household must either more, $i_{t+1}\neq i_t$, or re£nance, $\kappa_{t+1}\neq\kappa_t+1$. Equation (1.19) is the value function when the household cannot cover their recurring housing expenses out of their liquid assets and their net equity after selling or re£nancing their home is negative. These households must move to a rental unit ,$i_{t+1}=i_r$, and have both their consumption and remaining wealth limited to ω. Equation (1.20) is the value function when the households can cover their recurring housing expenses out of their liquid assets. The only limits to their choices are those imbedded in the constraints in equation (2.9).

The value function conditional on next period's tenure choice i_{t+1} is:

$$V_t^{i_{t+1}}(i_t,A_t,H_t,\kappa_t)=\begin{cases}\max\limits_{c_t,\alpha_t}U(c_t,h(i_t))+\beta\rho_tV_t(i_{t+1},A_{t+1},H_{t+1},1)+ & i_{t+1}\in\{i_r,i_s,i_l\}\\ \beta(1-\rho_t)(\theta_AU_B(A_t)+\theta_HU_B(H_t)-\theta_DU_B(D_t)), & \\ \max\limits_{c_t,\alpha_t,\kappa_{t+1}}U(c_t,h(i_t))+\beta\rho_tV_t(i_{t+1},A_{t+1},H_{t+1},1)+ & i_{t+1}=i_t\\ \beta(1-\rho_t)(\theta_AU_B(A_t)+\theta_HU_B(H_t)-\theta_DU_B(D_t)), & \end{cases}\tag{1.21}$$

such that equations (2.4) to (1.20) hold.

The structure of this problem contains several signi£cant sources of non-continuity. The £rst is the discrete nature of housing tenure, which functions as both a choice and a state variable. The second main source of the non-continuity is the structure of the value function, which is de£ned as the maximum of over sixty-six different value functions, one for each possible combination of four tenure choices or two re£nance options and eleven portfolio allocations. This non-continuity of the model prevents the use of analytical methods to derive a solution. It also prevents the derivation of Euler equations. The model is instead solved using computational methods based on the methods used in Rust and Phelan (1997).

The code used to solve this problem is in C. One solution of the problem initially took roughly two weeks on a dual processor Pentium Xeon 1.8GHz with 512K L2 cache and 1GB of RAM running Linux. In order to improve the run-time, the code was re-written to take advantage of parallel processing, using the Message Passing Interface (MPI) standard. In this version of the code one processor is designated the master while a pool of other processors are designated slaves. As the model is solved recursively by year, the master distributes the current value function for all previous years to the slaves. Each slave then solves for the optimal value function for a sub-set of state spaces for the given year. The slaves then return the new value function values to the master. The master then combines the new values with the value function for the previous year, completing the recursion for one year. The problem was solved using 61 high-performance Digital Alpha 64-bit microprocessors running at 450MHz each on a scalable parallel Cray T3E at the Pittsburgh Supercomputing Center. One solution involved roughly 1.3 billion evaluations of the value function and took roughly eight and a half hours.

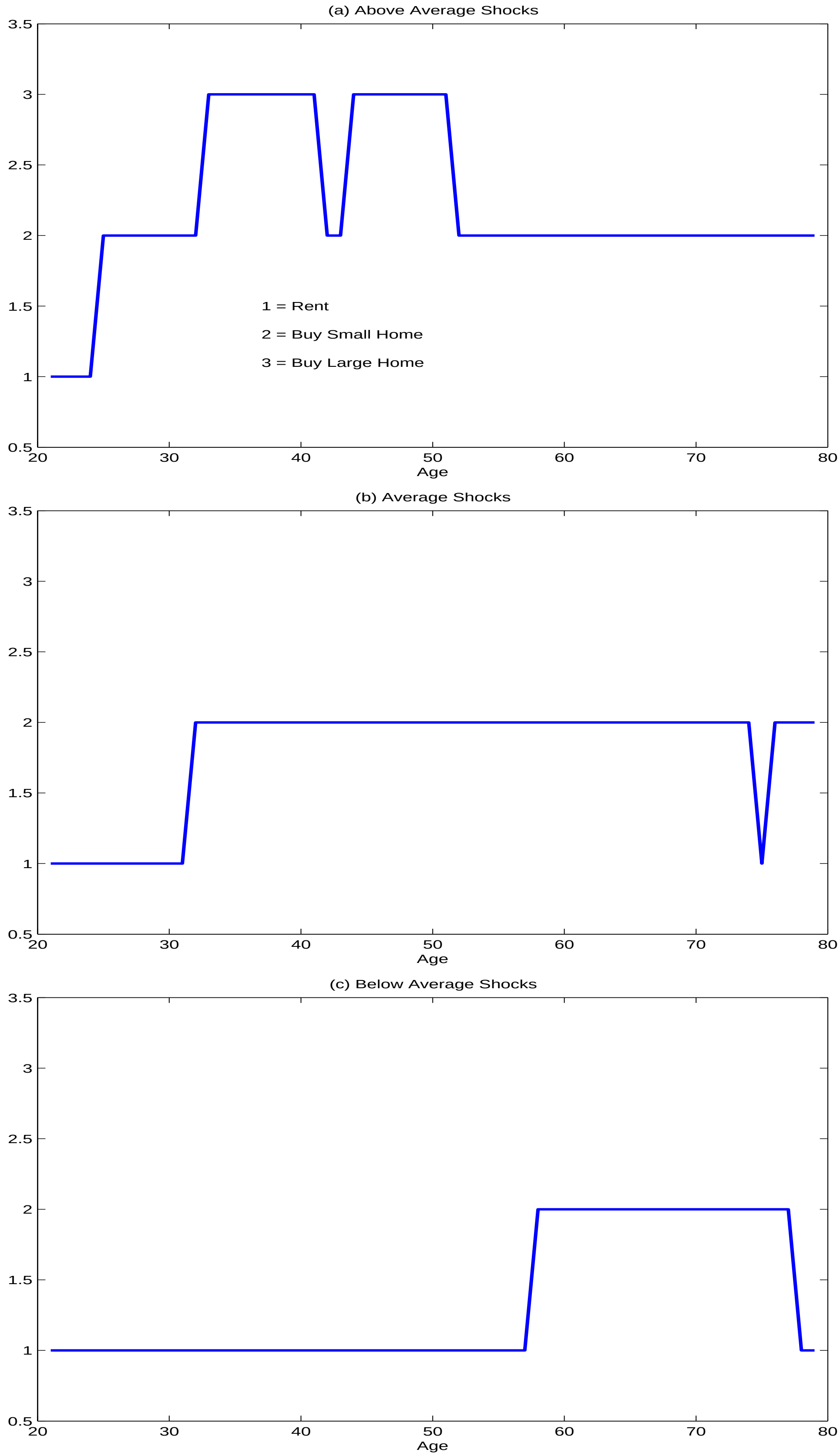
1.4 Baseline Model Results.

The parameter values for the model calibration are chosen to be consistent with other models in the relevant literature. The parameter values for the size of small and large homes are set so that they represent, respectively, a home 80% and 120% the size of a median priced home. The ϕ value of 0.2 re¤ects the share of total household expenditures allocated to housing expenditures in the 2001 Consumer Expenditure Survey from the U.S. Department of Labor. This paper does not represent a serious attempt to calibrate a model of housing wealth or to estimate the maximum likelihood parameters of such a model. The goal is to see how closely the model can match certain stylized facts while using fairly standard and common parameter values. Appendix A contains more information on the values of the market and preference parameters chosen. A series of graphs of the policy functions, from one of the calibrated models, for households receiving different series of shocks are then presented, to illuminate the factors driving the economic decisions of the household. Finally, some results from simulations based on the baseline model are given. The baseline model matches several patterns seen in the empirical data.

1.4.1 Policy Functions

Figures 1.2 through 1.5 report sample policy functions for a range of households. Each £gures contains the policy functions for three different types of households over the life-cycle, based on the type of shocks to income and the returns to both housing and risky assets. In each £gure, the top panel reports the policy function for a household that receives in each period above average shocks, the middle panel

Figure 1.2: Housing Tenure Policy Functions



reports the policy functions for a household receiving average shocks, and the £nal panel reports the policy function for a household that receives in each period below average shocks. It is important to note that these households do not realize that their future shocks have been arti£cially pre-ordained. They each believe that the shocks each period are independent from those in other periods, just as was the case when the model was solved.

The three panels in Figure 1.2 shows the tenure choices for each of our three sample households as a function of age. Naturally the household with the above average shocks is the £rst to purchase a home in their mid-twenties. The average household is only able to afford this transition in their earlier thirties while the below average household is forced to wait until their mid-£fties. The above average household is also able to trade-up to a larger home in their earlier thirties. In about ten-years they trade back down to a small home, shifting a signi£cant portion of their wealth from housing to £nancial assets and reducing their mortgage payment. After a few more years of above average returns, they trade-up again, only to trade-down again after age 50. Once they reach this age, they can lock in their nominal mortgage payments for the rest of their life by purchasing a smaller home. The average household stays in their home until the mid-seventies when they spend a brief time renting, before buying another small home. The below average household sells their home in their late-seventies and rents for the rest of their life.

Figure 1.3 shows the consumption policy functions and realized wages for each of the three households. The higher realized investment returns allows the above average household to consume more than their annual wage by the time they are £fty. As they continue to receive above average shocks, they continue to increase their consumption. One interesting results is that each of these three households reduce their consumption immediately prior to purchasing a home. They also increase their consumption when they trade-down. Households who choose not to move also have higher levels of consumption. Since they are not adjusting their housing consumption, they compensate by increasing their consumption of non-durables. This pattern of behavior is similar to that described in Martin (2001)

Figure 2.2 shows how the housing and £nancial wealth policy function for the three households. It shows how £nancial wealth falls when households purchase homes, representing the effect of the down-payment and transaction costs. The £gure also shows how households shift wealth back from housing

Figure 1.3: Consumption Policy Functions and Realized Wages

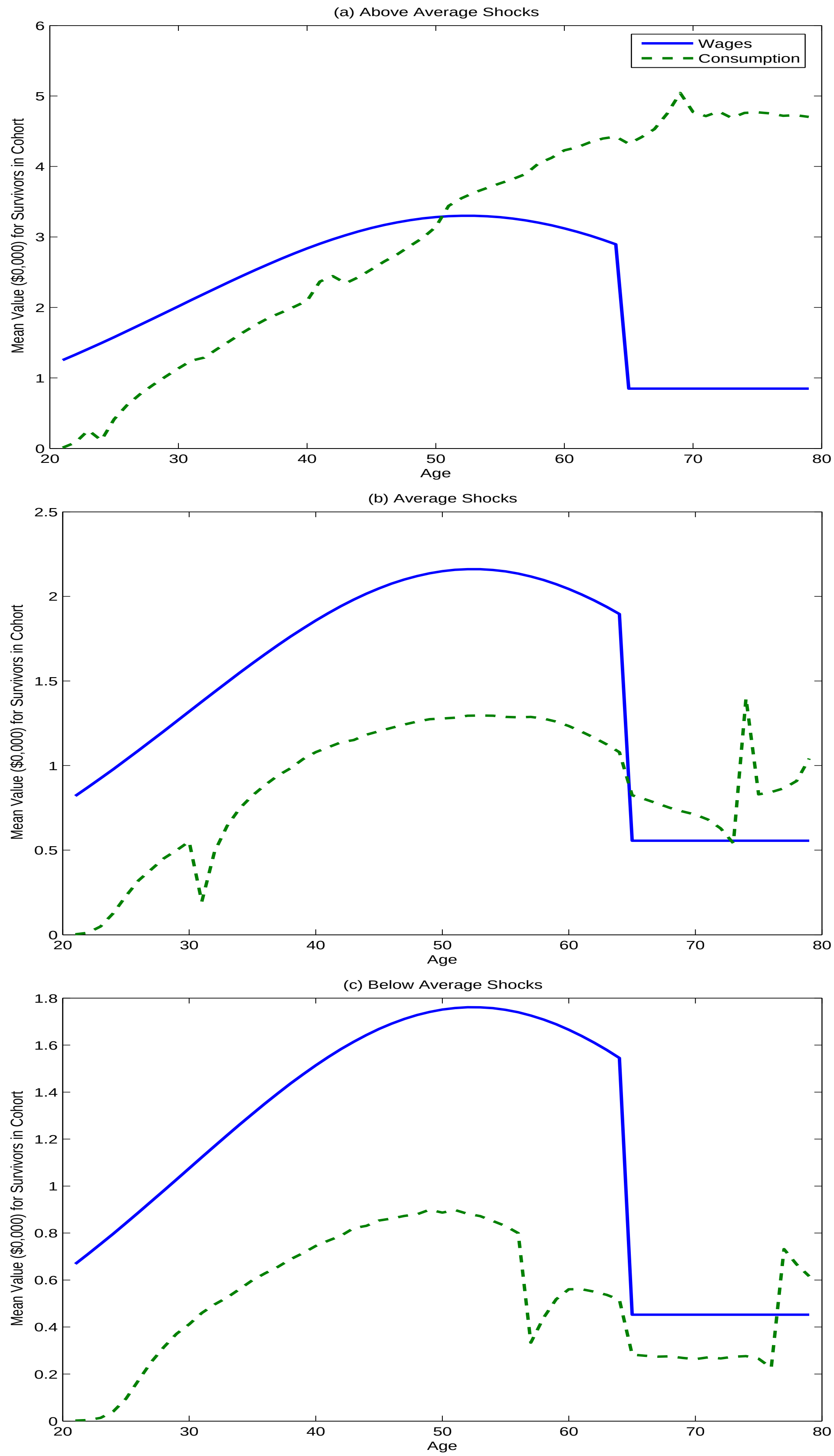


Figure 1.4: Home Equity and Financial Wealth Policy Functions

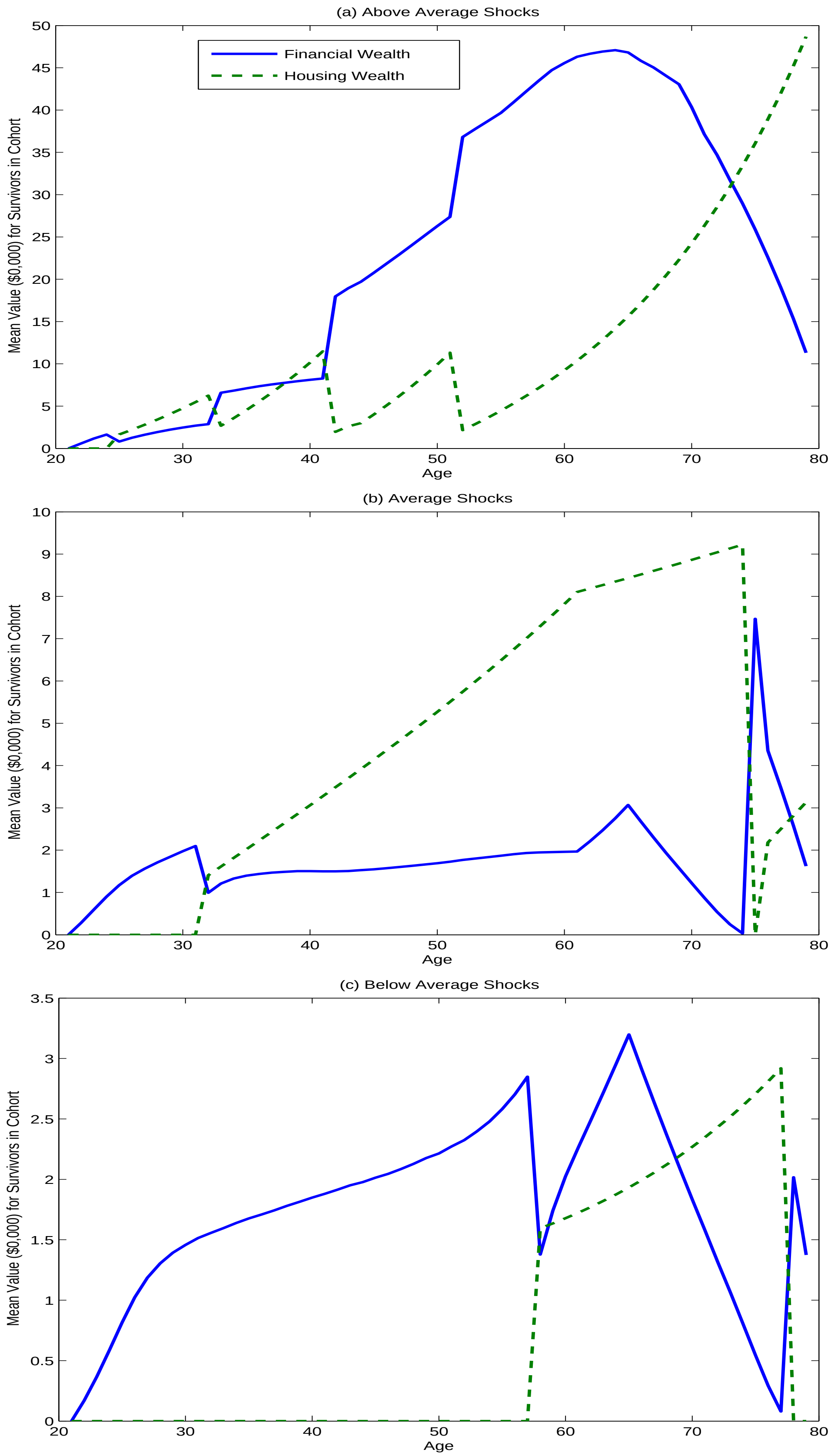
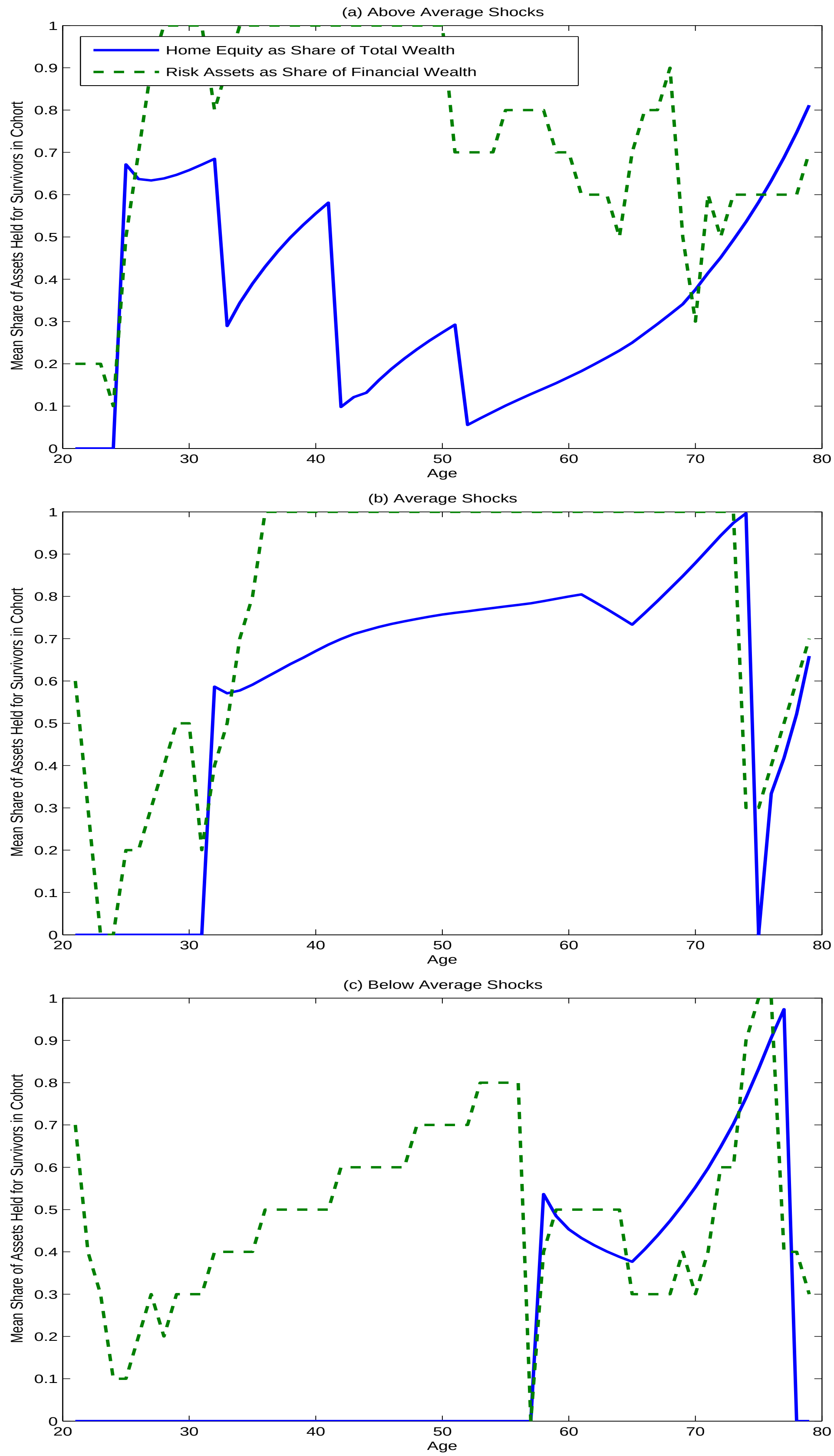


Figure 1.5: Portfolio Allocation Policy Function



to £nancial assets. Figure 1.5 reports the portfolio allocation policy functions for the three households. Households who are remaining renters invest a smaller amount of their portfolio in risky assets. They are focused on saving for a downpayment as quickly as possible, giving them a fairly short time horizon. The renters therefore choose a conservative portfolio that is more tilted towards asset protection than asset growth. Those households purchasing homes now own a second risky asset, their house, that is uncorrelated with the risky £nancial asset. In response to their increased diversi£cation, they increase their investment in the risky asset. In the period in which households purchase their home they also sharply reduce their holdings in the risky asset.

1.4.2 Simulation Results

To better explore the implications of the model, 1,000 simulations are generated using the calibrated model. The table and £gures below contain the results from these simulations. Households begin at age 20 as renters with no assets. Households retire at age 65 and live to at most 80 years of age. The simulations track their accumulation of housing and £nancial wealth over their lifetime. Figures 2.1 and 2.4 present the simulation results across the life cycle. These £gures show the role of housing over the life cycle, and how consumption and investment decisions are linked to housing decisions.

Figure 2.1 shows the consumption and income paths over the life-cycle. The sharp drop in income in retirement can be seen in panel (a), while consumption is much smoother. Panel (b) shows the path of consumption as a share of total wealth. Younger households who are aggressively saving for a downpayment consume the smallest share of their wealth. Once households become homeowners, their consumption as a share of total wealth climbs, peaking near 16% around the age of 30. As households approach retirement, they start to accumulate more wealth, and consumption as a share of total wealth starts to fall reaching a low point of 9% at age 65. In retirement households draw down their savings and consumption as a share of total wealth climbs again. At retirement the average household has roughly forty-£ve times their annual income saved in both housing and £nancial wealth.

The importance of housing wealth in retirement is emphasized by the next set of £gures. Figure 2.3 (a) shows that housing wealth has a hump over the life cycle, reaching a peak at 60 and starting to

Figure 1.6: Consumption and Income

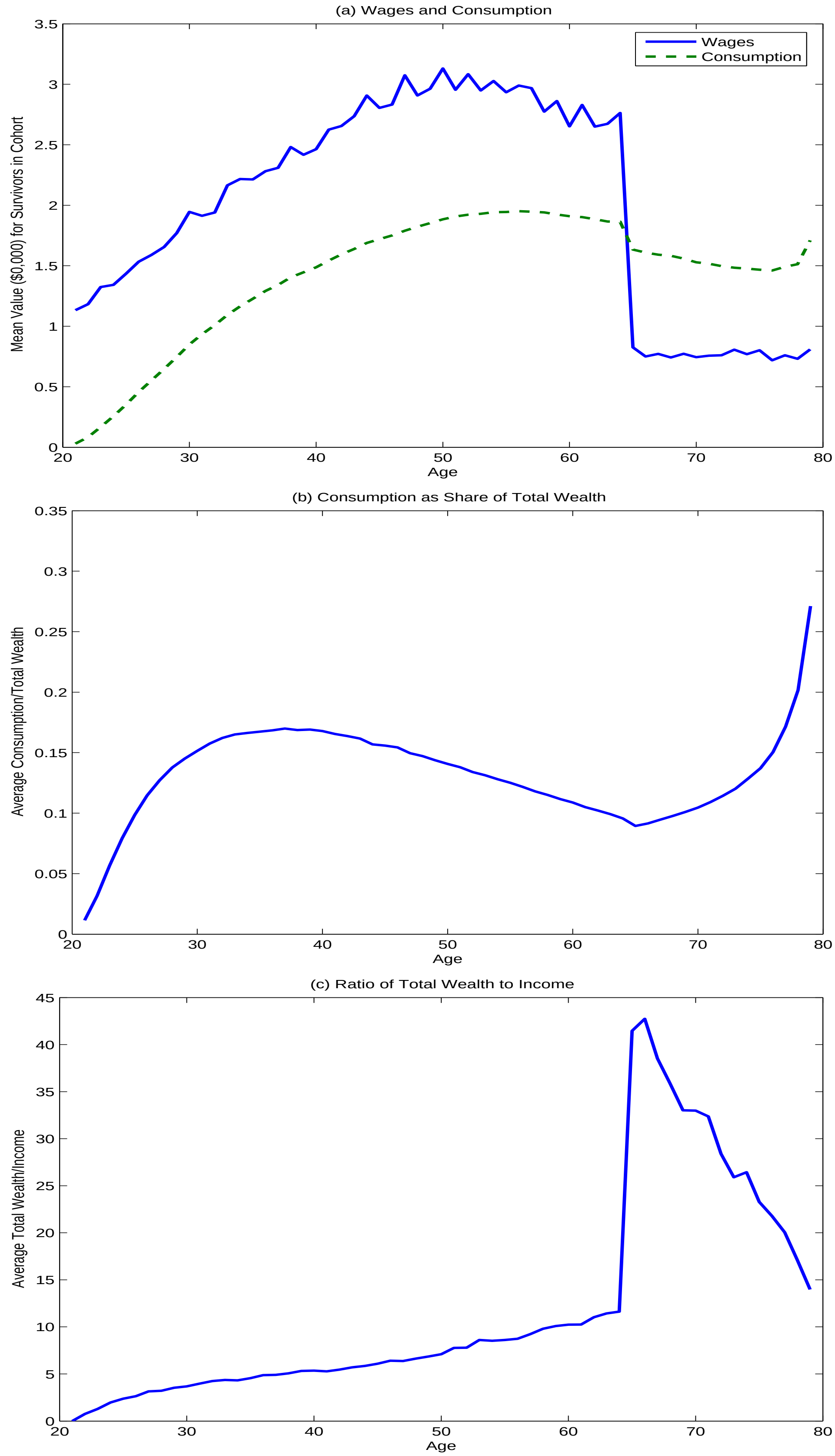
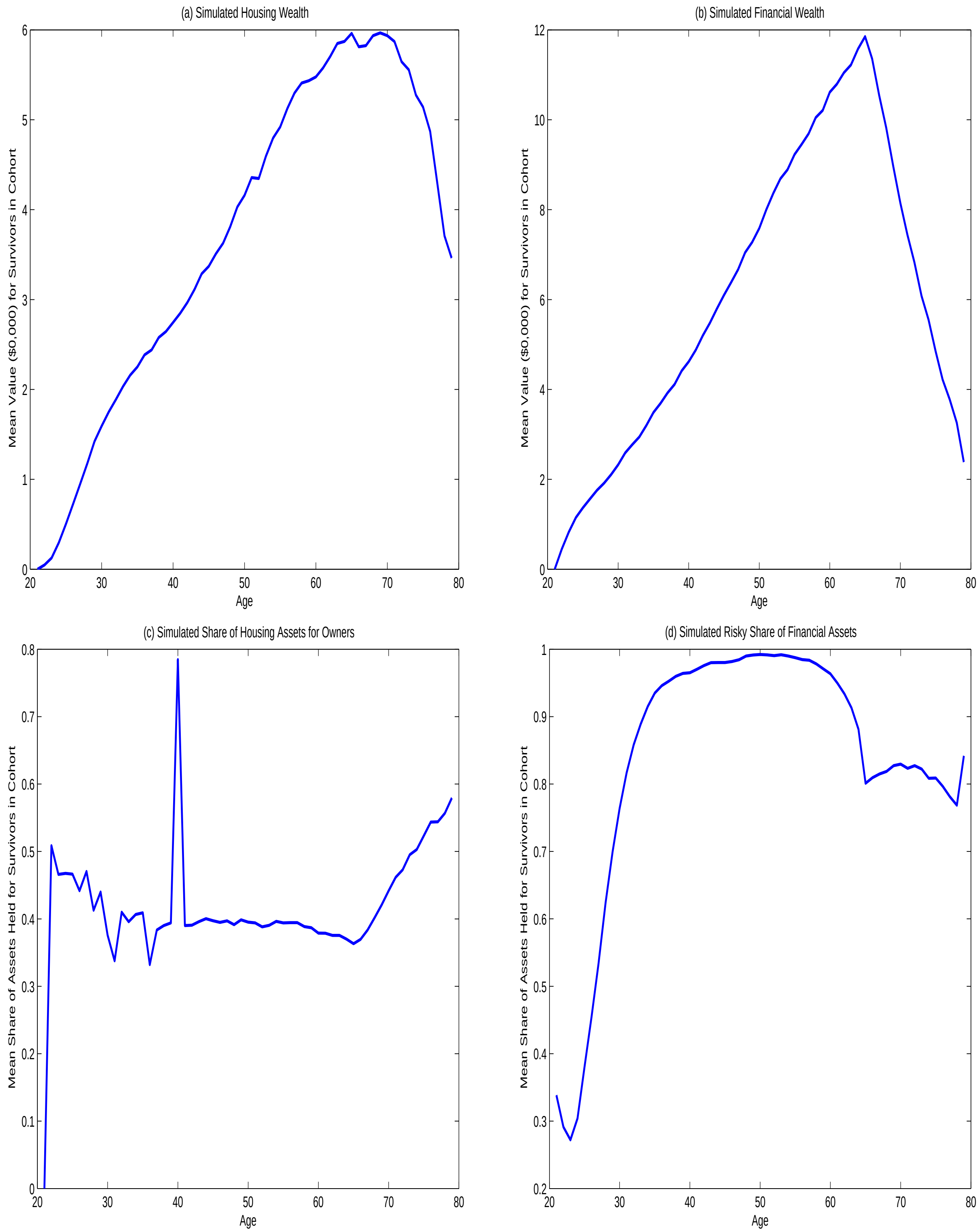


Figure 1.7: Wealth and Portfolio Choice

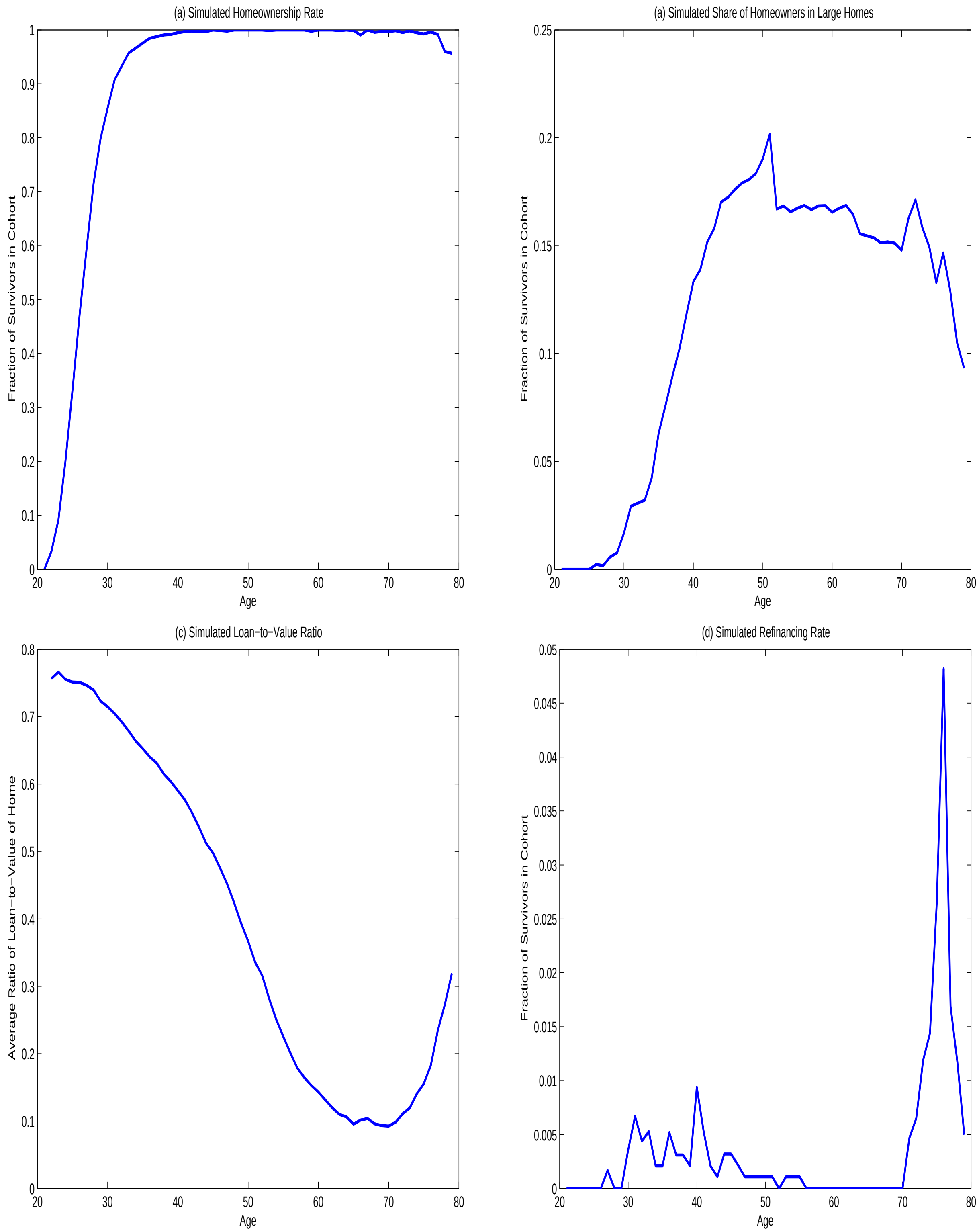


decline as households approach retirement. The brief plateau in the growth of housing wealth at age 50 is caused by many households either trading down to smaller homes or re£nancing their existing mortgage in order to lock in nominal mortgage payments for the rest of their expected life. Financial wealth, shown in Figure 2.3 (b), is more sharply humped and peaks at age 65.

One implication of the model is that accumulated home equity is used to £nance the consumption of non-durables in only late in retirement. The actual role of housing wealth among the elderly is a bit more complicated. Venti and Wise (2000) found that housing wealth was not in fact used to support non-housing consumption. They £nd that households resort to their home equity only when faced by a signi£cant shock such as the death of a spouse or a serious illness. This is similar to the £nding in Sheiner and Weiss (1992) that anticipation of death and illness signi£cantly increases the probability that households reduce their home equity. These conclusions £nd additional support in the results of this model, in that households do not tap into housing wealth in retirement until their reserves of £nancial wealth have been depleted. However the model does result in more rapid decline in housing wealth than seen in the data. The lack of health status as a state variable and the connection between health status and retiree tenure choice might explain this failure of the model.

Figures 2.3 (c) and 2.3 (d) provide the most signi£cant results of the model. As Figure 2.3 (c) shows, the simulated share of assets held in housing is consistently near 40%, a bit below the empirical average of 67%. The housing share is high among young households who must invest a large portion of their savings in a downpayment. As £nancial wealth grows faster than housing wealth this share falls initially. The jagged nature of the curve re¤ects a combination of re£nancing and trading up as younger households try to keep their portfolios balanced while taking advantage of their greater £nancial resources to purchase larger homes. The rate of increase in the share climbs in retirement, as households draw down £nancial wealth prior to extracting home equity. Household's face signi£cant transaction costs, due in part to the nature of the mortgage contract, to access their home equity. As a result, households turn to £nancial equity initially to fund consumption in retirement. This partially matches the ”over-investment” in housing seen in the empirical data, as reported by Flavin and Yamashita, using a model of rational, forward looking agents. The implication is that while some degree ”over-investment” in housing is the result of something

Figure 1.8: Housing Tenure Choice



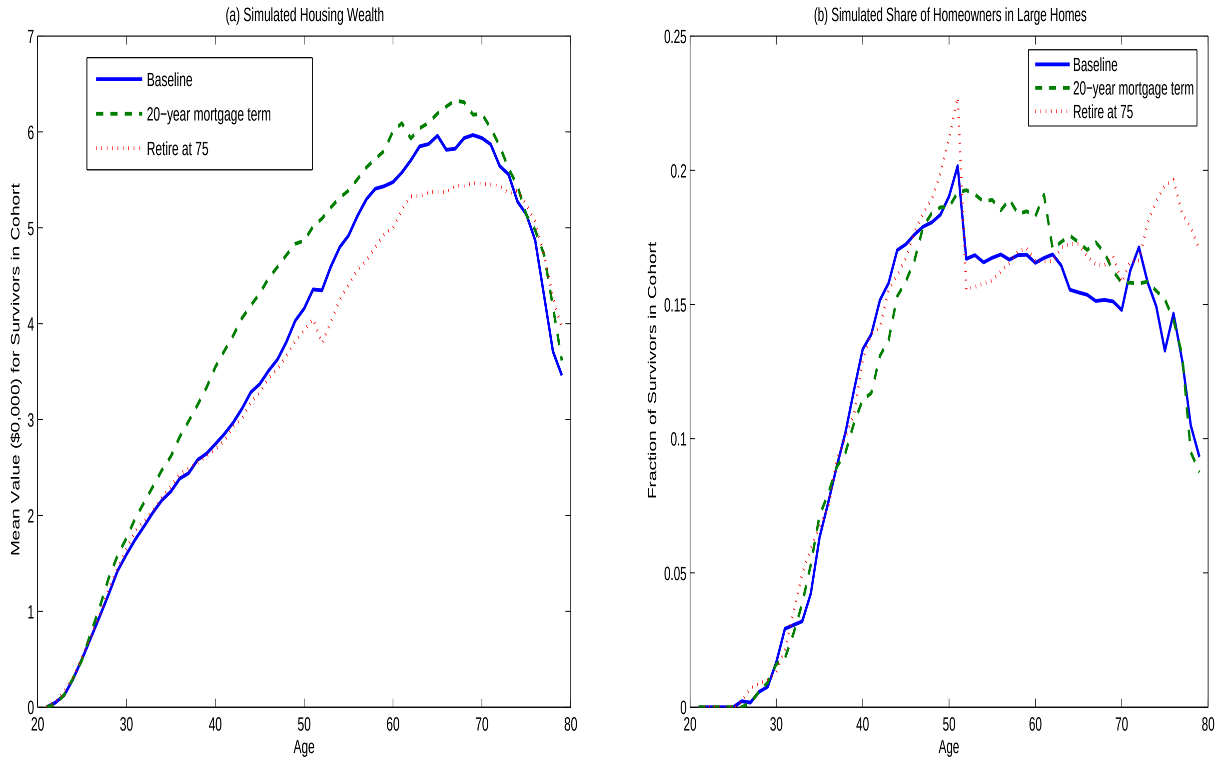
innate in the nature of the housing good or the mortgage contract used to purchase it and not the result of sub-optimal behavior by non-rational consumers, the actual level of ”over-investment” in housing seen empirically cannot be fully explained with this model.

Figure 2.3 (d) shows the pattern of allocation in the £nancial portfolio over the life cycle. Young households who are aggressively saving for or already have large shares of their wealth tied up in down-payments invest less in the risky asset, as do older households who have drawn down their £nancial wealth relative to their housing wealth. The risky portfolio share peaks around age 50, just when the households start to actively shift their total portfolio away from home equity.

The £nal set of £gures from the simulations document the role of housing over the life-cycle. Figure 2.4 (a) shows home-ownership increasing rapidly for younger households and declining very slightly in retirement. The share of homeowners living in larger homes has a similar hump, as seen in Figure 2.4 (b), with a sharp drop at age 50. Both of these charts document the strategy of households trading down in retirement to access housing wealth to £nance consumption. Figure 2.4 (c) documents an interesting pattern. Households who have recently purchased their homes are required to have an initial loan-to-value ratio of 80%. They are then able to pay down their mortgage through the regular amortization schedule and the average loan-to-value ratio falls. The average loan-to-value ratio seems to stabilize at 10% before climbing late in retirement in response to a surge in cash-out re£nancing. Figure 2.4 (d) reports the level of re£nancing activity over the life-cycle. Younger households and those who have just purchased their homes take advantage of re£nancing to re-balance their portfolios and smooth their income. Older households start to use cash-out re£nances to access their equity.

In Figure 2.4 (b) there was a sharp drop in the share of households living in large homes at age 50, with the share falling from a high of 20% to 16%. The timing of this sudden shift into smaller homes is a result of the 30-year mortgage combined with a maximum age of 80 imposed by the model speci£cations. Households take advantage of the 30-year mortgage term to lock in their nominal mortgage payments for the rest of their natural lives. Figuree 1.9 provides additional support for this hypothesis. In addition to the baseline simulations this £gure also reports the simulations with the a 20-year mortgage and when retirement is delayed until 75. The goal is to demonstrate that the shift into smaller homes is driven by the

Figure 1.9: Why Trade Down at 50?



length of the mortgage term and not the proximity to retirement. When the retirement age is 75 and the mortgage term is 30 years, the shift to smalle homes still happens at age 50. When the mortgage term is shortened to 20 years and the retirement age remains at 65, the shift to smaller homes occurs at age 60. These alternate scenarios show that the shift to smaller homes is driven by the household's desire to lock-in their nominal mortage payment in retirement. The bene£t of this strategy is that while they will continue to receive a constant stream of utility from their home, the real value of the mortgage payments will fall due to in¤ation. In effect, households are purchasing an annuity where the stream of real payments, the difference between the implicit rent and the real mortgage cost, will increase with time and be at its highest during retirement when income is at its lowest.

Table 2.5 below shows some of the sample statistics from the simulation results. The share of the total portfolio held in home equity for large homeowners is 35.5% and for small homeowners is 42.5%. These numbers show that the model is partially successful in capturing the "over-investment" in housing. The model also captures how wealthier, better diversi£ed households tend to own larger homes. These results also show how renters, who are aggressively saving for a down payment, have the smallest risky asset portfolio share.

Table 1.1: Simulation Results - Baseline Model

	Total	Rental Units	Small Homes	Large Homes
Percent	100%	12.6%	76.2%	11.2%
Consumption	13,820	2,140	15,190	17,570
	(7,380)	(2,440)	(6,230)	(5,890)
Financial Assets	58,090	9,670	60,810	94,010
	(58,840)	(11,120)	(57,670)	(64,490)
Risky Asset Share	83.3%	28.9%	91.3%	90.0%
	(26.3%)	(21.8%)	(15.4%)	(15.6%)
Tenure Length	8.5	1.0	9.4	10.3
	(9.0)	(0.0)	(9.2)	(8.8)
Net Equity in Home			37,710	50,240
			(28,530)	(38,010)
Home Equity Share			42.5%	35.5%
			(195.3%)	(28.1%)

Note: The standard deviations are presented in parentheses.

1.4.3 Tenure Transitions

Table 1.2 more fully explores the role of housing tenure decisions in the model. It demonstrates that households are eager to move out of rental housing with almost 20% of all renters purchasing homes in the next period. Households that have saved enough money by their mid-twenties are able to move into small homes. In a only one case out of the 1,000 simulations, does a household move directly from a rental to a large home. This household, in particular, had just recieved a very large positive income shock that allowed them to £nance the purchase of the home. Huseholds that are still saving for a downpayment tend to have the least held in risky assets, only 27.1% of the £nancial portfolio. Households that have already saved enough to purchase a home hold more in risky assets.

The transition out of small homes seldom occurs. Almost 98.2% of small home-owners remain in small homes. Half of those who do remain are trading up to larger homes, while one-quarter are returning the rental market and one-quarter are extracting home equity through cash-out re£nancing. Households who run into £nancial trouble and are forced to return to the rental market do so fairly quickly, averaging less than four years in their current home. Given that their average age is close to 60, while the average age of a £rst-time home buyer is close to 30, these are households who became homeowners late in life due to poor income and return on equity shocks early in the life-cycle. As relatively recent homeowners, they have not yet accumulated a signi£cant amount of home equity. Households with low loan-to-value ratios but high share of housing in their portfolio are the most likely to take cash-out re£nances. Households who are staying put and not re£nancing have the largest risky asset share in their £nancial portfolio, while those being forced to move to rental housing have the lowest. Households trading up also hold lower shares of risky assets in their £nancial portfolios. This is another example of the inverse relationship between demand for home equity and for risky assets. Recent poor income and investment shocks contribute to the decision to return to rental housing while very strong positive shocks to housing encourage the households to trade-up.

Table 1.2: Tenure Transitions - Baseline Model

Current Status		Not Moving	Rent	Buy Small Home	Buy Large Home	Cash-Out Re£
Renter	Transition Probability		82.2%	17.79%	0.01%	
	Financial Wealth		7,690	18,820	12,960	
	Risky Portfolio Share		27.1%	37.2%	80.0%	
	Age		24.2	29.0	29.0	
	Risky Asset Shock Last Period		5.5%	5.4%	-7.8%	
	Wage Shock Last Period		3,090	2,640	4,440	
Small Home	Transition Probability	98.2%	0.5%		0.9%	0.4%
	Financial Wealth	61,390	7,880		45,120	1,400
	Housing Wealth	36,950	66,970		89,180	73,390
	Risky Portfolio Share	91.8%	45.3%		76.9%	59.1%
	Portfolio Share of Housing	41.8%	87.1%		69.3%	86.8%
	Loan-To-Value Ratio	38.4%	22.4%		26.0%	20.8%
	Age	49.5	59.0		45.6	57.8
	Tenure Length	9.5	3.6		8.7	7.9
	Housing Shock Last Period	1.0%	0.3%		1.7%	0.5%
	Risky Asset Shock Last Period	5.4%	6.8%		4.3%	5.7%
	Wage Shock Last Period	6,170	2,720		4,440	4,650
Large Home	Transition Probability	96.0%	0.1%	3.9%		
	Financial Wealth	95,320	1,980	64,150		
	Housing Wealth	48,830	45,580	84,550		
	Risky Portfolio Share	90.7%	52.0%	72.3%		
	Portfolio Share of Housing	34.5%	95.6%	58.7%		
	Loan-To-Value Ratio	47.6%	8.1%	40.0%		
	Age	54.4	78.2	57.9		
	Tenure Length	10.5	4.8	5.5		
	Housing Shock Last Period	1.0%	-2.5%	0.8%		
	Risky Asset Shock Last Period	5.1%	10.4%	6.0%		
	Wage Shock Last Period	6,610	2,410	10,420		

Once households have managed to move into large homes, they naturally prefer to stay there. Of these homeowners, 96%, do not move. Interestly, none of these households utilize cash-out re£nancing to extract home equity. They do trade down to smaller homes or to rental units. Most of the movers are trading down into smaller homes. The households have a higher portfolio share of housing, a lower LTV ratio, and lower share of their £nancial portfolio in risky assets than those households not trading down. Households trading down to smaller homes also have large recent positive income shocks, allowing them the pay for the transaction costs associated with the move. Households with very little £nancial wealth who have also had recent poor income shocks are more likely to move directly into rental units. These households are also signi£cantly older than those trading down to smaller homes or staying put. Again, these homeowners take the most conservative positions in the £nancial portfolio.

This section has established the most signi£cant accomplishment of the model the ability to partially match the ”over-investment” in housing seen in the data within a framework of rational, forward-looking agents. This section has also argued that the optimal share of risky assets in the £nancial portfolio is effected by both the level of investment in housing and the endogenous tenure choices of the household. The next section will build on these results with a detailed examination of how the unique nature of housing wealth affects the demand for housing and the allocation of household portfolios.

1.5 Alternative Scenarios.

The previous section provided evidence that the baseline model can match certain stylized facts about housing wealth over the life-cycle. This section determines exactly in what way does these three speci£c aspects of housing wealth affect the demand for housing and £nancial portfolio allocation over the life-cycle. This is accomplished through a series of comparative static exercises. The three aspects of housing wealth being investigated are in each turn excluded from the model. Each alternative model is then re-solved and the simulations regenerated. The levels of wealth accumulation, housing demand, re£nance activity, and portfolio allocation under each alternative assumption are then compared to the base case. Table 1.3 summarizes how the model is altered for each of the alternative scenarios. Table 1.4 summarizes the effects of each scenario on the demand for housing wealth, £nancial assets, total portfolio share of housing, and the £nancial portfolio share of risky assets.

Table 1.3: Assumptions for Alternative Scenarios

Alternative Assumption	Model Effects
Dual Investment/Consumption Role	
Consumption Only	Replace (1.16) with (1.22)
	Replace (1.17) with (1.23)
	Replace (1.5) with (1.24)
Investment Only	Replace (2.2) with (1.25)
	Replace (C.7) with (1.26)
Nominal Mortgage Contract	
High In¤ation	$\nu = 6\%$
Real Mortgage Contract	$\nu = 0\%$
Taxes	
Tax Implicit Rent	Replace (C.7) with (1.27)
Tax Capital Gains	Replace (1.16) with (1.28)
No Mortgage Int. Deduction	$I_t(i_t, \kappa_t) = 0, i_t \in i_r, i_s, i_l, i_t$

Table 1.4: Results of Alternative Scenarios

Alternative Assumption	H_t	A_t	$\frac{H_t}{H_t+A_t}$	α_t
Consumption Only	NA	$\leftrightarrow$	NA	$\downarrow$
Investment Only	$\uparrow$	$\downarrow$	$\uparrow$	$\uparrow$
High In¤ation	$\uparrow$,$\downarrow$ in 50's	$\uparrow$	$\downarrow$ in 50's	$\uparrow$ young,$\downarrow$ old
Real Mortgage Contract	$\uparrow$,$\downarrow$ old	$\leftrightarrow$	$\leftrightarrow$	$\downarrow$ young
Tax Implicit Rent	$\downarrow$	$\leftrightarrow$	$\leftrightarrow$	$\downarrow$
Tax Capital Gains	$\downarrow$	$\uparrow$	$\downarrow$	$\downarrow$
No Mortgage Int. Deduction	$\uparrow$ old	$\uparrow$	$\leftrightarrow$	$\leftrightarrow$

1.5.1 Housing as an Investment and Consumption Good

The £rst set of alternate scenarios are used to examine the consumption and investment motives for housing demand in isolation. To rede£ne housing as only a consumption good, the equation for the net gain from a home sale is rede£ned. Households face the same downpayment constraints and transaction costs for selling a home. They also make the same mortgage payments and still must repay the outstanding mortgage balance when they sell the home. The difference is that these expenses merely purchase the stream of housing services associated with the home, not the home itself. Under this alternative, no such thing as housing wealth exists. Households have no home equity to access either by trading down or through cash out re£nances. This de£nition of housing several handicaps owner-occupied housing as a consumption good when compared to rental housing. The size of rental housing is allowed to shift so that the intra-period marginal utility from housing equals the intra-period marginal utility from non-durable consumption. In order to correct this handicap, rental housing in this scenario is restricted to be equal in size to that of a small home. The new equation for the net gain from selling a home is:

$$G_t(i_t, i_{t+1}, \kappa_t) = \begin{cases} -\max(D_t(i_t,\kappa_t) - H_t) - \mu P_t(i_{t+1}) - \tau H_t - \chi, & i_{t+1} \in i_r, i_s, i_l \\ 0, & i_{t+1} = i_t \end{cases} \tag{1.22}$$

and the new equation for the net gain from re£nancing is:

$$Z_t(\kappa_t, \kappa_{t+1}) = 0, \tag{1.23}$$

and the size of the rental unit is constrained to equal the size of a small home:

$$h(i_r) = h(i_s). \tag{1.24}$$

The ¤ip side of this scenario is one in which housing acts only as an investment good and does not directly enter the utility function. Under this scenario all households rent in every period of their life. The households always choose the number of housing units to rent such that intra-period marginal utility of housing is equal to the marginal utility of non-durable consumption. Households may also purchase small or large homes. However, now they do not consume the housing services associated with these homes. Rather, they rent these homes and receive a stream of income based on the market rental rates. Homes are still purchased with a mortgage and still have all their previous tax advantages. Now the utility function assumes that households always rent:

$$E\sum_{t=20}^{80} \beta^t \rho_t U(c_t, h(i_r)) + \beta^t(1-\rho_t)(\theta_A U_B(A_t) + \theta_H U_B(H_t) - \theta_D U_B(D_t)) \quad c_t > 0, \forall t \tag{1.25}$$

The housing costs for home owners include their new rent payment for the housing that they consume, $0.06P_t(i_r)$, and the rent payment they receive as landlord for the housing that they own, $0.06P_t(i_t)$;

$$X_t(i_t, \kappa_t) = \begin{cases} 0.06P_t(i_r) - 0.06P_t(i_t) + M_t(i_t,\kappa_t) + \delta H_t, & i_t \in i_s, i_l \\ 0.06P_t(i_r), & i_t = i_r \end{cases} \tag{1.26}$$

Figures 1.10 and 1.11 show the simulation results for the alternate scenarios where housing is a consumption good only and for when it is an investment good only. Note that when housing is a consumption good only, no housing wealth results and naturally no share of the total portfolio is held in housing. When housing is a consumption good only, households hold slightly more £nancial wealth. They also change the allocation of their £nancial portfolio, with the younger and older households holding fewer risky assets. Young households no longer are able to diversify across both risky £nancial assets and risky housing equity and invest less of their portfolio in risky assets. Older households no longer have a store of home equity that they may replenish their £nancial portfolio with through cash-out re£nances. As a results, they too invest a small share of their portfolio in risky assets. The demand for housing also drops with almost no households purchasing large homes. This result implies that the demand for large homes, absent any demographic factors, is driven primarily by the investment motive.

The results from the investment good only scenario are especially enlightening. A common explanation for the "over-investment" in housing is that household's simply desire to consume more house than they wish to invest in. Therefore, the consumption motive is often £ngered as the culprit for the large share of the household's total portfolio held in home equity. Interestingly enough, when the consumption motive is removed the demand for housing increases. As can be seen in Figure 1.10(a) the level of housing wealth increases, at the expense of £nancial wealth. The share of the total housing portfolio held in home equity also increases as does the share of the £nancial portfolio held in risky assets. This increase in exposure to risk from both housing and risky assets is in response to the homeowners now having a risk-free stream of rent payments from their housing investment. The presence of this risk-free income stream increases their tolerance of risk elsewhere in their portfolio. The demand for housing increases as well with both the home-ownership rate and the share of homeowners buying larger houses increasing.

It is important when comparing the results of these two scenarios to keep in mind that the consumption and investment motives of housing are not being examined in isolation. The advantage of using the detailed partial equilibrium model is the richness of the detail. The bene£ts from the tax treatment of housing and most importantly the mortgage contract are held constant across the scenarios. Investors are drawn to the ability to create a leveraged portfolio through the mortgage and receive a steady tax-free stream of

Figure 1.10: Wealth and Portfolio Choice

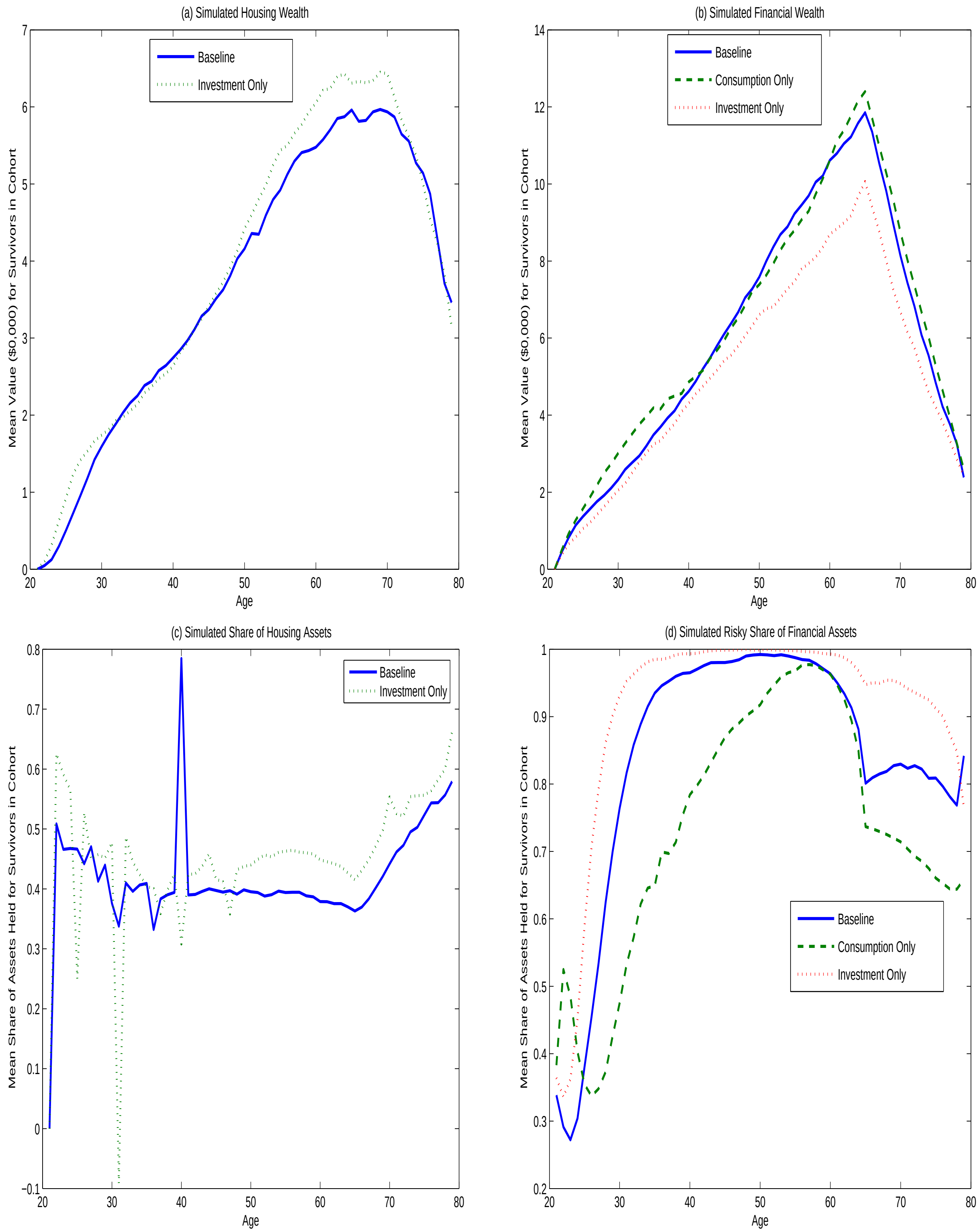
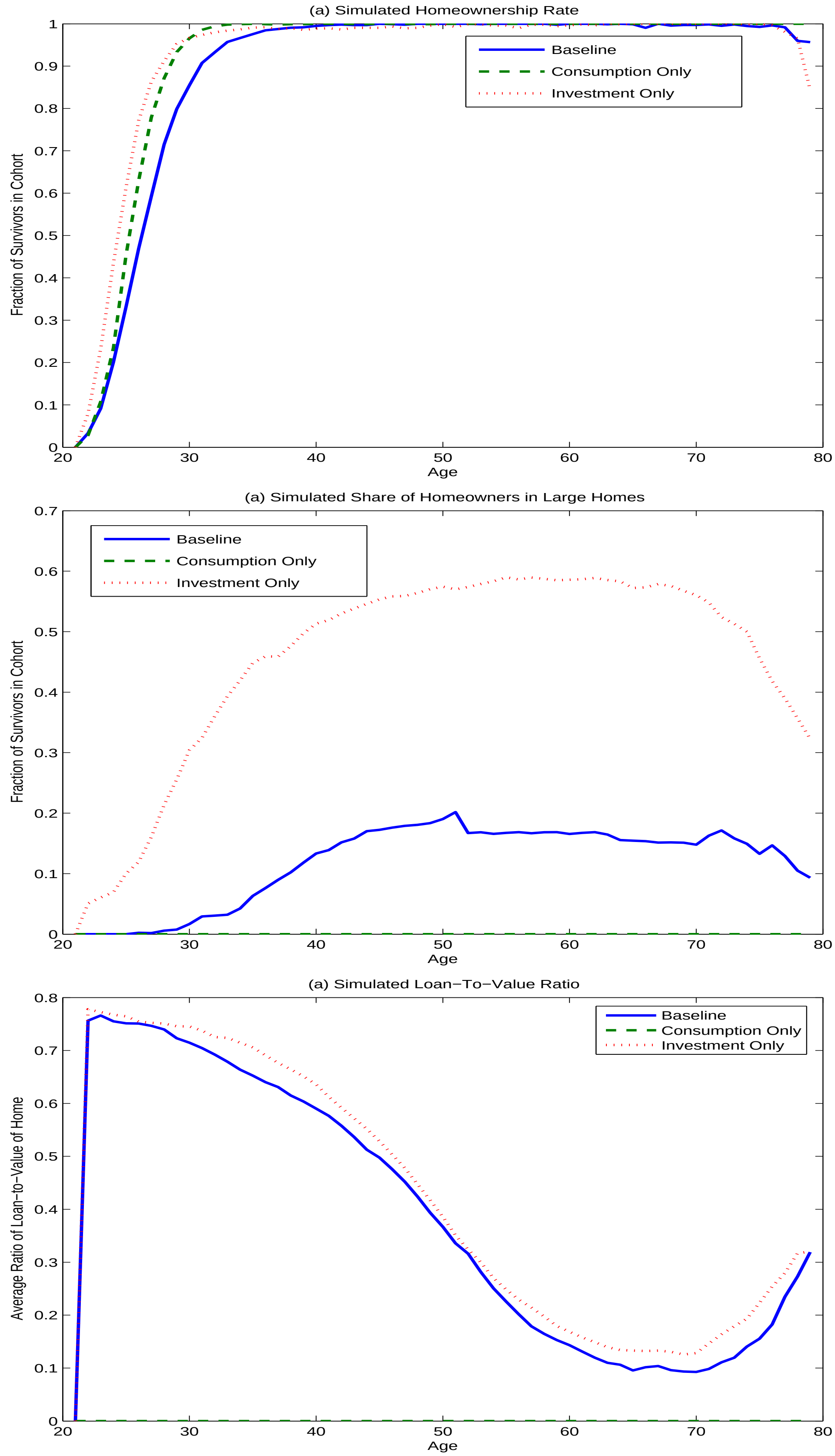
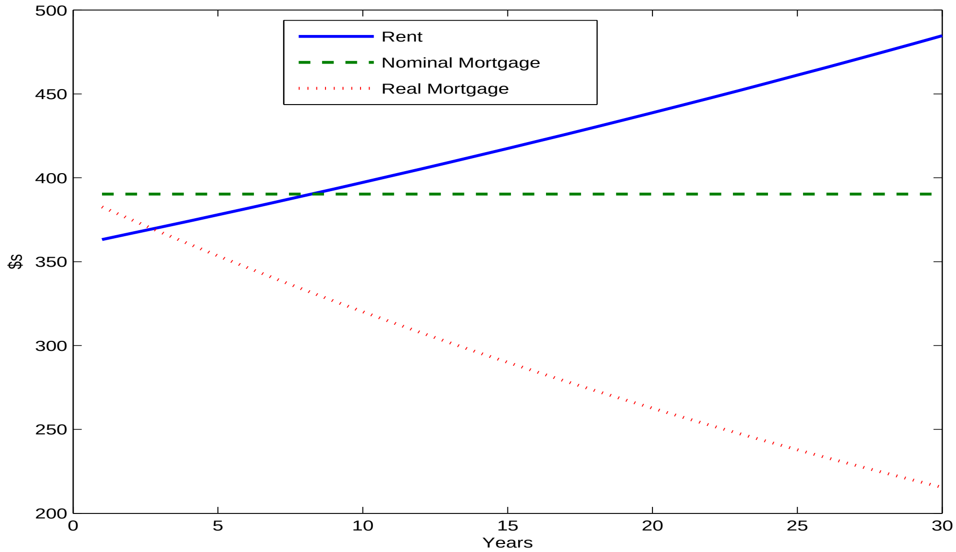


Figure 1.11: Housing Tenure Choice



dividends. Consumers appreciate the ability to lock in their housing costs at a £xed amount, even though they will never see the money they put into the house again. This is true even though, in both alternate scenarios, the deck is stacked against housing. The results emphasize the fact that the mortgage contract itself has signi£cant economic value to the household, above and beyond the attraction of housing as a consumption or investment good.

Figure 1.12: Rent and Mortgage Payments



1.5.2 Effects of In¤ation on Housing Wealth

The next set of scenarios are relatively more simple to model. All that is needed in order to simulate the effects of high in¤ation, or of mortgage contracts that are real and not nominal is to set the in¤ation parameter respectively to a higher level or to zero. The presence of nominal mortgage contracts effectively reduces the costs of home-ownership. The higher the in¤ation rate, the lower the costs of home-ownership, as can be seen in Figure 1.12 which documents how the real value of the mortgage payment declines over the life of the mortgage. This is of course factored into the rate of the orginal mortgage and partially explains the gap between the mortgage and risk-free rate. Figures 2.5 and 1.14 show how housing demand and portfolio allocation differs under different in¤ation rates. High in¤ation increases the rate at which the nominal mortgage payments are discounted over time. As a result, there is a much more pronounced move from large to small homes at age 50 under the high in¤ation scenario. Households are eager to purchase

Figure 1.13: Wealth and Portfolio Choice

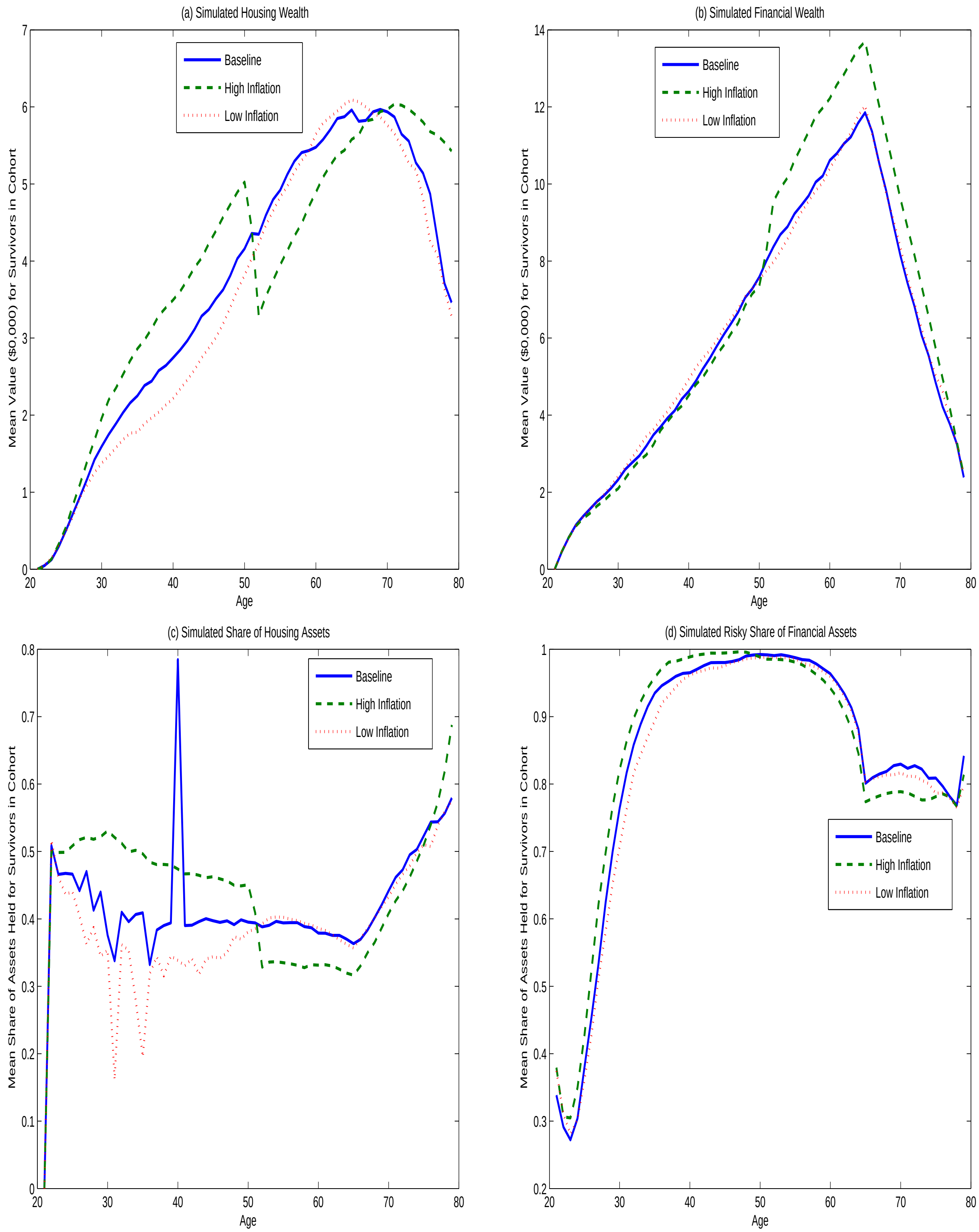
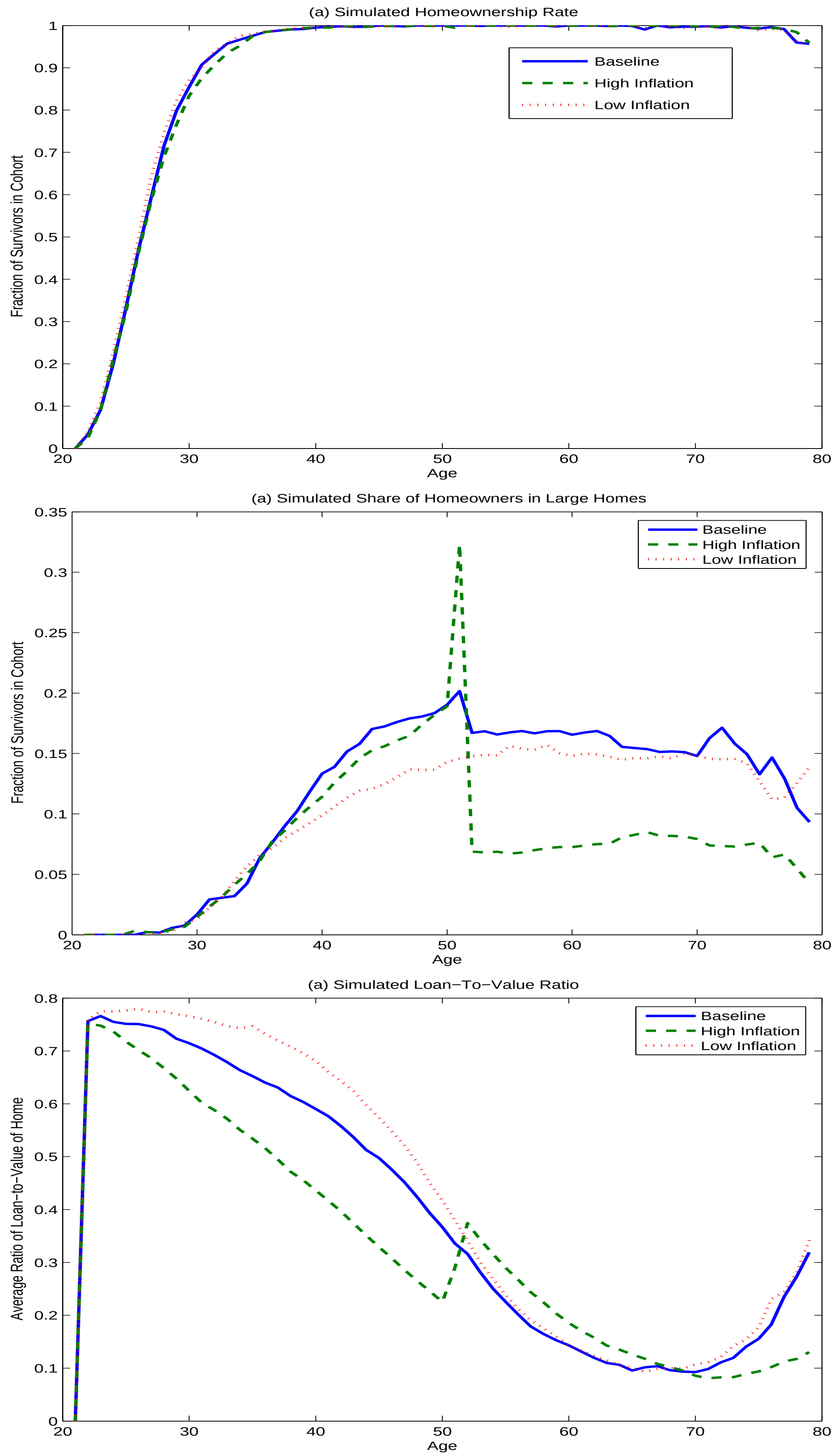


Figure 1.14: Housing Tenure Choice



small homes at age 50 and lock in their nominal mortgage payments for the rest of their life. In fact they almost never move or re£nance after age 50, due to the increase value of the in¤ation discounting of the nominal mortgage payment. The main effect of zero in¤ation is to reduce the demand for large homes and remove the tendency to lock in nominal mortgage payments at age 50 as the real mortgage payments no longer decline with the age of the loan.

None of these results should come as a surprise. A reduction in the cost of housing will increase demand. Reduced housing costs will also have a wealth effect, increasing the amount of housing and £nancial wealth households can accumulate. What is of interest is the non-neutrality of in¤ation even when the in¤ation is perfectly anticipated. As was the case previously, this result is dependent on the nature of the mortgage contract, again highlighting the importance of including mortgage contracts in models of housing wealth.

Homeowners face two different expenses in purchasing their homes. The £rst expense is the upfront costs, or the downpayment. The second expense is the mortgage payments made on a monthly basis over the life of the loan. These recurring expenses are signi£cant, in that if the household cannot make these payments they will default on the mortgage and loose their existing home equity. Households in this model trade down precisely because they fear they will not be able to make the mortgage payments once their income falls in retirement. Nominal mortgage payments under high in¤ation are especially attractive to households in their £fties. The real mortgage payment is intially high, during the prime of their earnings potential. The real mortgage payment then falls rapidly during retirment, just when their income also falls. Nominal mortgage payments allow households to shift the expense of housing forward while insuring the consumption of housing later. In this way housing is a form of annuity which provides housing services instead of cash payments. The ability to shift the cost of housing forward is due to the nominal mortgage contract. The higher the rate of in¤ation, the greater the shift in costs.

1.5.3 Tax Implications

The £nal aspect of housing wealth explored in this paper is three aspects of the tax treatment of housing: (1) the implicit rental from owner-occupied housing is taxed as regular income, (2) the capital

Figure 1.15: Wealth and Portfolio Choice

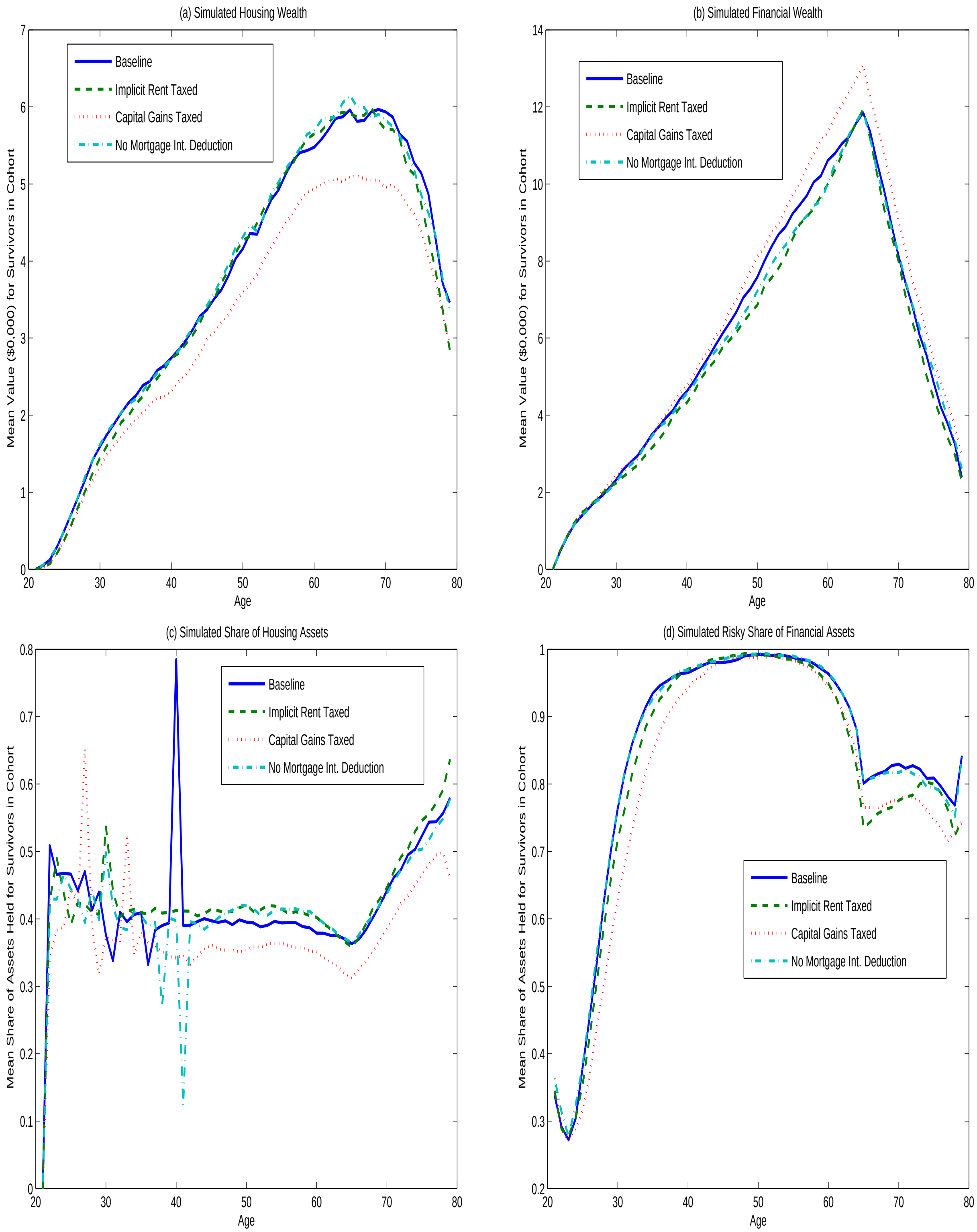
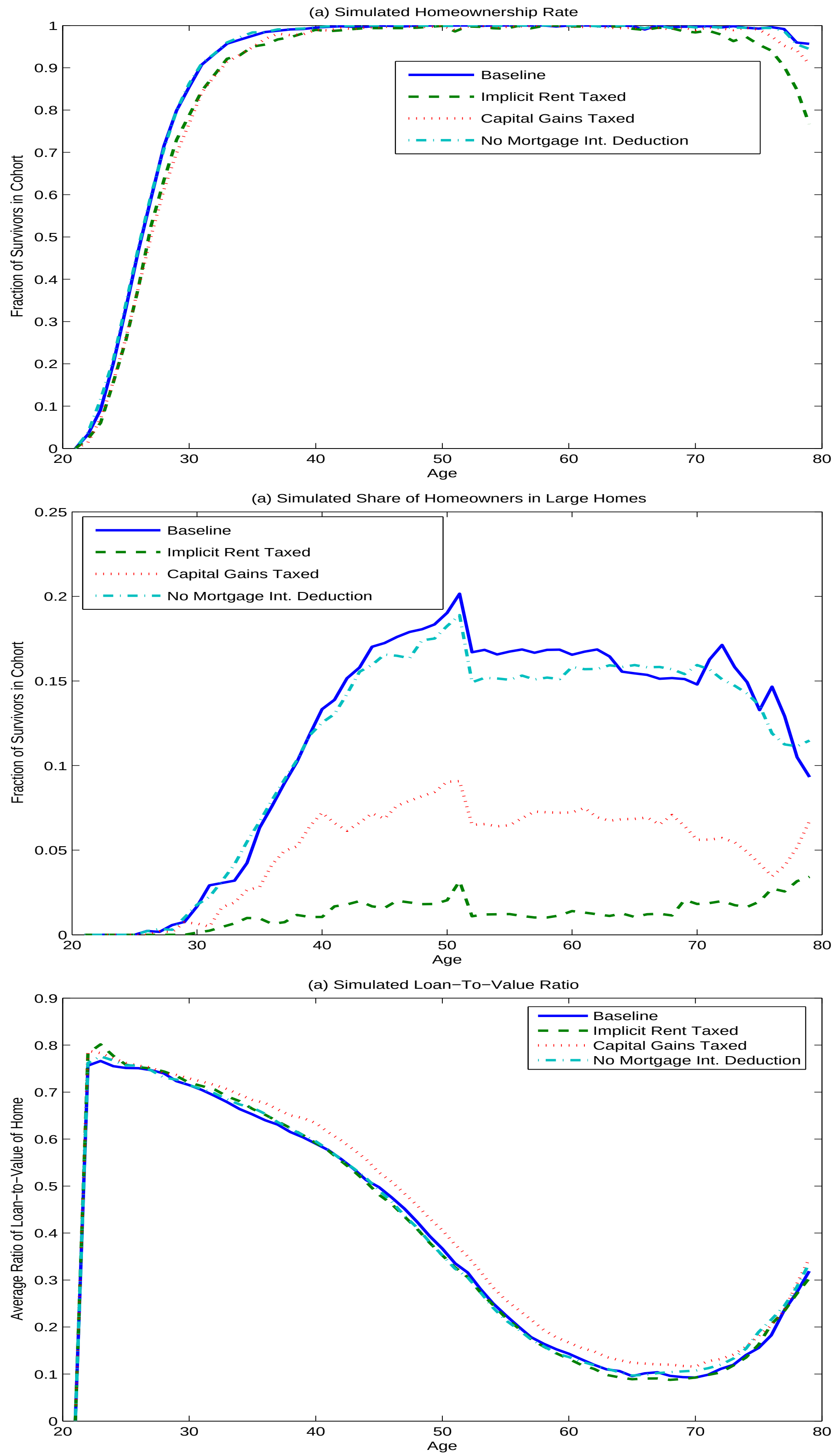


Figure 1.16: Housing Tenure Choice



gains from housing is taxed, and (3) mortgage interest is no longer tax-deductable. These £nal scenarios explore to what extent this bene£cial tax treatment contributes to the demand for housing and distorts household portfolio allocation. Under the £rst scenario, the household must pay tax on the level of implicit rent they receive from their home. Renters naturally receive no implicit rent, they are paying explicit rent out of after-tax income. The implicit rent is de£ned based on the market rent for the type of home and not the actual value of the individual home. The equation for the housing costs now is:

$$X_t(i_t, \kappa_t) = \begin{cases} M_t(i_t, \kappa_t) + \delta H_t + \gamma 0.06 P_t(i_t), & i_t \in i_s, i_l \\ 0.06 P_t(i_r), & i_t = i_r \end{cases} \tag{1.27}$$

The second version of this scenario imposes a tax on the capital gains from home sale. Recent tax legislation as progressively increase the amount of capital gains from home sales that can be shielded from tax.

$$G_t(i_t, i_{t+1}, \kappa_t) = \begin{cases} (1-\gamma)(H_t - D_t(i_t, \kappa_t)) - \mu P_t(i_{t+1}) - \tau H_t - \chi, & i_{t+1} \in i_r, i_s, i_l \\ 0, & i_{t+1} = i_t \end{cases} \tag{1.28}$$

The £nal version of this scenario simple suppresses the mortgage interest tax deduction. Figures 1.15 and 1.16 show the simulation results from this scenario. In the case of the repeal of the mortgage interest tax deduction, there is almost no change in the economic behavior of the households except a slight decline in the demand for large homes, suggesting that this policy's contribution to increasing home ownership is questionable at best. Taxing implicit rent slightly reduces the level of £nancial wealth held, the level of investment in risky assets and signi£cantly reduces the demand for larger homes. The taxation of capital gains reduces the level of housing wealth signi£cantly and slightly increases the level of £nancial wealth. Households also hold less of their portfolio in housing and less of their £nancial portfolio in risky assets. They also purchase homes later in life and purchase fewer large homes. Interestingly the capital gains provision seems to have the greatest effect on behavior, expect in the case of the demand for large homes, where the tax on implicit rent seems to have the greatest effect. These results make it clear that the tax treatment of housing has signi£cant and important impacts on economic behavior over the life-cycle.

1.6 Conclusion.

One of the goals of this paper is to explain the life-cycle patterns in both home ownership and portfolio allocation using a model of rational agents. Two key innovations are incorporated in the model. First, housing is explicitly modeled as both a consumption and investment good, as opposed to examining just one aspect in isolation from the other. Second, mortgage contracts are explicitly introduced into the model. The result is a more realistic treatment of the role of housing in an agent's economic decision-making over its lifetime. The model is then used to explore the relationship between the housing share and risky asset share of household portfolios.

The baseline model succeeds in partially replicating home equity's large position in household level portfolios. The implication is that while some degree ”over-investment” in housing is the result of something innate in the nature of the housing good or the mortgage contract used to purchase it and not the result of sub-optimal behavior by non-rational consumers, the actual level of ”over-investment” in housing seen empirically cannot be fully explained. The transitory nature of housing, as households react to wealth and income shocks by trading up and down, is also captured by the model. Other key results are the importance of housing wealth in retirement and the role of cash-out re£nances. Finally, the model shows how the allocation of the £nancial portfolio varies in response to the position in housing wealth and tenure decisions. The intial introduction of risky housing can increase the demand for risky £nancial assets, as household gain the ability to diversify across uncorrelated risky assets. As the exposure to risky housing assets grows however, household respond to the increased background risk by reducing their demand for risky assets.

The baseline model is then compared with a set of alternate scenarios to explore three key aspects of housing wealth: (1) housing's dual role as a consumption and investment good; (2) the signi£cance of the mortgage contract being in nominal and not real terms; and (3) the bene£ts of the tax treatment of owner-occupied housing. The results show that the “over-investment” in housing is not just a function of consumption demand but can also be driven by the bene£ts inherent in the mortgage contract. It also shows that the nominal mortgage contract results in the non-neutrality of perfectly expected in¤ation. Finally, the contribution of the favorable tax treatment on housing demand is documented.

Chapter 2

Mortgage Contracts and the Heterogeneity in the Total Return on Housing

2.1 Introduction.

Of all the assets held by households, home equity is second in importance only to human capital. Households hold on average more than half of their portfolios in home equity. Recent work has explored how a household's holdings of home equity might distort the allocation of their £nancial portfolio. The unique nature of home equity as an investment asset complicates efforts to measure its total rate of return and the risk associated with it. This paper explores how three aspects of home equity can affect the risk and return facing the household: (1) the role of the mortgage contract, (2) the consumption role of housing, and (3) the uncertain holding period of housing.

Home equity differs from £nancial assets in many ways. There are large transaction costs associated with the purchase of a home. There is no secondary market for home equity. A house is a large, non-divisible asset that is inescapably tied with a given geographic location and the associated labor market. However the most signi£cant aspect of home equity is the use of a mortgage contract by the homeowner to purchase the house. This paper focuses on three speci£c effects of the mortgage contract on the risk and return on housing: (1) the cost of the associated stream of mortgage payments, (2) the mortgage interest tax deduction, and (3) the leveraging effect of the mortgage.

Calculating the rate of return on a £nancial asset is fairly straightforward. The total return is simply divided by the original purchase amount. The situation is complicated when a household takes out a mortgage to purchases a home. The asset in question, the home, is inextricably linked with a liability, the mortgage. The original cost of establishing a portfolio consisting of the home and the associated mortgage is the amount of the initial downpayment. A naive de£nition of the payoff would be the difference between the value of the asset and the related liability at time of sale, i.e. the value of the house minus the remaining balance of the mortgage. However, in addition to the initial downpayment, the household commits to making a stream of mortgage payments for the life of the mortgage. A de£nition of the total return on housing must take into account the oppurtunity costs associated with this stream of payments.

Owner-occupant households with mortgages bene£t from generous tax treatment. They are allowed to deduct from taxable income the portion of mortgage payments that go toward interest payments. This bene£t introduces two important sources of variation in the total return on housing. First, households with higher marginal tax rates reap a greater bene£t from the mortgage interest tax deduction, thereby reducing the progressivity of the tax system and increasing the total return on housing for those with higher incomes. Secondly, the deduction applies only to the interest portion of the mortgage payment, not the entire payment. With a standard self-amortizing loan, the interest portion of the payment is initially quite large and slowly shrinks over time. As a result, two identical households holding two identical homes will have different total returns on housing if they hold mortgages of different ages.

The £nal, and perhaps most signi£cant, aspect of home equity explored in this paper is the leveraging effect of the mortgage. A household is only required to put up a fraction of a home's value as a downpayment, while retaining the entire gain or loss associated with the home. In effect, the household holds a leveraged portfolio in the local real estate market. As with any leveraged portfolio, this signi£cantly increases both the risk and return association with the investment. Home equity also differs in a quite signi£cant way from a traditional leveraged portfolio in £nancial assets. With a traditional leveraged portfolio the investor must maintain a minimum equity position. If the value of the underlying asset falls too far, the investor faces a margin call and must either provide additional equity or sell the portfolio at the current market value. A homeowner faces no such margin call if the value of her home falls below the remaining balance of the mortgage.

The possibility of negative equity signi£cantly complicates the analysis of housing as an investment good. A further complication is that households have the option to default and walk away from both the house and the related mortgage at a cost to their future access to credit. Research has shown that the probability of negative equity is one of the key predictors of mortgage defaults, see Deng, Quigley and Van Order (2002) for a recent example. It is important to note that the mere existence of negative equity does not force a default. The borrower only faces the requirement to repay the negative equity if they sell their home. If the choice to move is entirely endogenous, the homeowner may choose to remain in the home until the local housing market recovers and she no longer faces a negative equity position. The homeowner must address this negative equity position only if she is unable to make her required mortgage payments or faces an exogenous need to move. Such an exogenous move might be driven by a change in household composition through marriage or divorce or an income shock through a job loss or signi£cant illness. In calculating the risk and return on housing, special attention must be paid to the possibility of negative equity.

Several recent papers have explored how a household with a large position in housing might respond to the undiversi£ed risk associated with housing by lowering demand for risky £nancial assets. Most of these papers do not address the heterogenity in the return on housing caused by institutional features of the tax code and of mortgage contracts. If the mean and variance of the rate of return on housing vary with property, mortgage, and borrower characteristics, so will the demand for risky assets. If macroeconomic shifts affect the housing and mortgage choices of households, such as a shift to higher loan-to-value ratios in response to rapidly increasing prices, they might also affect the demand for risky assets by changing the mean and variance of housing returns.

This paper develops an alternative measure of the return on housing that incorporates the consumption stream and the required mortgage payments associated with owner-occupied housing. This measure is then used to demonstrate how the total return on housing varies with anticipated holding length, terms of the mortgage contract, and borrower income level using both simulated returns and data from the American Housing Survey.

2.2 Literature Review.

Many papers have explored the return on housing; however, few have explicitly accounted for the effect of mortgage contracts on that return. One common measure of the return on housing is the user cost. As de£ned in Poterba (1984),the user cost equals the "after-tax depreciation, repair cost, property taxes, mortgage interest payments, and the oppurtunity cost of housing equity, minus the capital gain on the housing structure." While this measure has proved very useful and is widely accepted, it does have several signi£cant drawbacks. The measure does not capture the value associated with either the stream of mortgage payments or the stream of implicit rents received from the house. This measure also does not vary with holding period or re¤ect the risks associated with negative total return.

The connection between a household's holdings in housing and the allocation of its £nancial portfolio has been examined in several papers. Flavin and Yamashita (2002) document that households holding larger positions in home equity hold smaller positions in £nancial equities. They abstract completely from the mortgage contract and de£ne the return on housing solely as capital gains and implicit rents minus maintenance costs and property taxes. Fratantoni (1997) solves a £nite-horizon model with exogenous housing consumption and shows that introducing housing in the model reduces the share of risky assets held by households. Fratantoni (2001) then shows that the commitment to make future mortgage payments results in a lower level of £nancial equity holdings.

Englund, Hwang, and Quigley (2000) estimate a VAR model of investment returns that includes both risky assets and housing. They measure the return on housing using repeat sales in Sweden. The authors do not include the effects of the mortgage contract on the return on housing, but do observe how the risk and return varies with the holding period. Case and Shiller (1990) £nd that persistent excess returns do exist in the housing market and are positively related to the ratio of construction costs to prices, real per capita income growth, and increases in the adult population. Their measure represents an annual return on housing for an existing home owner, but not the annualized return realized after a home sale. Therefore the measure does not take into account how the annualized return varies over the length of a mortgage. Additionally, their analysis is focused on MSA level housing returns, not individual returns.

The measure of housing return developed in this paper is closest to that of Hendershott and Hu (1981). Their measure incorporates the effects of the stream of mortgage payments and implicit rents associated with the home. The measure in this paper differs most signi£cantly by including the oppurtunity cost of these streams, instead of just the nominal level of the streams. In both Case and Shiller and Hendershott and Hu, the authors develop measures of the implicit rents either from MSA level rental rents or by assuming that certain market clearing conditions are met. The implicit rent measure used in this paper is based on an econometric estimates of the capitalization rate (discussed in Appendix C) and should provide a better measure of the implicit rent. The other significant difference in this work is its focus on explaining variation in the return on housing at the individual level versus the MSA or economy-wide level.

2.3 Theory.

This section defines a measure that captures the total return on housing, including the stream of consumption services and mortgage payments associated with owner-occupied housing. This measure is similar to that developed in Hendershott and Hu (1981). The total rate of return is defined as interest rate that sets the net present value (NPV) of the household's outflows equal to the net present value of its inflows. The outflows include the intial downpayment and the net present value of the stream of mortgage payments and maintenance costs. The inflows include the net present value of the stream of implicit rent generated by the home. The final component of the total return measure is the net present value of the net proceeds of the sale of the home, or the current home value net of transaction costs and the remaining mortgage balance at time of sale. The net proceeds from the home sale may be either positive or negative. When the value of the home is greater than the sum of the transaction costs and the remaining mortgage balance, the net proceeds represents an inflow for the household. When the sum of the transaction costs and the remaining mortgage balance is greater than the value of the home, the net proceeds represents another outflow for the household.

This treatment of the net proceeds is important. Previous definitions of the return on housing have not explicitly addressed the risk of negative equity and how that effects the rate of return. However, this treatment, while more detailed, still includes a significant ommission. A household holding a mortgage on a home has the option to default on the mortgage, and surrender the property to the lender. The default will result in certain costs for the household, such as significantly increasing their future borrowing costs. However, if the household has a large negative equity position in their home, defaulting on the mortgage is the optimal strategy . A true measure the rate of total return would include a lower bound for the outflows associated with negative net proceeds. The lower bound would be the point at which it would be optimal for a household to exercise their default option and walk away from the negative equity position in their home. The outflows beyound this point would be fixed at the value associated with the households increased borrowing costs resulting from the default. The increase in borrower costs will vary a great deal across households, depending on their stage in the life-cycle and whether they plan to be net lenders or borrowers in the future. A measure of the total rate of return on housing that incorporated this household speci£c lower bound on the net proceeds would result in even greater observed heterogenity in housing returns.

The rate of total return on housing is de£ned as the compound annual growth rate required to provide set the net present value of out¤ows equal to the net present value of in¤ows after a holding period of t years. The formula for the total ex post rate of total return on housing is;

$$[(H_0 - B_0) - I(NP_t < 0)(-NP_t) + \sum_i^t (M_i + P_i - \gamma(y)I_i)](1 + TR_t^H)^t = [I(NP_t > 0)NP_t + \sum_i^t D_i] \quad (2.1)$$

$$TR_t^H = \left(\frac{I(NP_t > 0)NP_t + \sum_i^t D_i}{(H_0 - B_0) - I(NP_t < 0)(-NP_t) + \sum_i^t (M_i + P_i - \gamma(y)I_i)} \right)^{\frac{1}{t}} - 1 \quad (2.2)$$

where,

- TR_t^H represents the annualized total rate of return on housing at time t;
- NP_t represents the NPV of the net proceeds from the home sale at time t;
- I_i represents the NPV of the interest payments at time i;
- M_i represents the NPV of the property taxes and maintenance costs at time i;
- D_i represents the NPV of the implicit rent, or dividend, at time i;
- P_i represents the NPV of the mortgage payments at time i;
- $(H_0 - B_0)$ is the difference between the home value and intial mortgage balance at time 0, or the downpayment; and,
- $\gamma(y)$ is the marginal tax rate for income level y.

In reality, there are many sources of uncertainty associated with the total return on housing. The expected holding time t is not perfectly forecastable. Households might be forced to sell their house due to unforeseen shocks to household composition, i.e. divorce or job loss. Property taxes and maintenance costs may vary stochastically. Households may choose to re£nance their mortgages, take out additional home equity, or make improvements on their homes. Some households might choose mortgage contracts, such as adjustable-rate mortgages, that introduce additional sources of uncertainty into the total return on housing. However, the main thrust of this paper's argument is that the total return on housing will vary with anticipated holding length, terms of the mortgage contract, and borrower income level. Including additional sources of risk would only strengthen the key argument by introducing additional sources of heterogeneity in the return on housing, and is left to future work.

The net proceeds from the sale of a house is the difference between the value of the home and the sum of the transaction costs and the remaining mortgage balance. The formula for the net proceeds if the home is sold at time t is,

$$NP_t = (H_t - \tau H_t - B_t)(1+\nu)^{-t}, \tag{2.3}$$

where H_t represents the value of the home at time t, B_t represents the mortgage balance at time t and τ is the transaction costs associated with the home sale.

The only source of stochastic risk in the present de£nition of the total rate of return on housing is the appreciation rate of the home. The value of the home at time t is de£ned as

$$H_t = (1+\widetilde{r_h})^t H_0, \tag{2.4}$$

where,

$$\widetilde{r_h} \sim N(\eta_h, \sigma_h^2) \tag{2.5}$$

and H_0 is the initial purchase price of the home, $\widetilde{r_h}$ is the realized rate of appreciation on housing; η_h is the expected rate of appreciation on housing, and σ_h^2 is the variance of the house price growth. In general, the distribution of $\widetilde{r_h}$ is not independent of t. Case and Shiller (1990) found positive serial correlation in the return on housing over the short run and negative serial correlation over the long run. The inclusion of a more realistic stochastic process for home appreciation would result in increased heterogenity in the return on housing. Households purchasing their home during an upswing in local home prices will anticipate a very different path of appreciation that those purchasing during a fall in local home prices. The effect of cycles in local housing markets on the composition and growth of household portfolios will be examined in a companion paper.

The value of the consumption stream associated with owning a home is de£ned as the market rent the property would command. Naturally this value will change as the value of the underlying property changes. The formula for the NPV of the implicit rent received by the household in period i is,

$$D_i = (\mu(1+\tilde{r_h})^i H_0)(1+\nu)^{-t}, \tag{2.6}$$

where μ is the rent-to-price ratio. It is assumed that the rent-to-price ratio is constant over the holding period. Again, ¤uctuations in the rent-to-price ratio would be yet another source of stochastic risk that would only increase the degree of heterogeneity in the return on housing.

The household is assumed to £nance the purchase of its home with a standard £xed-rate, self-amortizing mortgage. The remaining balance in period t is de£ned as,

$$B_t = B_0 \frac{1-(1+\pi(\frac{B_0}{H_0}))^{t-\kappa}}{1-(1+\pi(\frac{B_0}{H_0}))^{-\kappa}}, \tag{2.7}$$

where B_0 is the initial mortgage balance, $\pi(\frac{B_0}{H_0})$ is the nominal mortgage interest rate, and κ is the term of the mortgage. The mortgage interest rate is an increasing function of the loan-to-value ratio, $(\frac{B_0}{H_0})$. Households willing to invest more equity bene£t from a lower mortgage interest rate. The NPV of the £xed nominal mortgage payment associated with this mortgage is de£ned as;

$$P_i = \left(\pi(\frac{B_0}{H_0})B_0[1-(1+\pi(\frac{B_0}{H_0}))^{-\kappa}]^{-1}\right)(1+\nu)^{-i}. \tag{2.8}$$

Note that this value is constant across all periods. The portion of the mortgage payment that goes toward interest on the mortgage is deductible under current tax policy; the proportion that goes towards paying down the principal is not deductible. The NPV of the amount of the interest repaid in period i is given by the formula,

$$I_i = \left(\pi(\frac{B_0}{H_0})B_0 \frac{1-(1+\pi(\frac{B_0}{H_0}))^{i-\kappa}}{1-(1+\pi(\frac{B_0}{H_0}))^{-\kappa}} \right) (1+\nu)^{-i} \tag{2.9}$$

Note that this value is decreasing in i. Property taxes could also be included in this term. Their inclusion would increase the heteorgenity in the return on housing, both due to variation in property tax rates and increasing the variation in the mortgage interest tax deduction due the progressive income tax.

The £nal component of the total return on housing is the NPV of the property tax and maintenance costs associated with owning a home. It is assumed that these costs are a constant fraction of the current value of the home and do not increase with the age of the home. The formula is

$$M_i = (\delta(1+\tilde{r}_h)^i H_0)(1+\nu)^{-i}, \tag{2.10}$$

where δ is the annual percent of home value spent on maintenance and property taxes.

A longstanding puzzle in the £nance literature is the high share of households' portfolios held in home equity. It is instructive to observe how optimal portfolio allocation is different when this alternate measure of the return on housing de£ned is used. Assume the households only have two risky assets, their home and a diversi£ed portfolio of equities. The portfolio pays no dividends. The return on housing de£ned in equation (2.2) is contingent on the length of the holding period. For consistency, it is necessary to calculate a similar holding period speci£c return on equities. The value of the equity portfolio has an annual rate of appreciation that is an i.i.d. normal random variable with the following distribution:

$$\tilde{r}_s \sim N(\eta_s, \sigma_s^2) \tag{2.11}$$

where η_s is the expected rate of appreciation on equities and σ_h^2 is the variance of the appreciation of equities. The formula for the rate of return on equities after t periods is

$$E_t = (1+\tilde{r}_s)^t E_0 \tag{2.12}$$

$$r_{s_t} = \left(\frac{(E_t - \gamma_C(E_t - E_0))(1+\nu)^{-i}}{E_0} \right)^{\frac{1}{t}} - 1, \tag{2.13}$$

where E_0 is the intital investment in the equity portfolio and γ_C is the tax rate on capital gains.

The formulas for both the return on housing and return on equities presented here are fairly complex. Instead of deriving the formula for the expected return and standard deviation analytically, the next section simulates the values of both the home and the portfolio of equities over the life of the mortgage, using equations (2.4) and (2.12). Equations (2.2) and (2.13) are then used to calculate the rate of return by year over the life of the loan. The result is an estimate of the rate of return and standard deviation of both housing and equities conditional on holding period. These estimates can be used to determine the composition of an optimal risky portfolio of these two assets conditional on holding period. The optimal risky portfolio, as de£ned by the Markowitz portfolio selection model, is the portfolio that maximizes the slope of the capital allocation line, S_p. This is done by maximizing the following objective function,

$$\max_{\alpha_h} S_p = \frac{\alpha_h E(TR_h^H) + (1-\alpha_h)E(r_{s_t})}{\alpha_h^2 \sigma^2_{TR_h^H} + (1-\alpha_h)^2 \sigma^2_{r_{s_t}}}, \tag{2.14}$$

where α_h is the share of the risky portfolio held in housing. Solving equation (2.14) provides the formula for the optimal portfolio share,

$$\alpha_h = \frac{E(TR_h^H)\sigma^2_{r_{s_t}}}{E(TR_h^H)\sigma^2_{r_{s_t}} + E(r_{s_t})\sigma^2_{TR_h^H}} \tag{2.15}$$

It is important to keep in mind that equation (2.15) provides the optimal portfolio allocation conditional on the holding period. The de£nitions of the risk and return used abstracts from several important sources of risk, most signi£cantly the risk associated with exogenous moving shocks. The optimal portfolio allocation also ignores the role of downpayment constraints on home purchase. The idea behind this particular thought experiment is not to nail down the true optimal portfolio allocation between equities and housing, but to document how the optimal portfolio share varies with the holding period, the mortgage terms, and the income of the borrower. The true optimal portfolio share of housing, accounting for all sources of risk and binding downpayment constraints would no doubt be different, but the variation in the optimal portfolio share doumented below should remain.

2.4 Simulation Results.

The expected total return on housing, as de£ned in equation (2.2) if a function of the holding period, the mortgage terms, and the income of the borrower. Equations (2.4) and (2.12) were used to generate 10,000 simulated paths of the value of the home and of the equity portfolio over the life of the mortgage. To demonstrate how the risk and return vary with the holding period the two equations are evaluated at each period for the life of a mortgage. The assumed values of the parameters are reported in Table 2.1. Figure 2.3 reports how the risk, return, and optimal portfolio shares vary with the expected holding period. The £gure contains four different de£nitions of return. The primary de£nition of housing return includes the mortgage interest tax deduction. The other de£nitions are alternate versions of the primary de£ntion. The second de£nition excludes the contribution of the mortgage interest tax deduction. The third de£nition excludes the contribution of the implicit rent payments. The fourth and £nal de£nition excludes both the bene£ts of the implicit rent and the costs of the mortgage payments and maintance, including only the return due to capital gains.

The £rst panel shows how the different measures of the total rate of return on housing varies with holding period. Given the large transaction costs associated with selling a home, a household must wait several years until their expected appreciation can cover the transaction costs. For the £rst two de£nitions of return, the rate of return levels off by year £ve and declines slightly over the rest of the holding period. The rate of return is concave over the holding period for all de£nitions of return. Naturally, excluding the bene£ts from the mortgage interest tax deduction or implicit rent signi£cantly lowers the rate of return. The second panel reports the probability of negative total return as a function of holding period. Negative total returns are de£ned as when the NPV of out¤ows exceeds the NPV of in¤ows. Immediately after a home purchase, the probability of negative total return is quite high due to the large transaction costs. In the absence of the bene£ts from implicit rent, the probability remains very high for all holding periods. For the other de£nitions the probability drops rapidly with holding period, as the mortgage balance is paid down and housing continues to apperciate. The £nal panel reports the standard deviation of the return on housing. For all de£nitions of the return on housing, the standard deviation is quite high for short holding periods. As the length of the holding period increases, the standard deviation falls. The standard deviation is signi£cantly lower when the role of implicit rent is accounted for. The falling standard deviation is due to two factors. First, The i.i.d. distribution of the appreciation rate of housing encourages mean reversion over time. Second, longer holding periods reduce the size of the mortgage balance, reducing the amount of leverage in housing, in turn lowering standard deviation associated with the investment.

Table 2.1: Parameter Assumptions

Parameter Name and De£nition	Symbol	Value
In¤ation Rate	ν	2%
Initial price of house, in period 0	H_0	100
Initial mortgage balance, in period 0	B_0	80
Initial equity portfolio balance, in period 0	E_0	100
Annual appreciation rate for housing	η_h	3%
Standard deviation of housing spperciation	σ_h	11.5%
Mean of return on risky asset	η_s	8%
Standard deviation of risky asset return	σ_s	15.7%
Rent-to-price ratio	μ	8%
Nominal Mortgage interest rate	π	8%
Mortgage term	κ	30 years
Percent of home price lost to transaction costs	τ	10%
Maintenance and Property Taxes	δ	3%
Capital Gains Tax Rate	γ_C	15%

Note: Units are in $10,000s or percent.

The concave nature of the return on housing over the holding period warrants further investigation. This concavity is robust across different de£nitions of return and different parameter values. Figure 2.2 reports the average values of the components of housing return. This chart graphs the average value from the simulations of the net present value of the home, the mortgage balance, and both the sum of net implicit rent recieved to date and the sum of mortgage payments paid to date. The implicit rent is reported net of maintance costs and property taxes. Both the value of the home and the value of the net implicit rent are increasing linearly with holding period. The value of the mortgage balance is decreasing linearly, while the value of the mortgage payments in increasing, but is concave over the holding period. The mortgage payments are concave over the holding period because they are £xed in nominal terms. While the ¤ow value of the implicit rent increases steadily with the value of the home, the ¤ow value of the real mortgage payments fall over time due to the effects of in¤ation. The value of the stream of mortgage payments continues to rise over the holding period, but at a slower rate as the holding period lengthens.

The primary de£nition of return, including the effects of the mortgage intrest tax deduction, is used

Figure 2.1: Alternate Measures of Risk and Return

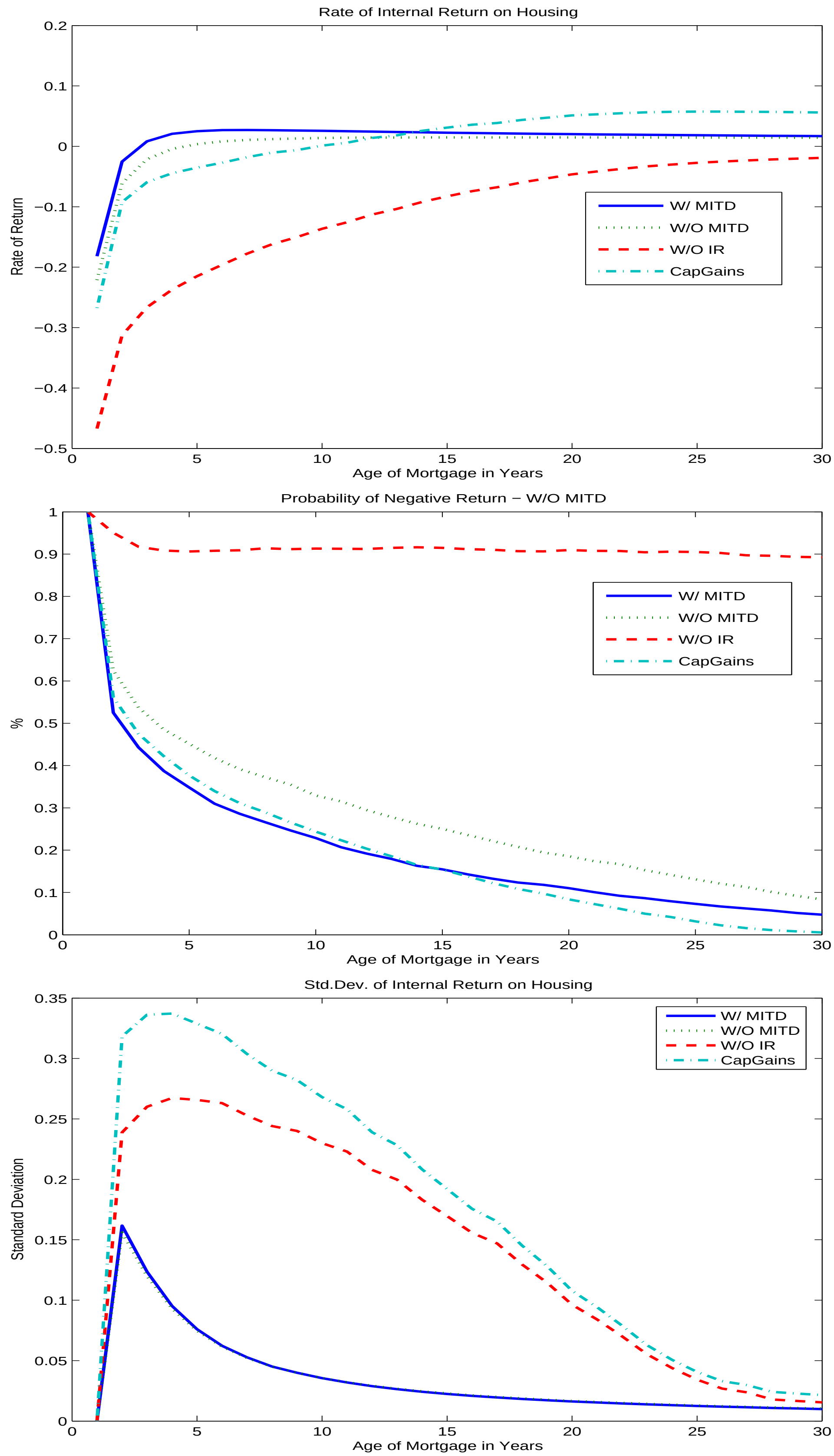
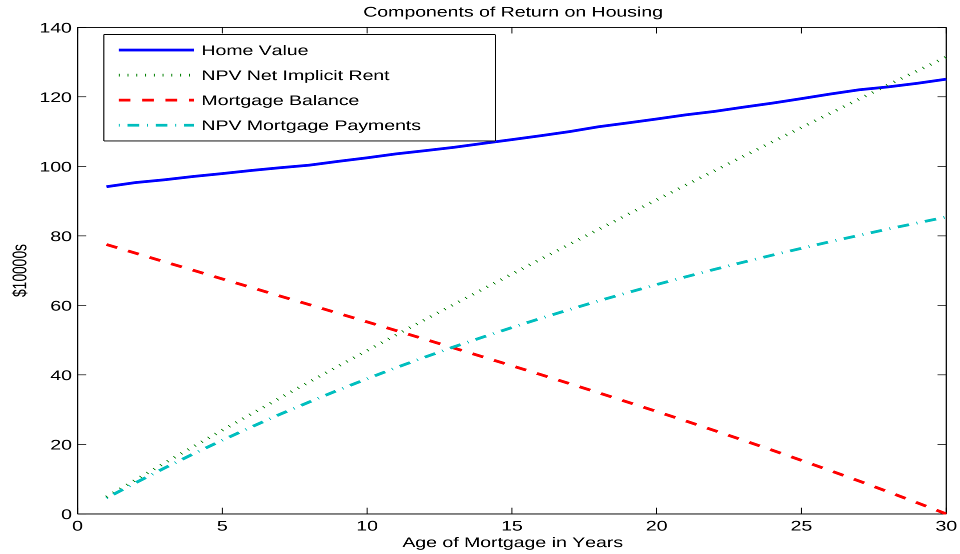


Figure 2.2: Components of Return on Housing



remainder of this section. Figure 2.3 reports the both how the return and standard deviation on housing and equities varies with holding period and how the optimal portfolio allocation also changes. The return on both housing and equities is concave over the holding period. The standard deviation for both is falling over the holding period. For shorter holding period, equities are actually less risky investments. The risk associated with housing falls more quickly over the holding period, as the level of leverage in housing falls. The £nal panel takes these measures of risk and return on housing and converts them into optimal portfolio shares. The base case is the optimal portfolio using soley the rates of apperication for housing and equities and the associated standard deviations irrespective of holding period, mortgage contracts, or taxes. Households who plan to move after only a few years would prefer to hold a negative position in housing. As the expected holding period increases the standard deviation of housing decreases, the expected total rate of return increases, and the optimal share held in housing increases dramatically. The implication is that the longer the expected holding period for the home buyer, the fewer stocks they purchase.

A great deal of variation exists in the mortgage interest rates paid by households. Lenders generally require higher interest rates for loans that are riskier. One way that households might reduce their interest rate is by increasing their downpayment. Figure 2.4 shows the risk and return of housing as a function of the loan-to-value ratio for holding periods of 5, 10, and 20 years. It is assumed that the mortgage interest rate is a declining function of the loan-to-value ratio, with a 100% LTV mortgage being charged 8% and a 80% LTV

Figure 2.3: Risk, Return and Portfolio Allocation as a Function of Holding Period

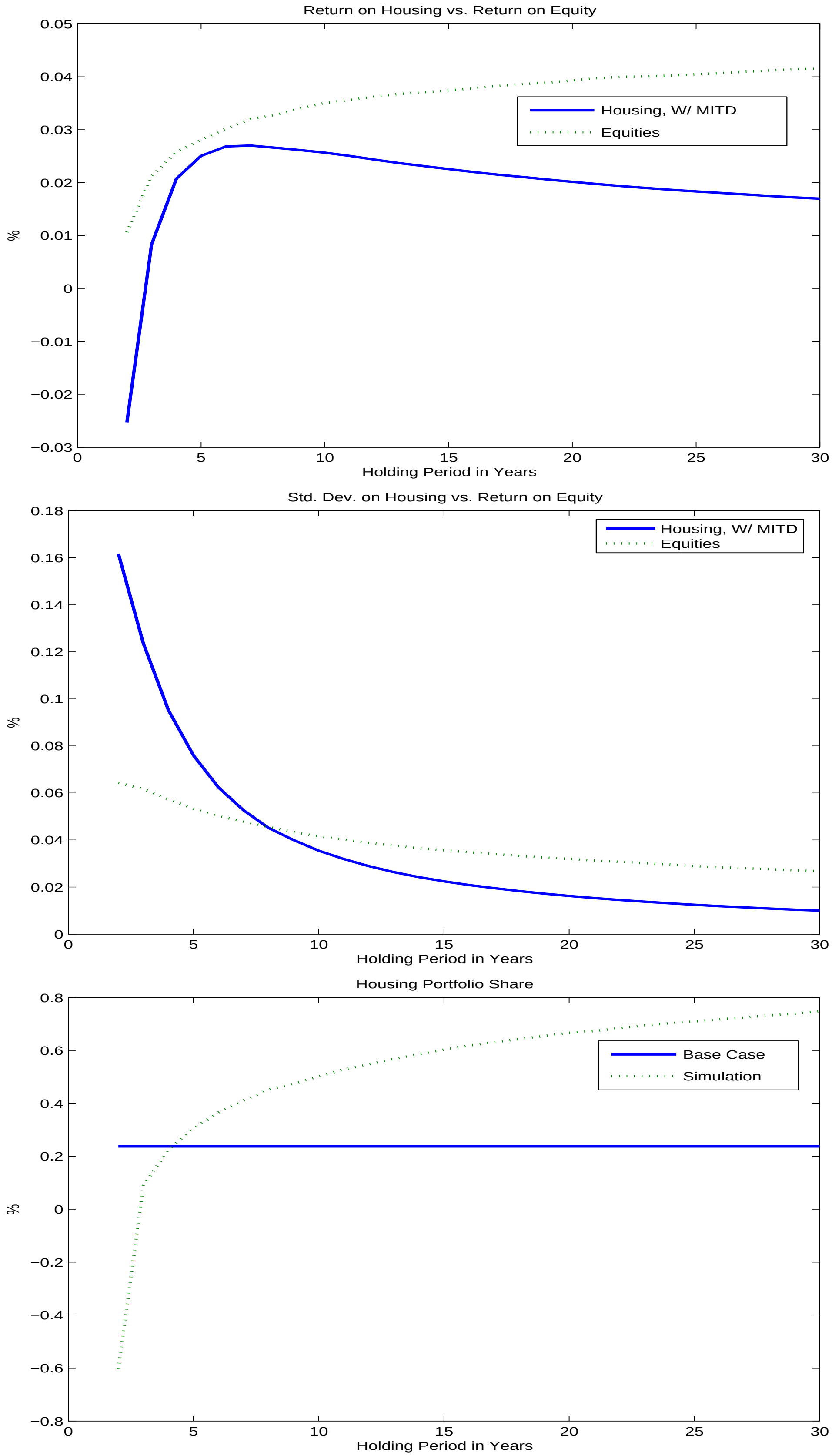
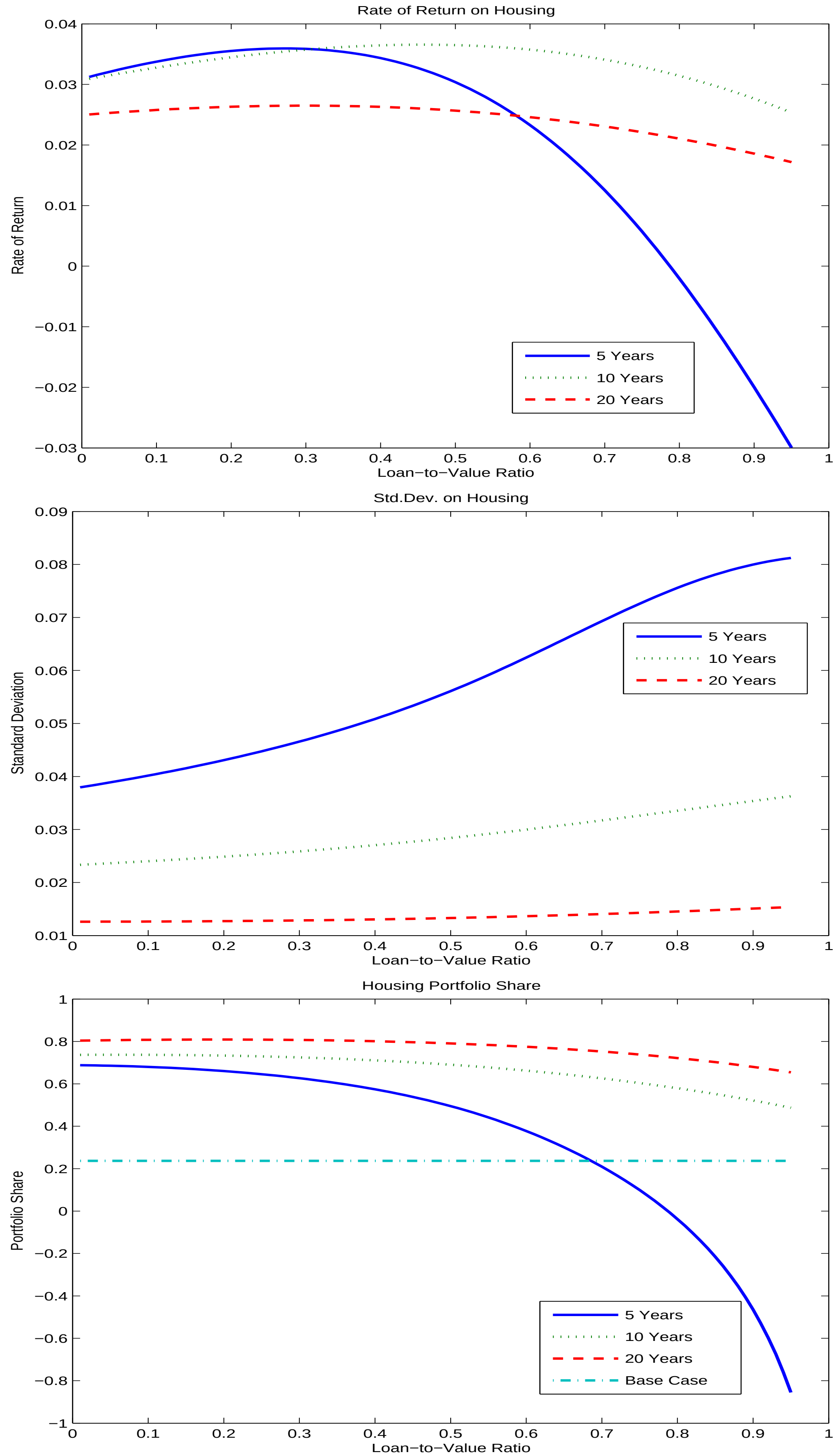


Figure 2.4: Risk, Return and Portfolio Allocation as a Function of LTV Ratio



mortgage being charged 6.4%. Higher downpayments reduce the interest rate paid by the household, but also reduce the impact of leveraging on the return on housing. As a result, the return on housing is concave over the loan-to-value ratio. For loans with high downpayments the bene£ts of increasing leveraging offset the costs of higher interest rates, and the return increases as the LTV ratio increases. For loans with low downpayments, the costs of higher interest rates swamps the increased bene£ts of leveraging, and the rate of return falls as the LTV ratio increases. The standard deviation steadily increases as the LTV ratio increases in response to the increased leverage. Longer holding periods result in lower mortgage balances, reduced leverage, and both lower rates of return and lower standard deviation. Lower LTVs result in lower housing risk and therefore the household holds more of their portfolio in housing, as shown in the third panel.

Figure 2.5 shows how the mortgage interest tax deduction results in an increasing expected total rate of return on housing. The values for the fucntion $\gamma(y)$ are reported in Appendix D and are based on estimates from the CPS data. The progressive tax structure results in households with higher incomes receiving a greater bene£t from the mortgage interest tax deduction due to their higher marginal tax rate. The £gure shows that as income increases, so does the return on housing and the optimal share of the portfolio held in housing. This effect is mitigated the longer the expected holding period, since the importance of the mortgage interest tax deduction to the total return falls as the holding period increases.

The preceding £gures support the argument that the return and risk on housing vary signi£cantly with the holding period. Figure 2.6 shows how the distribution of both the total dollar return and the total rate of return for holding periods of 5, 10, and 20 years. As holding period increases, the distribution of the total dollar return, as shown in the bottom panel, becomes more skewed toward the right as the probability of a negative total return falls. As a result, the distribution of the toal rate of return becomes more symmetric and concentrated. The reason for the increasing skewness in total dollar return is two-fold. First the remaining mortgage balance is steadily falling over time, and while the stock value of the stream of mortgage payments is increasing, it is increasing at a slower rate. This is because, as seen in Figure 2.2, the ¤ow value of the real mortgage payments is falling over time. Second, while the mortgage payments remain £xed as the holding period increases, the implicit rent recieved increases as the value of the home increases. These two factors act in concert to increase the skewness of the total return.

Figure 2.5: Risk, Return and Portfolio Allocation as a Function of Income

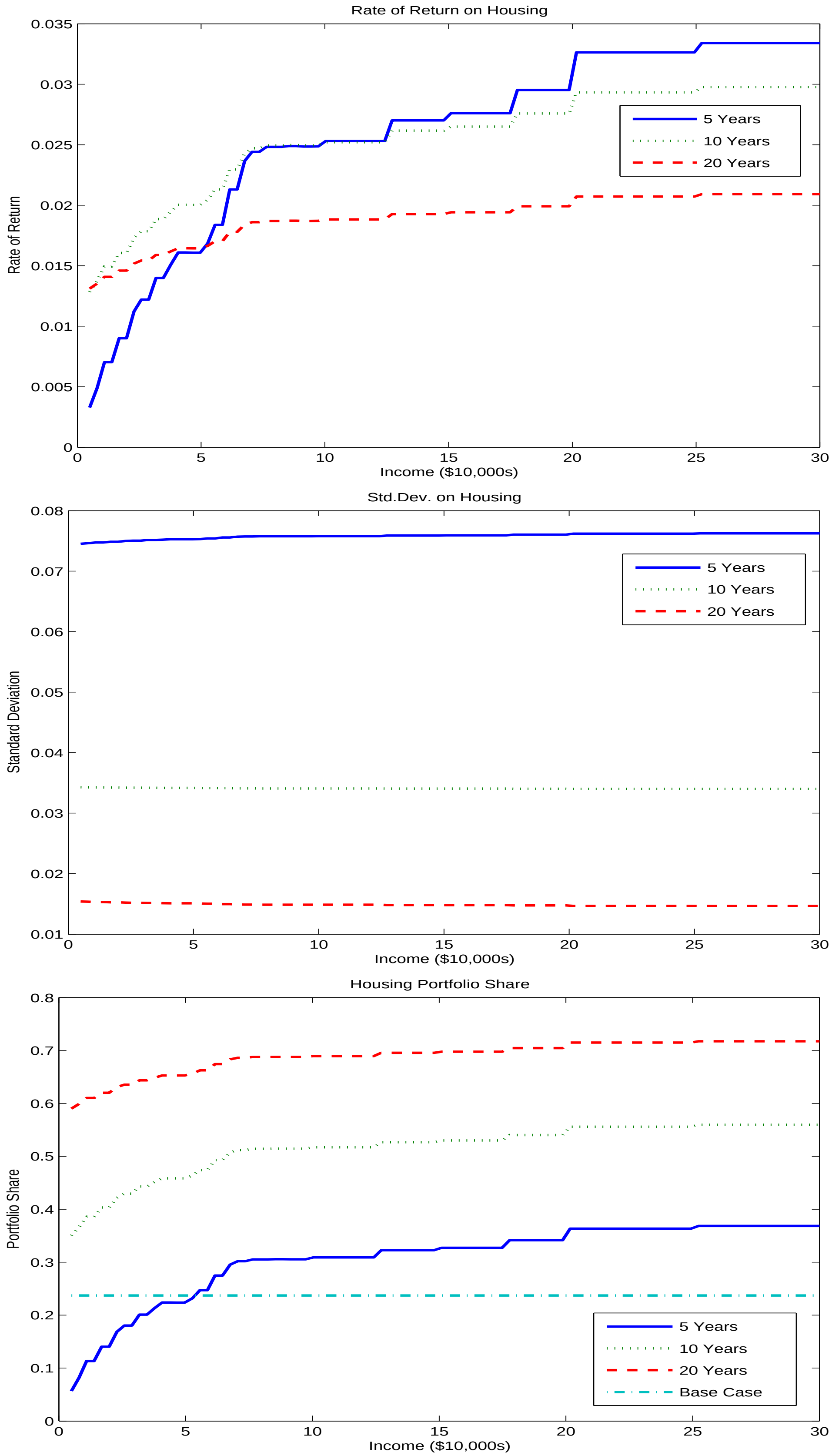
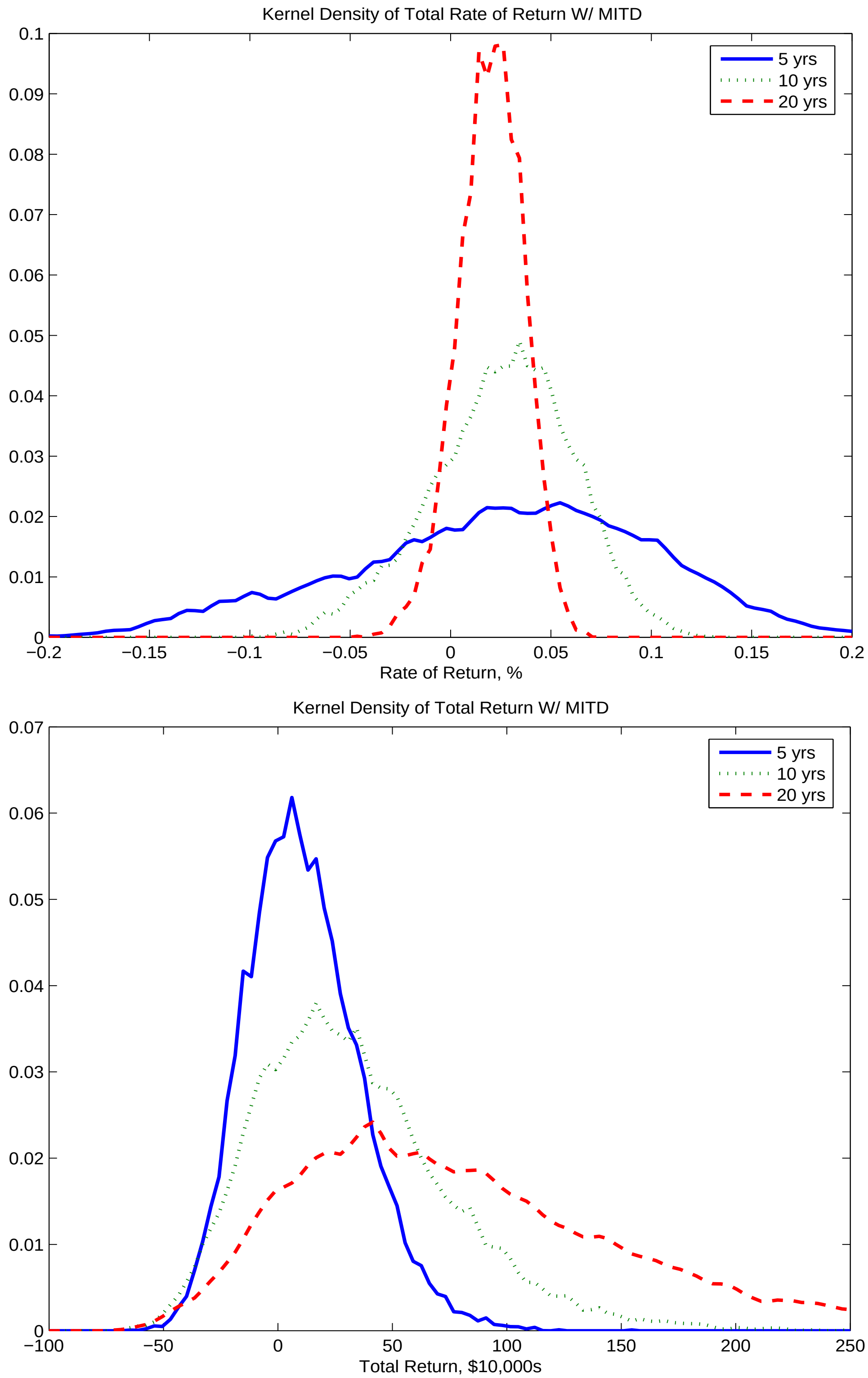


Figure 2.6: Distribution of Total Return and Conditional Rate of Total Return



2.5 Empirical Results.

The previous sections provided argued that the total rate of return on housing varies with the expected holding period, mortgage terms, and borrower income. This section takes the above de£nition of the total return on housing and estimates the effects of property, mortgage, and borrower characteristics on the risk and return on housing using data from the 1985-2002 American Housing Survey. The sample is restricted to households with £xed-rate mortgages who have not re£nanced or moved since purchasing the home. Households with second mortgages or adjustable rate mortgages are excluded. The sample was limited to a set of 20 MSAs where there was suf£cient data to estimate rent-to-price ratios by MSA and by property type. Seperate rent-to-price ratios were estimated for single-family detached, single-family attached, and multifamly properties. The methodology for estimating these rent-to-price ratios is discussed in Appendix A.

A small number of obserations had inconsistent values for several key variables and were dropped from the analysis. This included observations where the either total family annual income or the initial purchase price of the home was less than $1,000, the initial mortgage balance was less than $100, or the initial loan-to-value ratio was less than 1% or greater than 120%. Observations where it was not possible to determine the age of the mortgage or where the interest rate was missing were excluded. Observations with unrealistic year-to-year changes in the home value were excluded. The resulting sample contains 9,711 observations.

The compound annual total rate of return on housing is calculated for each survey year in which the household meets the above conditions, whether or not the household sold their home. The holding period is de£ned as the length of time since the home was purchased. As was the case in the previous section, it is assumed that the household pays transaction costs equal to 6% of the home when it is sold. The return is calculated both with and without the effects of the mortgage interest tax deduction (MITD). Versions of the return are also calculated without the effects of implicit rent and considering only the effect of capital gains. Appreciation rates were taken from survey year to survey year and annualized. Appreciation rates are only available for households in the same unit in consectutive panel years.

Tables 2.2 and 2.3 report the explanatory and dependent variables used in the analysis in this section.

Table 2.2: Dependent Variables

	Number	Mean	Standard Deviation
CAG Rate of Return with MITD	9,711	8.6%	22.6%
CAG Rate of Return without MITD	9,711	8.5%	22.5%
CAG Rate of Return without Implicit Rent	9,711	-9.0%	27.1%
CAG Rate of Return with Only Capital Gains	9,711	19.1%	79.7%
Probability of Negative Payoff with MITD	9,711	8.4%	
Probability of Negative Payoff without MITD	9,711	18.7%	
Probability of Negative Payoff without Implicit Rent	9,711	66.4%	
Probability of Negative Payoff Only Capital Gains	9,711	18.8%	
Appreciation Rate	6,511	1.9%	10.6%
Appreciation Rate plus Rent-to-Price Ratio	6,511	9.8%	10.7%

The rent-to-price ratios were estimated by year and MSA from the AHS data. The MSA housing price index data was taken from published Of£ce of Federal Housing Enterprice Oversight (OFHEO) data. In calculating the marginal tax rate, the reported household income was used.

Table 2.3: Independent Variables

	Mean	Standard Deviation
MSA HPI Change	5.7%	5.4%
MSA Rent-to-Price Ratio	7.8%	2.4%
Central City	35.2%	47.8%
Excellent Neighborhood	28.0%	44.9%
Poor Neighborhood	1.1%	10.4%
Poor Public Schools	4.1%	19.9%
SF Detached	79.0%	40.7%
SF Attached	12.1%	32.6%
Inadequate Housing	1.4%	11.5%
1985 Value/Median MSA 1985 Value	90.9%	54.6%
30 Year Term	90.1%	29.9%
Interest Rate	8.8%	1.9%
Loan-to-Value Ratio	79.7%	18.6%
Payment-to-Income Ratio	20.3%	34.5%
Age of Mortgage	8.9	7.2
1^{st}-Time Homebuyer	25.6%	43.6%
High School	47.6%	49.9%
College	43.9%	49.6%
Black	10.6%	30.7%
Married	75.5%	43.0%
Children in Household	48.4%	50.0%
Log Income	10.8	0.7

Figure 2.7 shows an estimate of the distribution of both the total dollar return and the total rate of return for three different measures of return from Table 2.2. The de£nition of the appreciation rate is based on year to year changes while the capital gains measure is a function of the appreciation in the home since purchase, the remaining mortgage balance, the intial downpayment, and the length of holding period. The

£rst panel shows that the distributions for the total rate of return are dispersed and have a slight skew towards the right. A large number of the observations have very small but positive total returns. This distribution then trails off to the right and drops sharply to the left. This measure results in more observations with negative total returns than the capital gains measure due cases where the net present value of the mortgage payments exceeds the net present value of the implicit rent. This group would consist of households with high mortgage payments and low rent-to-price ratios.

Figures 2.8 and 2.9 report a series of distributions of the total return and rate of total return conditional on several home or borrower characteristics. In the upper panels of Figure 2.8 the data is divided based on whether the property type is single-family detached or not. The distibution of the total rate of return for homes single-family detached homes was higher than the distribution of the rate of return for other homes. The distibution for the total return for single-family detached homes had a more pronouced righward skew than the distribution for other homes. The lower panels of Figure 2.8 show the distributions for households with family income above and below the median. The distributions for the total rate of return was slightly higher for families with higher income. Households with higher income have greater rightward skew in their distribution of total dollar returns and sign£cantly lower probability of negative or very small total dollar returns.

The upper panels of Figure 2.9 show the distributions of the total rate of return and total dollar returns by race. The distribution for the total rate of return for non-blacks is skewed to the right and have a signi£cantly lower probabiliy of negative or very small total dollar returns. The lower panels of Figure 2.9 provide the £nal set of distributions, broken out by education. College educated households have signi£cantly greater variation in the total rate of return and as well as a higher probability of large dollar returns. Figures 2.8 and 2.9 suggest than both risk and return might vary with borrower characteristics. However such a univariate analysis masks the many interactions between the characteristics of the household and their mortgage and housing choices.

Table 2.4 contains the results from a set of logistic regressions on the probability of a negative dollar return for different housing return measures. For the capital gains only de£nition, a negative total return is equivalent to negative equity. The £rst section of the table contains variables associated with the location

Figure 2.7: Distribution of Return on Housing from AHS

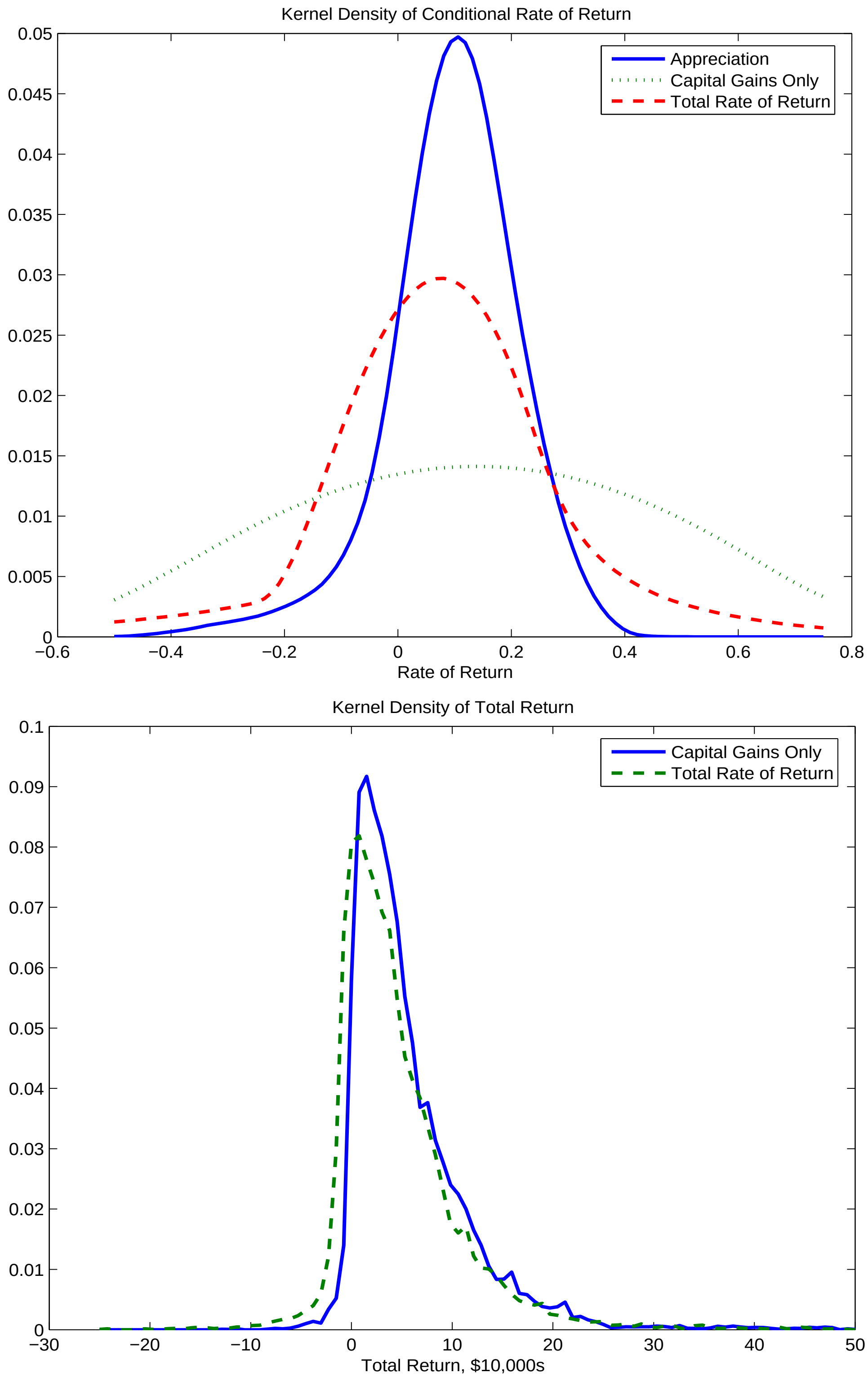


Figure 2.8: Distribution of Total Return and Rate of Total Return

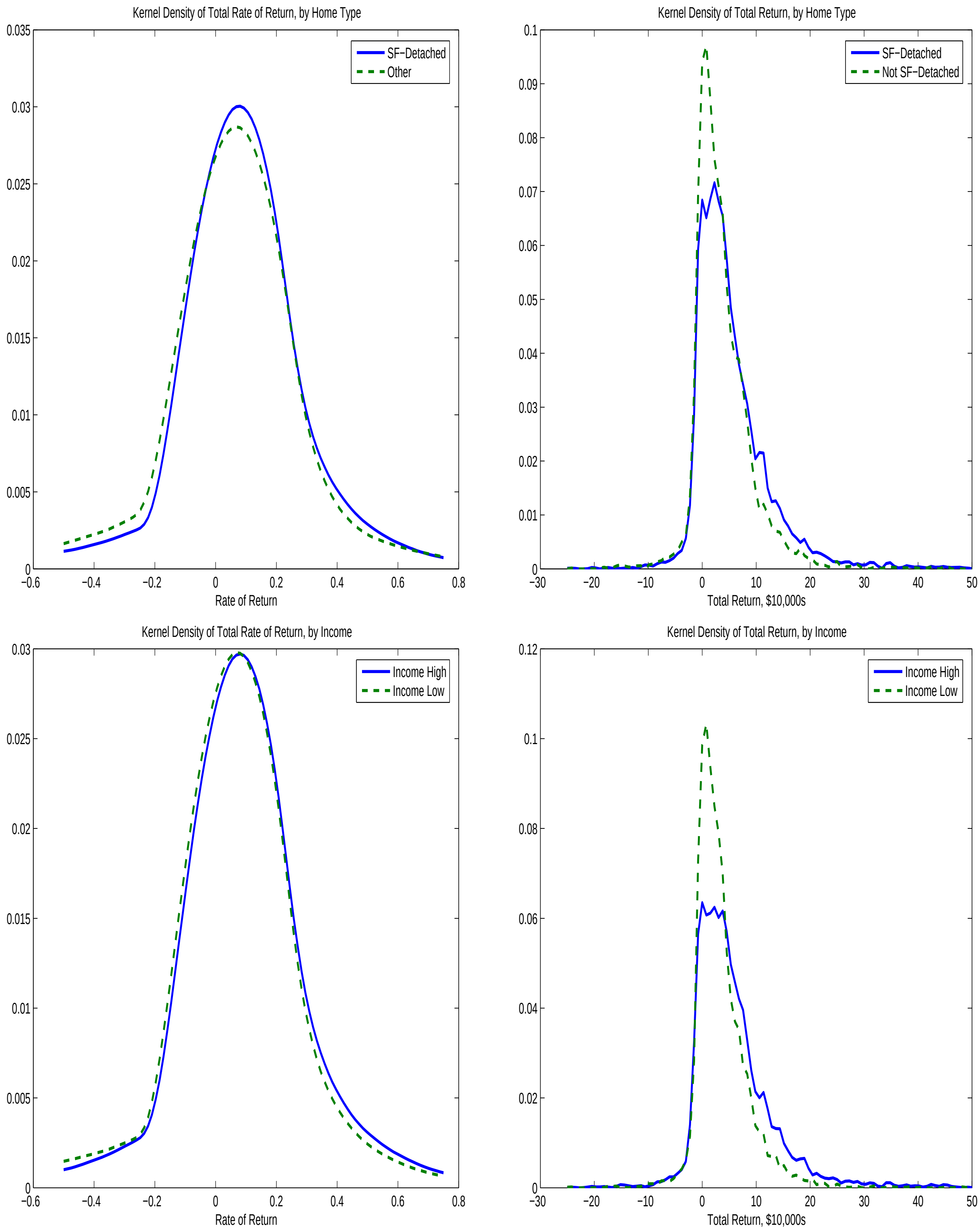
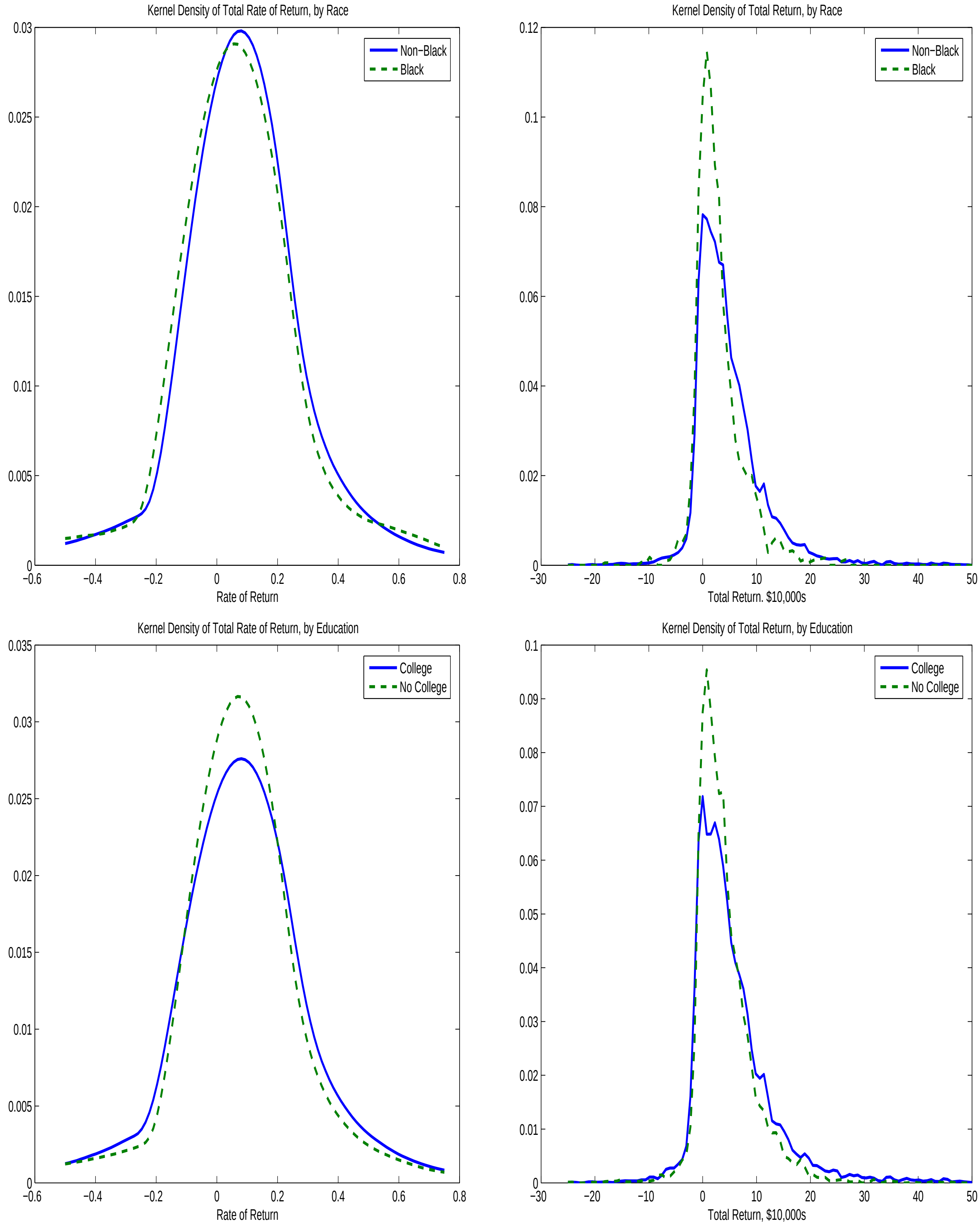


Figure 2.9: Distribution of Total Return and Rate of Total Return



of the property. When local home prices have been increasing, the probability of a negative total return decreases. Higher rent-to-price ratios reduce the probability of negative return only when the implicit rent is taken into account. A higher rent-to-price ratio increases the value of the consumption stream the home provides, increasing the overall return. Higher rent-to-price ratios increases the probability of negative return when implicit rent is not taken into account. This re¤ects the negative correlation between rent-to-price ratios and appreication rates discussed in more detail below. Neighborhood quality, a central city location, and school quality do not explain much of the variability in negative total returns.

The next set of variables contains information on property characteristics. The reference category for structure type is mobile homes and apartments. Households in single-family detached homes are less likely to have negative total returns than those in single-family attached units. Single-family attached homes are in turn are less likely than mobile homes or multi-family units to have negative total returns. The ratio of the value of the unit in 1985 to the median value for the MSA in 1985 was used as a consistent measure of how expensive a unit is. This ratio is not particularly signi£cant in the probability of negative total return regressions.

Mortgage characteristics are included in the next group of variables. Households with 30-year mortgages have a higher probability of negative total dollar return than those with shorter term mortgages due to the slower rate at which they pay down their mortgage balances. When implicit rent is accounted for the interest rate is signi£cant and negative, but not the LTV ratio. When the implicit rent is not included in the measure of return, the LTV ratio is signi£cant and negative, but not the interest rate. The negative effect of the LTV ratio is inutitive. Naturally, the larger the intial equity position, the more the household can lose before suffering a negative total return when the investment produces no dividends and only capital gains. Higher interest rates also reduces the return on housing by increasing the costs. For returns without implicit rent this relationship is still negative, just not signi£cant. The probability of a negative total return declines with the age of the mortgage, as the remaining mortgage balance is paid down.

The next group of variables focuses on borrower characteristics. High school and college educated households are less likely to have negative total dollar returns. Purchasing a home is a daunting and time consuming task with a large degree of asymmetric information. Households with more education might be

Table 2.4: Probability of Negative Total Return

	W/O MITD	W/ MITD	W/O Implicit Rent	Cap. Gains Only
Constant	**3.565****	**4.0353****	**1.379***	-1.172
	(0.666)	(0.669)	(0.539)	(0.737)
MSA HPI Chg	**-1.403***	**-1.484***	**-4.345****	**-7.127****
	(0.580)	(0.583)	(0.433)	(0.639)
MSA RTP Ratio	**-9.269****	**-9.429****	**26.262****	**7.781****
	(1.408)	(1.420)	(1.228)	(1.395)
Central City	0.0770	0.103	-0.0114	**0.190****
	(0.0644)	(0.0648)	(0.0518)	(0.0665)
Ex. Nbhd	-0.0384	-0.0290	**-0.124***	-0.0923
	(0.0685)	(0.0690)	(0.0535)	(0.0712)
Poor Nbhd	0.426	0.394	**0.641***	0.396
	(0.265)	(0.267)	(0.265)	(0.295)
Poor Sch	-0.0576	-0.0827	0.0240	0.0522
	(0.160)	(0.161)	(0.117)	(0.155)
SF-Detch	**-0.740****	**-0.757****	**-0.631****	**-1.0230****
	(0.105)	(0.105)	(0.0969)	(0.104)
SF-Attcd	**-0.494****	**-0.544****	**-0.330****	**-1.0261****
	(0.125)	(0.278)	(0.115)	(0.126)
Inadeq.	-0.474	**-0.552***	**-0.399***	0.203
	(0.269)	(0.278)	(0.200)	(0.241)
Val85/	0.0405	0.0264	**-0.216****	0.0149
MedMSAVal85	(0.0637)	(0.0644)	(0.0478)	(0.0626)
30yr	**0.345****	**0.314****	**0.721****	**1.0208****
	(0.101)	(0.102)	(0.0779)	(0.103)
Int.	**-4.967****	**-5.812****	-1.887	0.516
	(1.647)	(1.663)	(1.370)	(1.692)
LTV	0.174	0.107	**-0.894****	**-1.713****
	(0.175)	(0.176)	(0.138)	(0.174)
PTI	-0.0647	-0.0739	0.0960	**0.653****
	(0.0951)	(0.0956)	(0.0911)	(0.107)
Age	**-0.604****	**-0.583****	**-0.298****	**-0.489****
	(0.0162)	(0.0162)	(0.0143)	(0.0185)
Age^2	**0.0216****	**0.0209****	**0.0161****	**0.0117****
	(0.000627)	(0.000624)	(0.000717)	(0.000899)
1^{st}Time	-0.0145	-0.0323	-0.0600	0.0526
	(0.0678)	(0.0685)	(0.0549)	(0.0696)
HighSch	**-0.339****	**-0.286***	**-0.204***	-0.146
	(0.110)	(0.111)	(0.0924)	(0.123)
College	**-0.326****	**-0.258***	-0.177	-0.159
	(0.116)	(0.116)	(0.0968)	(0.127)
Black	**0.476****	**0.482****	**0.322****	0.183
	(0.0981)	(0.0982)	(0.0845)	(0.108)
Married	-0.0292	-0.0251	0.0930	0.0615
	(0.0739)	(0.0744)	(0.0602)	(0.0771)
Children	0.0150	0.0592	0.0871	0.00921
	(0.0660)	(0.0665)	(0.0514)	(0.0670)
Log(Inc)	**-0.123***	**-0.167****	-0.0631	**0.252****
	(0.0549)	(0.0551)	(0.0440)	(0.0615)
Log L	-3,621	-3,587	-5,327	-3,355
Num Obs.	9,722	9,722	9,722	9,722

Note: The standard deviations are presented in parentheses. ** represents signi£cance at the 1% level and * represents signi£cance at the 5% level.

more adept at the home search and purchase process and therefore purchase homes and acquire mortgages less likely to produce negative total dollar returns. Blacks are more likely to have negative total returns. Both race and educational effects are only signi£cant when the cost of the mortgage payments are accounted for. The effect of the mortgage interest tax deduction is to reduce the probability of a negative total return for households with high levels of income and higher corresponding marginal tax rates. Income still have a negative and signi£cant impact even when the mortgage interest tax deduction is not accounted for, but has a positive effect on the probability of negative equity. This might re¤ect a selection effect. These measures of return are unrealized measures. Negative equity is a problem that must be addressed only when the home is sold, or if the household is unable to make the mortgage payments. High income households have lower probability of missing mortgage payments, and therefore assign less concern to the problems of unrealized negative equity. They feel they can continue to make their payments, until the local housing market recovers and they pay down the balance on their mortgage.

Table 2.5 reports the results for OLS regressions of the measures of housing return. The £rst columns uses the appreciation rate while the next four columns use the same measures of return used in Table 2.4, conditional on a positive total return. The explanatory variables are the same as those used in the logistic regression of the probability of negative total dollar return. Increases in the local MSA home price index have positive and signi£cant effects on all the measures of housing return. The local rent-to-price ratio has a positive and signi£cant effect only when the implicit rent is included in the measure of housing return. Otherwise its impact is negative and signi£cant. These results support the hypothesis that, to some extent, housing markets are clearing. That is, in markets where housing provides a large dividend to owners through a high rent-to-price ratio, the rate of appreciation is lower. Conversely, in other markets the rate of appreciation is higher to compensate for lower dividends. Homes in the central city had lower rates of appreciation. The rate of appreciation also is sensitive to the reported quality of the neighborhood, with homes in excellent neighborhoods having on average a greater rate of appreciation than homes in poor neighborhoods. However, for the most part, none of the measures of total return are sensistive to the location or neighborhood quality of the home.

The effects of property type are as expected. Single-family homes have higher rates of appreciation

Table 2.5: Model of Return on Housing

	Appreciation	W/O MITD	W/ MITD	W/O Implicit Rent	Cap. Gains Only
Constant	**-0.130****	**-0.298****	**-0.323****	**-0.292****	**0.445****
	(0.0291)	(0.0403)	(0.0406)	(0.0452)	(0.168)
MSA HPI Chg	**0.600****	**0.309****	**0.315****	**0.511****	**0.638****
	(0.0245)	(0.0379)	(0.0378)	(0.0435)	(0.104)
MSA RTP Ratio	**-0.172****	**0.644****	**0.626****	**-0.987****	**-0.892***
	(0.0564)	(0.0993)	(0.100)	(0.108)	(0.294)
Central City	**-0.01291****	-0.00431	-0.00501	-0.00377	0.0219
	(0.00293)	(0.00496)	(0.00496)	(0.00550)	(0.0184)
Ex. Nbhd	**0.0109****	0.00542	0.00646	0.00458	-0.00686
	(0.00285)	(0.00503)	(0.00501)	(0.00549)	(0.0153)
Poor Nbh	**-0.0338****	0.00560	0.00606	-0.0108	-0.0280
	(0.00144)	(0.0246)	(0.0252)	(0.0274)	(0.0647)
Poor Sch	0.000910	0.00832	0.00542	0.00876	-0.0417
	(0.00644)	(0.00981)	(0.00973)	(0.0121)	(0.0215)
SF-Detch	**0.0333****	**0.0673****	**0.0685****	**0.0903****	**0.126****
	(0.00626)	(0.00958)	(0.00967)	(0.0109)	(0.0301)
SF-Attcd	**0.0298****	**0.0445****	**0.0465****	**0.0576** **	**0.0818***
	(0.00701)	(0.0109)	(0.0110)	(0.0124)	(0.0331)
Inadeq.	0.0145	0.00643	0.0197	0.0346	-0.0718
	(0.00866)	(0.0208)	(0.0206)	(0.0229)	(0.0406)
Val85/	**-0.00912****	**-0.00922***	-0.00698	**-0.0136****	-0.0164
MedMSAVal85	(0.00303)	(0.00431)	(0.00426)	(0.00517)	(0.0121)
30yr	0.00851	**-0.0319****	**-0.0298***	**-0.0886****	**-0.148****
	(0.00448)	(0.00794)	(0.00808)	(0.00839)	(0.0332)
Int.	-0.0687	0.216	0.195	**0.588****	-0.319
	(0.0820)	(0.143)	(0.143)	(0.158)	(0.578)
LTV	-0.00388	**0.114****	**0.140****	**-0.156****	**0.690****
	(0.00747)	(0.0114)	(0.0115)	(0.0129)	(0.0444)
PTI	0.00604	0.00463	0.00390	-0.00968	**-0.0917****
	(0.00381)	(0.00537)	(0.00548)	(0.00719)	(0.0209)
Age	-0.000362	**0.0122****	**0.00753****	**0.0398****	**-0.0109****
	(0.000550)	(0.00114)	(0.00114)	(0.00117))	(0.00423)
Age^2	0.00000606	**-0.00201****	**-0.000466****	**-0.00121****	**0.000135****
	(0.0000214)	(0.0000316)	(0.0000316)	(0.000316)	(0.000118)
1stTime	0.00184	-0.00201	-0.00209	-0.00236	-0.0162
	(0.00272)	(0.00515)	(0.00514)	(0.00565)	(0.0182)
HighSch	**0.0169****	**0.0177***	**0.0172****	**0.0214***	0.0428
	(0.00584)	(0.00837)	(0.00837)	(0.00962)	(0.0263)
College	**0.0245****	**0.0283****	**0.0281****	**0.0360****	0.0103
	(0.00595)	(0.00897)	(0.00896)	(0.0102)	(0.0255)
Black	**-0.0151****	**-0.0258****	**-0.0263****	**-0.0254****	-0.00679
	(0.00487)	(0.00843)	(0.0153)	(0.00921)	(0.0354)
Married	0.000371	-0.00367	-0.00202	-0.00291	-0.0135
	(0.00336)	(0.00591)	(0.01099)	(0.00660)	(0.0216)
Children	0.0000808	-0.00379	-0.00586	-0.00238	-0.0121
	(0.000853)	(0.00498)	(0.00955)	(0.00545)	(0.0156)
Log(Inc)	**0.00890****	**0.0120****	**0.0154****	**0.0113****	**-0.0572***
	(0.00234)	(0.00330)	(0.00790)	(0.00372)	(0.0154)
R^2	0.119	0.052	0.058	0.202	0.039
Num Obs.	6,510	9,722	9,722	9,722	9,722

Note: The standard deviations are presented in parentheses. ** represents signi£cance at the 1% level and * represents signi£cance at the 5% level.

than do mobile and multi-family homes. This results, combined with the estimated rent-to-price ratios in Appendix B, provide additional support that housing markets are clearing. Single family homes have higher rates of appreciation but lower provide lower dividends due to lower rent-to-price ratios. Multifamily units have lower rates of appreciation, but provide higher dividends through higher rent-to-price ratios. Further work will explore the differences in appreciation rates and rent-to-price ratios across property types. More expensive units, as measured by the ratio of the value of the unit to the median MSA level value in 1985 have slightly lower rates of both return and appreciation. The effects of the mortgage terms on the total rate of return on housing are also as expected. Households with 30 year £xed rate terms are paying down their mortgage balance more slowly, resulting in a lower rate of total return. Higher LTV ratios result in higher rates of return by increasing the effects of leveraging, although this effect turn negative when the cost of the mortgage payments but not the bene£ts of the implicit rent are included. The return is concave over the holding period increases, as suggested by the simulation results.

The last set of independent variables represents the effects of borrower characterisitics. Households with higher level of education or income have higher rates of return and appreciation while blacks have lower rates of return and appreciation. The one exception, as was the case the the models of the probability of negative total return, is the measure including only capital gains. The results from the appreciation regression indicates that households with higher level of education or income do in fact purchase homes that appreciate at higher rates and blacks purchase homes that appreciate at lower rates. However, when the size of the downpayment and remaining mortgage balance are used to calculate the rate of return from capital gains, neither income, education, or race are signi£cant. When the costs of the mortgage payments are then accounted for, all these characteristics are once more signi£cant.

One possible explanation that £ts this pattern is that households that have low income, low education, or who are black might purchase homes with lower downpayments. If the cost of the downpayment is the primary measure of the out¤ow associated with the investment, this might result in what appears to be higher rates of return even when the appreciation on the underlying property is low. Once the true cost of the mortgage is accounted for, the true rate of return is lower for this group. In fact the impacts of income, education, property type, and race all increase once the effects of the mortgage contract and implicit rent are accounted for. Households with low income, low education, or who are black are losing out not once but twice. The homes they purchase appreciate at lower rates, and the mortgages they take out further reduces their rate of return on their investment.

2.6 Conclusions.

The goal of this paper was two-fold. The £rst goal was to develop an alternative measure of the total rate of return on housing that accurately accounts for the role of the mortgage contracts and the stream of housing services associated with owner-occupied housing. The second goal was to provide both theoretical and empirical evidence that the total return on housing varies with property, mortgage, and borrower characteristics.

The alternative measure developed here shows that the total rate of return on housing is concave over the holding period. The probability of negative equity peaks early in the holding period and then declines, as does the standard deviation of the total rate of return. The total rate of return on housing is also concave over the LTV ratio, as the bene£ts of higher leverage are balanced with higher interest rates. The mortgage interest tax deduction increases the returns for higher-income borrowers through their higher marginal tax rates. As the risk and return of housing varies with the holding period, mortgage terms, and income level, so does the optimal portfolio share of investments held in equities.

Property, mortgage, and borrower characterisics all have signi£cant effect on the total rate of return on housing. Single-family homes, espcially single-family detached homes, provide higher rates of return. Higher levels of human capital, measured either as the level of education or household income, signi£cantly decreases the probability of a negative total return and increases the appreciation rate of the home itself. The high degree of assymentric information and uncertainty associated with the home search and purchase process allows households with higher levels of human capital to make signi£cantly better investment decisions. Households that have low income, low education, or who are black have a higher probability of negative total return and lower total rates of both return and appreciation. The role of the mortgage contract seems to augment the effect of income, education, race and property type on the rate of return on housing.

To use only the appreciation rate of housing to measure return ignores the effects of the mortgage contract on the total rate of return on housing. The total rate of return measure developed here captures capture how the risk and return on housing varies with mortgage, property, and borrower characteristics. Existing papers have documented how the demand for risky assets vary with the holdings of home equity, but have not explored the heterogenity of the risk and return on housing as a funciton of mortgage, property, and borrower characteristics. The next step in this research is to see if there is empirical evidence of household's demand for risk assests varying with the probability of a negative total return and total rate of return on housing.

Appendix A

Baseline Model Parameter Values

The parameter values for the baseline model are chosen to be consistent with other models in the relevant literature. As was discussed in the Section 3, the income process consists of a deterministic and a transitory factor. The income process is based on the results of regressions of Social Security earnings on age and age-squared. The dependent variable is the log of the wage income in constant 1990 dollars. The transitory factor of wage is re¤ected in the estimated standard error of the regression. The wage is converted from log to level terms in the model. At age 65 the level of the deterministic wage falls to a ¤at level equal to 60% of the last period's income before any transitory shocks, representing a system of forced retirement and a de£ned bene£t pension plan. The coef£cients and standard deviation used in this version of the model are shown in Table A.1 below.

Table A.1: Log Income Regression Results

Constant	ψ_0	7.28626
Coef£cient Age	ψ_1	0.10278
Coef£cient of Age^2	ψ_2	-0.00098
Std. Dev.	σ_w	0.80778
R^2		15.5%
Probability of Unemployment	υ	1%

The market price of a housing unit is the result of setting the deterministic home price at age 60 with the National Association of Realtors' 1990 median home price. It is assumed that a median home consists of 10 housing units. The home prices are converted to constant 1990 dollars and the deterministic home price series are calculated using the historical average return. The average and standard deviation of the return on housing are at taken from Li and Yao (2004) and are consistent with Campbell Cocco (2003). The mortgage interest rate used is the average rate on loans with 80% loan-to-value ratios as reported by Freddie Mac from 1969 to 2001, adjusting for the in¤ation rate. The percent required for downpayment represents the minimum needed to avoid paying mortgage insurance. The transaction, maintenance, and moving costs are based on survey data provided by the National Association of Realtors. The values chosen for the current version of the model are presented in Table A.2 below. The risk and return on risky assets follows Yao and Zhang (2004).

Table A.2: Values of Market Parameters

Parameter Name and De£nition	Symbol	Value
Real risk free rate of return	r	2%
Price of 1 housing unit, at age 60	$P_{60}(1)$	1.003
Size of small homes	$h(i_s)$	8
Size of large homes	$h(i_l)$	12
Mean of real return on housing	η_h	1%
Standard deviation of housing return	σ_h	11.5%
Mean of real return on risky asset	η_s	6%
Standard deviation of risky asset return	σ_s	15.7%
Probability of 100% loss on risky asset	ς	1%
Mortgage interest rate	π	5%
Percent required as downpayment	μ	20%
Percent of home price lost to transaction costs	τ	10%
Maintenance costs	δ	0.7%
Moving costs	χ	0.3
Tax Rate	γ	30%
Re£nancing Costs	ζ	3%
In¤ation	ν	2%

Note: Units are in $10,000s or percent.

The values for the preference parameters shown in Table A.3 below were chosen to replicate certain stylized facts about the role of owner-occupied housing in portfolios, speci£cally the large share of total wealth held in home equity. An λ value of 2 represents a relatively low, but realistic, level of risk aversion. An β value of 0.96 is a commonly used discount rate. The ϕ value of 0.2 re¤ects the share of total household expenditures allocated to housing expenditures in the 2001 Consumer Expenditure Survey from the U.S. Department of Labor. The discount rate for bequests are 0.8 for θ_A, 0.8 for θ_H, and 0.8 for θ_M. They are chosen to imply that households would rather consume one additional dollar than leave an additional dollar as a bequest and that households place a premium on leaving their homes as bequests relative to other assets.

Table A.3: Values of Structural Parameters in Calibrated Model

λ	β	ϕ	θ_A	θ_H	θ_M
2	0.96	0.2	0.8	0.8	0.8

Appendix B

Model Parameter De£nitions

Table B.1: Model Parameter De£nitions

Parameter Name and De£nition	Symbol
Consumption	c_t
Tenure Choice, next period	i_{t+1}
Share of Financial Assets held in risky assets	α
Age of Mortgage (Re£nancing=Change Age of Mortgage)	κ_{t+1}
Tenure Choice, this period	i_t
Current Age of Mortgage	κ_t
Value of Financial Assets	A_t
Value of Home	H_t
Tenure Choice, rent	i_r
Tenure Choice, own small house	i_s
Tenure Choice, own large house	i_l
Number of housing service units for tenure choice i_t	$h(i_t)$
Realized Earnings	$\widetilde{e_t}$
Remaining Mortgage Balance	D_t
Recurring Housing Costs	$X_t(i_t, \kappa_t)$
Mortgage Interest paid	$I_t(i_t, \kappa_t)$
Net Gain/Loss from Home Sale/Purchase	$G_t(i_t, i_{t+1}, \kappa_t)$
Net Gain from Cash-Out Re£nancing	$Z_t(\kappa_t, \kappa_{t+1})$
Mortgage Payment	$M_t(i_t, \kappa_t)$
Risk Aversion	λ
Discount rate	β
Housing Utility Coef£cient	ϕ
Bequest Parameter - Financial Assets	θ_A
Bequest Parameter - Housing	θ_H
Bequest Parameter - Mortgage Debt	θ_M
Survival Probability	ρ_t

Appendix C

Estimating Rent-to-Price Ratios

A key component of the return on housing is the stream of implicit rent consumed by the owner. In order to quantify the value of this stream, it is necessary to estmate a rent-to-price ratio. This appendix describes the methodology used to estimate rent-to-price ratios by year and MSA using the AHS data following Phillips (1988). Assuming that markets clear, the asset value of the home should equal the net present value of the rental income the home provides, or

$$V = \sum_{i=1}^{n} \frac{R_t - C_t}{(1+r)^t}, \tag{C.1}$$

where V is the asset value of the home, R_t is the market clearing rent in period t, C_t is the £nancing and operating cost in year t, r is the discount rate, and n is the property's useful life. This relationship can be rewritten as

$$V = \frac{R_1 - C_1}{1+r} + \sum_{i=2}^{k} \frac{R_t - C_t}{(1+r)^t} + \sum_{i=k}^{n} \frac{R_t - C_t}{(1+r)^t} \tag{C.2}$$

where the £rst term represents current year net rent, the second term is the net present value of the rental stream up until period k, and the £nal term represents the home's resale value in period k.

The current rent-to-price ratio is de£ned as

$$\mu = \frac{R_1}{V}. \tag{C.3}$$

The formula can be rearranged as follows:

$$V = \frac{R_1}{\mu} \tag{C.4}$$

implying that the rent-to-price ratio can be interpreted as the rate at which current rents are capitalized into asset values.

Estimating these rent-to-price ratios would be quite straight-forward if we possesed data on both current rents and asset values of individual homes. In most datasets, including the AHS used here, there is data on assets prices or current rent, but not both. These rent-to-price rates are imputed using a tenure hedonic model based on Phillips (1988) in form of

$$ln(P_{it}) = \beta_{it}X + \gamma_{it}TENURE + \theta_{it}TENURE * Y + \varepsilon_{it}, \tag{C.5}$$

where P_{it} is the natural logarithm of home values and rents in city i at time t, X is a vector of unit characterisics in city i at time t, Y is a matrix of property type, and $TENURE$ equals 1 if the unit is owner-occupied and 0 if it is a rental unit.

The difference between the rental and owner-occupied equations is

$$ln(R_{it}) - ln(V_{it}) = -\gamma_{it} - \theta_{it} * Y, \tag{C.6}$$

or, equivalently,

$$ln(\frac{R_{it}}{V_{it}}) = -\gamma_{it} - \theta_{it} * Y. \tag{C.7}$$

Therefore the vector of rent-to-price ratios by property type for city i at time t can be imputed as

$$\mu_{it} = \frac{R_{it}}{V_{it}} = e^{-\gamma_{it} - \theta_{it} * Y}. \tag{C.8}$$

The model is estimated over a set of MSAs using the AHS from 1985 to 2003. The vector of property types includes single-family detached, single-family attached, and multi-family. The resulting imputations of μ_{it} are then merged back in with the AHS data where they are used to calculate the implicit rent generated by owner-occupied housing. The estimated values of μ_{it} are provided in Table **??**. In addition to the $TENURE$ dummy, the explanatory variables include the number of rooms, number of bathrooms, and dummies for central city location, single-family detached, single-family attached, multi-family, air-conditioning, excellent quality neighborhood, poor quality neighborhood, and garage.

Table C.1: Estimated Rent-to-Price Ratios

MSA	Property Type	1985	1987	1989	1991	1993	1995	1997	1999	2001
Anaheim, CA	SF-Detached	6.34%	6.25%	4.86%	5.37%	5.11%	5.37%	8.36%	6.17%	4.98%
	SF-Attached	6.58%	4.85%	5.08%	4.53%	7.24%	6.70%	9.70%	8.28%	6.11%
	MF	6.95%	7.93%	8.05%	6.45%	7.06%	8.57%	11.61%	8.57%	11.61%
Atlanta, GA	SF-Detached	8.54%	8.50%	9.45%	10.40%	8.86%	9.03%	6.72%	8.30%	6.87%
	SF-Attached	6.32%	9.85%	5.72%	6.91%	7.82%	10.64%	12.74%	9.23%	7.58%
	MF	9.31%	6.96%	9.61%	9.44%	8.88%	10.46%	12.62%	9.27%	9.88%
Baltimore, MD	SF-Detached	7.50%	7.25%	6.14%	10.14%	6.24%	9.74%	9.00%	5.74%	6.22%
	SF-Attached	9.71%	8.43%	8.31%	10.14%	10.16%	9.74%	9.00%	10.95%	11.83%
	MF	9.49%	8.15%	8.03%	10.14%	7.99%	9.74%	9.00%	5.74%	11.83%
Boston, MA	SF-Detached	6.18%	5.40%	5.68%	5.73%	7.02%	6.86%	7.28%	6.79%	5.45%
	SF-Attached	3.15%	16.12%	4.35%	5.61%	2.85%	17.84%	15.12%	1.26%	3.00%
	MF	6.22%	4.98%	5.41%	5.77%	8.49%	7.69%	9.05%	8.90%	7.00%
Chicago, IL	SF-Detached	6.42%	6.40%	6.56%	5.65%	6.48%	6.42%	9.38%	7.74%	8.20%
	SF-Attached	7.15%	7.99%	6.32%	8.36%	4.95%	6.68%	8.59%	10.22%	9.53%
	MF	11.08%	9.40%	10.11%	8.81%	9.54%	9.30%	12.66%	11.43%	8.98%
Dallas, TX	SF-Detached	6.88%	8.63%	8.57%	9.52%	10.98%	10.91%	10.44%	9.33%	10.75%
	SF-Attached	7.36%	4.59%	9.91%	8.88%	10.88%	12.45%	12.46%	14.37%	9.78%
	MF	9.21%	12.07%	14.99%	7.96%	19.27%	14.58%	9.72%	16.67%	13.08%
Detroit, MI	SF-Detached	10.69%	10.29%	10.65%	10.64%	12.38%	11.11%	9.15%	7.86%	6.93%
	SF-Attached	13.08%	9.42%	12.92%	13.82%	11.41%	12.88%	14.36%	9.66%	9.39%
	MF	16.53%	23.42%	13.92%	15.54%	13.11%	13.05%	16.22%	10.70%	11.09%
Houston, TX	SF-Detached	9.77%	8.23%	10.44%	10.52%	10.32%	10.80%	12.27%	12.83%	11.37%
	SF-Attached	8.62%	8.37%	18.13%	10.24%	11.15%	10.09%	13.38%	14.91%	12.46%
	MF	6.02%	10.41%	12.10%	14.24%	15.71%	16.46%	18.67%	21.17%	18.10%
Los Angelos, CA	SF-Detached	5.41%	5.75%	4.28%	4.54%	4.83%	5.22%	5.54%	5.91%	4.55%
	SF-Attached	5.72%	6.83%	5.24%	5.12%	4.57%	6.62%	6.66%	5.90%	5.41%
	MF	5.72%	6.96%	4.92%	5.38%	5.05%	6.00%	6.96%	8.07%	9.29%
Miami, FL	SF-Detached	9.18%	7.19%	9.01%	7.71%	7.49%	7.82%	7.38%	6.79%	8.27%
	SF-Attached	8.12%	9.75%	9.65%	10.33%	10.86%	9.58%	8.31%	7.98%	8.24%
	MF	11.35%	11.25%	11.86%	11.53%	9.86%	12.18%	11.69%	8.23%	10.49%

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Table C.1 – continuted from previous page

MSA	Property Type	1985	1987	1989	1991	1993	1995	1997	1999	2001
Minneapolis, MN	SF-Detached	8.59%	8.02%	9.12%	8.31%	7.98%	6.80%	11.76%	9.26%	7.97%
	SF-Attached	9.47%	11.27%	9.18%	9.29%	9.32%	9.78%	10.00%	8.64%	10.70%
	MF	8.59%	9.87%	10.70%	12.08%	12.30%	11.17%	11.13%	10.67%	12.02%
New York, NY	SF-Detached	9.50%	5.38%	3.94%	6.67%	6.24%	7.48%	5.06%	4.41%	11.52%
	SF-Attached	4.97%	5.38%	3.74%	6.67%	6.24%	7.48%	4.41%	5.56%	11.52%
	MF	9.50%	5.38%	5.19%	6.67%	6.24%	7.48%	10.65%	9.66%	11.52%
Newark, NJ	SF-Detached	4.96%	6.85%	5.94%	6.47%	5.26%	8.46%	12.64%	10.47%	7.62%
	SF-Attached	9.39%	6.85%	5.94%	6.47%	9.13%	8.46%	12.64%	10.47%	7.62%
	MF	9.39%	6.85%	5.94%	6.47%	9.13%	8.46%	12.64%	10.47%	7.62%
Oakland, CA	SF-Detached	5.99%	6.18%	4.67%	4.99%	5.17%	5.88%	6.01%	5.31%	3.74%
	SF-Attached	7.85%	6.09%	5.55%	4.66%	5.56%	8.63%	5.52%	5.56%	4.65%
	MF	5.62%	7.72%	4.85%	5.82%	4.66%	5.12%	10.75%	6.48%	4.36%
Philadelphia, PA	SF-Detached	6.62%	5.91%	5.82%	7.73%	7.36%	6.83%	8.39%	6.36%	6.90%
	SF-Attached	8.65%	10.23%	9.65%	8.87%	10.44%	9.70%	13.56%	10.96%	11.10%
	MF	11.44%	8.59%	8.63%	10.44%	8.78%	10.70%	8.86%	16.68%	9.87%
Phoenix, AZ	SF-Detached	8.27%	8.72%	10.84%	8.57%	7.65%	8.33%	7.56%	8.10%	8.16%
	SF-Attached	9.40%	4.70%	15.67%	9.88%	10.75%	9.37%	8.39%	9.95%	10.97%
	MF	10.92%	11.26%	8.48%	9.30%	12.97%	12.07%	9.80%	6.94%	10.95%
San Diego, CA	SF-Detached	6.44%	5.92%	7.09%	5.21%	6.12%	6.19%	7.55%	7.95%	4.73%
	SF-Attached	6.37%	6.43%	9.23%	5.66%	5.25%	5.68%	22.09%	10.47%	4.53%
	MF	7.74%	7.47%	6.82%	4.77%	6.23%	5.64%	25.37%	7.92%	4.83%
San Francisco, CA	SF-Detached	4.93%	4.38%	3.28%	3.98%	3.95%	4.57%	12.60%	4.28%	2.90%
	SF-Attached	4.21%	4.51%	2.89%	3.98%	4.40%	3.63%	4.76%	5.16%	1.50%
	MF	5.98%	5.72%	4.77%	3.98%	5.66%	4.98%	9.57%	5.69%	3.66%
Seattle, WA	SF-Detached	7.08%	8.63%	6.74%	5.68%	5.85%	6.03%	4.91%	6.01%	4.03%
	SF-Attached	5.79%	5.90%	10.73%	10.67%	5.85%	3.58%	0.01%	5.77%	6.47%
	MF	6.24%	6.32%	10.03%	9.99%	7.49%	6.64%	7.49%	7.58%	7.47%
Washington, DC	SF-Detached	7.00%	6.20%	6.49%	5.69%	5.86%	5.99%	6.91%	7.45%	5.01%
	SF-Attached	7.42%	6.37%	6.32%	6.75%	6.85%	6.50%	6.58%	8.88%	9.09%
	MF	8.71%	8.40%	7.43%	7.81%	8.49%	9.37%	14.97%	15.19%	8.60%

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Table C.1 – continuted from previous page

MSA	Property Type	1985	1987	1989	1991	1993	1995	1997	1999	2001
United States	SF-Detached	7.03%	6.60%	6.22%	6.58%	6.57%	6.92%	7.53%	6.93%	6.04%
	SF-Attached	8.35%	8.04%	7.54%	7.77%	7.92%	8.94%	9.30%	9.45%	8.44%
	MF	9.28%	7.26%	6.82%	7.39%	7.45%	8.35%	11.17%	10.07%	8.99%

Appendix D

Income Tax Rates

Table D.1: Progressive Income Tax Structure

Income Range	Marginal Tax Rate
$0 to $5000	0.15%
$5000 to $10000	2.38%
$10000 to $15000	5.27%
$15000 to $20000	7.93%
$20000 to $25000	10.86%
$25000 to $30000	12.15%
$30000 to $35000	14.48%
$35000 to $40000	15.92%
$40000 to $45000	17.19%
$45000 to $50000	17.17%
$50000 to $55000	18.16%
$55000 to $60000	20.09%
$60000 to $65000	23.75%
$65000 to $70000	26.64%
$70000 to $75000	27.57%
$75000 to $85000	28.07%
$85000 to $90000	28.15%
$90000 to $95000	28.10%
$95000 to $100000	28.12%
$100000 to $125000	28.65%
$125000 to $150000	30.71%
$150000 to $175000	31.42%
$175000 to $200000	33.71%
$200000 to $250000	37.34%
$250000 or more	38.24%

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