Subprime Mortgages, Mortgage Choice, and Hyperbolic Discounting

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Abstract

This paper examines the implications of offering households the choice between traditional fully-amortizing mortgages that require substantial down payments (CPMs) and mortgages that involve lower initial payments (LIPs) because of a lower down payment requirement and a non-traditional amortization structure. I examine the issue in an equilibrium model in which households make decisions as if they discount hyperbolically rather than exponentially. More households choose LIPs under hyperbolic discounting than under exponential discounting. Allowing households access to LIPs exacerbates rather than mitigates the undersaving of hyperbolic discounters.

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1 Introduction

Mortgages that have lower initial payments than traditional fully amortizing mortgages have been at the heart of the recent foreclosure crisis. The mortgage products with the highest default rates have been those with subprime features, i.e., features that reduce the size of the initial payments. The increase in the foreclosure rate has spurred calls for more regulation of the mortgage products available to consumers (e.g., Bar-Gill and Warren [2008]) and the creation of the Consumer Financial Protection Bureau. While it is almost certain that limiting access to mortgages with very small down payments or non-traditional amortization structures would reduce foreclosures rates, there has been little economic analysis of the costs and benefits of allowing households access to such products.

In this paper, I examine the implications of offering households the choice between 30 year mortgages requiring substantial down payments and with traditional amortization structures (constant payment mortgages, hereafter CPMs) and mortgages with lower initial payments (low initial payment mortgages, hereafter LIPs) in an equilibrium model in which households make decisions as though they are quasi-hyperbolic discounters. Although I consider the case of exponential discounting, I focus on the hyperbolic case as economists increasingly recognize that household behavior is inconsistent with preferences that assume a constant intertemporal discount rate. Rather, the evidence suggests that households behave as though they discount the immediate future much more heavily than the distant future.[1]

Furthermore, there may be benefits and costs from introducing LIPs in a hyperbolic economy that are not present when households discount the future exponentially. In particular, when households suffer from temptation preferences, they may benefit from access to a savings commitment technology. Because moving is costly, home ownership can serve as such a commitment mechanism thus enabling households to save more adequately for their retirement (Laibson, 1997). LIPs enable more households to become home owners and access this commitment device. Increasing access to the commitment device may increase savings. It may also improve welfare. A hyperbolic household may, however, be tempted to

[1] See, for example, Angeletos, Laibson, Repetto, Tobacman, and Weinberg (2001), Laibson, Repetto, and Tobacman (2007), Skiba and Tobacman (2008), Paserman (2008), Fang and Silverman (2009), and DellaVigna (2009).

enter home ownership in situations in which it cannot afford to be a home owner or to buy a home that is larger than the one it can afford. Such households may subsequently default on their mortgages or struggle to make payments such that they would be better off in a world in which they did not have the option of an LIP.

To study the effects of allowing households access to LIPs, I calibrate an equilibrium life cycle model of mortgage choice. The model is an endowment economy with an exogenous relative price of housing and riskless interest rate. Mortgage rates are endogenous. The model has elements similar to the models in Corbae and Quintin (2010) and Garriga and Schlagenhauf (2009). One key difference between these models and mine is that I characterize the household's intertemporal discounting as hyperbolic while households in Corbae and Quintin (2010) and Garriga and Schlagenhauf (2009) discount the future geometrically. Households in my model are sophisticated quasi-hyperbolic discounters such that, as Krusell, Kuruşçu, and Smith (2010) show, preferences are a special case of the temptation preferences of Gul and Pesendorfer (2001). I evaluate welfare as though the household discounted geometrically consistent with the Gul and Pesendorfer (2001) framework.

I find that households are more likely to choose a subprime mortgage if they discount hyperbolically than if they discount exponentially. The steady state implications of allowing households access to LIPs are as follows: First, allowing households access to LIPs lowers the saving rate. For most age groups, savings are lower, both in absolute terms and relative to what exponential households would save, when households are able to finance home ownership with an LIP. The intuition behind this result is that, when households can only become home owners by making a substantial down payment and owner-occupying is preferred to renting, households begin saving earlier. When a down payment is no longer required, households save less because they can be home owners with little to no saving. Second, introducing LIPs raises the home ownership rate. The increase is about 7 percentage points in the benchmark parameterization. Third, introducing LIPs doubles the foreclosure rate.

Finally, I find that, in the benchmark parameterization, welfare is higher when households have access to LIPs and CPMs than when they have access only to CPMs. In the benchmark parameterization, the expected lifetime utility of a newly born household is 0.11% higher in the economy with LIPs. This is largely because LIPs raise the home ownership rate among

young households and, in the model, ownership of a home provides a household with more utility than renting an identical home. Although allowing households access to LIPs raises the expected lifetime utility at birth for all income groups, the welfare gains are highest for households born as the highest income earners. However, the net effect on welfare from introducing LIPs depends crucially on the utility premium from owner-occupying. The gain in welfare from the availability of LIPs is decreasing in the value of the premium to owner-occupying and for a small enough (albeit positive) value of the utility premium, average expected lifetime utility is lower in the economy with LIPs.

This paper is the first that I know of to study the implications of hyperbolic discounting for mortgage choice. Chambers, Garriga, and Schlagenhauf (2009), Barlevy and Fisher (2010), and Piskorski and Tchistyi (2010) study how consumers choose between a CPM and mortgages with subprime features. Chambers, Garriga, and Schlagenhauf (2009) show that, when consumers discount the future exponentially, there is strong age dependence in mortgage choice. I also find strong age dependence in mortgage choice in a hyperbolic setting. Barlevy and Fisher (2010) assume households discount the future exponentially and suggest housing market speculation as a reason for the choice of an interest only mortgage. Piskorski and Tchistyi (2010) suggest that households with more variable income are more likely to benefit from mortgages with subprime features. A much longer literature (see, for example, Campbell and Cocco [2003], Campbell [2006], and Koijen, Van Hemert, and Van Nieuwerburgh [2009] and the references therein) studies consumers' choices between adjustable and fixed rate mortgages. I study only fixed rate mortgages in this paper.

This paper is also the first paper that I know of to analyze the consequences of allowing households access to LIPs when households discount hyperbolically. Work by Garriga and Schlagenhauf (2009) and Corbae and Quintin (2010) has shown that introducing LIPs generates a quantitatively important increase in the foreclosure rate. I find that this result continues to hold in a hyperbolic setting. In empirical work, by Gerardi, Rosen, and Willen (2010) show that the introduction of non-standard mortgage products such as LIPs, improves consumers' ability to align their housing consumption with future income.

The remainder of the paper proceeds as follows: The next section presents the model used to study mortgage choice and the equilibrium in the two economies as well as the solution

method. Section 3 presents the benchmark parameterization of the model. The results are in Section 4. I conduct some sensitivity analyses in Section 5. Section 6 concludes.

2 The Model

I study an overlapping generations endowment economy in which households live for at most J periods of which $J_{RET} < J$ are spent "working". Each period, the household makes decisions regarding its tenure, assets, and mortgage choice. If the household chooses to rent, it must rent a home of quality h_1. If a household chooses to own its home, it chooses what quality of home to buy, and selects between a CPM and an LIP. The mortgage rate for each mortgage type is computed as the rate that makes the expected present value of the mortgage equal to the mortgage balance at origination. There are a small number of home qualities; a small number of home qualities reduces the computation required to solve the model.

The price of a unit of housing (in terms of the non-housing consumption good) is exogenous. Households face idiosyncratic income and home quality risk.[2] Stochastic home values are represented by assuming the home will decrease or increase in quality with exogenously given probability; the home quality follows a Markov chain. If a financial intermediary is forced to foreclose on a borrower, it incurs a cost χ (a percentage of the home value at the time of foreclosure) to rehabilitate the home to the quality it was at the time of foreclosure.

Similar to Campbell and Cocco (2010) and Corbae and Quintin (2010), there is no option to refinance to keep the model computationally tractable. Prepayment in the model thus corresponds to a sale of the home. When the household wishes to sell its home, it must pay a fixed cost that is a percent of the value of the home. The sale of the home may be viewed as a particular kind of refinancing: the household may refinance into the same value of home with a new mortgage if it pays the fixed moving cost. Viewed this way, the moving cost is akin to a prepayment penalty. The moving cost is what makes the home a commitment device for saving. Because the household cannot easily change its housing investment decision, taking

[2] See, among others, Case and Shiller (1989), Goetzmann (1993), Quigley and Van Order (1995), Deng, Quigley, and Van Order (2000), and Flavin and Yamashita (2002) for evidence that a substantial portion of the variation in home values is idiosyncratic.

on a mortgage commits the household to a particular savings path.

There is no intentional bequest motive in the model. This is consistent with the empirical evidence in Hurd (1989); Hurd finds that most bequests are accidental and that the intentional bequest motive is quite small. When a household dies, it is immediately replaced by a newly born household which begins life with no assets.

The timing in the model is as in Corbae and Quintin. At the beginning of each period, the household learns its income for that period and, if it is an owner, whether its home has appreciated or depreciated in value. The household then makes its tenure, housing, mortgage termination, mortgage product, and consumption decisions. If the household chooses to enter into a new mortgage contract, it makes the down payment at the start of the period. At the end of the period, the household receives its income, consumes, and makes rent or mortgage payments. As in Corbae and Quintin's benchmark specification, mortgages are non-recourse in the sense that the lender cannot seize assets other than the house if the borrower defaults on the mortgage.

2.1 Households

Households that choose to own a home take on a T period mortgage. The household's state vector is $\{j, a, H, h, n, h_O, \kappa, y\}$ where $j \in \{0, ..., J-1\}$ represents the household's age, a represents the household's assets, $H \in \{0, 1\}$ is the household's tenure, $h \in \{h_1, h_2, h_3\}$ is the home quality, $n \in \{0, ..., T\}$ is the number of periods the household has remaining on in its current mortgage, and $h_O \in \{h_2, h_3\}$ denotes the home quality that the household chose at origination. As in Gervais (2002), Corbae and Quintin (2010), and Nakajima (2010), the poorest quality home a household can buy is h_2 rather than h_1. Income, y, is exogenously given and follows a Markov process. $\kappa \in \{CPM, LIP\}$ represents the household's mortgage type.

I interpret hyperbolic discounting a special case of temptation preferences (Krusell, Kuruşçu, and Smith, 2010) and thus avoid the multiple selves' problem of computing welfare. Households therefore make decisions discounting the next period by $\beta\alpha$, $\beta \leq 1$, but their actual welfare is computed using geometric discounting, i.e., $\beta = 1$. For $\beta < 1$, households are sophisticated hyperbolic discounters in that they are aware of their temptation problem.

The household aged j that enters the period with assets a, tenure H, home quality h, n periods remaining on its mortgage, mortgage type κ, and income y thus chooses its tenure, housing, mortgage, and assets to maximize

$$u\left(c, h', H'\right) + \beta\alpha\pi_j EV\left(j+1, a', H', h', n', h'_O, \kappa', y'\right) \tag{1}$$

where

$$\begin{aligned} V\left(j, a, H, h, n, h_O, \kappa, y\right) &= \left\{ \begin{array}{c} u\left(c, h', H'\right) + \\ \alpha\pi_j EV\left(j+1, a', H', h', n', h'_O, \kappa', y'\right) \end{array} \right\}, \\ n' &= \left\{ \begin{array}{c} \left(1 - \mathbf{1}_S - \mathbf{1}_D\right)\max\left(0, n-1\right) + \mathbf{1}_B(T-1) \text{ if } H' = 1 \\ 0 \text{ if } H' = 0 \end{array} \right\}, \end{aligned}$$

The indicator function $\mathbf{1}_B$ takes on a value of one if the household buys a new home in that period, and hence takes on a new mortgage, and 0 otherwise. The indicator $\mathbf{1}_D$ takes on a value of 1 if the household chooses to default in that period, 0 otherwise. The indicator $\mathbf{1}_S$ takes a value of 1 if the household chooses to sell its home, 0 otherwise. π_j is the probability that a household that has survived to age j survives to age $j+1$.

For a household that starts the period as a renter ($H = 0$), the constraint on (1) is

$$c + a' = y + (1+r)\left(a - H'\mathbf{1}_{CPM}\nu q h'\right) - H'\left(p_T\left(\kappa\right) + \delta h'\right) - \left(1 - H'\right)Rh_1 \tag{2}$$

where q is the price per unit of housing, $p_n\left(\kappa\right)$ is the payment due on a mortgage of type κ with n periods remaining, δ is the depreciation rate, and R is the rental rate. The indictor function $\mathbf{1}_{CPM}$ takes on a value of 1 if the household uses a CPM to finance home ownership and 0 otherwise such that (2) captures the fact that the household need only make a down payment if it both becomes an owner ($H' = 1$) and chooses a CPM ($\mathbf{1}_{CPM} = 1$).

If the household starts the period as an owner ($H = 1$), it decides whether to default on its mortgage and whether to sell its home. If the household decides to default, $H' = 0$. The

constraints on (1) if $H = 1$ are thus

$$
\begin{aligned}
c + a' &= y + (1+r)\left(a + \mathbf{1}_S\left[q(1-\sigma)h - b_n(\kappa)\right] - H'\mathbf{1}_B\mathbf{1}_{CPM}\nu q h'\right) \\
&\quad -H'\left[(1-\mathbf{1}_B)p_n(\kappa) + \mathbf{1}_B p_T(\kappa') + \delta h'\right] - (1-H')Rh_1, \\
H' &\equiv 0 \text{ if } \mathbf{1}_D = 1, \qquad (3) \\
\kappa' &\left\{\begin{array}{ll} \in \{CPM, LIP\} & \text{if } \mathbf{1}_B = 1 \\ = \kappa & \text{if } \mathbf{1}_S \cup \mathbf{1}_D = 0 \\ = \emptyset & \text{if } H' = 0 \end{array}\right\}, \text{ and} \qquad (4) \\
h'_O &\equiv h_O \text{ if } \mathbf{1}_B = 0. \qquad (5)
\end{aligned}
$$

where σ represents the transactions cost of selling a home and $b_n(\kappa)$ is the outstanding balance on a mortgage of type κ with n periods remaining on its term.

The interpretation of (3) is that if the household chooses to default on its mortgage, it must rent for that period. Equations (4) and (5) represent the fact that the household cannot refinance. Equation (4) says that the household can only enter into a new mortgage contract when it buys a new home and κ is null if the household chooses to rent. Equation (5) is mechanical: it says merely that the household's state variable for the home quality at origination does not change if the household does not buy a new home.

2.1.1 The Benefits of Home Ownership

In this framework, there are two benefits of owning a home relative to renting. First a premium for owning relative to renting is built into the felicity function through its dependence on tenure chosen in that period, H'. In this respect, I follow Hu (2005), Chatterjee and Eyigungor (2009), and Corbae and Quintin (2010). Arguably, the owner-occupied utility premium captures the benefit from a household being able to customize an owner-occupied home (e.g., paint the kitchen purple or install carpeting instead of wood floors) and any psychic benefit from owning relative to renting.

Second, households can only rent a home of quality h_1; if a household wants to consume housing services associated with a home of quality h_2 or h_3, it must be a home owner. I follow Corbae and Quintin (2010) in this respect. These assumptions are important to

generate home ownership rates similar to what we observe in the data. The assumption that all rental homes are of quality h_1 also implies that the housing share of expenditure is declining in income. The assumptions are also important for understanding the results regarding welfare.

2.2 Financial Intermediary

As in Corbae and Quintin (2010), the financial intermediary is an infinitely lived company that accepts household savings and makes mortgage loans. It earns the exogenously given rate r on savings. Each period, it pays a servicing cost ϕ, a percent of the value of the mortgage, on each mortgage it holds. It also holds a stock of housing capital which it can rent out at rate R per unit or sell to households as owner-occupied housing. It incurs the maintenance cost δ on its housing stock and a cost χqh of rehabilitating housing units it acquires through foreclosure. In equilibrium, it must make zero profits. Since the value of a home must be equal to the present value of future rents, in equilibrium each unit of housing rents at rate $R = rq + \delta$ where q is the price per unit of housing.

2.3 Mortgage Choice

A mortgage contract, denoted by κ, may be a traditional constant-payment, fixed-rate mortgage (CPM) or an LIP mortgage. A CPM entails a down payment of ν percent of the value of the home, payments designed to fully amortize the mortgage over T periods, and an interest rate r_{CPM}. If the household takes out an LIP mortgage, it makes no down payment and pays only the interest on the mortgage during the first n_{LIP} periods. The principal on an LIP is amortized over the remaining $T - n_{LIP}$ periods. An LIP mortgage is characterized by an interest rate r_{LIP}. The equilibrium concept in this paper lies is the same as that in Garriga and Schlagenhauf (2009) and Athreya (2002): the equilibrium is a pooling equilibrium where the financial intermediary offers the same interest rate to all borrowers in a particular product category. In Corbae and Quintin (2010), the mortgage interest rate is specific to a single household's asset, income, and housing combination such that it represents financial intermediaries assessing the risk of individual households.

The main reason I choose the pooling equilibrium concept is computational. Because the model here is a life cycle model and households can transition between renting and owning at any point in time, unlike the infinite horizon model in Corbae and Quintin (2010), it is computationally very challenging to construct equilibrium interest rates in this setting. Introducing interest rates specific to each individual is unlikely to qualitatively change the predictions of the model. Indeed, despite having different equilibrium concepts, household leverage has similar implications in Corbae and Quintin (2010) and Garriga and Schlagenhauf (2009).

2.4 Home Values

As in Corbae and Quintin (2010), stochastic house prices are captured by households facing an exogenously given probability that their house changes in quality and, hence, value. In particular, a home owner that currently owns a home of quality h_2 faces a probability λ that the home will increase to quality h_3 and a probability λ that the home will decrease to quality h_1. A home owner that currently owns a home of quality h_3 faces a probability λ that the home will depreciate to quality h_2. A home owner that owns a home of quality h_1 faces a probability λ that the home will increase to a home of quality h_2. Rental units, all of which are of quality h_1, do not change in quality.

2.5 Steady State Equilibrium and Computation

In equilibrium, lenders make zero profits. This implies that the contract rates r_{CPM} and r_{LIP} are the rates that equate the expected present value of the mortgage to the loan balance at origination. The opportunity cost of the lender's funds is the riskless interest rate, r; it costs lenders ϕ to service the mortgage rate. Lenders thus compute the present value of the mortgage rate by discounting the expected cash flows by $r + \phi$. An equilibrium is thus a set of interest rates $\{r_{CPM}, r_{LIP}\}$ such that the average present value of a mortgage contract κ is equal to the size of the mortgage at origination.

The solution algorithm consists of two loops. In an inner loop, I solve the household's problem using grid search over each of the choice variables for a given mortgage rate (r_{CPM} in

the economy with only CPMs) or pair of interest rates (r_{CPM} and r_{LIP} in the economy with both CPMs and LIPs). Using grid search is slow but non-monotonicities and discontinuities are common in hyperbolic economies such that local optimization methods risk not finding the correct household. The asset grid consists of a total of 140 points. The distribution of points along the asset grid is: 40 equally-spaced points between 0 and $\nu q h_2$; 20 equally-spaced points between $\nu q h_2$ and $\nu q h_3$; 20 equally-spaced points between $\nu q h_3$ and $q h_2$; and 60 equally-spaced points between $q h_2$ and $3 q h_2$. I simulate the model over 20,000 households for 1,000 periods for each mortgage rate or rates. I drop the first 100 periods as burn-in iterations.

The outer loop solves for the mortgage rate or rates. After solving the household's problem and simulating the model based on the solution to the household's problem, I compute the average present value of a mortgage contract of type κ. With a large enough number of households and periods, the average present value of the mortgage contract will also be the expected present value of the mortgage contract. Thus, if the difference between the average present value of a mortgage contract and the loan balance at origination is sufficiently small, the mortgage rate (or rates) constitutes (constitute) an equilibrium.

I know of no theory that guarantees either existence or uniqueness of the equilibrium in this framework. While Krusell and Smith (2008) state that the household's problem has a unique equilibrium in a finite horizon setting such as the current model, that guarantees only that, conditional on a particular interest rate, the household's problem has a unique solution; there is nothing that guarantees that with many agents the equilibrium interest rate will be unique. As a result, I use grid search to find the equilibria in the model. While this process is time consuming, it is greatly accelerated by the use of parallel processing. In particular, I use the openMP framework to find all equilibria.

3 Parameterization

Table 1 summarizes the parameterization of the model. Several of the parameters are fixed based on empirical estimates. The remaining parameters are chosen to ensure that the model matches certain moments in the data. I choose these parameters to match home-

ownership rates, average mortgage rates, average foreclosure rates, and loan-to-income ratios at origination in the fifteen years prior to 2003. I focus on the years prior to 2003 since subprime mortgages were not widely used before 2003 such that data from the years before 2003 may be interpreted as data from a steady state without LIPs; see Corbae and Quintin (2010) for additional evidence that this period represents a steady state in the housing market. I target a home-ownership rate of 67%, an annual real mortgage rate of 5.33%, an annual foreclosure rate of 1.5%, and a loan-to-income (annual) ratio at origination of 273%.

3.1 Demographics

A period in the model corresponds to 3 years. The household is born at age 25, such that $j = 0$ corresponds to a chronological age of 25. The household lives until at most 85 years of age corresponding to $J = 20$. The age at which the household retires, J^{RET}, is 13 such that the household retires at a chronological age of 64. I take the survival probabilities, $\{\pi_j\}_{j=0}^{J-1}$, from Arias et al. (2008).

3.2 Income

I assume that the income process during working years follows an AR(1) process with a quadratic polynomial in age. That is, the process for income is

$$y_t = \rho y_{t-1} + \gamma_1 age_t + \gamma_2 age_t^2 + \varepsilon_t \tag{6}$$

where ε_t has variance σ_ε^2. I estimate the parameters of (6) using triennial PSID data on earnings from 1967 to 1992. I estimate the model using all heads of households between the ages of 25 and 64 that have positive labor income in the year prior to the survey, that have only high school degrees, and that are not part of the Survey of Economic Opportunities sample. The measure of income is all labor income. I convert income for all years into 1983$ prior to estimation using the CPI (all items). This estimation procedure yields $\hat{\rho} = 0.76$, and $\hat{\sigma}_\varepsilon^2 = 8817$. I then approximate (6) with a three state Markov chain using the approach of Tauchen and Hussey (1991). After retirement, labor income is set to 60% of income in the last working year following Cocco, Gomes, and Maenhout (2005) and Yao and Zhang

(2005).

Figure 1 shows the income profiles for the three states (low, medium, and high income). The transition probability matrix that governs the transitions between states is

$$\begin{matrix} 0.7049 & 0.2877 & 0.0073 \\ 0.1667 & 0.6667 & 0.1667 \\ 0.0073 & 0.2877 & 0.7049 \end{matrix} .$$

For example, a household that is a low income earner in period t has a 70.5% chance of being a low income earner in period $t+1$, a 28.8% of being a medium income earner in period $t+1$, and a 0.007% chance of being a high income earner in period $t+1$. The ergodic distribution associated with this Markov chain is such that, in the steady state, 26.85% of households have low income, 46.3% of households have medium income, and 26.85% of households have high income. In the simulations, income at birth is randomly allocated to match the ergodic distribution.

3.3 Preferences

The key parameter in the model is the short-term discount rate, β. I set this to 0.7 in the benchmark specification based on the estimates of Laibson, Repetto, and Tobacman (2007). In the same estimation, Laibson, Repetto, and Tobacman (2007) estimate the long-term annual discount rate to 0.95; I thus set α to 0.95^3.

The felicity function is

$$u(c, h, H) = \psi \ln c + (1 - \psi) \ln h + \theta \mathbf{1}_{h > h_1}$$

following Corbae and Quintin (2010). I set ψ to 0.76 implying that renters spend 24% of their consumption expenditure on housing based on the estimates Davis and Ortalo-Magné (2011). There are no good estimates for θ such that I use θ to calibrate the model to match certain characteristics of the data.

3.4 Housing Costs

Based on the estimates of Campbell, Giglio, and Pathak (2010), I set χ, the foreclosure discount, to 0.25. I choose λ, the probability of an idiosyncratic home value shock, the home qualities, h_1, h_2, and h_3, the relative price of housing, q, and the mortgage servicing cost, ϕ, to calibrate the model to match the key moments in the data. The calibration implies that the price of the homes in 1983\$ (the same units as income) are \$30,937, \$47,828, and \$70,335. By comparison, the median home price in the 1980 US census was \$54,022 in 1983\$. I set T, the mortgage term, to 10 such that mortgages have 30 year terms. For CPMs, households must make a 20% down payment such that $\nu = 0.2$. LIPs have one period of interest only payment such that $n_{LIP} = 1$ and the mortgage corresponds to something similar to a 3/27, a very popular subprime mortgage product. The three-year risk-free rate, r, is 12%. Selling costs, ρ, are 8% of the value of the home as in Cocco (2004). I use δ, the per period depreciation rate on housing, to calibrate the model to match particular moments in the data.

4 Results

4.1 Equilibrium with only CPMs

Columns 2 and 3 of Table 2 present equilibrium statistics regarding the model when the household has access only to CPMs. There is a unique equilibrium with positive home ownership. By construction, the home ownership rate, the mortgage rate, the foreclosure rate, and the average loan-income ratio are close to those in the data (column 1) when households exhibit hyperbolic discounting. Perhaps surprisingly, the home ownership rate when households discount the future exponentially ($\beta = 1$) is higher than when households discount the future hyperbolically; the home ownership rate in the hyperbolic economy is 67% while it is 78% in the exponential economy.

As Figure 2 illustrates, the aggregate home ownership rate is lower in the economy with hyperbolic discounting primarily because hyperbolic discounters often transition out of home ownership at fairly young ages (such as between ages 2 and 3) and become renters earlier

into their retirement. The home ownership rate among households aged 18 periods (79 years chronologically) is less than 50% in the hyperbolic economy while it remains near 75% in the exponential economy owing to greater asset holdings by older households in that economy. The home ownership rate among households aged 25 to 31 years is quite similar across the two economies.

In the hyperbolic economy, more home owners transition out of home ownership into renting by a foreclosure as evidenced by the foreclosure rate in the hyperbolic economy. The annual foreclosure rate in the hyperbolic economy is 1.62% while it is 0.96% in the exponential economy. The higher foreclosure rate in the hyperbolic economy in turn implies a slightly higher mortgage interest rate in that economy: the equilibrium annual mortgage interest rate in the exponential economy is 5.08% while it is 5.33% in the hyperbolic economy.

Home ownership is concentrated among higher income earners in both the hyperbolic and the exponential economies. In the hyperbolic economy, the home ownership rate among the lowest earning households is only 25% while it is 77% for middle income earners and 90% for high income earners. In the exponential economy, the home ownership rate among low earners is 50%, double that in the hyperbolic economy. Middle income earners in the exponential economy have a home ownership rate of 85% and high income earners have a home ownership rate of 93%. The low home ownership rate among low income households is due to both the minimum quality of owner occupied housing and the persistence of the income processes. The large difference in home ownership rates for low income households between the exponential and hyperbolic economies suggests that the down payment constraint is a major impediment for low income households. When households discount the future hyperbolically, low income households have a great deal of difficulty acquiring the down payment due to the undersaving problem.

Households in the hyperbolic economy save considerably less as Figure 3, which shows the ratio of net worth to triennial income by age, illustrates. Across households of all ages, the average net worth in the hyperbolic economy is less than half the average net worth in the exponential economy. Although the net worth to income ratio is always lower in the hyperbolic economy than in the exponential economy, the undersaving is particularly pronounced for older households. The sharp spike in the figure at the retirement age is

because the denominator is income at that age which drops off steeply at retirement. The gap between net worth in the hyperbolic and exponential economies grows at retirement because households in the hyperbolic economy exit home ownership much earlier than households in the exponential economy. Without the required payments that home ownership requires, payments that increase home equity, hyperbolic households quickly deplete their assets. Most exponential households stay home owners until the very last period of life and only then liquidate their housing holdings.

Nevertheless, the expected lifetime utility of an age 0 household is not substantially lower in the hyperbolic economy than in the exponential economy. Welfare is only 0.19% lower in the hyperbolic economy than in the exponential economy. The small difference in lifetime expected utility of newly born households masks differences in welfare across age groups. As Figure 4 shows, the average expected lifetime utility of retirees in the hyperbolic economy is 3% to 4% lower than that of retirees in the exponential economy. This is largely because it is in retirement that households in the hyperbolic economy face the consequences of their undersaving.

4.2 Equilibrium with CPMs and LIPs

Columns 4 and 5 of Table 2 presents the equilibrium of the model when the household has access to the LIP mortgage which, in the benchmark calibration, is a mortgage without any down payment and for which the payments are interest only for the first 3 years. Column 4 presents the equilibrium when households discount hyperbolically and column 5 illustrates the equilibrium when households exponentially. More households choose LIPs in the hyperbolic economy than in the exponential economy. In the hyperbolic economy, fully 53% of new originations are LIPs while in the exponential economy only 35% of originations are LIPs. Because LIPs are more likely to terminate through foreclosure, and thus have a higher interest rate, the average mortgage rate in the exponential economy is above that in the hyperbolic economy. The greater use of LIPs in the hyperbolic economy also implies a slightly greater increase in the home ownership rate and a more pronounced drop in household savings than in the exponential economy.

The average annual mortgage rate in the hyperbolic economy with LIPs is about 70 basis

points higher than the average mortgage rate in the exponential economy with LIPs. This is largely because more households in the hyperbolic economy choose an LIP than in the exponential economy with LIPs. When LIPs are available, the CPM mortgage rate is only 8 basis points lower in the exponential economy than the corresponding rates in the hyperbolic economy and the LIP mortgage rate is in fact 8 basis points lower in the hyperbolic economy. Because fewer households choose LIPs in the exponential economy, the foreclosure rate in the exponential economy rises more modestly than in the hyperbolic economy.

4.2.1 Equilibrium in the Hyperbolic Economy in Detail

When households discount the future hyperbolically, the home ownership rate rises by 7 percentage points, to 74%, from the equilibrium in which the household only has access to traditional CPMs. As Figure 5 illustrates, the home ownership rate is higher in the economy with LIPs largely because households enter into home ownership earlier. In the economy with only CPMs, no household has acquired the down payment required to become a home owner until age 31. Once the household is able to enter home ownership without a down payment, 73% of households are home owners by the start of period 1, i.e., at age 28. The home ownership rate in the economy with CPMs and LIPs remains substantially above that in the economy with only CPMs until households reach their late forties. The home ownership rate for middle aged households is similar in the two economies. The home ownership rate for elderly households is slightly higher in the economy with LIPs than in the economy with only CPMs as households can use LIPs to remain home owners while still exhausting their savings.

In the hyperbolic economy, the introduction of LIPs does not raise the home ownership rate of all income groups, however. The home ownership rate of low income households in fact falls from 25% to 22% as a result of the introduction of LIPs. This is likely due to low income households choosing foreclosure more frequently after the introduction of LIPs. The home ownership rate of middle income earners rises from 77% to 90% as a result of introducing LIPs while that of high income households rises from 90% to 97%.

There is little change in the quality of the homes that households purchase as a result of the introduction of LIPs. In the economy with only CPMs, luxury homes (homes of

quality h_3) are almost exclusively purchased by high income households. This remains true in the economy with both CPMs and LIPs. Furthermore, the share of originations to high income households for the purchase of luxury homes is similar in the two economies. In the economy with only CPMs, 38% of originations to high income households are for the purchase of luxury homes while, in the economy with CPMs and LIPs, 45% of originations to high income households are for the purchase of luxury homes.

The introduction of LIPs increases the rent to income ratio from 33% to 40%. The increase in the rent to income ratio arises because a larger fraction of renters are low income earners in the economy with LIPs than in the economy with only CPMs. Because low income earners spend a greater share of their income on rent, the economy-wide average rent-income ratio rises.

The equilibrium annual interest rate on CPMs falls by 25 basis points to 5.08% once households have access to LIPs. The reason that the interest rate on CPMs falls is that the households that were most likely to default in the economy with only CPMs now choose LIPs. As Figure 6 illustrates, it is primarily middle-aged households that opt for CPMs once LIPs are available. In the first period of life, all households that choose home ownership opt for LIPs. The fraction of home owners using LIPs falls steadily until the retirement age; at retirement, no households use LIPs. After retirement, the fraction of home owners using LIPs gradually rises with age until it reaches 95% in the last period before households are certain to die. Young households, who are responsible for most of the default in the economy, almost exclusively finance their home with LIPs such that the default rate on CPM mortgages falls.

Averaged over the number of mortgages outstanding, the annual foreclosure rate in the economy with CPMs and LIPs is 3.24%. This foreclosure rate is double that of the economy in which households only have access to CPMs. The high foreclosure rate on LIPs results in an equilibrium annual interest rate of 7.75% on these products. The average mortgage rate, as a percent of mortgages outstanding, rises to 6.08% when LIPs are introduced from 5.33% in the economy with only CPMs.

4.2.2 LIPs and Savings

Figures 7 and 8 illustrate that the welfare gain from LIPs is not because introducing LIPs raises average savings. The availability of LIPs exacerbates the undersaving of hyperbolic households of all ages. Figure 7 compares average net worth to triennial income ratios by age in the hyperbolic economy in which households only have access to CPMs and the hyperbolic economy in which households have access to both CPMs and LIPs. Net worth at every age is lower once households have access to LIPs than when they can only take on CPMs. The gap is largest for retirees where the undersaving problem is most acute. The intuition behind this result is that, rather than encouraging households to save, the higher home ownership rate can be sustained with less savings. In the economy with only CPMs, a household must have savings at least equal to the down payment if it wants to own a home. In contrast, in the LIP economy, many households save very little and yet are still able to be home owners. Because many retirees in the hyperbolic economy with LIPs finance home ownership with LIPs, retirees save far less once they have access to LIPs.

In an overlapping generations model with constraints on unsecured borrowing, Jappelli and Pagano (1994) find that even exponentially discounting households save less in aggregate once borrowing constraints are relaxed. A similar effect is at work in the present model such that, even when households discount the future exponentially, introducing LIPs lowers savings. However, Figure 8 shows that the fall in saving from the introduction of LIPs is more acute with hyperbolic discounting. Figure 8 plots what households save in the hyperbolic equilibrium relative to what they would save in the exponential equilibrium. The figure shows the ratio of average net worth by age in the hyperbolic economy as a percent of average net worth in the exponential economy when households only have access to CPMs and when both CPMs and LIPs are available. Thus, savings in the hyperbolic economy are lower after the introduction of LIPs both absolutely and relative to what exponential households save in the exponential equilibrium.

4.2.3 LIP Terminations

As Table 3 illustrates, LIPs have much higher foreclosure rates than CPMs. One period (three years) after origination, more than 30% of LIPs have terminated through default while less than 7% of CPM originations have terminated through foreclosure. Of all LIP originations, 41% eventually terminate through foreclosure. 14% of CPM originations eventually terminate through foreclosure. As home equity is the main driver of default, and LIP home owners have no home equity in the first period, three quarters of the defaults on LIPs occur in the period immediately after origination. Defaults on both LIPs and CPMs are rare more than two periods after origination since households have paid a substantial amount of principal on their mortgage by that period.

The high interest rate on LIPs gives households that choose not to default a strong incentive to prepay their mortgages. In this economy, prepayment corresponds to a sale of the home. After the LIP mortgage becomes fully amortizing, the payment on an LIP mortgage is much higher than the payment on a CPM of the same amount. As a result, a quarter of households with LIPs prepay their mortgages in the period immediately after origination. Only 8% of households with CPMs prepay their mortgages in the period after origination.

The finding that LIPs terminate much more quickly than CPMs is consistent with the empirical evidence on subprime mortgages Demyanyk (2009) presents. Demyanyk finds a three-year termination rate of 80% for subprime mortgages. The three-year termination rate in my model is somewhat lower at 56% likely due to refinancing not being permitted. The median CPM terminates about 3 periods (9 years) after origination. In later periods, the share of LIP originations that prepay is lower for LIPs than it is for CPMs; however, this effect is entirely due to there being far fewer LIPs than CPMs outstanding after three periods.

4.2.4 LIPs and Expected Utility

Average expected lifetime utility at age 0 is 0.11% higher in the economy in which the household has access to LIPs. This is a little more than half of the difference between

expected lifetime utility in the hyperbolic economy with only CPMs and the exponential economy with only CPMs. The increase in welfare is not because the availability of LIPs allows low income earners alone to enter home ownership. Only 15% of low income households that are home owners finance their purchase with an LIP. 23% of middle and high income home owners finance home ownership with an LIP.

As Table 4 shows, in both the hyperbolic and the exponential economies, introducing LIPs raises expected lifetime utility at age 0 for all three income groups. Perhaps surprisingly, the welfare gain is largest among households that begin life in the highest income category. In the hyperbolic economy, expected lifetime utility is higher by 0.22% for the highest earning households at birth while the availability of LIPs raises expected lifetime utility by only 0.07% for households that start life as middle or low income earners. The differential impact on expected lifetime utility by income is also present in the exponential model although it is somewhat less pronounced. In the exponential model, high income households see their expected lifetime utility rise by 0.17% as a result of the introduction of LIPs while middle and low income households see their expected lifetime utility rise by 0.09% and 0.08%.

Households accrue the benefit from the introduction of LIPs in the first period of life as Figure 9 illustrates. Figure 9 shows average expected lifetime utility in the hyperbolic economies with and without LIPs by age. The increase in lifetime utility at age 0 is almost exclusively because LIPs enable very young households to enter home ownership without restricting their consumption to save for a down payment. The down payment requirement in the economy with only CPMs prevents young households from entering home ownership. The welfare benefit accrues exclusively to young households. After age 0, average expected lifetime utility is slightly lower in the economy in which households have access to LIPs.

Part of the reason that LIPs raise expected lifetime utility is because they raise the home ownership rate. Recall that the benchmark calibration assumes that households receive a utility premium of 0.13 in every period they are home owners relative to when they are renters. The increase in the home ownership rate from the introduction of LIPs is not much larger when households discount the future hyperbolically than when households discount the future exponentially suggesting that the increase in welfare has little to do with allowing households access to the commitment mechanism home ownership may provide to households

that suffer from temptation problem.

5 Sensitivity Analysis

5.1 The Importance of Preferences

An important assumption in the calibration of the model is that households get a utility premium from ownership. In particular, in the benchmark calibration, I assume that $\theta = 0.13$. I make this assumption to match the home ownership rate in the data with the home ownership rate generated by the model. To understand the importance of this assumption, in this subsection I compute the equilibria of the model under different assumptions for θ.

Table 5 presents the equilibrium of the model when $\theta = 0.1$, $0.075, 0.05$, and 0.025. For the benchmark assumption of $\theta = 0.13$, the average gain at birth from introducing LIPs is 0.11%. Decreasing θ to 0.10 reduces the average welfare gain from LIPs to 0.08% of average expected lifetime utility at age 0. All three income groups continue to experience higher expected lifetime utility at birth when LIPs are available and it continues to be the case that high income earners benefit more. The home ownership rate falls to 63% in the economy with only CPMs available and to 70% in the economy with LIPs and CPMs available as the gains from home ownership fall. Foreclosure rates rise slightly (to 1.9% annually in the economy with only CPMs and to 3.3% in the economy with CPMs and LIPs) as the value of staying a home owner falls. The increase in foreclosure rates in turn raises the cost of credit by about 17 basis points. As in the case with $\theta = 0.13$, introducing LIPs depresses savings both in absolute terms and relative to what households save in the exponential equilibrium.

When θ falls to 0.075, the gain in average expected lifetime utility from introducing LIPs is only 0.03%. Furthermore, households born as middle income earners no longer have higher expected lifetime utility as a result of introducing LIPs. Access to LIPs raises the home ownership rate by about 8.5 percentage points and increases the foreclosure rate by about two thirds. Finally, the availability of LIPs continues to depress savings, both absolutely and relative to what households save in the equilibrium in the exponential economy.

When θ falls to 0.05, average welfare falls after LIPs are introduced. LIPs continue to

exacerbate the undersaving problem both in absolute terms and relative to what households save in the equilibrium in the exponential economy. With $\theta = 0.05$, the utility benefit from greater home ownership is no longer sufficient to offset the greater degree of undersaving that results from LIPs. Introducing LIPs reduces expected lifetime utility for middle and low income earners while expected lifetime utility of high income households is almost unaffected. The availability of LIPs raises the home ownership rate by only three percentage points (from 57% to 60%), rather than the seven percentage points in the benchmark parameterization. As households get less benefit from owner-occupying, they become more willing to walk away from a negative equity situation such that the annual mortgage rate on LIPs rises to 9.75%. Although the interest rate on LIPs is much higher than for higher values of θ, the average mortgage rate is not higher than in the benchmark parameterization or for higher values of θ. The average mortgage rate does not rise because far fewer households opt for an LIP when the interest rate is close to 10% and they get only a small benefit from home ownership. Because fewer households choose LIPs, the fall in savings from the introduction of LIPs is less acute for $\theta = 0.05$ than for higher values of θ.

When θ is further reduced, to 0.025, introducing LIPs has less of an effect on the equilibrium. With $\theta = 0.025$, the rate on LIPs rises to 10%. As a result, very few households opt for LIPs such that the average mortgage rate is lowest for the case of $\theta = 0.025$ despite both the LIP and the CPM rates being highest. Households that finance home ownership with an LIP for higher values of θ now choose to rent instead. The availability of LIPs thus raises the home ownership rate by only about 1.5 percentage points. Average expected lifetime utility at age 0 is slightly lower after the introduction of LIPs. Allowing households access to LIPs results has almost no effect on aggregate savings.

When $\theta = 0.0$, the only equilibrium is one in which households borrow using only CPMs. That is, there is no LIP rate that both compensates lenders for the high default risk and for which borrowers choose an LIP.

5.2 Separating the Components of the LIP

The benchmark version of the model assumes that the LIP differs from the CPM in two ways. First, the LIP requires no down payment. Second, the first payment on the LIP is

interest only. To understand the role of each of these features separately, in this subsection I consider two alternative versions of the model. Column 3 of Table 6 presents the equilibrium of a version of the model in which the LIP requires a 20% down payment but for which the payment in the first period is interest only. Offering households an interest only mortgage changes the equilibrium very little. The interest only mortgage has a substantially higher default rate such that it also carries a much higher rate than the CPM. As a result, few households opt for the LIP. Only 2% of originations are LIPs such that the equilibrium is much the same as when the only mortgages available are CPMs.

Column 4 of Table 6 summarizes the equilibrium of a version of the model in which the LIP requires no down payment but amortizes over the full 10 period term such that there is no interest only period. The home ownership rate rises to 75%, a rate even higher than for the benchmark LIP. The main reason is that, without the interest only period, the rate on the LIP is only 6.75% rather than the 7.75% for the benchmark LIP. The interest rate on the LIP is in turn lower because fully amortizing LIPs are much less likely to end in foreclosure. Although a greater share of originations are LIPs in the economy with fully amortizing LIPs than in the benchmark case, the foreclosure rate is only 2.5% rather than 3.4% in the benchmark case. The fall in savings from the introduction of LIPs is similar to the benchmark case.

These results suggest that the combination of non-standard mortgage features can greatly affect outcomes. Although introducing the IO feature alone had little effect on the equilibrium, adding the IO feature to a low down payment mortgage substantially increases the foreclosure rate, lowers the home ownership rate, and actually decreases welfare.

5.3 A Bequest Motive

In the benchmark version of the model, there is no bequest motive. Any savings at the end of the life are due to uncertainty regarding longevity. In this subsection, I explore whether the results are sensitive to this assumption by including a bequest motive in household preferences. The bequest motive is modeled in a similar fashion to Campbell and Cocco (2003), Cocco (2004), and Cocco, Gomes, and Maenhout (2005).

In particular, in this version of the model I assume that the household maximizes

$$(7) \qquad u(c, h', H') + \beta\alpha\pi_j EV(j+1, a', H', h', n', h'_O, \kappa', y') + \beta\alpha(1-\pi_j) E \ln W$$

rather than equation (1). W represents net worth in (7) and $V(\cdot)$ in (7) is defined by

$$V(j, a, H, h, n, h_O, \kappa, y) = \left\{ \begin{array}{c} u(c, h', H') + \\ \alpha\pi_j EV(j+1, a', H', h', n', h'_O, \kappa', y') \\ +\alpha(1-\pi_j) E \ln W \end{array} \right\}.$$

In computing expected net worth, I assume that when a household dies its heirs pay the housing selling cost and liquidate the housing position.

Columns 5 and 6 of Table 6 present the equilibrium of the model with only CPMs and the model with CPMs and LIPs when there is a bequest motive. The first thing to note is that average net worth rises considerably. The increase in savings is largely due to changes in the saving behavior of older households; the savings behavior of young households is similar to the benchmark economy. Second, fewer households choose LIPs. In the benchmark version of the model, LIPs are the instrument of choice for both young households and retirees. This leads to 53% of mortgage originations being LIPs. With a bequest motive, LIPs are primarily used by only the young as Figure 6 illustrates such that only 38% of originations are LIPs. In the benchmark version of the model, older households use LIPs to dissave while remaining home owners. When there is a bequest motive, they no longer wish to dissave as much and so are content to finance home ownership with a CPM.

The introduction of LIPs continues to decrease savings when there is a bequest motive. The fall in savings is largely due to young households who actually use LIPs when there is a bequest motive. The rise in the home ownership rate from the introduction of LIPs, of about 6 percentage points, is similar to the benchmark case. The foreclosure rate rises from 1.2% to 2.1% after LIPs are introduced.

6 Conclusions

This paper studied how hyperbolically discounting households choose between a traditional fully amortizing mortgage that requires a substantial down payment and a product that offers low initial payments in an equilibrium life cycle framework. The LIPs in the model have similar features to popular subprime mortgage products. Households are more likely to choose an LIP when they discount hyperbolically than when they discount exponentially. I find a strong age dependence in which households choose an LIP; LIPs are chosen primarily by young households and retirees. In the model, the majority of LIPs are terminated within three years of origination consistent with empirical evidence on subprime mortgage terminations. I also find that allowing households access to LIPs exacerbates the undersaving problem that arises when households behave hyperbolically. In the benchmark calibration, introducing LIPs doubles the steady state foreclosure rate and raises the steady state home ownership rate by about 7 percentage points. Perhaps surprisingly, the home ownership rate is always lower when households discount the future hyperbolically than when they discount the future exponentially.

In the benchmark parameterization of the model, the welfare of a newly born household is higher in the steady state in which access to LIPs is unrestricted. Several caveats are in order regarding the robustness of the result regarding welfare. First, the result depends critically on the assumption for the utility premium from owner-occupying. For a low, but positive, value of the owner-occupier premium, welfare is lower in the steady state with LIPs. Second, the model is an endowment economy. In a production economy, the lower savings rate that subprime induces may lower capital formation such that wages would fall. Such a decline in wages would likely reduce aggregate welfare. Third, the welfare calculations in this paper do not incorporate any externalities from a higher foreclosure rate. The foreclosure rate is substantially higher in the economy with LIPs. In the benchmark economy in which households can borrow using only CPMs, the annual foreclosure rate is 1.6% while, in the economy with both CPMs and LIPs, it is 3.2%. The welfare calculations in the model do not assume that foreclosures entail any negative externalities. While evidence (e.g., Campbell, Giglio, and Pathak, 2010) suggests that foreclosures lower the prices of nearby homes not in

foreclosure, it is unclear how to translate such price declines into aggregate welfare and I have not attempted to do so here. The welfare gains would shrink if there are large externalities associated with foreclosures.[3] Finally, it is important to bear in mind that I compare welfare only in the two steady states; I do not study the economy as it transitions to the new steady state with LIPs.

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[3] On the other hand, the home ownership rate rises from 67% to 74% as a result of the introduction of LIPs. If home ownership entails positive externalities (as found by, among others, Green and White [1997], DiPasquale and Glaeser [1999], Aaronson [2000], Barker and Miller [2009], and Englehardt, Eriksen, Gale, and Mills [2010]), introducing LIPs would result in larger welfare gains than I find here.

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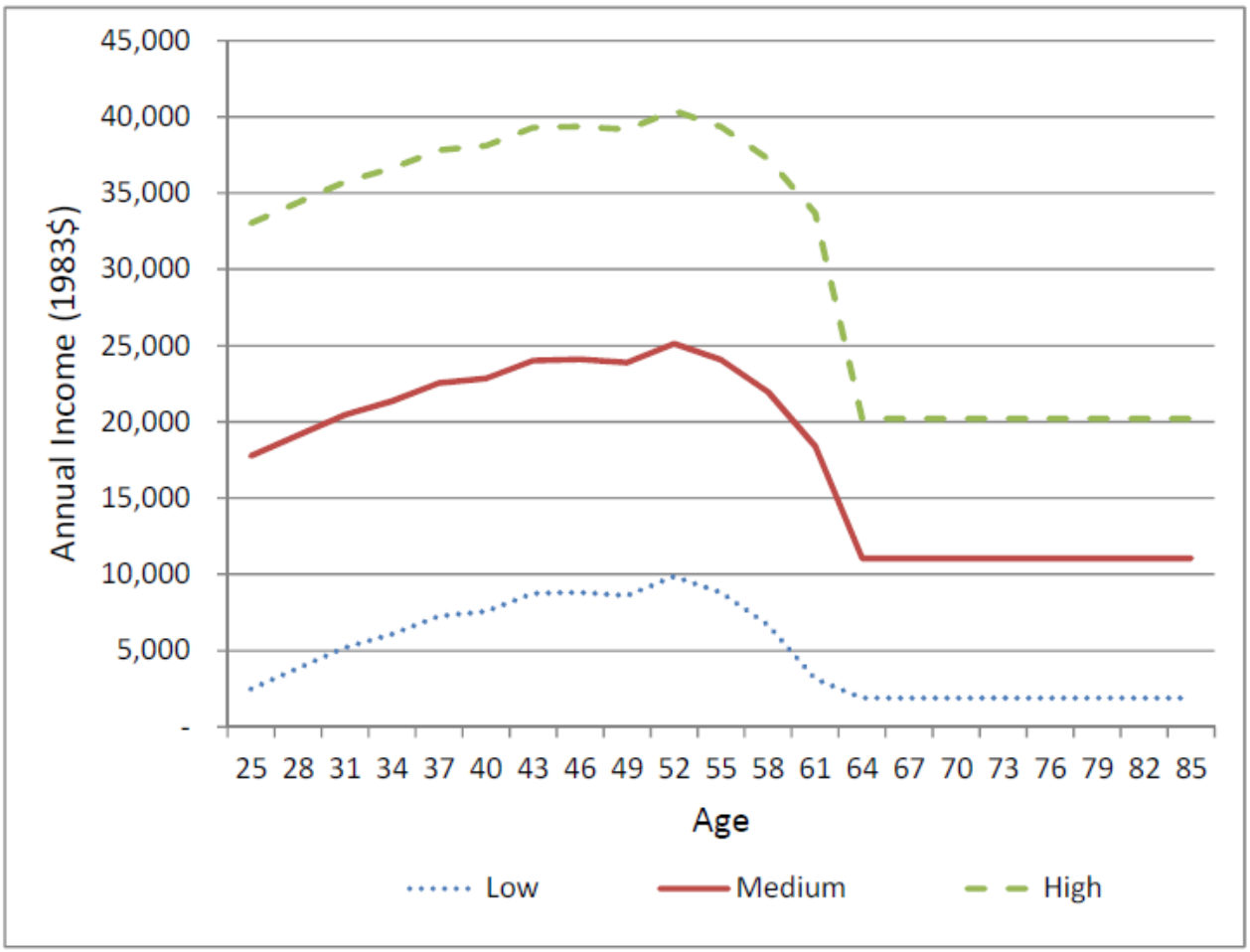

Figure 1: Income Profiles Used in the Model
Three states of Markov Chain used to approximate AR(1) process for income estimated from PSID Data. See text for details.

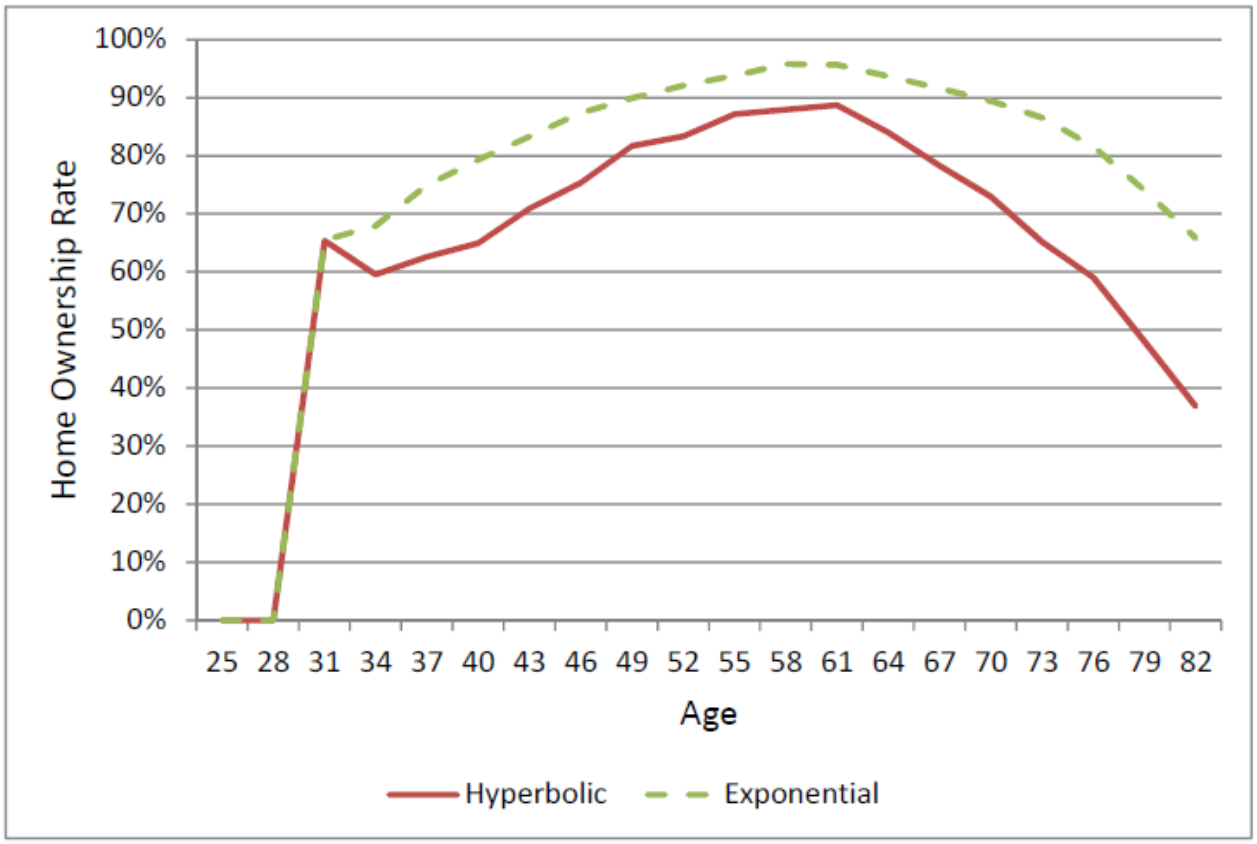

Figure 2: Home Ownership Rates by Age in the Hyperbolic and Exponential Economies (CPMs Only)

Note: Home ownership rates are at start of period.

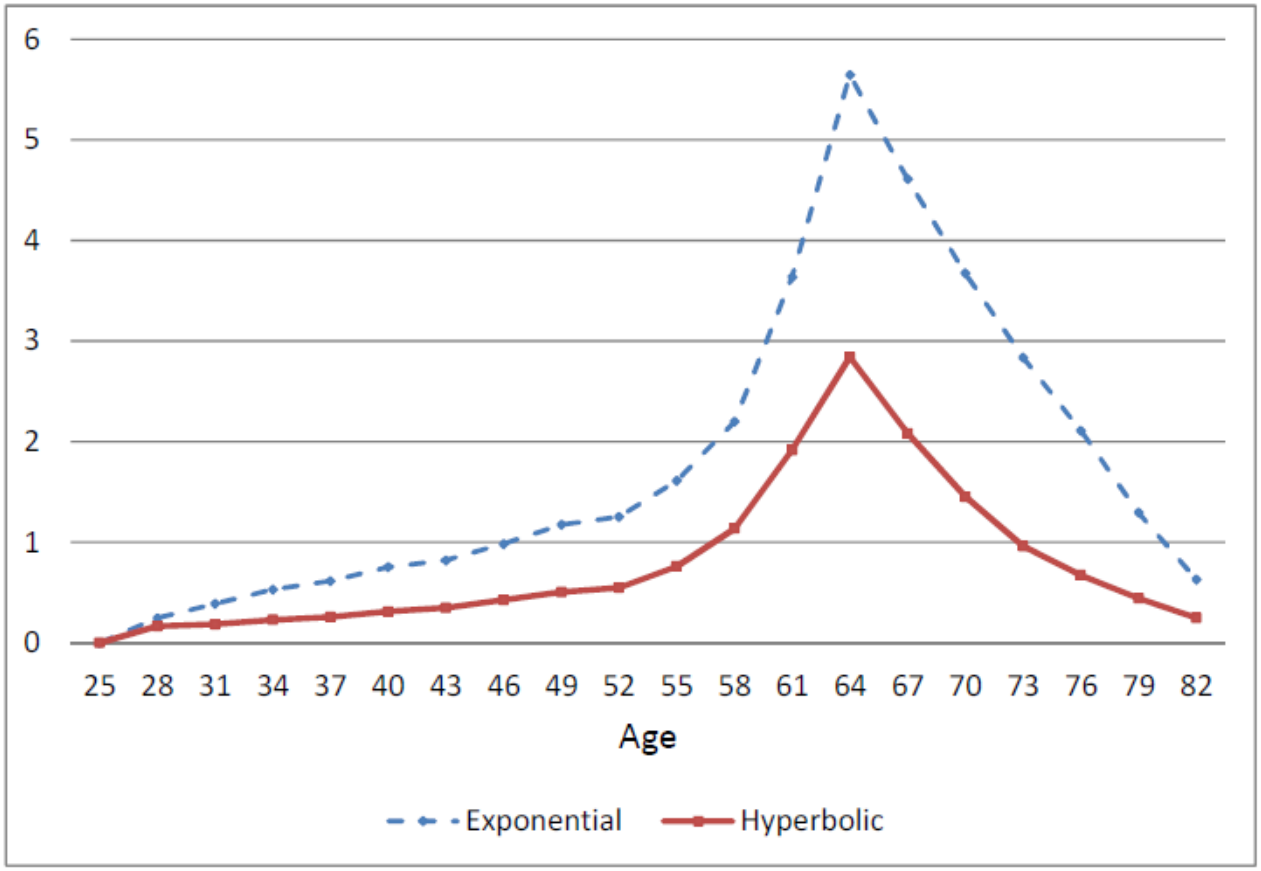

Figure 3: Average Net Worth to Income Ratios by Age in the Hyperbolic and Exponential Economies

Note: Net Worth to Income at Start of Period.

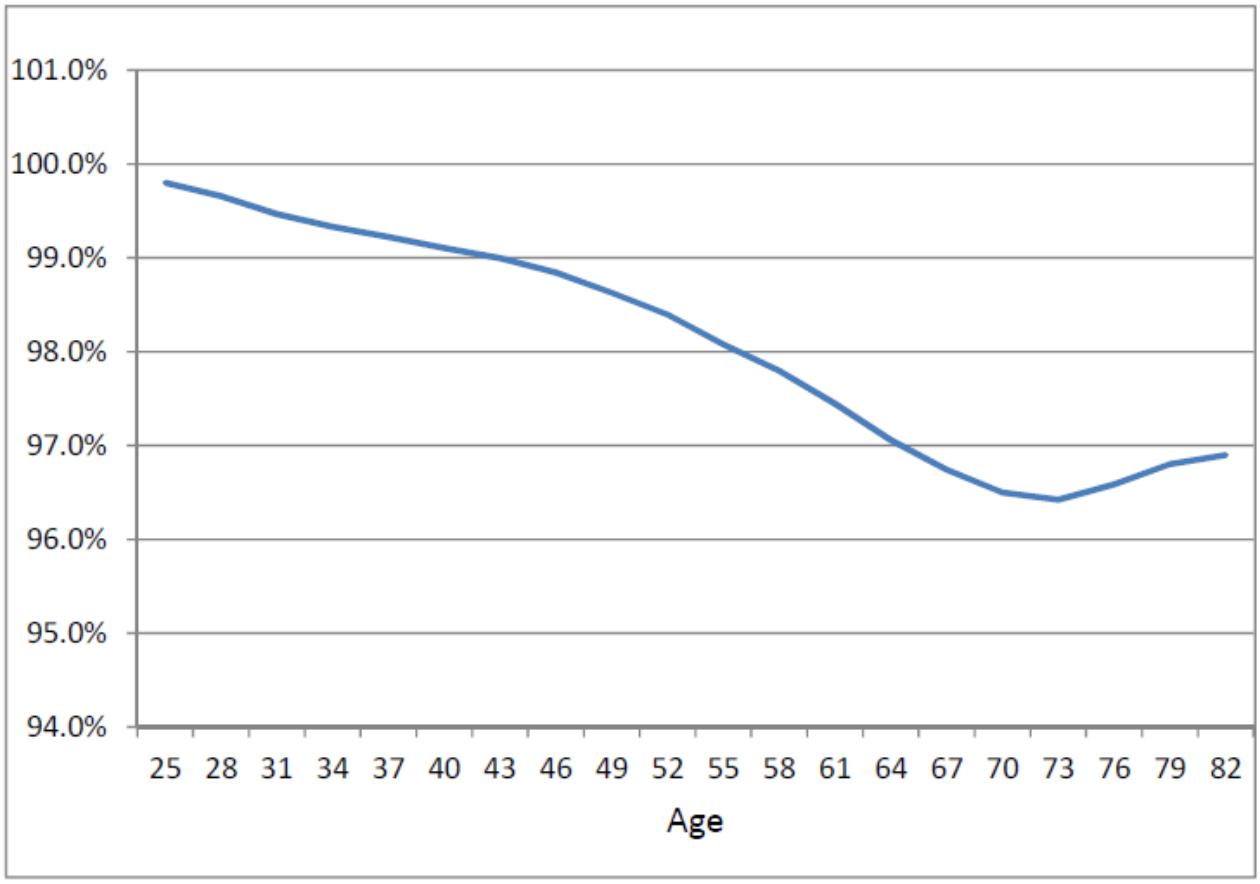

Figure 4: Ratio by Age of Lifetime Expected Utility in Hyperbolic Economy to Lifetime Expected Utility in Exponential Economy (CPMs Only)
Note: Expected Lifetime Utility at Start of Period

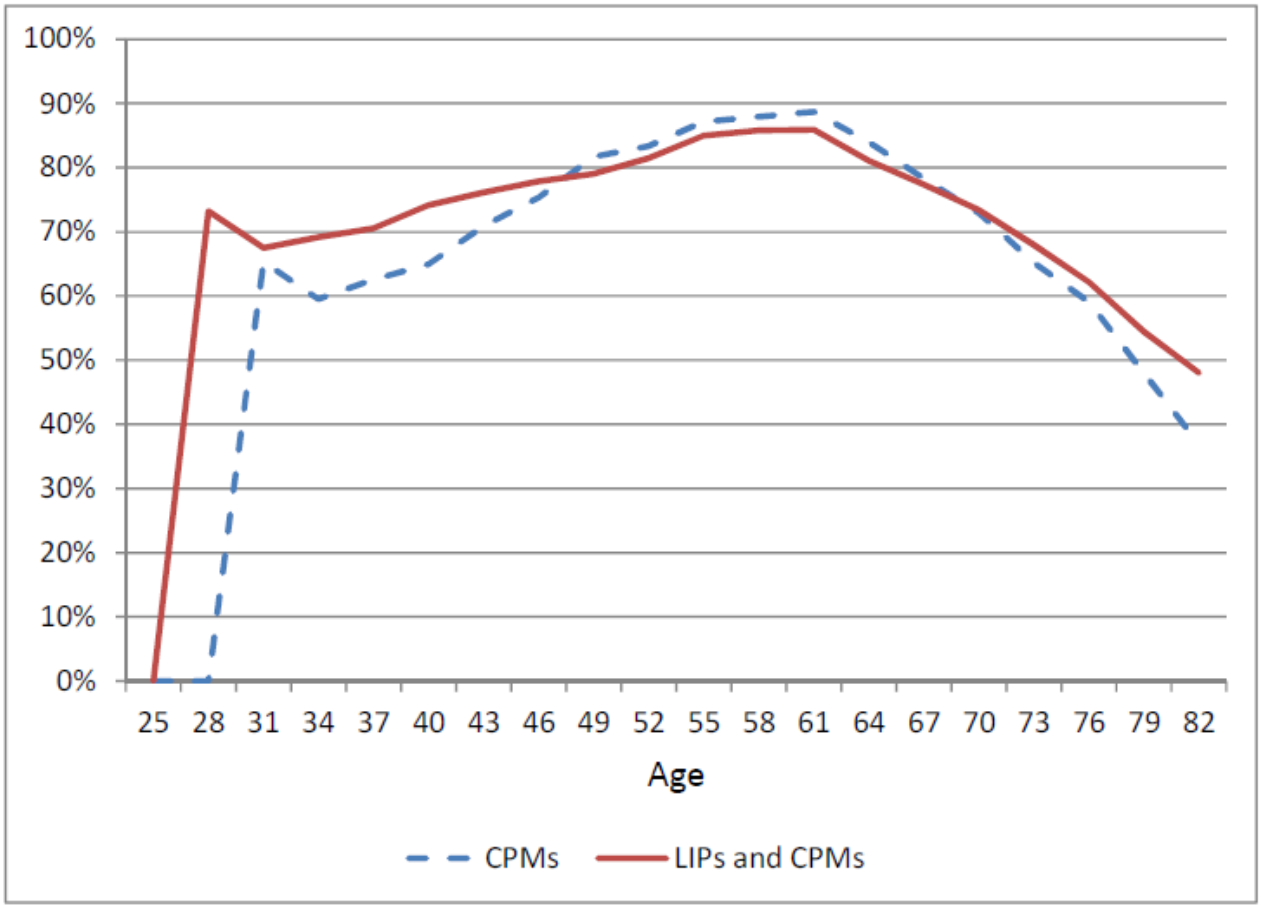

Figure 5: Home Ownership Rates in the Hyperbolic Economies
Note: Home Ownership Rates at Start of Period.

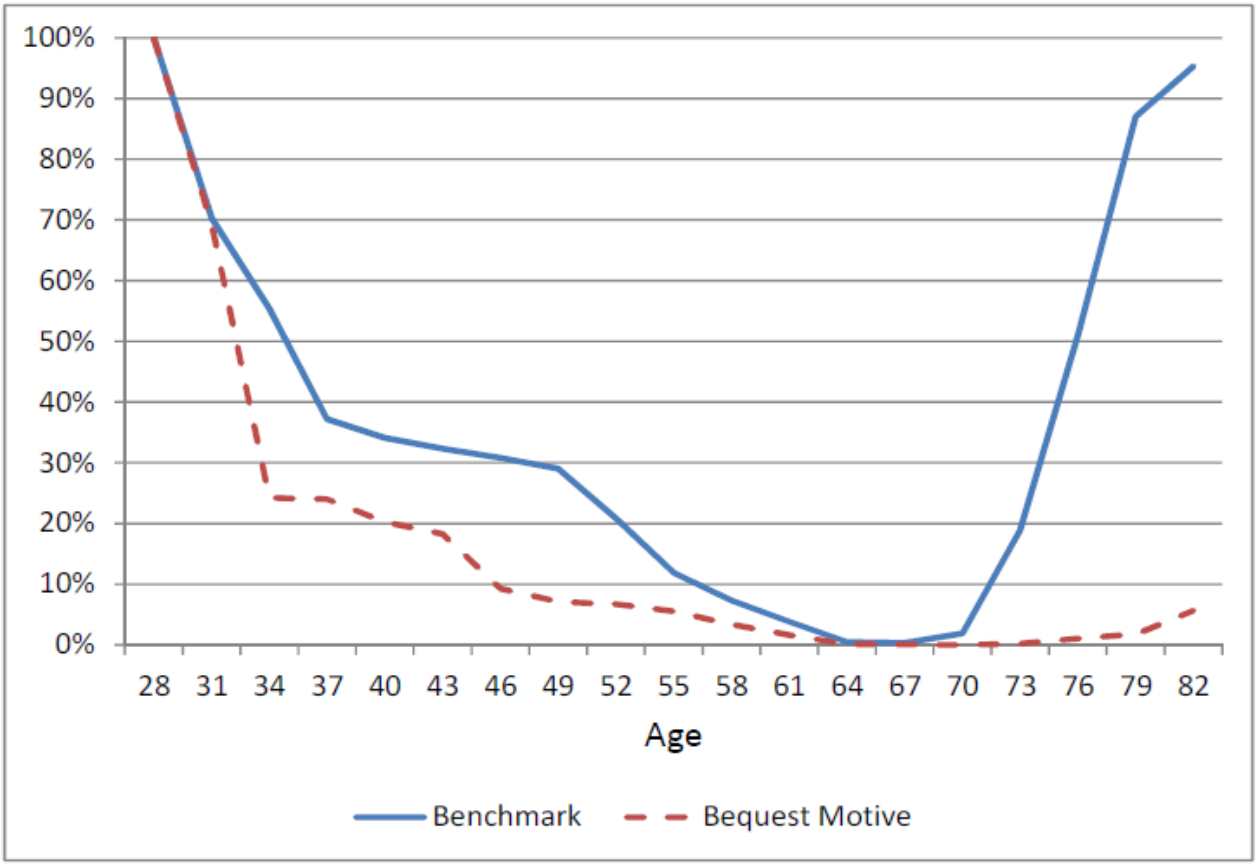

Figure 6: Share of Home Owners Using LIPs (Hyperbolic Economy)

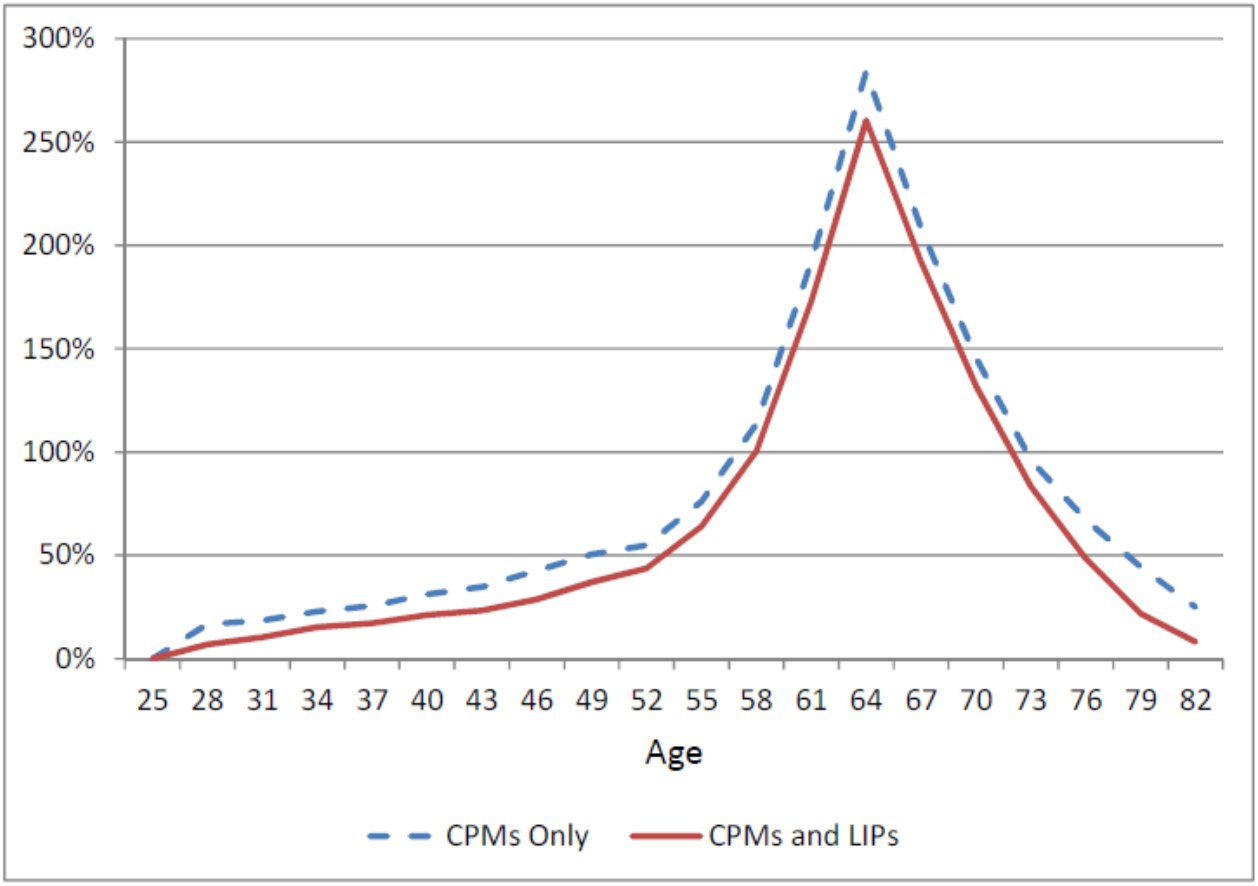

Figure 7: Net Worth / Income with CPMs and with CPMs and LIPs (Hyperbolic Discounting)
Note: Net worth at start of period.

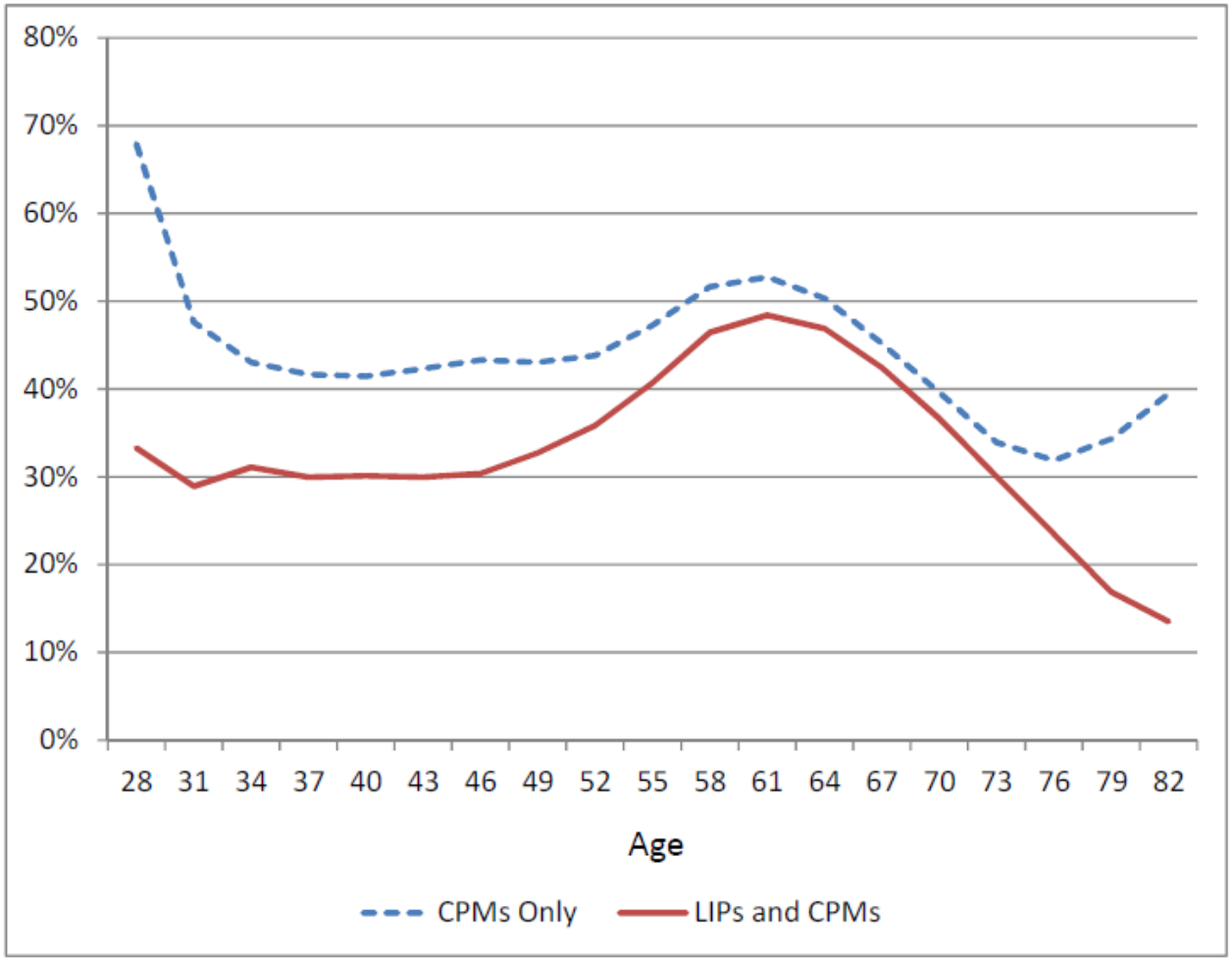

Figure 8: Ratio of Average Net Worth to Income, Hyperbolic Economy / Exponential Economy
Note: Net Worth at start of period.

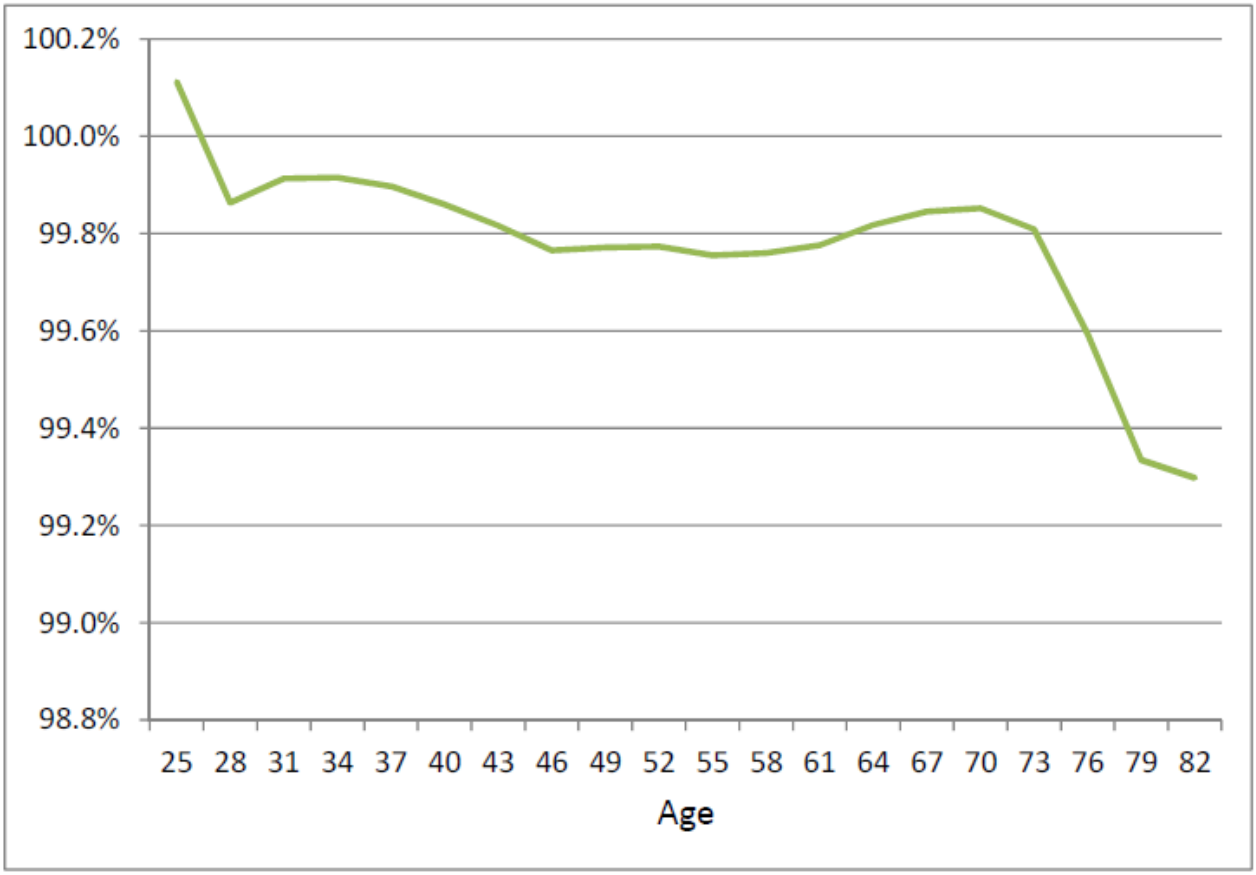

Figure 9: Ratio of Average Expected Lifetime Utility by Age (CPMs and LIPs / CPMs Only) in the Hyperbolic Economies
Note: Expected utility at start of period.

Table 1: Benchmark Parameterization

Parameter	Description	Value	Fixed or Calibrated
α	3-Yr Discount Factor	0.857	Fixed based on Laibson, Repetto, and Tobacman (2007)
β	Short Term Discount Factor	0.70	Fixed based on Laibson, Repetto, and Tobacman (2007)
ν	Down Payment Share for CPMs	0.2	Fixed
r	3-Yr Real Risk-Free Rate	0.12	Fixed
ψ	Non-housing Consumption Share	0.76	Fixed based on Davis and Ortalo-Magne (2011)
θ	Owner-occupied Premium	0.13	Calibrated
h1	Small House Size	29,389.8	Calibrated
h2	Mid-Size House Size	45,420.5	Calibrated
h3	Large House Size	66,794.9	Calibrated
q	Relative Price of Housing	1.053	Calibrated
λ	House price shock probability	0.15	Calibrated
ϕ	Servicing Cost	0.02	Calibrated
χ	Foreclosure Discount	0.25	Fixed based on Campbell, Giglio, and Pathak (2010)
δ	Housing depreciation	0.04	Calibrated
ρ	Selling costs	0.08	Fixed
T	Mortgage Contract Term	10	Fixed
J	Maximum Life Span	20	Fixed
Jret	Retirement Age	13	Fixed
nLIP	Interest Only Period for LIPs	1	Fixed

Table 2: Steady State Equilibria

	(1)	(2)	(3)	(4)	(5)
		Only CPMs Available		CPMs and LIPs Available	
		Hyperbolic Discounting	Exponential Discounting	Hyperbolic Discounting	Exponential Discounting
Moment	Data	β=0.7	β=1.0	β=0.7	β=1.0
Annual CPM Mortgage Rate	5.33%	5.33%	5.08%	5.08%	5.00%
Annual LIP Mortgage Rate		-	-	7.75%	7.83%
Average Mortgage Rate		5.33%	5.08%	6.08%	5.38%
Home Ownership Rate	67.0%	66.5%	77.7%	73.5%	84.1%
Annual Foreclosure Rate	1.50%	1.62%	0.96%	3.24%	1.65%
Average Loan-Income (Annual) Ratio at Origination	2.73	2.42	3.35	2.74	3.17
Average Rent-Income Ratio		0.33	0.33	0.40	0.43
Average Expected Lifetime Utility of Age 0 Agent		68.12	68.26	68.20	68.33
Average Net Worth / Triennial Income		0.74	1.65	0.62	1.61
LIP Share of Mortgage Originations		-	-	53%	35%
Increase in Average Expected Lifetime Utility with LIPs				0.11%	0.11%

Notes: Average Mortgage and Average Foreclosure Rates are percentages of all mortgages outstanding.

Table 3: Cumulative Terminnation Rates (% of Originations) by Periods since Origination in Hyperbolic Economy with LIPs

Periods Since Origination	CPMs			LIPs		
	By Default	By Prepayment	By Default or Prepayment	By Default	By Prepayment	By Default or Prepayment
1	6.3%	8.3%	14.5%	30.5%	25.5%	56.0%
2	10.1%	20.9%	31.0%	38.9%	36.1%	75.0%
3	12.7%	37.0%	49.8%	40.4%	44.1%	84.6%
4	13.5%	47.5%	61.0%	40.9%	46.5%	87.4%
5	14.0%	54.4%	68.4%	41.1%	47.3%	88.4%
6	14.2%	59.7%	73.9%	41.1%	47.8%	89.0%
7	14.2%	62.7%	76.9%	41.1%	48.1%	89.2%
8	14.2%	65.1%	79.3%	41.1%	48.2%	89.3%
9	14.2%	67.4%	81.6%	41.1%	48.7%	89.8%

Table 4: Expected Lifetime Utility at Age 0 by Income

	Income	Only CPMs Available	CPMs and LIPs Available	% Increase from LIP Availability
β=0.7 Hyperbolic	Lowest	64.64	64.69	0.07%
	Middle	68.77	68.82	0.07%
	Highest	70.49	70.65	0.22%
β=1.0 Exponential	Lowest	64.73	64.78	0.08%
	Middle	68.91	68.97	0.09%
	Highest	70.67	70.79	0.17%

Table 5: Steady State Equilibria, Lower Utility Premium from Owner-Occupying

	Only CPMs Available					CPMs and LIPs Available				
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
	β=0.7	β=0.7	β=0.7	β=0.7	β=0.7	*β=0.7*	β=0.7	β=0.7	β=0.7	β=0.7
Moment	*θ=0.13*	θ=0.10	θ=0.075	θ=0.05	θ=0.025	*θ=0.13*	θ=0.10	θ=0.075	θ=0.05	θ=0.025
Annual CPM Mortgage Rate	5.33%	5.42%	5.50%	5.42%	5.42%	*5.08%*	5.17%	5.17%	5.50%	5.58%
Annual LIP Mortgage Rate	-	-	-	-	-	*7.75%*	7.92%	7.83%	9.75%	10.00%
Average Mortgage Rate	5.33%	5.42%	5.50%	5.42%	5.42%	*6.08%*	6.18%	6.24%	6.16%	5.93%
Home Ownership Rate	66.5%	62.7%	59.7%	56.7%	54.4%	*73.5%*	70.4%	68.2%	59.8%	55.9%
Annual Foreclosure Rate	1.62%	1.86%	1.95%	1.99%	1.99%	*3.24%*	3.27%	3.48%	3.36%	2.84%
Average Loan-Income (Annual) Ratio at Origination	2.42	2.25	2.09	2.01	1.94	*2.74*	2.51	2.45	2.03	1.88
Average Rent-Income Ratio	0.33	0.32	0.31	0.30	0.29	*0.40*	0.38	0.37	0.32	0.30
Average Expected Lifetime Utility of Age 0 Agent	68.12	67.99	67.90	67.81	67.72	*68.20*	68.05	67.92	67.79	67.71
Average Net Worth / Triennial Income	0.74	0.69	0.67	0.64	0.60	0.62	0.61	0.57	0.60	0.61
% of Home Owners with LIPs	-	-	-	-	-	53%	51%	53%	31%	18%
Increase in Average Expected Lifetime Utility with LIPs						*0.11%*	0.08%	0.03%	-0.02%	-0.02%

Notes: Average Mortgage and Foreclosure Rates are percentages of all mortgages outstanding. The benchmark calibration used in the rest of the paper corresponds to the results in columns (1) and (6).

Table 6: Sensitivity Analyses

Moment	(1) Benchmark Only CPMs Available	(2) Benchmark CPMs and LIPs	(3) LIP with 20% down	(4) LIP with standard amortization	(5) Bequest Motive Only CPMs Available	(6) Bequest Motive CPMs and LIPs
Annual CPM Mortgage Rate	5.33%	5.08%	5.33%	5.00%	5.17%	5.08%
Annual LIP Mortgage Rate	-	7.75%	6.08%	6.75%	-	7.83%
Average Mortgage Rate	5.33%	6.08%	5.34%	5.78%	5.17%	5.63%
Home Ownership Rate	66.5%	73.5%	66.4%	75.2%	72.5%	78.3%
Annual Foreclosure Rate	1.62%	3.24%	1.65%	2.50%	1.17%	2.06%
Average Loan-Income (Annual) Ratio at Origination	2.42	2.74	2.39	2.74	2.62	2.57
Average Rent-Income Ratio	0.33	0.40	0.33	0.42	0.35	0.43
Average Expected Lifetime Utility of Age 0 Agent	68.12	68.20	68.13	68.23	68.88	68.93
Average Net Worth / Triennial Income	0.74	0.62	0.75	0.65	1.05	0.99
LIP Share of Mortgage Originations	-	53%	2%	55%	-	38%
Increase in Average Expected Lifetime Utility with LIPs		0.11%	0.00%	0.16%		0.07%

Notes: Average Mortgage and Average Foreclosure Rates are percentages of all mortgages outstanding. The model in column (3) allows households to choose between the CPM and a mortgage that requires a 20% down payment and has interest only payments for the first three years. The model in column (4) allows households to choose between the CPM and a mortgage with no down payment but amortization over the full 30 years.