Home Ownership, Household Leverage, and Hyperbolic Discounting

Andra C. Ghent*  
January 19, 2013

Abstract

I examine tenure and mortgage choice in an equilibrium model in which households make decisions as if they discount hyperbolically rather than exponentially. Overall, hyperbolic discounting does not seem to explain the high rates of home ownership or portfolio concentration in housing in the data. I then study the choice between mortgages that require a substantial down payment and mortgages that require no down payment. Allowing households access to no down payment mortgages exacerbates rather than mitigates the undersaving of hyperbolic discounters. However, even when households discount hyperbolically, welfare is higher when households have access to no down payment mortgages.

*W.P. Carey School of Business, Arizona State University; email aghent@asu.edu; phone 480-965-4689. I am grateful to Odegaard Bernt Arne, Oren Bar-Gill, João Cocco, John Cotter, Andreas Lehnert, Jeremy Tobacman, and workshop participants at the AREUEA annual meeting, the AREUEA mid-year meeting, Baruch College, the EUROFIDAI 9th International Paris Finance Meeting, the Federal Reserve Bank of Chicago, Fordham University, Georgetown University, Santa Clara University, and the Weimer School for helpful comments. An earlier draft of this paper circulated under the title, “Subprime Mortgages, Mortgage Choice, and Hyperbolic Discounting”. This research was supported, in part, under National Science Foundation Grants CNS-0958379 and CNS-0855217 and the City University of New York High Performance Computing Center.
1 Introduction

A growing body of literature recognizes 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.\(^1\) Nevertheless, economists have not studied the implications of such preferences for housing, the largest portion of household wealth, or mortgages, the largest fixed income asset class in the US.\(^2\) The implications of hyperbolic discounting for mortgage choice are particularly important to consider in the regulation of residential mortgage products. The mortgage products with the highest default rates have been those that involve little or no down payment. 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 will reduce the foreclosure rate, there has been little economic analysis of the costs and benefits of allowing households access to such products. At the time of writing, the Consumer Financial Protection Bureau declined to include down payment requirements in its new requirements for residential mortgage underwriting (Wyatt, 2013). However, it continues to consider such a regulatory option as do other agencies that regulate residential mortgages such as the Federal Reserve (Carrns, 2013).

\(^1\)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).

\(^2\)In 2008, mortgage debt (all property types) in the United States was $14.7 trillion dollars. By comparison, corporate and foreign bonds constituted $11.3 trillion dollars, U.S. treasury securities $5.8 trillion, and municipal securities $2.7 trillion (Ling and Archer, 2010).
There may be benefits and costs from introducing no down payment mortgages 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). Low down payment mortgages enable more households to become home owners and access this commitment device. Increasing access to the commitment device may thus increase savings. It may also improve welfare. A hyperbolic household may, however, be tempted to 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 alternative mortgage product.

To study these issues, I examine the implications of offering households the choice between renting and owning as well as between different mortgage types in an equilibrium life cycle model in which households make decisions as though they are quasi-hyperbolic discounters. In the model, households can transition between home ownership and renting at any time by either selling the home (prepaying the mortgage) or defaulting. I consider the case of exponential discounting as a comparison to understand the role of hyperbolic discounting in tenure choice. I first consider a version of the model in which households only have access to fully amortizing fixed rate mortgages that require a substantial down payment. I then give households the option of instead choosing a no down payment mortgage.

The model is an endowment economy with an exogenous relative price of housing and
riskless interest rate. Households cannot borrow against labor income. 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.

Households are more likely to choose a mortgage that does not require a down payment if they discount hyperbolically than if they discount exponentially. More surprisingly, I find that allowing households access to no down payment mortgages 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 no down payment mortgages. The intuition behind this result is that, although introducing no down payment mortgages raises the home ownership rate, 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. The increase in the home ownership rate from no down payment mortgages is about 8 percentage points in the benchmark parameterization.

I find that welfare is higher when hyperbolically discounting households have access to no down payment mortgages than when they have access only to traditional mortgages.
The result differs from the model of Heidhues and Koszegi (2010) who construct a general model of credit with backloaded payments but do not incorporate life cycle features or the particular characteristics of housing and mortgages. In my model, no down payment mortgages can increase welfare because they 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. In the presence of incomplete markets, the benefit of no down payment mortgages from allowing households to smooth life cycle consumption far outweighs any loss due to time inconsistency in preferences. The net effect on welfare from introducing no down payment mortgages depends crucially on the utility premium from owner-occupying, however. The gain in welfare from the availability of no down payment mortgages 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 no down payment mortgages.

I find that the home ownership rate is lower when households discount the future hyperbolically than when households discount the future exponentially. Although households may want access to home ownership to commit themselves to a savings plan, households that discount hyperbolically exit home ownership more quickly through foreclosure and in their retirement years than households that discount exponentially such that the aggregate home ownership rate is lower. I also compare the home ownership rate in the hyperbolic economy to an economy in which households simply discount the future heavily but not hyperbolically. Although the home ownership rate is higher in the economy with hyperbolic discounting than in the economy with heavy discounting of the future, the concentration of household wealth in housing is higher when households discount the future more heavily.
These findings suggest that the commitment mechanism for savings that housing can provide to households is not a quantitatively important determinant of housing decisions. Rather, consumption motivations, the lumpiness of housing investment, and life cycle dynamics are the main drivers of household choices about housing.

This paper is the first that I know of to model the implications of hyperbolic discounting for housing decisions and mortgage choice. Chambers, Garriga, and Schlagenhauf (2009), Barlevy and Fisher (2010), Piskorski and Tchistyi (2010), Amromin, Huang, Sialm, and Zhong (2011) study how consumers choose between traditional fully amortizing mortgages with substantial down payments 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. In empirical work, Amromin, Huang, Sialm, and Zhong (2011) and Gerardi, Goette, and Meier (2011) study the role of financial sophistication in the choice between traditional mortgages and mortgages with subprime features. In empirical work, Gerardi, Rosen, and Willen (2010) show that the introduction of non-standard mortgage products improves consumers’ ability to align their housing consumption with future income. 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 rate mortgages (ARMs) and fixed rate mortgages (FRMs). I study only fixed rate
mortgages in this paper.

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 a mortgage (when given a choice). 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. 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. As in other models with

\footnote{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.}
mortgage choice and foreclosure, I model home prices as exogenous to focus on modeling mortgage contracts and mortgage default in more detail. If a financial intermediary is forced to foreclose on a borrower, it incurs a cost $\chi$ (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 (2011) 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 on a mortgage commits the household to a particular savings path.

There is no intentional bequest motive in the benchmark version of 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) and Corbae and Quintin (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. $\kappa \in \{TRAD, NDP\}$ represents the household’s mortgage type. A TRAD mortgage is a traditional mortgage that requires a down payment of $v$ percent, full amortization over the term of $T$ periods, and carries a constant interest rate of $r_{TRAD}$. An NDP mortgage is a mortgage that requires no down payment, is fully amortizing over $T$ periods, and carries a constant interest rate of $r_{NDP}$.

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 \( \kappa \), and income \( y \) thus chooses its tenure, housing, mortgage, and assets to maximize

\[
(1) \quad u(c, h', H') + \beta \alpha \pi_j EV(j + 1, a', H', h', n', h'_O, \kappa', y')
\]

where

\[
V(j, a, H, h, n, h_O, \kappa, y) = \begin{cases} 
  u(c, h', H') + \alpha \pi_j EV(j + 1, a', H', h', n', h'_O, \kappa', y'), \\
  \alpha \pi_j EV(j + 1, a', H', h', n', h'_O, \kappa', y') 
\end{cases},
\]

\[
n' = \begin{cases} 
  (1 - 1_S - 1_D) \max (0, n - 1) + 1_B (T - 1) \text{ if } H' = 1, \\
  0 \text{ if } H' = 0
\end{cases},
\]

The indicator function \( 1_B \) 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 \( 1_D \) takes on a value of 1 if the household chooses to default in that period, 0 otherwise. The indicator \( 1_S \) takes a value of 1 if the household chooses to sell its home, 0 otherwise. \( \pi_j \) 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

\[
(2) \quad c + a' = y + (1 + r) (a - H' 1_{TRAD} q h') - H' (p_T(\kappa) + \delta h') - (1 - H') R h_1
\]

where \( q \) is the price per unit of housing, \( p_n(\kappa) \) is the payment due on a mortgage of type \( \kappa \) with \( n \) periods remaining, \( \delta \) is the depreciation rate, and \( R \) is the rental rate. The indictor
function $1_{TRAD}$ takes on a value of 1 if the household uses a TRAD mortgage 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 TRAD ($1_{TRAD} = 1$).

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

$$c + a' = y + (1 + r) (a + 1_S [q (1 - \sigma) h - b_n (\kappa)] - H'1_B 1_{TRAD} \nu q h') - H' [(1 - 1_B) p_n (\kappa) + 1_B p_T (\kappa') + \delta h'] - (1 - H') Rh_1,$$

(3) \quad $H' \equiv 0$ if $1_D = 1$,

(4) \quad $\kappa' \begin{cases} \in \{TRAD, NDP\} & \text{if } 1_B = 1 \\ = \kappa & \text{if } 1_S \cup 1_D = 0 \\ = \emptyset & \text{if } H' = 0 \end{cases}$, and

(5) \quad $h'_O \equiv h_O$ if $1_B = 0$.

where $\sigma$ represents the transactions cost of selling a home and $b_n (\kappa)$ is the outstanding balance on a mortgage of type $\kappa$ 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 $\kappa$ is null if the household chooses to rent. Households in the model either have no choice of mortgages or choose between TRAD and NDP. 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.

\section*{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.

\section*{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 \( \phi \), 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 $\delta$ on its housing stock and a cost $\chi h$ 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 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 $\lambda$ that the home will increase to quality $h_3$ and a probability $\lambda$ that the home will decrease to quality $h_1$. A home owner that currently owns a home of quality $h_3$ faces a probability $\lambda$ that the home will depreciate to quality $h_2$. A home owner that owns a home of quality $h_1$ faces a probability $\lambda$ 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.

2.4 Steady State Equilibrium and Computation

In equilibrium, lenders make zero profits. This implies that the contract rates, $r_{TRAD}$ and $r_{NDP}$ are the rates that equate the expected present value of the mortgage to the loan balance at origination. The equilibrium concept in this paper 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. Introducing interest rates specific to each individual is unlikely to qualitatively change the predictions of the model and substantially increases the computational cost of solving the model. Indeed, despite having different equilibrium concepts, household leverage has similar implications in Corbae and Quintin (2010) and Garriga and Schlagenhauf (2009). The opportunity cost of the lender’s funds is the riskless interest rate, \( r \); it costs lenders \( \phi \) 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, \( \{ r_{TRAD}, r_{NDP} \} \), such that the average present value of a mortgage contract \( \kappa \) 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 \( r_{TRAD} \) in the economy with only TRADs) or pair of interest rates. 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 \( vqh_2 \); 20 equally-spaced points between \( vqh_2 \) and \( vqh_3 \); 20 equally-spaced points between \( vqh_3 \) and \( qh_2 \); and 60 equally-spaced points between \( qh_2 \) and \( 3qh_2 \). 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 $\kappa$. 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 (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 no down payment 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 NDPs; 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

$$y_t = \rho y_{t-1} + \gamma_1 \text{age}_t + \gamma_2 \text{age}_t^2 + \epsilon_t \quad (6)$$

where $\epsilon_t$ has variance $\sigma^2_{\epsilon}$. 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 $\hat{\sigma}^2_{\epsilon} = 8817$. After removing the age-specific mean of income, 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).
The transition probability matrix that governs the transitions between states is

\[
\begin{pmatrix}
0.7049 & 0.2877 & 0.0073 \\
0.1667 & 0.6667 & 0.1667 \\
0.0073 & 0.2877 & 0.7049
\end{pmatrix}
\]

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, \( \beta \). 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 \( \alpha \) to 0.95\(^3\).

The felicity function is

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

following Corbae and Quintin (2010). I set \( \psi \) 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 $\theta$ such that I use $\theta$ to calibrate the model to match certain characteristics of the data.

3.4 Housing Costs

Based on the estimates of Campbell, Giglio, and Pathak (2011), I set $\chi$, the foreclosure discount, to 0.25. I choose $\lambda$, 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, $\phi$, 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 TRADs, households must make a 20% down payment such that $\nu = 0.2$. The three-year risk-free rate, $r$, is 12%. Selling costs, $\rho$, are 8% of the value of the home as in Cocco (2005). I use $\delta$, 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 Traditional Mortgages

Columns 2 and 3 of Table 2 present equilibrium statistics regarding the model when the household has access only to TRADs. 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. 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 1 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 chronological ages 31 and 34) 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 the same in 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 1.61% 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% which is a rate 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.

Not surprisingly, households in the hyperbolic economy save considerably less than household in the exponential economy. I compute net worth as home equity (home value - outstanding mortgage balance) plus holdings of the riskless asset. 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 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. A larger fraction of household savings in the hyperbolic economy is housing, however.

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 0.2% 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. 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.

4.1.1 A High Discount Rate Economy

The comparison so far is perhaps not entirely fair to hyperbolic discounting since the economy with hyperbolic discounting is characterized by both a different discount shape and a different discount rate. To disentangle the role of a high discount rate from the role of the shape of the discounting, in column 4 of Table 2, I present the equilibrium when households simply discount the future very heavily. I set $\alpha = 0.95^3 \times 0.7 = 0.6$ and $\beta = 1.0$. At 54%, the home ownership rate is indeed much lower in the high discount rate economy than in the hyperbolic economy. In the high discount rate economy, almost no low income households are home owners. Rather, home ownership seems primarily driven by households that would prefer to live in larger homes than the rental sized home. This leads to housing occupying an extremely high share of household net worth.

Overall, comparing housing choices in the hyperbolic economy with those in the exponential economy and the high discount rate economy, the hyperbolic economy cannot be said to reproduce the stylized facts better than the exponential economy. Although it produces a greater concentration of household wealth along the intensive margin than the exponential economy, it produces less concentration along the extensive margin. The comparison with the high discount rate economy suggests that its failure along the extensive margin is not because it simply leads to lower overall savings.
4.2 Equilibrium with Traditional and No Down Payment Mortgages

Columns 5 and 6 of Table 2 present the equilibrium of the model when the household has access to the NDP mortgage. Column 5 presents the equilibrium when households discount hyperbolically and column 6 illustrates the equilibrium when households discount exponentially. More households choose NDPs in the hyperbolic economy than in the exponential economy. In the hyperbolic economy, fully 58% of new originations are NDPs while in the exponential economy only 37% of originations are NDPs. Because NDPs 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 NDPs 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 NDPs is 55 basis points higher than the average mortgage rate in the exponential economy with NDPs. This is largely because more households in the hyperbolic economy choose an NDP than in the exponential economy with NDPs. When NDPs are available, the TRAD mortgage rate is only 8 basis points lower in the exponential economy than the corresponding rates in the hyperbolic economy. The NDP mortgage rate is in fact 17 basis points lower in the hyperbolic economy; in the exponential economy, only the riskiest households choose NDPs. Because fewer households choose NDPs 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 8 percentage points, to 74.6%, from the equilibrium in which the household only has access to TRADs. As Figure 2 illustrates, the home ownership rate is higher in the economy with NDPs largely because households enter into home ownership earlier consistent with the empirical findings of Duca and Rosenthal (1994). In the economy with only TRADs, 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. Until households reach their late forties, the home ownership rate in the economy with TRADs and NDPs remains substantially above that in the economy with only TRADs. 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 NDPs than in the economy with only TRADs as households can use NDPs to remain home owners while still exhausting their savings.

In the hyperbolic economy, the introduction of NDPs 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 NDPs. This is likely due to low income households choosing foreclosure more frequently after the introduction of NDPs. The home ownership rate of middle income earners rises from 77% to 92% as a result of introducing NDPs while that of high income households rises from 90% to 97%.

There is some change in the quality of the homes that high income households purchase
as a result of the introduction of NDPs. In the economy with only TRADs, luxury homes (homes of quality $h_3$) are almost exclusively purchased by high income households. This remains true in the economy with both TRADs and NDPs. In the economy with only TRADs, 38% of originations to high income households are for the purchase of luxury homes while, in the economy with TRADs and NDPs, half of originations to high income households are for the purchase of luxury homes.

The introduction of NDPs increases the rent to income ratio from 33% to 41%. The increase in the rent to income ratio arises because a larger fraction of renters are low income earners in the economy with NDPs than in the economy with only TRADs. 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 TRADs falls by 25 basis points to 5.08% once households have access to NDPs. The reason that the interest rate on TRADs falls is that the households that were most likely to default in the economy with only TRADs now choose NDPs. As Figure 3 illustrates, it is primarily middle-aged households that opt for TRADs once NDPs are available. In the first period of life, all households that choose home ownership opt for NDPs. The fraction of home owners using NDPs falls steadily until the retirement age; at retirement, almost no households use NDPs. After retirement, the fraction of home owners using NDPs gradually rises with age until it reaches 98% 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 NDPs such that the default rate on TRAD mortgages falls.

Averaged over the number of mortgages outstanding, the annual foreclosure rate in the
economy with TRADs and NDPs is 2.62%. This foreclosure rate is 63% higher than that of the economy in which households only have access to TRADs. The high foreclosure rate on NDPs results in an equilibrium annual interest rate of 6.75% on these products. The average mortgage rate, as a percent of mortgages outstanding, rises to 5.9% when NDPs are introduced from 5.33% in the economy with only TRADs.

4.2.2 NDPs and Savings

Figures 4 and 5 illustrate that the welfare gain from NDPs is not because introducing NDPs raises average savings. The availability of NDPs exacerbates the undersaving of hyperbolic households of all ages. Figure 4 compares average net worth to annualized income ratios by age in the hyperbolic economy in which households only have access to TRADs and the hyperbolic economy in which households have access to both TRADs and NDPs. Net worth at every age is lower once households have access to NDPs than when they can only take on TRADs. 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 TRADs, a household must have savings at least equal to the down payment if it wants to own a home. In contrast, in the NDP economy, many households save very little and yet are still able to be home owners. Because many retirees in the hyperbolic economy finance home ownership with NDPs, retirees save far less once they have access to NDPs.

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 NDPs lowers savings. However, Figure 5 shows that the fall in saving from the introduction of NDPs is more acute with hyperbolic discounting. Figure 5 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 TRADs and when both TRADs and NDPs are available. Thus, savings in the hyperbolic economy are lower after the introduction of NDPs both absolutely and relative to what exponential households save in the exponential equilibrium.

4.2.3 NDP Terminations

Not surprisingly, NDPs have much higher foreclosure rates than TRADs. One period (three years) after origination, 24% of NDPs have terminated through default while less than 5% of TRAD originations have terminated through foreclosure. Note that the high foreclosure rate on NDPs is the steady state foreclosure rate on these mortgages, not the result of exceptional aggregate home price changes or mispricing on the part of lenders. Of all NDP originations, a third eventually terminate through foreclosure. 12% of TRAD originations eventually terminate through foreclosure. As home equity is the main driver of default, and NDP home owners have no home equity in the first period, three quarters of the defaults on NDPs occur in the period immediately after origination. Defaults on both NDPs and TRADs are rare more than three periods after origination since households have paid a substantial amount of principal on their mortgage by that period.
4.2.4 NDPs and Expected Utility

Average expected lifetime utility at age 0 is 0.15% higher in the economy in which the household has access to NDPs. This is about the three quarters of the difference between expected lifetime utility in the hyperbolic economy with only TRADs and the exponential economy with only TRADs. As Table 3 shows, in both the hyperbolic and the exponential economies, introducing NDPs 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 0.20% for the highest earning households at birth while the availability of NDPs raises expected lifetime utility by only 0.14% and 0.11% for households that start life as middle or low income earners. The main reason that there are smaller benefits for low income households is that few of them are home owners and, as previously discussed, introducing NDPs does nothing to raise the home ownership rate among low income households. High income households benefit disproportionately because, in addition to increasing their home ownership rate by buying earlier in life and selling later in life, there is a shift in the composition of their home purchases towards more luxury homes. 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 on average by only 0.13% such that the welfare benefits from introducing NDPs are in fact higher in the hyperbolic economy.

Households accrue the benefit from the introduction of NDPs in the first period of life as Figure 6 illustrates. Figure 6 shows average expected lifetime utility in the hyperbolic
economies with and without NDPs by age. The increase in lifetime utility at age 0 is almost
exclusively because NDPs 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 TRADs 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 NDPs.

Part of the reason that NDPs 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 NDPs 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 problems.

When considering the welfare implications of NDPs, however, it is important to bear
in mind certain considerations that the model does not capture. First, the model is an
endowment economy. In a production economy, the lower savings rate that allowing higher
leverage induces may lower capital formation such that wages would fall. Such a decline
in wages may reduce aggregate welfare. Second, the welfare calculations in this paper do
not incorporate any externalities from a higher foreclosure rate or a higher home ownership
rate. The welfare calculations in the model do not assume that foreclosures entail any
negative externalities. While evidence (e.g., Campbell, Giglio, and Pathak, 2011) 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 since, in the benchmark calibration, introducing NDPs raises the steady state foreclosure rate by more than 60% and raises the steady state home ownership rate by about 8 percentage points. On the other hand, the home ownership rate rises from 67% to 75% as a result of the introduction of NDPs. 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, Englehardt, Eriksen, Gale, and Mills, 2010, and Green, Painter, and White, 2012), introducing NDPs would result in larger welfare gains than I find here. Third, 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 NDPs.

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 equilibrium of the model under different assumptions for $\theta$.

Table 4 presents the equilibrium of the model when $\theta = 0.1$, 0.05, and 0. For the benchmark assumption of $\theta = 0.13$, the average gain at birth from introducing NDPs is
0.15%. Decreasing $\theta$ to 0.10 reduces the average welfare gain from NDPs to 0.09% of average expected lifetime utility at age 0. All three income groups continue to experience higher expected lifetime utility at birth when NDPs 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 TRADs available and to 71% in the economy with NDPs and TRADs available as the gains from home ownership fall. Foreclosure rates rise slightly (to 1.9% annually in the economy with only TRADs and to 3% in the economy with TRADs and NDPs) as the value of staying a home owner falls. As in the case with $\theta = 0.13$, introducing NDPs depresses savings both in absolute terms and relative to what households save in the exponential equilibrium.

When $\theta$ falls to 0.05, average welfare falls after NDPs are introduced. NDPs 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 NDPs. Introducing NDPs reduces expected lifetime utility for middle and low income earners while expected lifetime utility of high income households is almost unaffected. 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 NDPs rises to 7.5%. Although the interest rate on NDPs is much higher than for higher values of $\theta$, the average mortgage rate is only slightly higher than for higher values of $\theta$. The average mortgage rate does not rise very much because far fewer households opt for an NDP when the interest rate is 7.5% and they get only a small benefit from home ownership. Because fewer households choose NDPs, the fall in savings from the introduction of NDPs is less acute for $\theta = 0.05$
than for higher values of $\theta$.

When $\theta$ is reduced to 0, introducing NDPs has less of an effect on the equilibrium. With $\theta = 0$, the rate on NDPs rises to 9%. As a result, very few households opt for NDPs such that the average mortgage rate is lowest for the case of $\theta = 0$ despite both the NDP and the TRAD mortgage rates being highest for $\theta = 0$. There is no discernible effect on welfare because only a small fraction, 10%, of mortgage originations are NDPs. Households that finance home ownership with an NDP for higher values of $\theta$ now choose to rent instead. The availability of NDPs thus raises the home ownership rate by only about 1.5 percentage points. Average expected lifetime utility at age 0 is virtually unchanged after the introduction of NDPs. Allowing households access to NDPs results also has almost no effect on aggregate savings.

**5.2 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 (2005), and Cocco, Gomes, and Maenhout (2005).

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

\[
(7) \quad u(c, h', H') + \beta \alpha \pi_j EV (j + 1, a', H', h', n', h_O', \kappa', y') + \beta \alpha (1 - \pi_j) E \ln W
\]
rather than equation (1). \( W \) represents net worth in (7) and \( V(\cdot) \) in (7) is defined by

\[
V(j, a, H, h, n, h_O, \kappa, y) = \begin{cases} 
  u(c, h', H') + \\
  \alpha \pi_j E V(j + 1, a', H', h', n', h'_O, \kappa', y') \\
  + \alpha (1 - \pi_j) E \ln W
\end{cases}
\]

In computing expected net worth, I assume that when a household dies the housing position is liquidated and the financial intermediary is repaid the debt if the house value is adequate or receives the house value. Households in the model continue, however, to enter life with no assets.

Columns 3 and 4 of Table 5 present the equilibrium of the model with only TRADs and the model with TRADs and NDPs 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 NDPs. In the benchmark version of the model, NDPs are the instrument of choice for both young households and retirees. This leads to 58% of mortgage originations being NDPs. With a bequest motive, NDPs are primarily used by only the young as Figure 3 illustrates such that only 40% of originations are NDPs. In the benchmark version of the model, older households use NDPs 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 TRAD.

The introduction of NDPs continues to decrease savings when there is a bequest motive. The fall in savings is largely due to young households who actually use NDPs when there is
a bequest motive. The rise in the home ownership rate from the introduction of NDPs, of about 6 percentage points, is slightly lower than the increase of about 8 percentage points in the benchmark case. The foreclosure rate rises from 1.2% to 2% after NDPs are introduced.

6 Conclusions

A common intuition from behavioral models is a greater role for a paternalistic government to help households overcome their own limitations. The goal of this paper has been to explore the effect of restricting household choice in a setting in which households suffer from a particular behavioral limitation. In particular, this paper studied how hyperbolically discounting households choose between a mortgage that requires a substantial down payment and a product that requires no down payment in an equilibrium life cycle framework. I find that allowing households access to NDPs exacerbates the undersaving problem that arises when households behave hyperbolically. However, the welfare of a newly born household is higher in the steady state in which access to NDPs is unrestricted. The result is largely because, in an incomplete markets setting, high leverage mortgages are an important tool that households can use to smooth their lifetime consumption. Young households that would prefer to own their homes are able to own earlier in their life cycle and can become home owners without drastically curtailing their consumption to save up for a down payment. In the most plausible calibrations of the model, the consumption smoothing benefits of high leverage mortgages far outweigh the adverse effects that even a high degree of hyperbolic discounting may entail. Regulators should thus bear in mind that, even in the presence of deviations from standard preferences or cognitive biases, limiting the choice of financial
products can adversely affect welfare.

References


Amromin, Gene, Jennifer Huang, Clemens Sialm, and Edward Zhong, 2011. “Complex Mortgages”. Manuscript, University of Texas at Austin.


California.


<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
<th>Fixed or Calibrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>3-Yr Discount Factor</td>
<td>0.857</td>
<td>Fixed based on Laibson, Repetto, and Tobacman (2007)</td>
</tr>
<tr>
<td>$\beta$</td>
<td>Short Term Discount Factor</td>
<td>0.70</td>
<td>Fixed based on Laibson, Repetto, and Tobacman (2007)</td>
</tr>
<tr>
<td>$\nu$</td>
<td>Down Payment Share for TRADs</td>
<td>20%</td>
<td>Fixed</td>
</tr>
<tr>
<td>$r$</td>
<td>3-Yr Real Risk-Free Rate</td>
<td>0.12</td>
<td>Fixed</td>
</tr>
<tr>
<td>$\psi$</td>
<td>Non-housing Consumption Share</td>
<td>0.76</td>
<td>Fixed based on Davis and Ortalo-Magné (2011)</td>
</tr>
<tr>
<td>$\theta$</td>
<td>Owner-occupied Premium</td>
<td>0.13</td>
<td>Calibrated</td>
</tr>
<tr>
<td>$h_1$</td>
<td>Small House Size</td>
<td>29,390</td>
<td>Calibrated</td>
</tr>
<tr>
<td>$h_2$</td>
<td>Mid-Size House Size</td>
<td>45,421</td>
<td>Calibrated</td>
</tr>
<tr>
<td>$h_3$</td>
<td>Large House Size</td>
<td>66,795</td>
<td>Calibrated</td>
</tr>
<tr>
<td>$q$</td>
<td>Relative Price of Housing</td>
<td>1.053</td>
<td>Calibrated</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>House Price Shock Probability</td>
<td>0.15</td>
<td>Calibrated</td>
</tr>
<tr>
<td>$\phi$</td>
<td>Servicing Cost</td>
<td>0.02</td>
<td>Calibrated</td>
</tr>
<tr>
<td>$\chi$</td>
<td>Foreclosure Discount</td>
<td>0.25</td>
<td>Fixed based on Campbell, Giglio, and Pathak (2011)</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Housing Depreciation</td>
<td>0.04</td>
<td>Calibrated</td>
</tr>
<tr>
<td>$\rho$</td>
<td>Selling Costs</td>
<td>0.08</td>
<td>Fixed</td>
</tr>
<tr>
<td>$T$</td>
<td>Mortgage Contract Term</td>
<td>10</td>
<td>Fixed</td>
</tr>
<tr>
<td>$J$</td>
<td>Maximum Life Span</td>
<td>20</td>
<td>Fixed</td>
</tr>
<tr>
<td>$J_{ret}$</td>
<td>Retirement Age</td>
<td>13</td>
<td>Fixed</td>
</tr>
</tbody>
</table>
Table 2: Steady State Equilibria

<table>
<thead>
<tr>
<th>Moment</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Data</td>
<td>$\beta = 0.7$</td>
<td>$\beta = 0.95$</td>
<td>$\beta = 1.0$</td>
<td>$\alpha = 0.95$</td>
<td>$\alpha = 1.0$</td>
</tr>
<tr>
<td>Annual TRAD Mortgage Rate</td>
<td>5.33%</td>
<td>5.33%</td>
<td>5.08%</td>
<td>5.50%</td>
<td>5.08%</td>
<td>5.00%</td>
</tr>
<tr>
<td>Annual NDP Mortgage Rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>5.90%</td>
<td>5.35%</td>
</tr>
<tr>
<td>Average Mortgage Rate</td>
<td>5.33%</td>
<td>5.08%</td>
<td>5.50%</td>
<td>5.90%</td>
<td>5.35%</td>
<td></td>
</tr>
<tr>
<td>Home Ownership Rate</td>
<td>67.0%</td>
<td>66.5%</td>
<td>77.7%</td>
<td>54.0%</td>
<td>74.6%</td>
<td>84.0%</td>
</tr>
<tr>
<td>Annual Foreclosure Rate</td>
<td>1.50%</td>
<td>1.61%</td>
<td>0.96%</td>
<td>2.19%</td>
<td>2.62%</td>
<td>1.56%</td>
</tr>
<tr>
<td>Average Loan-Income (Annual)</td>
<td>2.73</td>
<td>2.42</td>
<td>3.34</td>
<td>1.97</td>
<td>2.79</td>
<td>3.18</td>
</tr>
<tr>
<td>Ratio at Origination</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Rent-Income Ratio</td>
<td>0.33</td>
<td>0.33</td>
<td>0.30</td>
<td>0.41</td>
<td>0.43</td>
<td></td>
</tr>
<tr>
<td>Average Net Worth / Annual Income</td>
<td>2.23</td>
<td>4.95</td>
<td>0.85</td>
<td>1.87</td>
<td>4.75</td>
<td></td>
</tr>
<tr>
<td>Home Value / Net Worth</td>
<td>1.02</td>
<td>0.69</td>
<td>1.81</td>
<td>1.34</td>
<td>0.75</td>
<td></td>
</tr>
<tr>
<td>TRAD Share of Mortgage Origins</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>10%</td>
<td>63%</td>
<td></td>
</tr>
<tr>
<td>Average Expected Lifetime</td>
<td>68.12</td>
<td>68.26</td>
<td>26.02</td>
<td>68.23</td>
<td>68.35</td>
<td></td>
</tr>
<tr>
<td>Utility of Age 0 Agent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase in Average Expected Lifetime Utility with NDPs</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.15%</td>
<td>0.13%</td>
<td></td>
</tr>
</tbody>
</table>

Notes: 1) Average mortgage and foreclosure rates are percentages of all mortgages outstanding. 2) TRAD is a mortgage that requires a 20% down payment. 3) An NDP mortgage is a mortgage that requires no down payment. 4) $\alpha$ is the long-term (standard) discount rate. 5) $\beta$ is the short-term discount rate that controls the degree to which preferences are hyperbolic. 6) Net worth is home equity + holdings of riskless bonds.

Table 3: Expected Lifetime Utility at Age 0 by Income

<table>
<thead>
<tr>
<th>Income</th>
<th>Only TRADs Available</th>
<th>TRADs and NDPs Available</th>
<th>% Increase from NDP Availability</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\beta = 0.7$ Hyperbolic</td>
<td>Lowest</td>
<td>64.64</td>
<td>64.71</td>
</tr>
<tr>
<td></td>
<td>Middle</td>
<td>68.77</td>
<td>68.86</td>
</tr>
<tr>
<td></td>
<td>Highest</td>
<td>70.49</td>
<td>70.63</td>
</tr>
<tr>
<td></td>
<td>Lowest</td>
<td>64.73</td>
<td>64.79</td>
</tr>
<tr>
<td>$\beta = 1.0$ Exponential</td>
<td>Middle</td>
<td>68.91</td>
<td>68.99</td>
</tr>
<tr>
<td></td>
<td>Highest</td>
<td>70.67</td>
<td>70.81</td>
</tr>
</tbody>
</table>
Table 4: Steady State Equilibria, Lower Utility Premium from Owner-Occupying

<table>
<thead>
<tr>
<th>Moment</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
<th>(7)</th>
<th>(8)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRADs Available</td>
<td>TRADs and NDPs Available</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \beta = 0.7 )</td>
<td>( \beta = 0.7 )</td>
<td>( \beta = 0.7 )</td>
<td>( \beta = 0.7 )</td>
<td>( \beta = 0.7 )</td>
<td>( \beta = 0.7 )</td>
<td>( \beta = 0.7 )</td>
<td>( \beta = 0.7 )</td>
<td></td>
</tr>
<tr>
<td>( \theta = 0.13 )</td>
<td>( \theta = 0.10 )</td>
<td>( \theta = 0.05 )</td>
<td>( \theta = 0.0 )</td>
<td>( \theta = 0.13 )</td>
<td>( \theta = 0.10 )</td>
<td>( \theta = 0.05 )</td>
<td>( \theta = 0.0 )</td>
<td></td>
</tr>
<tr>
<td>Annual TRAD Mortgage Rate</td>
<td>5.33%</td>
<td>5.42%</td>
<td>5.50%</td>
<td>5.42%</td>
<td>5.08%</td>
<td>5.17%</td>
<td>5.33%</td>
<td>5.50%</td>
</tr>
<tr>
<td>Annual NDP Mortgage Rate</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>6.75%</td>
<td>6.92%</td>
<td>7.50%</td>
<td>9.00%</td>
</tr>
<tr>
<td>Average Mortgage Rate</td>
<td>5.33%</td>
<td>5.42%</td>
<td>5.50%</td>
<td>5.42%</td>
<td>5.90%</td>
<td>6.04%</td>
<td>6.27%</td>
<td>5.67%</td>
</tr>
<tr>
<td>Home Ownership Rate</td>
<td>66.5%</td>
<td>62.7%</td>
<td>56.2%</td>
<td>48.7%</td>
<td>74.6%</td>
<td>71.1%</td>
<td>65.0%</td>
<td>50.0%</td>
</tr>
<tr>
<td>Annual Foreclosure Rate</td>
<td>1.61%</td>
<td>1.86%</td>
<td>1.99%</td>
<td>1.95%</td>
<td>2.62%</td>
<td>2.95%</td>
<td>3.66%</td>
<td>2.36%</td>
</tr>
<tr>
<td>Average Loan-Income (Annual) Ratio at Origination</td>
<td>2.42</td>
<td>2.25</td>
<td>1.97</td>
<td>1.91</td>
<td>2.79</td>
<td>2.60</td>
<td>2.37</td>
<td>1.89</td>
</tr>
<tr>
<td>Average Rent-Income Ratio</td>
<td>0.33</td>
<td>0.32</td>
<td>0.30</td>
<td>0.27</td>
<td>0.41</td>
<td>0.39</td>
<td>0.36</td>
<td>0.28</td>
</tr>
<tr>
<td>Average Expected Lifetime Utility of Age 0 Agent</td>
<td>68.12</td>
<td>67.99</td>
<td>67.80</td>
<td>67.60</td>
<td>68.23</td>
<td>68.06</td>
<td>67.79</td>
<td>67.60</td>
</tr>
<tr>
<td>Average Net Worth / Annual Income</td>
<td>2.23</td>
<td>2.07</td>
<td>1.86</td>
<td>1.65</td>
<td>1.87</td>
<td>1.80</td>
<td>1.68</td>
<td>1.65</td>
</tr>
<tr>
<td>TRAD Mortgage Share</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>42%</td>
<td>44%</td>
<td>46%</td>
<td>90%</td>
</tr>
<tr>
<td>Increase in Average Expected Lifetime Utility with LIPs</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.15%</td>
<td>0.09%</td>
<td>-0.02%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

Notes: 1) Average mortgage and foreclosure rates are percentages of all mortgages outstanding. 2) The benchmark calibration used in the rest of the paper corresponds to the results in columns (1) and (5).

Table 5: A Bequest Motive

<table>
<thead>
<tr>
<th>Moment</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRADs Available</td>
<td>TRADs and NDPs Available</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benchmark Bequest Motive</td>
<td>Bequest Motive</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual TRAD Mortgage Rate</td>
<td>5.33%</td>
<td>5.08%</td>
<td>5.17%</td>
<td>5.08%</td>
</tr>
<tr>
<td>Annual NDP Mortgage Rate</td>
<td>-</td>
<td>6.75%</td>
<td>-</td>
<td>6.92%</td>
</tr>
<tr>
<td>Average Mortgage Rate</td>
<td>5.33%</td>
<td>5.90%</td>
<td>5.17%</td>
<td>5.59%</td>
</tr>
<tr>
<td>Home Ownership Rate</td>
<td>66.5%</td>
<td>74.6%</td>
<td>72.4%</td>
<td>78.0%</td>
</tr>
<tr>
<td>Annual Foreclosure Rate</td>
<td>1.61%</td>
<td>2.62%</td>
<td>1.17%</td>
<td>1.96%</td>
</tr>
<tr>
<td>Average Loan-Income (Annual) Ratio at Origination</td>
<td>2.42</td>
<td>2.79</td>
<td>2.62</td>
<td>2.62</td>
</tr>
<tr>
<td>Average Rent-Income Ratio</td>
<td>0.33</td>
<td>0.41</td>
<td>0.35</td>
<td>0.43</td>
</tr>
<tr>
<td>Average Expected Lifetime Utility of Age 0 Agent</td>
<td>68.12</td>
<td>68.23</td>
<td>68.88</td>
<td>68.94</td>
</tr>
<tr>
<td>Average Net Worth / Annual Income</td>
<td>2.23</td>
<td>1.87</td>
<td>3.15</td>
<td>2.94</td>
</tr>
<tr>
<td>NDP Share of Mortgage Originations</td>
<td>100%</td>
<td>42%</td>
<td>100%</td>
<td>60%</td>
</tr>
<tr>
<td>Increase in Average Expected Lifetime Utility with NDPs</td>
<td>-</td>
<td>0.15%</td>
<td>-</td>
<td>0.08%</td>
</tr>
</tbody>
</table>

Notes: Average mortgage and foreclosure rates are percentages of all mortgages outstanding.
Figure 1: Home Ownership Rates by Age in the Hyperbolic and Exponential Economies (TRADs Only)
Note: Home ownership rates at start of period.
Figure 2: Home Ownership Rates in the Hyperbolic Economies
Note: Home ownership rates at start of period.
Figure 3: Share of Mortgagors Using No Down Payment Mortgages (Hyperbolic Economy)
Figure 4: Net Worth / Income with TRADs and with TRADs and NDPs (Hyperbolic Discounting)
Notes: 1) Net worth at start of period. 2) Net worth is home value - mortgage balance + bond holdings.
Figure 5: Ratio of Average Net Worth to Income, Hyperbolic Economy / Exponential Economy

Notes: 1) Net worth at start of period. 2) Net worth is home value - mortgage balance + bond holdings.
Figure 6: Ratio of Average Expected Lifetime Utility by Age (TRADs and NDPs / TRADs Only) in the Hyperbolic Economies
Note: Expected utility at start of period.