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2021 KLEIN LECTURE: AMERICAN DREAM DELAYED: SHIFTING DETERMINANTS OF HOMEOWNERSHIP*

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We develop and estimate a dynamic model of female labor supply, fertility, and transition from renting to first homeownership with panel data, to investigate declining U.S. homeownership over the past decades. Higher house prices and increased female wage rates (that is the opportunity cost of leisure) cause households to postpone their first-home purchase, because leisure and fertility are complementary to homeownership. Education and female workforce participation are reinforcing factors that raise the value of owning a home. Our estimates show the effects of rising house prices and wage rates more than offset the effects of greater education and workforce participation.

1. INTRODUCTION

The average age of a first-time home buyer increased from 28 years old in the 1970s to 30 in the 1990s and now stands at 32.[1] Delaying the transition to homeownership resulted in the stagnation and subsequent reduction of homeownership rates for all cohorts of population in working age (Goodman et al., 2015). As homeowners rarely revert to renting permanent accommodation and the rate of reverting to renting is fairly stable over the period, the decline in home ownership is almost entirely attributable to postponing the first home purchase. Figure 1 illustrates that the delay in first homeownership coincided with postponing marriage and fertility; the average age of mother at first birth rose from 22 forty years ago to 24 two decades ago, and currently stands at about 26. Labor-force participation of females in their fecund period rose dramatically from 48% in the 1970s to 74% in the 1990s and continues to increase.

Ordering the magnitude of the changes between the decades, female labor force participation increased most between 1970 and 1980, a rise that was followed by successively smaller increments in the next two decades. With respect to age at marriage, first birth and first homeownership, the biggest jump occurs for all three between 1980 and 1990 and the smallest, again for all three, occurs between 1990 and 2000. Qualitatively these three trends match, but not quantitatively: first home purchase was postponed more than marriage and first birth, which virtually coincide at all four census points.

There are many studies showing that household decisions about fertility, labor supply, and housing are jointly determined. Homeownership is associated with lower job-to-job mobility,

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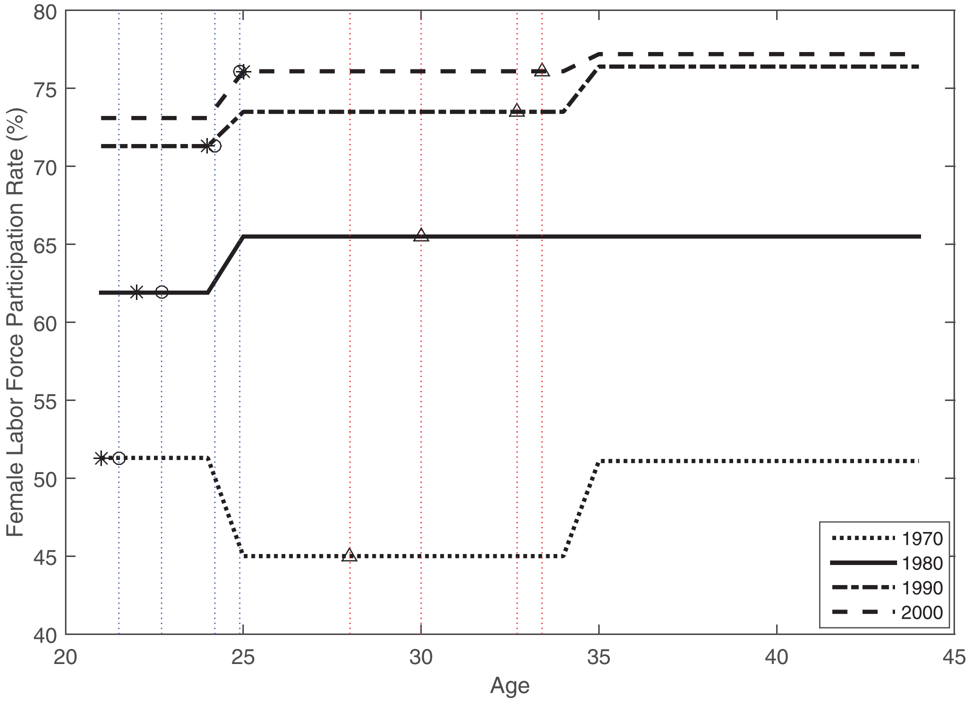
[1] U.S. Bureau of the Census, American Housing Survey, Chicago Title and Trust Co. survey, and authors own calculations based on the Panel Study of Income Dynamics.



NOTES: "star" denotes median age at first marriage, "circle" denotes average age at first birth, "triangle" denotes average age at first homeownership Age at first marriage is taken from the U.S. Census Bureau, age at first birth is taken from the National Vital Statistical Reports (Mathews and Hamilton, 2002), age at first homeownership is computed from the PSID, whereas labor force participation rates are taken from publications of the U.S. Bureau of Labor Statistics (Toossi, 2002, 2012).

FIGURE 1

LABOR FORCE PARTICIPATION RATE BY AGE FOR 1970–2000

lower unemployment risk, and higher wage rates (Munch et al., 2008).[2] Increased women's labor force participation is tightly linked to the delay in giving birth to children, due to the competing allocation of time between work and raising children (Hotz and Miller, 1988). Childbearing is strongly associated with the transition to homeownership (Öst, 2012). According to Fannie Mae's National Housing Survey, a very important reason for buying a home is that homeownership provides the best environment for raising children. Therefore, delays in fertility stemming from greater female labor force participation might cause women and their partners to postpone homeownership. As marriage and homeownership are correlated, the decline in marriage might also explain the reduction in homeownership (Fisher and Gervais, 2011; Fischer and Khorunzhina, 2019; Chang, 2020). Unanticipated increases in house prices reduce the utility of first-time home buyers at the point of purchase but increase the utility of those with housing equity, differentially affecting fertility rates (Dettling and Kearney, 2014).

Although the inseparable nature of labor supply, fertility, and homeownership choices is widely acknowledged, a unifying framework integrating these joint decisions has yet to be analyzed. Our analysis seeks to fill this gap by developing and estimating a dynamic discrete choice model of female labor supply and the timing of births as well as the transition from tenant to homeowner with the Panel Study of Income Dynamics (PSID), in order to explain the secular decline in homeownership within the United States. Although the PSID is not fully representative of the U.S. economy, the trends in our sample, described in the next section, reflect national aggregates.

[2] A related literature frames homeownership around uncertainty about income and home prices (Attanasio et al., 2012; Bajari et al., 2013; Paz-Pardo, 2021).

To provide a satisfactory explanation, we must overcome challenges in identification and counterfactual prediction arising from the nonstationary secular trends mentioned above, compounded by the path of interest rates, which first rose and then fell over this period. Inferring the tastes of individuals from their behavior in nonstationary environments is further complicated by the fact that choices made after the panel ends factor into decisions made during the times they are sampled. Identification is less straightforward in such short panels than in long panels, where the full life cycle of sampled individuals are observed or a synthetic cohort can be constructed. In short panels, trade-offs between current (observed) choices and future (unobserved) choices are less informative about underlying preferences and technology.[3] Moreover, forecasting is problematic because nonstationary stochastic processes are not typically identified off their data-generating processes, and in many panel data sets there are only a few time series observations to estimate aggregate trends.

In identification and estimation, we leverage the close relationship between the conditional choice probabilities (CCPs) and their current utilities and associated continuation values (or conditional valuation functions) that are weighted sums of future expected utilities. Our model exploits the finite dependence property in estimation.[4] There is finite dependence in this model because we assume females receive (additively separable) utility from their children, but after some time that benefit does not affect their current choices, and their human capital from prior work decays to zero. Consequently, conditional on age, education, and marital status, females who are no longer fecund, have no recent working experience, and whose youngest child is beyond school age, have the same state variables and face the same choice set, conditionally independent of their personal histories. This property allows us to construct differences in the continuation values that only depend on the CCP values a few periods into the future, enabling estimation off a short panel.

Section 3 explains our model and empirical strategy. The parameters of the model capture household fixed costs of transition to homeownership, preferences over homeownership, working (and leisure) choices, and the number and timing of children. Technical details on the estimation are relegated to the Appendix. The results of the structural estimation are reported in Section 4. The estimated preference parameters are mostly statistically significant with intuitively appealing signs and magnitudes. Moreover, the one-period ahead forecasts obtained from solving our model with the estimated parameters track both individual life-cycle decisions and aggregate secular changes over this period quite well. All else being equal, households prefer becoming homeowner earlier in life. We explain the delay in homeownership not as a preference, but rather a result of a trade-off between homeownership and other important life-cycle decisions. The estimated preference parameters suggest that the transition to homeownership is positively related to labor market participation and the presence of children in a household.[5] This finding implies that whereas an increase in labor market participation can speed up the transition to homeownership, having fewer children later in life slows it down.

Given a path for wages, interest rates, house prices, and educational attainment, the estimated model can be used to disentangle the effects of fertility decisions and labor supply on housing choices and to quantify the dynamic feedback that homeownership induces on households' fertility choices and labor supply.

A second challenge in analyzing nonstationary environments is how to make inferences about counterfactuals when the nonstationary process is unknown, almost always the case for a short panel. Even in a model where individuals have perfect foresight, it is impossible to make predictions about future realizations of such processes without extra information drawn

[3] See Arcidiacono and Miller (2020) for an analysis of identification of dynamic discrete choice models when there are short panels.

[4] See Arcidiacono and Miller (2011, 2019) for analyses of finite dependence.

[5] In a related study, Miller and Sieg (1997) investigate decisions in housing consumption and male labor supply, controlling for children, and find children have a positive effect on the demand for housing but do not have much effect on labor supply of males.

from outside the data set. Here we follow a common practice in macroeconomics of comparing the long run steady states of different regimes. Our counterfactuals compare wages, educational backgrounds, house prices, and interest rates roughly corresponding to the beginning and end of the two-decade sample frame.[6]

Section 5 reports the results from simulating the counterfactual regimes. Summarizing, higher female wages lead to postponing the first home purchase. The effects are indirect, because workforce participation by itself raises the value of homeownership: however, higher base wages also increase the opportunity cost of leisure and child care and reduce fertility, which are complementary activities to homeownership. These negative effects outweigh the amenity value of owning a home when working. A second contributing factor to the secular decline in homeownership is higher house prices, which prompt households to postpone purchasing their own home, and also choosing smaller homes if they buy. We find that increasing educational attainment leads to earlier homeownership, and the direct effects of greater benefits from homeownership to more educated females are reinforced by their greater labor-force participation. Thus later cohorts, more educated than their predecessors, retarded the trend away from homeownership. Finally, we find that lower interest rates induce households to postpone homeownership, a feature that is evident in the data, both in our sample period and also in the years that followed; it is also a characteristic of the solution to our estimated dynamic optimization model. Intuitively households save throughout their lifecycle, and the wealth effect from an earlier purchase dominates the intertemporal lifecycle substitution effect of reducing consumption when young. However, as interest rates rose and then fell over this period, we hesitate to emphasize the role of interest rates in explaining the decline in homeownership over this period. Section 6 concludes. Overall, rising house prices and higher female wages explained the trend in postponing homeownership over that 20 year period, a trend that was ameliorated by greater female educational attainment.

2. LIFECYCLE PATTERNS AND SECULAR CHANGES

Our empirical analysis draws on the PSID for the years 1968 through 1993. This data set and the time frame has three key advantages for the purpose of this study. First, it contains broad and comprehensive information on household housing, labor supply, income, and detailed family characteristics for a moderately representative sample of households of the U.S. population. [7] Second, the PSID data set has a panel dimension so that we can measure household transition to homeownership, intertemporal labor-supply dynamics, and changes in family composition due to births of children. Third, this time frame captures the secular changes at the heart of this study well, with declining fertility, increased female education, rising female workforce participation, and decreasing homeownership.[8]

Our model controls for whether the household is headed by a couple or a single woman, along with the characteristics of partners. The study is conducted from the perspective of females: they bear the children; mothers spend more time with their children than fathers; throughout the period, under consideration mothers were almost invariably awarded child custody in the event of divorce; on average, females spent more time at home than males because their workforce participation rate was lower; female labor supply exhibited more variation in the lifecycle over the time frame in which households are most likely to purchase their first home. Most first homeownership choices are made before the age of 45, female labor-force participation settles in this phase of life, and almost all births occur then too. For these

[6] In our framework, it is also straightforward to predict the evolution of one steady state to another, and these results are available from the authors on request.

[7] We exclude the poverty subsample and the Latino subsample added to the PSID closer to the end of our study period.

[8] In addition we avoid the disruptions in the years leading up to the housing boom and subsequent bust in 2006, as well as the complications associated with the PSID changing its format from an annual to a biennial survey in 1997.

TABLE 1
SUMMARY STATISTICS

	Full sample	Owners	Renters
Age	32.4	33.9	29.7
Education	13.0	13.0	12.9
Married	0.82	0.92	0.64
Number of children	1.53	1.67	1.28
Home ownership rate	0.64		
House value for home owners		66,381	
Annual rent for renters			2,956
Move to owned house	0.087		
own-to-own**		0.062	
rent-to-own***		0.064	
Move to rental house	0.126		
rent-to-rent***			0.329
own-to-rent***			0.041
Number of rooms in dwelling	5.8	6.4	4.7
Labor force participation	0.753	0.736	0.783
Hours worked*	1497	1479	1527
Labor income*	11,070	11,504	10,341
Number of observations	43,504	27,871	15,633

Sample averages for females between 22 and 45 years old; data cover 1968 through 1993.
*Conditional on working.
**Including observations on households who spend one or two years of renting between two consecutive home ownerships.
***Excluding observations on households who spend one or two years of renting between two consecutive home ownerships.

reasons, our study considers single and married females in their fecund stage of life between the ages of 22 and 45.

Demographic characteristics include age, education and marital status of the individual, family size of household, number of children, and their ages. Labor-force participation data include number of hours put into working activities and earnings. We also used information on household housing arrangements, including number of rooms in a dwelling, indicator for homeownership, value of primary residence for homeowners, and amount of rent paid by tenants. All monetary values, such as house value for homeowners, rent paid by tenants, and labor income, are adjusted for inflation using Consumer Price Index and converted into 1984 dollars.

Table 1 presents summary statistics for the data sample used in the analysis. Over the observed time period, the average homeownership rate for the sample of 22–45 years old females constitutes 64%, thus matching the homeownership rate reported by other nationally representative data over the same time period (e.g., U.S. Bureau of the Census, Housing Vacancy Rate Survey, Smith et al., 1988). The demographic profile of homeowners differs from tenants along several dimensions, some of which are directly related to their age, where they are in the lifecycle. Compared to tenants, homeowners are older, slightly more educated, more likely to be married, have more children, have more living space, are less likely to work, and, conditional on workforce participation, work fewer hours.

Some of these differences can be attributed to the fact that homeowners have progressed further through their lifecycle than tenants. Because they are older, homeowners are more likely to be married and have more children, and if their children are young they are likely to work less hours, but conditional on working they are also likely to have more experience and hence earn a higher wage. These kinds of differences require a dynamic approach to be satisfactorily resolved.

The table also shows tenants move much more frequently than homeowners. Almost one third of tenants move each year, and about 6% of homeowners were tenants in the previous year. Presumably the costs of moving increase with the size of the household, for example,

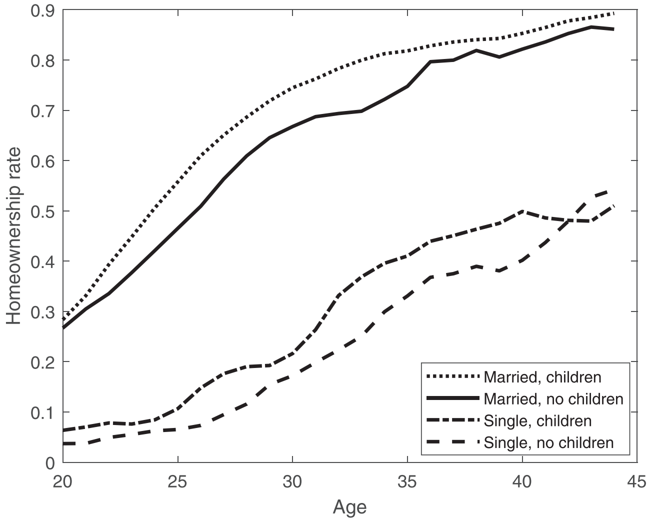


FIGURE 2

AVERAGE HOMEOWNERSHIP RATE

from school aged children switching schools, to spouses coordinating employment. As rental contracts are generally designed for a much shorter term duration than home purchase, it is reasonable to speculate that as households grow, their preferences shift toward homeownership, and hence delays in forming multiperson households might be associated with postponing home purchase.

There is, however, scant evidence that the reverse movement, from ownership to renting, changed over the period under consideration. Our estimates from the PSID, illustrated in Figure A1 of the Appendix, show that over the period 1970 through 1995 the transition from ownership to rental was roughly constant at four percent reported in Table 1, experiencing a statistically insignificant and quantitatively small decline. Thus, the decline in homeownership over this period was almost entirely driven by fewer transitions from renting to ownership instead of greater transitions in the other direction.

Figure 2 illustrates homeownership profile over the life cycle, broken down by marital status and children. Broadly speaking, larger and older households are more likely to be homeowners. For both married and single households, homeownership is greater for households with children. On average, the homeownership rate of families with children is 5–7% higher compared to families with the same marital status but without children. Similarly households with two heads are more likely to be homeowners than single headed households.

Figure 3 illustrates the delay in fertility is associated with the delay in homeownership. As the average age at having first child steadily increased, the average age at the birth of second child also increased with the timing between consecutive birth at about two years in the 1970s and 1980s, and a reduction of the average time between the first and second child to 1.5 years by the 1990s. Figure 3 shows the timing of purchase of the first home has a delayed pattern over the life cycle similar to the delay in fertility. Figure 3 shows the age at first homeownership closely follows the birth of the second child. In the early 1970s, first homeownership occurs on average one year after the birth of the second child, while in the late 1970s and up to the early 1990s, the timing of the first homeownership and the birth of the second child nearly coincide. Indeed, two-thirds of households have one or more children at the time of purchase of their first home; half of first time home buyers have only one or two children, and one third have only one child at the time of home purchase. Most firstborns were at least one year old at the time of the home purchase, observations consistent with the findings of Öst (2012).

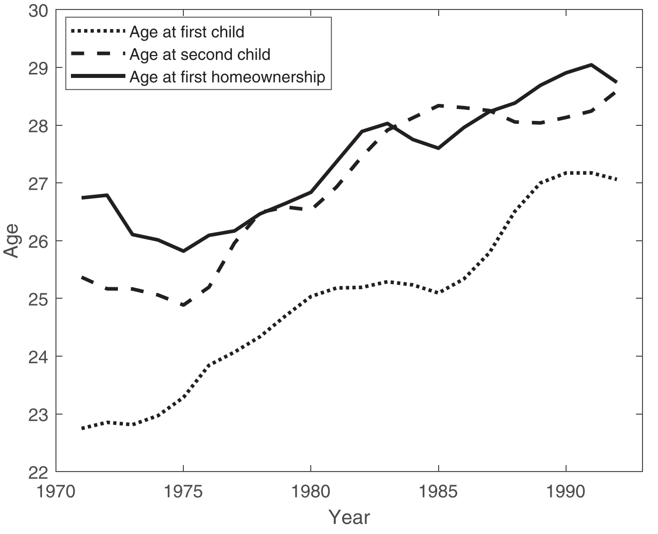


FIGURE 3

TIMING OF CHILDREN AND FIRST HOMEOWNERSHIP

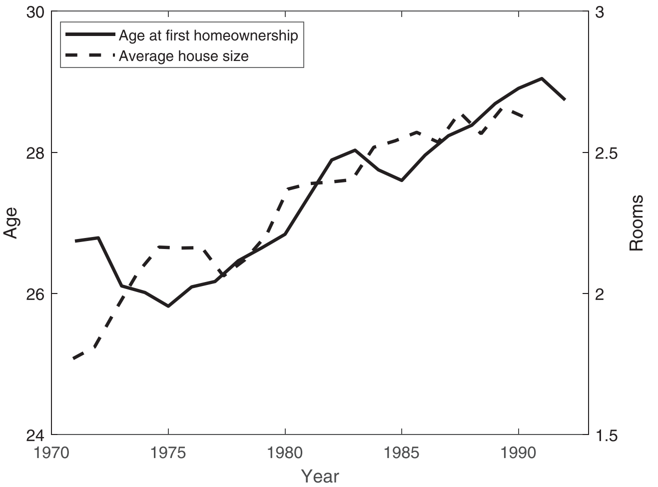


FIGURE 4

FIRST HOMEOWNERSHIP AND AVERAGE HOME SIZE ADJUSTED BY FAMILY SIZE

Postponing homeownership is associated with ultimately purchasing a larger residence. Figure 4 illustrates the delay is aligned with the growing size of first home as a number of rooms per family member (the right-hand scale). The U.S. Census Bureau reports that over time the average size of a single-family house increased from 1600 square feet in 1970 to 2400 square feet in 2010. Furthermore, increased residential housing size is observed not only for homeowners, but also for tenants. In an economy where household size grows though time, and large households prefer more dwelling space, households tend to be tenants when they are young and homeowners when they are older. Moreover, exogenously delayed home purchase would plausibly induce both average rental tenements and increased homeowner dwellings to increase in size. Part of the puzzle, then, is to explain how these behavioral shifts were resolved by the underlying driving factors over this period.

3. THE MODEL

The evidence presented above strongly suggests that households jointly determine their fertility, labor supply, and housing decisions over the life cycle. The first parts of this section develop a dynamic model of discrete choice of housing demand, fertility choice, and labor supply to explain households' decision-making process. Then we propose an estimator for the preferences of the model.

Only a tiny fraction of mothers put their babies out for adoption, and very few homeowners become tenants, rarely selling their first homes within a few years of purchase.[9] Empirically it is not possible to separately estimate (nonparametrically) the current utility a household receives from a child on an annual basis. Therefore, we assume giving birth and becoming homeowner are irreversible choices, and model the expected lifetime benefits from offspring at their point of birth. Of course all the benefits from having children do not literally occur at the time of birth, but there is an observational equivalence when only data on births, not current benefits of children, are available. For similar reasons, we model the expected lifetime benefits of first homeownership as accruing at the point of sale. When becoming a homeowner, the household balances the transaction cost of purchase and a size inertia inherent to homeownership against the benefits of tailoring their own property to individual tastes and having more geographic stability to cultivate social and economic opportunities within the neighborhood.

Current female labor supply is treated as a period-by-period decision; her choices affect her future wages through learning by doing, inducing persistence in labor supply over time. Hours worked are modeled as a stochastic process conditional on participation and the state variables in the model, including past participation and past hours. Finally, as the timing of first birth and marriage are correlated (Figure 1), and since it essentially involves an implicit (sometimes explicit) contract about dividing assets on separation, we treat the event of marriage as a stochastic process driven by the state variables (such as the age and number of children) instead of an explicit choice variable, and interpret declining marriage rates throughout this period as reflecting a decline in activities that facilitate the marriage contract, not a causal factor itself.

3.1. *Choices.* For each period $t \in \{1, 2, \dots\}$ the household makes a continuous current consumption choice denoted by c_t, a discrete labor-force participation choice $l_t \in \{0, 1\}$, where working is denoted by $l_t = 1$, and a fertility choice $b_t \in \{0, 1\}$, where a birth is indicated by $b_t = 1$. If she is a tenant at t, she also decides whether to continue renting by setting $h_t = 0$ or changing her accommodation status and purchasing a home, by setting $h_t = 1$. We assume giving birth is only possible up to age T_1, and at age T_2, where $T_2 \geq T_1$ the household retires, and, if still a tenant at that age, remains one forever. These assumptions are innocuous because our empirical work focuses on women less than 45 years old. To represent the choice set parsimoniously, define the indicator variables d_{jt} for $j \in \{0, 1, \dots, 7\}$ and $t \in \{1, 2, \dots\}$ as

$$d_{jt} \equiv 1\left\{ j = \begin{bmatrix} (1-h_t)b_t(1-l_t) + 2(1-h_t)(1-b_t)l_t + 3(1-h_t)b_t l_t \\ +4h_t(1-b_t)(1-l_t) + 5h_t b_t(1-l_t) + 6h_t(1-b_t)l_t + 7h_t b_t l_t \end{bmatrix} \right\}.$$

Thus $d_{jt} \in \{0, 1\}$ and $\sum_{j=0}^{7} d_{jt} = 1$. The base choice $d_{0t} = 1$ involves setting $(h_t, b_t, l_t) = (0, 0, 0)$. Purchasing the first home is a once-in-a-lifetime decision, so if $h_t = 1$, then $h_\tau = 0$ for all $\tau \in \{t+1, t+2, \dots\}$, and hence $\sum_{j=0}^{3} d_{j\tau} = 1$. In this way, the model restricts homeowners to four (two) choices each period until (after) age T_1, while tenants pick one of the eight (four).

[9] Thus, we treat becoming a homeowner (or equivalently marrying/having a spouse who is/becomes one) as a stopping problem. With a larger data set on homeownership that covers the housing crisis after the financial crash of 2008, our model can be adapted to analyze foreclosure as an unanticipated event in a nonstationary economy.

3.2. *Household Preferences.* The household derives utility from consumption, leisure, offspring, and housing. Her preferences are characterized by a discounted sum of a time-additively separable, constant absolute risk-aversion utility function. [10] We model the household's lifetime utility from age t onward as

$$(1) \qquad -\sum_{\tau=t}^{\infty}\sum_{j=0}^{7}\beta^{\tau-t}d_{j\tau}\exp\left(-\left(u^h_{j\tau}+u^b_{j\tau}+u^l_{j\tau}\right)-\rho c_\tau-\epsilon_{j\tau}\right)$$

where β denotes the subjective discount factor, ρ is the constant absolute risk aversion parameter, u^h_{jt} indexes the expected lifetime utility payoff from becoming a homeowner, u^l_{jt} indexes the current utility payoff from leisure time, u^b_{jt} indexes the discounted utility stream from a(nother) birth, and ε_{jt} is a nonsystematic component of the flow utility capturing a choice-specific idiosyncratic taste shock for each (j, t).

The indices for homeownership, leisure and births are themselves mappings of socioeconomic demographics, partly determined by past and current interactive choices. In our framework, homeownership confers on the household a right to adapt their living quarters to their own lifestyle in ways that a landlord might object.[11] We define the homeownership index as

$$(2) \qquad u^h_t=\theta_0+\theta_1 l_t+\theta_2 b_t+\theta_3 b_t l_t+x'_t\theta_4+\theta_5 l_{t-1}+s_t[\theta_6+x'_t\theta_7+\theta_8 s_t+\theta_9 s_{t-1}+\theta_{10}l^*_t+\theta_{11}l^*_{t-1}],$$

where s_t measures house size in period t, $l^*_t \in [0, 1]$ is female labor supply in t, and x_t is a set of fixed or time varying attributes that characterize the decision maker (age, education, and marital status) along with previous fertility and labor-market outcomes. The choice dependent term in (1), u^h_{jt}, is then defined by evaluating u^h_t at the triplet (h_t, b_t, l_t) corresponding to the j^{th} choice.

Presumably u^h_t is concave increasing in s_t, implying $\theta_8 < 0$. The rationale for including s_{t-1} in the index is that when moving from a rental unit to homeownership, the change in size reflects the terms of trade between renting and owning: for example, relatively larger homes tend to be purchased if rental accommodation is relatively expensive. The last expression in (2) is an interaction with current labor supply that captures whether purchase is more likely to occur when the woman is working, and by extension whether she is more likely to work in the future.

The indices for fertility and labor supply follow the literature.[12] The lifetime utility of giving birth and raising one more child is given by

$$(3) \qquad u^b_t=\gamma_0+x'_t\gamma_1+\gamma_2 h_{t-1}+\gamma_3(1-m_t)h_{t-1}+\gamma_4 l_t+\gamma_5 s_t,$$

[10] Although Constant Elasticity of Substitution (CES) utility is commonly used in models with housing (Bajari et al., 2013; Li et al., 2016; Bruneel-Zupanc and Magnac, 2021; Khorunzhina, 2021), we adopt the CARA utility function, because we lack reliable information on wealth. During the period of 1968–1993, the PSID provides detailed questions on household wealth for only two years, 1984 and 1989, insufficient for modeling of changes in household wealth within a dynamic framework. As explained in Margiotta and Miller (2000), the CARA assumption is useful in this context because it is consistent with consumption smoothing from accumulated wealth and accommodates risk aversion in a parsimonious fashion. Relatedly, we abstract from financial constraints; see footnote 14.

[11] In this way, we implicitly treat moral hazard issues arising from tenants lack of care for the premises they rent, and other agency issues associated with landlord/tenant relationships.

[12] See, for example, Hotz and Miller (1988), Eckstein and Wolpin (1989), Altug and Miller (1998), Francesconi (2002), and Gayle and Miller (2006).

where $m_t \in \{0, 1\}$ is marital status with $m_t = 1$ indicating married, and the marginal lifetime utility of a second child is affected by the age of the first through x_t. Finally, we define

$$(4) \qquad \begin{aligned} u_t^l = {} & \delta_0 + x_t'\delta_1 + \delta_2 s_t + \delta_3 h_{t-1} + \delta_4(1 - m_t)h_{t-1} + \delta_5 l_{t-1} \\ & + l_t^*[\delta_6 + x_t'\delta_7 + \delta_8 l_t^* + \delta_9 l_{t-1}^* + \delta_{10} h_{t-1} + \delta_{11}(1 - m_t)h_{t-1}], \end{aligned}$$

where lagged labor supply affects the marginal utility of current leisure, defined as $1 - l_t^*$. The terms u_{jt}^b and u_{jt}^l in (1) are defined analogously to u_{jt}^h.

3.3. *Budget Constraint.* Instead of imposing stationarity in the economy, we allow rents, house prices, aggregate wages, and interest rates to fluctuate over time in an irregular manner, but to simplify the econometric implementation of our model, we assume the individuals in the model can forecast them perfectly.[13] We also abstract from financial constraints, including borrowing limits often geared to measures of current income.[14] Formally, we follow Altug and Miller (1990) and others, by assuming there are a complete set of markets. In the model, fertility and homeownership decisions are not driven by short-term financial exigencies but by life-cycle considerations.

Denote by W_t household financial wealth at the beginning of period t. Household income from real wages paid to the female if she works in period t, is denoted by Y_t. Rent in period t, denoted by $R_t(s_t)$, depends on house size s_t, as does the price of a house, denoted by $H_t(s_t)$. These definitions imply the law of motion after T_2 is $(1 + i_t)(W_t - c_t)$ and before T_2 is

$$(5) \quad W_{t+1} = \begin{cases} (1 + i_t)[W_t - c_t + \sum_{j=0}^{3} d_{jt} Y_t - R_t(s_t)] & \text{if } h_\tau = 0 \text{ for all } \tau \in \{1, \ldots, t\} \\ (1 + i_t)[W_t - c_t + \sum_{j=4}^{7} d_{jt} Y_t - \sum_{j=4}^{7} d_{jt}(1 + \varphi)H_t(s_t)] & \text{if } h_t = 1 \\ (1 + i_t)[W_t - c_t + \sum_{j=0}^{3} d_{jt} Y_t] & \text{if } h_\tau = 1 \text{ for some } \tau \in \{1, \ldots, t - 1\}, \end{cases}$$

where i_t denotes the one-period interest rate in period t, and φ is the real estate commission rate incurred by household on completing the transaction of home purchase.

3.4. *State Variables.* The state variables in the model include (1) those the household controls directly, namely the composition of the household, labor-force experience, and whether she owns her home or not, (2) those that affect life style but are optimized outside the model conditional on the discrete choices made inside the model, including the size and quality of housing accommodation, and (3) calendar time, which captures future movements in the nonstationary aggregates, including shifts in house prices, aggregate wages, and interest rates.

The timing and spacing of children affect the benefits they confer on the household. We track the number and ages of children until they turn 18, when the child becomes a young adult and is assumed to leave the household. We denote by a_{it} the age of the ith child in t for $i \in \{1, \ldots, I\}$. Let n_t denote the number of offspring living in the household in period t:

$$n_t = n_{t-1} + b_{t-1} - \sum_{i=1}^{I} I\{a_{it-1} = 17\}.$$

Thus $a_t \equiv (a_{1t}, \ldots, a_{It})$ represents both the number and ages of offspring under 18 in the household in period t.

[13] Iacoviello (2004), Kiyotaki et al. (2011), Poterba (1984), and Skinner (1989) among others allow for a similar treatment of the aggregate quantities in the models with housing.

[14] Tables A2 and A3 in the Appendix report results from running a logit regression to check whether financial constraints, proxied by household savings being less than two months of household income, is a predictor for housing transitions (first-time buying, moving to another homeownership, or abandoning homeownership). After controlling for income and a standard set of demographic determinants, we find this savings variable is statistically insignificant.

The household also decides whether to work or not, but we do not model how many hours labor-force participants work. Age, education, and hours worked in the previous period affect her current wage rate, which also implies lagged labor supply l^*_{t-1} is a state variable. House size and quality is not directly determined by the household in our framework, but nevertheless enters as a state variable because of their intertemporal dependence.

3.5. *Intertemporal Choices.* At the beginning of period t, the household observes the vector of disturbances to its preferences, $\varepsilon_t \equiv (\varepsilon_{0t}, \dots, \varepsilon_{7t})$, her nonhousing assets W_t and other state variables described above, denoted by z_t. Households are expected utility maximizers, sequentially optimizing the expected value of (1) subject to (5) by choosing $j \in \{0, \dots, 7\}$ if they are currently tenants less than T_1 years old, and otherwise choosing from the more restricted choice sets we defined.

We define $\pi H_t(s_t)$ as the downpayment on a house priced at $H_t(s_t)$ in period t. Let $\widetilde{R}_t(s_t)$ denote equal repayments in perpetuity starting in period $t+1$ on the loan $(1-\pi)H_t(s_t)$. A competitive loans market implies

$$\widetilde{R}_t(s_t) \equiv (1-\pi)H_t(s_t)\sum\nolimits_{\tau=t}^{\infty}\prod\nolimits_{r=t}^{\tau}(1+i_r)^{-1} \equiv (1-\pi)H_t(s_t)(B_t-1),$$

where B_t is the current price of a bond in t that pays one consumption unit each period in perpetuity. Denoting disposable income net of housing expenses by y_{jt}, it follows that

$$y_{jt} \equiv \begin{cases} \sum_{j=0}^{3} d_{jt}Y_t - R_t(s_t) & \text{if } h_\tau = 0 \text{ for all } \tau \in \{1,\dots,t\} \\ \sum_{j=4}^{7} d_{jt}[Y_t - (\pi+\varphi)H_t(s_t)] & \text{if } h_t = 1 \\ \sum_{j=0}^{3} d_{jt}Y_t - \widetilde{R}_t(s_t) & \text{if } h_\tau = 1 \text{ for some } \tau \in \{1,\dots,t-1\}. \end{cases}$$

Let $p_{jt}(z_t)$ denote the probability of choosing j at year t conditional on the value of the household state variable vector z_t (but not W_t), and denote by ε^*_{jt} the truncated variable that takes on the value of ε_{jt} only when $d_{jt} = 1$. Adapting Gayle et al. (2015) to our framework, let $A_{T+1}(z_{T+1}) \equiv 1$, and recursively define an index of household capital for a household at year t as

$$(6) \quad A_t(z_t) \equiv \sum_{j=0}^{7} p_{jt}(z_t)\exp\left(\frac{-u^h_{jt} - u^b_{jt} - u^l_{jt} - \rho y_{jt}}{B_t}\right)E_{jt}\left[\exp\left(\frac{-\varepsilon^*_{jt}}{B_t}\right)\right]A_{t+1}\left(z^{(j)}_{t+1}\right)^{1-\frac{1}{B_t}},$$

where $z^{(j)}_{t+1}$ is the value of the state vector at $t+1$ following the choice j in period t applied to z_t, the value of the state vector in period t. The index is strictly positive; lower values of $A_t(z_t)$ come from higher current income and lower rent, both incorporated within y_{jt}, as well as less distasteful x_t values that increase the sum of the three indices, $u^h_{jt} + u^b_{jt} + u^l_{jt}$. Denote by $d^o_t = (d^o_{1t}, \dots, d^o_{7t})$ the discrete choices that along with the optimal consumption choices, c^o_t, maximize the expected value of (1) subject to (5). The theorem below shows that all the household dynamics are transmitted through $A_t(z_t)$.

THEOREM 1. *For each $t \in \{1, 2, \dots\}$, the optimal choices d^o_t maximize:*

$$(7) \quad \sum_{j=0}^{7} d_{jt}\left[\rho y_{jt} + u^h_{jt} + u^b_{jt} + u^l_{jt} - (B_t - 1)\ln A_{t+1}\left(z^{(j)}_{t+1}\right) + \varepsilon_{jt}\right].$$

Intuitively, the household maximizes a weighted sum of net current income, the three indices in current utility, which in the case of a birth and homeownership also impound the future benefits of making a durable choice, as well as adjustments to household capital that reflect the option value for delaying homeownership, the impact of gaining work experience, and changes to family composition.

3.6. *Identification and Estimation.* The model is identified from (7) up to a probability distribution for $\varepsilon_t \equiv (\varepsilon_{0t}, \ldots, \varepsilon_{7t})$ and normalizing constants for each state.[15] We assume ε_{jt} is independently and identically distributed as a Type I extreme value with location and scale parameters (0,1). Let $p_{jt}(z_t) \equiv E_t[d^o_{jt}|z_t]$ denote the conditional choice probability (CCP) of optimally making the jth choice. Noting $u^h_{0t} = u^b_{0t} = u^l_{0t} = 0$, it is well known that under this parameterization of the disturbances:

$$\ln\left[\frac{p_{jt}(z_t)}{p_{0t}(z_t)}\right] = \rho(y_{jt} - y_{0t}) + u^h_{jt} + u^b_{jt} + u^l_{jt} - (B_t - 1)\ln\left[\frac{A_{t+1}\left(z^{(j)}_{t+1}\right)}{A_{t+1}\left(z^{(0)}_{t+1}\right)}\right].$$

Let $z^{(j)}_\tau$ define the value of the state vector in period $\tau \in \{t+1, \ldots, T\}$, when choice j made at t is followed by choice zero for all successive periods. Estimation is based on successively telescoping $\ln[A_{t+1}(z^{(j)}_{t+1})/A_{t+1}(z^{(0)}_{t+1})]$ into the future through to the end of the discrete choice phase at T. The following theorem provides the basis for the CCP estimator used in our application.

THEOREM 2. *For each* $j \in \{1, \ldots, 7\}$ *and* $t \in \{1, \ldots, T\}$*:*

$$\ln\left[\frac{p_{jt}(z_t)}{p_{0t}(z_t)}\right] = \rho(y_{jt} - y_{0t}) + u^h_{jt} + u^b_{jt} + u^l_{jt} + \sum_{\tau=t+1}^{T}\prod_{r=t+1}^{\tau}\left(\frac{1}{1+i_r}\right)\ln\left[\frac{p_{0\tau}\left(z^{(0)}_\tau\right)}{p_{0\tau}\left(z^{(j)}_\tau\right)}\right]$$

$$- \sum_{\tau=t+1}^{\infty}\prod_{r=t+1}^{\tau}\left(\frac{1}{1+i_r}\right)\rho\left[\widetilde{R}_t(s_t) - R_t(s_t)\right]. \tag{8}$$

This theorem shows that the log odds of the conditional-choice probability in period t for buying a house and working but not giving birth (setting $d_{6t} = 1$), versus the base choice of not working, not giving birth and continuing to rent (setting $d_{0t} = 1$), depends on four factors. First is the difference in net income this period $y_{jt} - y_{0t}$, scaled by the coefficient of absolute risk aversion ρ. The second factor is the difference in current utility this period $u^h_{jt} + u^b_{jt} + u^l_{jt}$ and the one from the baseline setting with $(h_t, b_t, l_t) = (0, 0, 0)$. Third is the difference in the discounted streams of rental payments from period $t+1$ onward, where both streams are generated by making the base choice, but one stream begins with the household owning a home and the other pertains to a household who never becomes a homeowner; the terms involving $\widetilde{R}_t(s_t) - R_t(s_t)$ on the second line of (8) comprise this factor. The remaining terms in (8), a discounted sum of future CCPs, are correction factors to account for the fact that always choosing the base action in future periods is not optimal.[16]

The estimation of the primitives in Equation (8) follows a two-step strategy.[17] The first step nonparametrically estimates the CCPs as nuisance parameters using a kernel estimator. The CCP estimates are substituted into Equation (8), and the parameters of the utility function are estimated off the empirical counterpart to the resulting moment conditions. Further details about the estimation procedure can be found in the Appendix.

[15] See Hotz and Miller (1993), Magnac and Thesmar (2002), and Arcidiacono and Miller (2019). In fact, this model is overidentified because the coefficients on preferences are not separately indexed by calendar time and state.

[16] See Proposition 1 of Hotz and Miller (1993).

[17] See Bruneel-Zupanc and Magnac (2021) for another study on housing choices using a related two-step CCP estimation procedure.

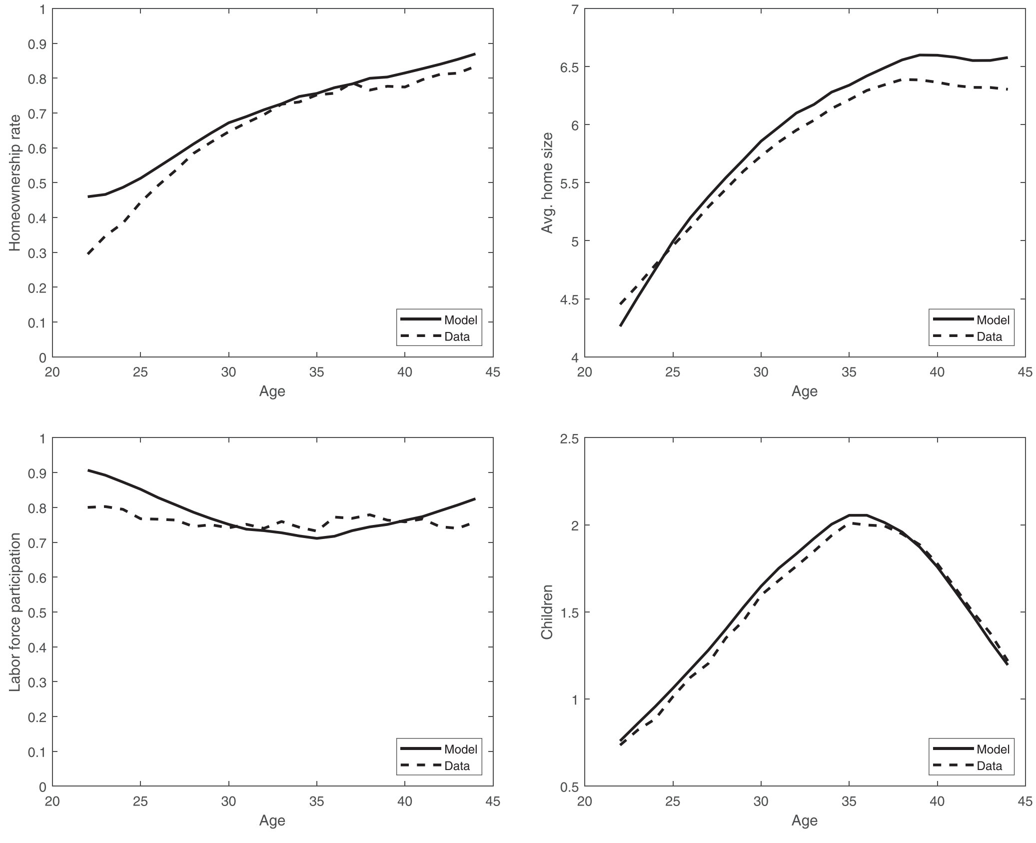


FIGURE 5

ONE-PERIOD IN-SAMPLE MODEL PREDICTION VERSUS DATA: LIFE-CYCLE DIMENSION

4. RESULTS

This section presents the structural parameter estimates of household preferences and compares the model predictions with in-sample behavior. First, we report on model fit by comparing household choices predicted by the model with choices observed in the data, and then we discuss the estimated utility function that characterizes the benefits of homeownership, children, and leisure.

4.1. *Model Fit.* From the PSID sample, we obtain relative frequencies on homeownership, labor-force participation and number of children, conditional on the state variables in the previous year, and compare these cell estimates with the model's predictions for one period ahead. Figure 5 displays the average lifecycle profile, Figure 6 the calender year averages (over the PSID sample). Only one set of time dummies is used in fitting the model: the period specific wage rate for a standardized unit of labor that enters the individual's competitive wage rate as a multiplicative factor. This standardized wage is estimated off an ancilliary wage equation, the bond price is data fed into the optimal decision rule, and under the CARA assumption, the subjective discount factor β is neither estimated nor assumed, dropping out of the estimation equations. Yet the one-period forecasts from the estimated model quite closely track the average lifecycle in this sample and also the sample population over this 25 year period.

Figure 5 tracks lifecycle in-sample one-period-ahead predictions for homeownership, home size, labor supply, and the number of children in a family by householder age, from 22 to

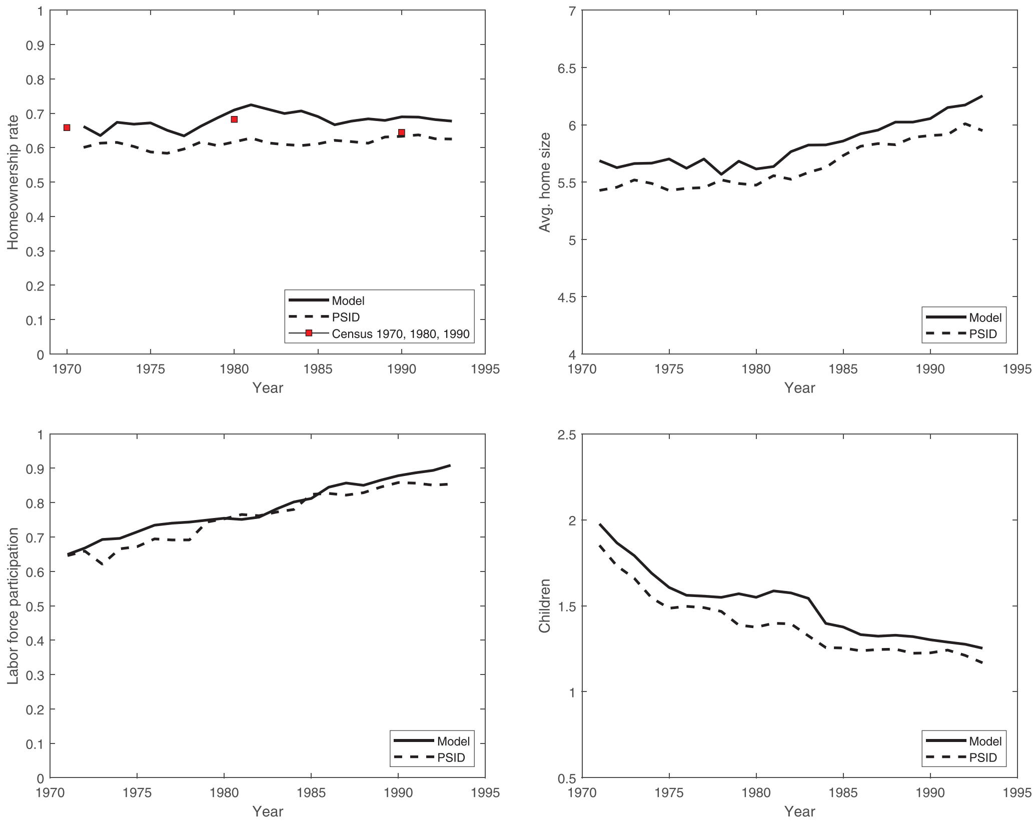


FIGURE 6

ONE-PERIOD IN-SAMPLE MODEL PREDICTION VERSUS DATA: TIME DIMENSION

45, relative to outcomes observed in the data. The model closely matches homeownership choices from age 25 and on, but over-predicts homeownership rate for the very young households between age 22 and 25. The model matches the overall level of labor-force participation, somewhat over-predicting working by the very young females, but staying within 5 percentage points from then on. The model provides a close description of the average number of children born to the households over the life cycle, reaching the peak at about age 35, followed by a decline. In summary, the model generates choices that track the lifecycle trends in homeownership, labor-force participation and family size, closely matching the choices observed in the data within the life phases we are focused on.

Figure 6 tracks in-sample one-period-ahead predictions for those same variables by calendar year relative to outcomes observed in the data. Aside from shifting demographics, variation in outcomes over time is generated by the time-variation in house prices, interest rates, and the effect of aggregate shocks on wages. Some life-cycle over-prediction for homeownership, home size, labor supply, and the number of children, evident from Figure 5, accumulates into a small over-prediction in Figure 6. Homeownership in our model is strongly affected by the interest rates, which dramatically increased from the 1970s to the 1980s and then, equally dramatically, declined from the 1980s to the 1990s: in our model, homeownership increases from the 1970s to the 1980s and subsequently declines from the 1980s to the 1990s. Curiously this dynamics in homeownership is not detected in the aggregated PSID data, but our model predictions are in agreement with the homeownership rate for working age population reported by Census: the rate grew from 0.66 in 1970 to 0.68 in 1980 and declined to 0.64 in

1990.[18] We explore the relationship between interest rates and homeownership in greater detail in the next section. The model closely captures the time dimension in working and births. Labor-force participation is strongly affected by the increase in aggregate factors captured in the estimation of the wage process. The increase in working is accompanied by the decline in births, and the average number of children in a household. Another interesting insight from Figure 6 is the influence of peaking interest rates in the 1980s on births and children, presumably related to the increase in homeownership.

4.2. *Utility Parameters.* Table 2 reports the estimated utility function, grouped by the utility components given in Equation (1), which incorporates parameters for the utility from housing services (2), raising children (3), and the disutility from working (4). Column (1) of Table 2 reports the estimated parameters of the fixed utility of buying a home (along with their estimated standard errors), column (2) shows the estimates of the utility of home size, column (3) reports the estimates of the utility of raising children, while columns (4) and (5), respectively, report the coefficient estimates of the fixed and marginal disutility from working.

Before describing the estimates in detail, we note that the trend evident in the time series in Figure 4, away from becoming homeowners earlier in life toward buying larger homes when they are older, has a cross-sectional analogue. Households face a trade-off between buying a smaller house earlier in life and being a home owner for a greater number of years, versus holding out for a larger residence that is lived in for fewer years: demographic groups that buy earlier tend to own smaller homes, and vice versa. There is only one exception to this rule: the older the youngest child, the less likely a renting household buys a home, and conditional on purchase, the smaller the home is likely to be. Loosely speaking, the shorter the time frame in which the maximal number of members anticipate living together, and the longer the delay until that time frame, the lower the premium the household is willing to pay for space. In this way, the size of the first home evolves over the lifecycle of a household that rents as it decides when to switch. However, the time trend in Figure 4 is not simply a composition effect of the results displayed in Table 2: a major demographic shift in this sample is the increased formal education of women, yet higher education is associated with the earlier purchase of a smaller home, at odds with the aggregate trend toward buying later and bigger.

Turning to the estimates, as indicated by the rows 2 and 3 in Table 2, buying a first home and having a child in the same year gives the strong disutility from simultaneously doing both, only exacerbated by concurrently working. Intuitively, undertaking all three activities at once is overwhelming. Column (2) shows the estimated utility from house size is increasing and concave. We find that new homeowners choose larger homes relative to the size of the previously rented homes, consistent with the stylized fact that rental-occupied housing is typically smaller than owner-occupied housing. Our findings support the hypothesis that among other factors, households value accommodation by the amount of total time spent at home, as roughly measured by the product of the number of household members and the frequency with which they spend time at home. Thus, column (1) shows the utility from becoming a homeowner is initially increasing (with the addition of a spouse and a first child) but declines in household size thereafter. On this interpretation, utility diminishes as the children grow older, aging children having the opposite effect of an aging spouse, because the former grow detached and eventually leave the household. On another dimension of time spent at home, working women, and those with greater market capital (as measured by labor-force participation in the previous period, which increases current wages) tend to prefer smaller homes. Such households are likely to spend less time at home, therefore benefit less during waking hours from housing space, and have less leisure time for housing upkeep, which is greater in bigger houses.

The estimated utility of becoming a homeowner is higher for younger and more educated women, but in the case of married women, dampened by having a younger and more

[18] Decennial Censuses (Ruggles et al., 2019) are used for construction of 1970–1990 homeownership rates.

TABLE 2
ESTIMATION RESULTS FOR UTILITY INDICES

	Utility from:				
	u_t^h		u_t^b	u_t^l	
	home purchase $h_t \times$ (1)	home size $h_t s_t \times$ (2)	birth $b_t \times$ (3)	work $l_t \times$ (4)	work hours $l_t l_t^* \times$ (5)
Constant	1.10	0.62	2.12	0.01	5.75
	(0.47)	(0.08)	(0.19)	(0.17)	(0.91)
Work(l_t)	0.60		−4.05		
	(0.50)		(0.25)		
Birth(b_t)	−3.25				
	(0.49)				
Work∗Birth($l_t b_t$)	−22.77				
	(0.52)				
Demographic characteristics (x_t)					
Female age	−0.20	0.04	−0.42	−0.03	0.07
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
Female education	0.44	−0.07	0.14	0.13	−0.45
	(0.03)	(0.01)	(0.01)	(0.01)	(0.05)
Husbands age	0.09	−0.01	−0.02	−0.01	0.07
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
Husbands education	−0.51	0.08	0.14	−0.08	0.26
	(0.03)	(0.01)	(0.01)	(0.01)	(0.04)
Single	−10.26	0.41	−5.78	1.66	−11.62
	(0.54)	(0.09)	(0.22)	(0.20)	(1.02)
Non-White	−8.94	0.48	−0.57	−1.33	9.52
	(0.20)	(0.04)	(0.08)	(0.07)	(0.40)
Single∗Non-White	−23.63	2.38	5.27	−1.13	13.61
	(0.50)	(0.09)	(0.17)	(0.15)	(0.76)
Children at $t-1$	3.67	−0.15	4.29	−0.73	−2.99
	(0.14)	(0.02)	(0.05)	(0.04)	(0.24)
Children sq. at $t-1$	−2.84	0.14	−2.47	0.08	−0.42
	(0.04)	(0.01)	(0.02)	(0.01)	(0.06)
Age of last child	−0.34	−0.06	−1.48	0.12	−0.39
	(0.02)	(0.01)	(0.01)	(0.01)	(0.03)
Homeowner at $t-1$ (h_{t-1})			2.65	−0.65	5.11
			(0.06)	(0.04)	(0.21)
Single∗Homeowner at $t-1$ (Single∗h_{t-1})			−16.37	−1.00	8.33
			(0.15)	(0.17)	(0.74)
Current home size (s_t)		−0.05	0.01	−0.01	
		(0.01)	(0.01)	(0.01)	
Prior home size (s_{t-1})		0.01			
		(0.00)			
Employed at $t-1$ (l_{t-1})	0.19			1.43	
	(0.04)			(0.03)	
Work time (l_t^*)		−2.11			−130.93
		(0.03)			(0.85)
Work time at $t-1$ (l_{t-1}^*)		−0.30			97.43
		(0.03)			(0.58)

Standard errors in parentheses.

educated spouse. Higher formal education is correlated with skills that facilitate business transactions in property acquisition. On the flip side, spouses with less formal education have a comparative advantage in home maintenance, which utilizes manual skills not taught much in schools. Similarly, homeownership confers greater control and security over one's living arrangements, features more highly valued by younger women and married women with older spouses. Finally, utility from homeownership is smaller for non-White households, consistent with the lower homeownership rates for these population segments.

Although the choices households make about buying their first home are informative about its value to them, the value derived from their labor supply and fertility choices are affected by their housing status. Column (3) shows the utility of married women from having a(nother) child is enhanced by living in their own home, although this is emphatically not true for single women. More generally, these findings are consistent with empirical evidence that homeownership is beneficial for families with children (Green and White, 1997; Haurin et al., 2002), and is highly correlated with the fertility decisions (Öst, 2012). Homeownership also affects the (mainly nonpecuniary) costs and benefits of labor supply, raising the cost of participation, as reported in column (4), but for those women supplying labor reducing the burden of working extra hours, column (5). Thus, homeowners tend toward a lower labor-force participation, but if they work, tend to choose longer working hours (which is consistent with having longer commuting costs, among other factors). This last finding contrasts with Table 1 that shows that if we do not condition on the characteristics of the household, the average number of hours worked by homeowners is lower.

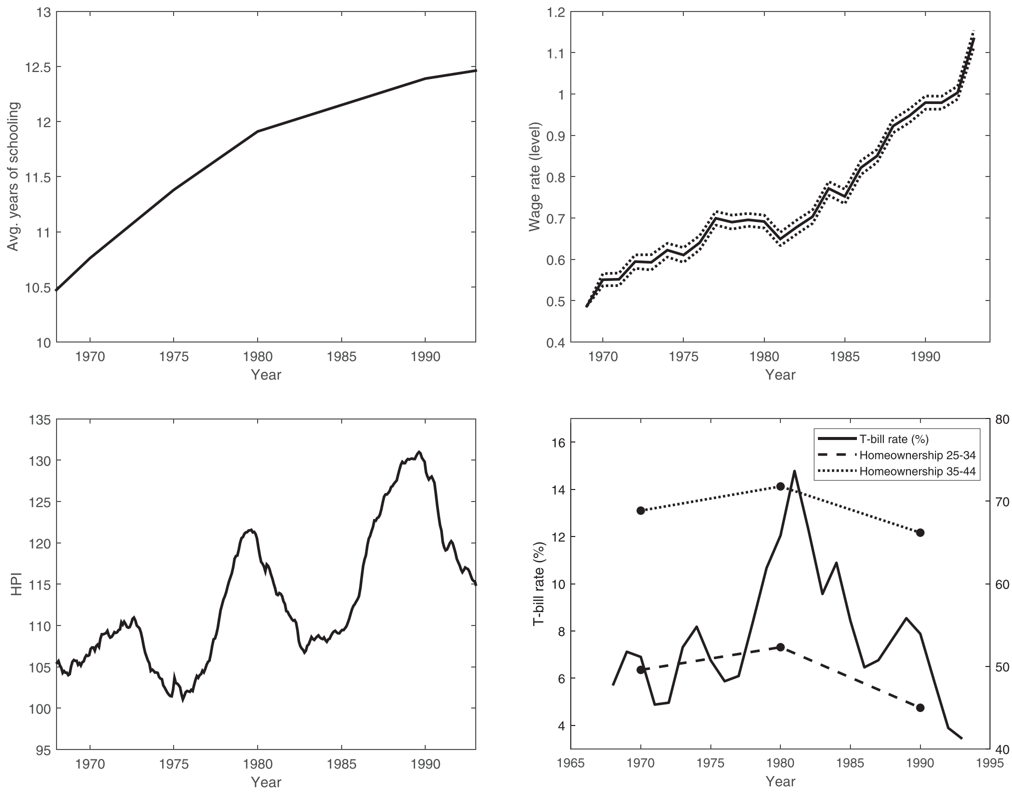
Our findings on the utility of giving birth to a child and the disutility of working and work hours, presented in columns (3)–(5) are also intuitive. The utility of giving birth declines with the number of children, age, and is larger for more educated households: these effects capture the higher fertility rates of more educated older households relative to less educated households, who tend to complete their families at an earlier age. The utility from giving birth is lower for single households, higher if a family already has children, and increasing in the age of their youngest child: since young children draw their mothers from the workforce, and human capital from working depreciates with absence, there are investment gains from bunching.

The utility of work declines with age, is higher for more educated and single households, and lower for non-White households. It is decreasing with children but higher for households with older children. Households are more likely to work if they worked in the previous periods. The utility of supply of working hours is increasing and concave. It is increasing with age, is lower for more educated and single households, and higher for non-white households. The utility from working hours is decreasing with the number of children in a family and with the age of youngest child.

5. COUNTERFACTUAL DECOMPOSITIONS

In our model, first home purchase, household composition and size, as well as female labor supply, are endogenous variables driven by pre-determined schooling attainment, and prices, namely wages, housing, and interest rates, that individual households are too small to affect through their own decision-making. Figure 7 shows that over this period educational attainment and female wages more or less monotonically increased, house prices peaked and slumped three times with an overall upward trend, while roughly speaking interest rates were quite volatile, rising in the first half of the period and falling in the second half. To disentangle the strength of these factors on the endogenous variables, the last part of our analysis conducts counterfactual simulations, by quantifying the response of homeownership, labor-force participation and child birth to greater education, wage increases, increasing house prices, and changes in interest rates.

Although any given factor might be dominant in predicting a particular counterfactual simulation (e.g., wages on labor supply), it is difficult to cleanly isolate the effect of each, as they are tightly interconnected both contemporaneously and through dynamic propagation. The simulations compare steady state allocations in an economy populated by households with the estimated utility function where wages, education attainment, interest rates, and house prices are comparable to those found at different points in the data. First, we construct two benchmark simulations for steady state economies approximating conditions in 1971 at the



NOTES: Educational attainment for female population 15 years old and over measured as the average years of total schooling, constructed based on data from Barro and Lee (2013). Wage rate is computed by the authors based on the PSID data sample. US National Home Price Index is based on Shiller (2015), whereas one–year Treasury constant maturity rate (GS1) is retrieved from FRED, Federal Reserve Bank of St. Louis. Decennial Censuses (Ruggles et al., 2019) are used for construction of 1970 – 1990 homeownership rates.

FIGURE 7

beginning of our data sample, and two decades later toward the end of the sample, in 1991. Then we simulate four further steady state economies, by changing just one factor at a time from its 1971 level to its level in 1991.

From a theoretical perspective, house prices, interest rates, and wages are endogenous within a general equilibrium framework, jointly determined by the preferences we estimate, as well as the supply of rental versus owned housing, the demand for labor, and the supply of credit. The fluctuations in house prices and interest rates are a major source of aggregate nonstationarities that our estimation procedure accounts for, but it would be a huge computational challenge to also solve for the general equilibrium of a nonstationary economy, further complicated by the fact that household decisions made toward the end of the sample are partly determined by aggregate effects that are only revealed after the sample ends. Although our approach is not definitive, it accounts for the endogeneity and dynamics of household composition, labor supply, and first home purchase, and therefore gives insight from the impact of the most important driving factors.

5.1. *Benchmark Economies.* According to Figure 7, the early parts of the data are characterized by the lower levels of education, a lower wage rate for a standardized skill unit which is captured by the time fixed effects, and relatively low levels of house price index and interest rates. Imposing these starting characteristics, we simulate benchmark patterns in homeowner-

TABLE 3
SIMULATION RESULTS

	21–25	26–30	31–35	36–40	41–45
Benchmark for 1971					
Homeownership rate	0.45	0.70	0.82	0.91	0.95
Home size	4.96	5.43	6.00	6.46	6.67
Labor force participation	0.88	0.77	0.67	0.62	0.74
Children	0.92	1.39	1.94	1.67	1.14
Benchmark for 1991					
Homeownership rate	0.45	0.70	0.83	0.91	0.95
Home size	4.76	4.80	5.23	5.64	5.84
Labor force participation	0.92	0.85	0.76	0.72	0.82
Children	0.75	1.16	1.65	1.49	1.03
Steady state change					
Δ Homeownership rate	−0.7%	−0.3%	0.3%	−0.5%	−0.9%
Δ Home size	−4.2%	−11.5%	−12.8%	−12.6%	−12.4%
Δ Labor force participation	4.1%	7.5%	9.5%	9.6%	7.7%
Δ Children	−18%	−16%	−15%	−11%	−10%

TABLE 4
COUNTERFACTUAL SIMULATION RESULTS

	Average age at		LFP (%)	
	First child	First homeownership	Before age 35	After age 35
Benchmark in 1971	22.9	28.0	78	67
Benchmark in 1991	23.5	27.8	85	76
A. Wage as in 1991	21.6	29.3	87	85
B. Education level as in 1991	23.7	27.5	79	67
C. House prices as in 1991	22.9	28.4	78	68
D. Interest rate as in 1991	23.3	27.0	72	55

ship, labor-force participation, and children using the estimated model parameters. Appendix A.1 explains how each stationary economy was simulated. Briefly, using the PSID sample, we first estimated processes for the house size, marital status, and wages as a function of the state variables. Then we solved the dynamic programming model recursively for different household types and cohorts at the steady states.

The top panel in Table 3 summarizes homeownership rates, average home size, labor-force participation, and average number of children for the benchmark 1971 stationary economy where the distribution of household types, wages, house prices, and interest rates are set to their 1971 values. Further, Table 4 reports average age at first child, first homeownership and labor-force participation rate for householders before and after age 35. Table 4 shows, in the 1971 stationary model economy, the average age at first birth is 22.9 years, 78% of younger women (ages 25–34) work while the labor-force participation rate for older women (between 35 and 45) is 67% , and the average age at becoming a homeowner is 28 years. These statistics are remarkably close to the data patterns for the PSID documented in Figure 1, and in the economy at large. According the National Vital Statistical System, the average age of mother at first birth in the United States was about 22 in the 1970s (Mathews and Hamilton, 2002). Although nationally representative records on the average age at first homeownership are scarce, Figure 3 shows the average age at first homeownership in the 1970s is around 27.

By 1991, the wage rate had almost doubled, average schooling per female increased by about 1.5 years, house prices grew by about 15% and interest rates were 1 percentage point higher than in 1971. The steady state for 1991 is calculated in a similar way to the 1971 economy: we hold the distribution of household types unchanged from 1971, adjust the prices to their 1991 values, and then resolve the optimization model. As Table 3 shows, the effect on

TABLE 5
COUNTERFACTUAL SIMULATION RESULTS

	21–25	26–30	31–35	36–40	41–45	21–25	26–30	31–35	36–40	41–45
	A. Wage as in 1991					B. Education level as in 1991				
Homeownership rate										
Experiment	0.42	0.63	0.76	0.88	0.94	0.46	0.74	0.86	0.93	0.96
Difference	−3.6%	−7.6%	−6.3%	−3.3%	−1.3%	0.6%	3.4%	3.5%	1.5%	0.9%
Home size										
Experiment	4.94	5.35	5.98	6.6	6.89	4.88	5.30	5.88	6.24	6.42
Difference	−0.4%	−1.5%	−0.3%	1.9%	3.4%	−1.7%	−2.4%	−1.9%	−3.3%	−3.7%
Labor force participation										
Experiment	0.92	0.87	0.82	0.81	0.90	0.89	0.79	0.68	0.62	0.73
Difference	4.3%	9.7%	15.4%	18.9%	15.6%	1.3%	1.8%	1.6%	−0.3%	−1.0%
Children										
Experiment	0.83	1.09	1.35	0.97	0.58	0.79	1.28	1.87	1.74	1.23
Difference	−10%	−21%	−30%	−42%	−50%	−14%	−8%	−3%	4%	8%
	C. House prices as in 1991					D. Interest rate as in 1991				
Homeownership rate										
Experiment	0.44	0.68	0.79	0.89	0.93	0.48	0.76	0.87	0.94	0.97
Difference	−0.9%	−2.6%	−3.2%	−2.5%	−2.2%	3.1%	6.0%	4.9%	2.8%	1.4%
Home size										
Experiment	4.86	5.06	5.51	6.00	6.23	4.96	5.37	5.87	6.22	6.36
Difference	−2.0%	−6.8%	−8.2%	−7.1%	−6.6%	0.0%	−1.0%	−2.2%	−3.7%	−4.6%
Labor force participation										
Experiment	0.88	0.78	0.68	0.64	0.76	0.87	0.72	0.57	0.49	0.63
Difference	0.0%	0.4%	1.0%	1.4%	1.2%	−1.4%	−5.2%	−10.2%	−13.6%	−11.7%
Children										
Experiment	0.91	1.37	1.90	1.62	1.10	0.99	1.63	2.37	2.18	1.54
Difference	0%	−1%	−2%	−3%	−4%	9%	17%	23%	31%	35%

homeownership is slightly ambiguous; it falls for all cohorts except for the 31–35 cohort. Overall the homeownership rate declines by 0.4% , but the average age at becoming a homeowner in the benchmark of 1991 also falls slightly from 28.0 to 27.8 (see Table 4). Table 4 further shows, with regards to fertility and labor supply, the average age at first child increased to 23.5, labor-force participation increased by 7 percentage points up to 85% for younger women (ages 25–34), and by 9 percentage points up to 76% for older women (ages 35–44).

5.2. *Wages.* The first policy experiment constitutes an overall and permanent increase in base wages from its level in 1971 to the level reached by 1991, almost double the 1971 level (as Figure 7 shows). Table 4 shows higher wages increase the opportunity cost of leisure and child care, increasing labor-force participation by 9% (18) for women less (more) than 35 (and less than 45) years old, and resulting in less children per household, and increased childlessness. Panel A of Table 5 shows that the differences are most stark at about age 35, where the gap between labor force participation rates is about 19% and the reduction in the average number of children per family is about 0.7. The longer a woman postpones giving birth, the higher the wages from accumulated work experience, and consequently the more attractive work and the weaker the incentives to give birth. The reduction in fertility later in a life cycle resulted in the average age at first birth shifting to earlier, now being 21.6 (see Table 4).

The effect of higher base wages on housing demand operates through multiple channels. All else equal, higher labor-market compensation and greater wealth increases spending on housing (and other goods), inducing homeownership at younger ages. However, the substitution effect away from domestic activities, including leisure and child rearing, reduces the demand for homeownership, a complementary good. The second effect, most evident in Table 5 from the decline in the number of children for all cohorts, dominates the first, leading to less homeownership. Panel A of Table 5 reports homeownership falls for every cohort, the average age at first home purchase rising by 1.3 years to 29.3 (see Table 4). The effect on home size is mixed: the solution to the estimated model shows that higher wages induce women to substitute smaller families and larger homes purchased later in life for larger families and smaller homes purchased earlier in life.

5.3. *Education.* The next policy experiment compares the benchmark 1971 steady state outcomes with those of a steady state in which education is increased by 1.5 years, roughly the amount Figure 7 shows average schooling per female increased between 1970 and 1990. Table 2 shows more educated females exhibit stronger preferences than the less educated toward home purchase, placing a lower premium on home size. Because they command higher wage rates (reported in Table A1 of Appendix), the opportunity cost of bearing offspring is higher, and lower fertility reduces the demand for homeownership and house size.

Solving the model with higher educational attainment, Panel B of Table 5 shows that the homeownership rate rises for every cohort. Furthermore Table 4 shows the average age at the time of purchasing the first home declining by approximately six months. The trade-off between age at purchase and size of home, evident in the cross section, is reinforced here: Table 5 shows the size of an average first home shrinks in this experiment. We conclude that if anything, increased educational attainment dampened the trend away from home ownership over this period.

Although not the main focus of this study, the effects on life cycle labor supply and fertility are also noteworthy. Overall there are fewer children, but because average age at first birth increases by almost a year (Table 4), the number of children in older households, that is for women over 35, rises, as shown in Panel B of Table 5. Our findings suggest delaying fertility is matched by younger women increasing their labor supply, and women over 40 reducing it.

5.4. *House Prices.* We also investigate how a 15% increase in house prices, the net increase over the two decades starting 1971, would affect steady state allocations. Intuitively, the wealth effect reduces the demand for all normal goods, while the substitution effect encourages households to reallocate their consumption bundle away from homeownership to other goods. Panel C of Table 5 shows the intuition for a static framework extends to this dynamic context, with the wealth effect dominating the substitution effect for nonhousing goods, not surprising given the share of expenditure on accommodation within the total household budget. Both the home ownership rate and the house size fall for every cohort (Table 5), while the average age at first purchase rises by 0.4 years (Table 4), implying even those who buy spend less of their summed discounted lifetime time in their own home. Fertility falls for all but the youngest cohort, where there is no change, yet labor-force participation increases for all cohorts except the youngest, essentially reducing nonwork time as well.

These results also highlight a major finding of our study. Comparing Panels A and C in Table 5, with the exception of the oldest cohort, the effect of increased female wages is markedly greater than the effect of rising house prices on the homeownership rate, and from Table 4, on the timing of first home purchase as well. Raising house prices and raising female wages have the same qualitative effects on home ownership rates and age at first purchase, but the quantitative impact of higher wages is greater: the key to understanding this result is that wages almost doubled but house prices only increased by about 15%. Nevertheless rising house prices do have a more pronounced negative effect on one dimension: when prices rise the size of the first house purchase falls across all cohorts by up to 8%, but when wages increase, the effect is ambiguous for the reasons mentioned above.

5.5. *Interest Rate.* The final counterfactual exercise we conducted determines how sensitive the endogenous choices are to interest-rate changes: following the same protocol, the benchmark model is simulated with the conditions of 1971, when interest rate was 4.8%, and then with the 1991 rate, 5.8%. When the interest rate rises, households, who are saving for the future, experience both a positive wealth effect and a substitution toward market goods consumed in the future. In our model, households have completed their education, so they are reducing their debt and saving for retirement. The combination of substitution and wealth effects are perhaps most apparent in labor-force participation and fertility. Panel D of Table 5 shows the number of births increase, especially later in life; similarly, the women are less likely to work, spending more time with children and on leisure, especially as they get older. Homeownership increases for all cohorts, while the size of first homes declines.

Unlike wages, educational attainment, and house prices that generally show a steady growth over the period of 1970–1990, interest rates had a decade of dramatic growth and then a decade of decline back to the levels of the 1970s. For this reason, we are reluctant to take a stand on how those fluctuations might have affected first home-purchase decisions over this period. We note, though, that this feature of the solution to our estimated model, homeownership rates, and interest rate moving together but house size moving in the opposite direction, corresponds to the stylized facts of more recent times out of sample: as current interest rates hit historical lows, homeownership rates for the working cohorts of population are also in decline (Goodman et al., 2015), and home sizes for owners grow larger.[19]

6. CONCLUSION

The delay in first home purchase fully accounts for the decline in homeownership in the United States over two decades spanning the 1970s through the 1990s. During that time, the average age of the first time home buyer and the average age of the mother at first birth increased by two years, and female labor-force participation grew substantially. There is widespread agreement that these trends are interrelated but previous empirical research has not sought to reconcile these three life-cycle choices, fertility, female labor supply, and home buying, to explain why Americans are making their first home purchase at an older age than previous generations did. Our lifecycle optimization model seeks to explain these trends within a competitive paradigm based on household responses to market fundamentals and changing demographics, specifically higher wages, greater education, higher house prices, and fluctuating interest rates. Our dynamic model provides an intuitive transmission mechanism linking the female labor market, fertility, and the housing market, and yields plausible estimates from the PSID data. Our counterfactuals provide a dynamic decomposition to explain what happened during the sample period.

One might speculate that higher levels of education would lead to lower homeownership, because college graduates start their working careers years after those with high school education, delay childbirth, and have smaller families. We find no support for this conjecture. Highly educated females value homeownership more than less educated women. Furthermore, controlling for the upward shift in female wages, a stronger schooling background increases labor-force participation; this also brings forward home purchase because working females also exhibit a preference for homeownership. Taken together these two factors more than offset the combined effect on homeownership of later entry into the workforce and the prospect of smaller families.

Similarly, we find no evidence that financial markets played an important role. Our estimated dynamic optimization model rationalizes why lower interest rates lead to reduced homeownership: savers lose wealth, leading them to decrease their consumption at every point in their life, and postpone their first home purchase. On this score, our model correctly predicts, out of sample, that the trend toward postponing first home ownership would be exacerbated after the sample period ended because of lower interest rates. In principle, a more complicated model than ours might also incorporate borrowing constraints and other housing market imperfections. We are skeptical the additional complexity can be justified. What is the compelling institutional feature that has increasingly curbed the ability of households to

[19] Reducing the interest rate by 1 percentage point in the benchmark model yields results similar to those reported in Panel D of Table 5, but with the opposite sign, results that are available from the authors on request.

borrow for home purchase? In the years following our sample period, the transition rate to homeownership further slowed, although interest rates continued to fall and by many accounts borrowing for homeownership became easier.

This essentially leaves two factors to explain why the American dream was delayed. First, housing prices increased over this period and, not surprisingly, reduced homeownership. Second, since first home purchase is coordinated with fertility outcomes, the solution to our dynamic model with the estimated parameters shows that the indirect effect of higher wages was to delay homeownership, because higher wages increased the opportunity cost of childcare, leading to postponing first birth, raising smaller families, and thus lowering and postponing the demand for homeownership. In short, we find there is strong complementarity between homeownership and raising children, who became more expensive relative to alternative uses of time and money. Empirically the magnitude of this transmission mechanism proved comparable to, if not more important than, the effect of increased house prices, in retarding first home purchases.

APPENDIX

PROOF OF THEOREM 1. Define the date zero price of a bond that pays a consumption unit each period from date t onward as

$$\widetilde{B}_t \equiv \sum_{s=t}^{\infty}\left(\frac{1}{1+i^{(s)}}\right) = \widetilde{B}_{t+1} + \frac{1}{1+i^{(t)}},$$

where $i^{(t)} \equiv \prod_{s=0}^{t}(1+i_s) - 1$ is the compound interest rate over the first t periods. Let

$$\widetilde{Q}_t \equiv \sum_{s=t}^{\infty}\frac{\ln\left[\beta^s\left(1+i^{(s)}\right)\right]}{\left(1+i^{(s)}\right)} = \widetilde{Q}_{t+1} + \frac{\ln\left[\beta^t\left(1+i^{(t)}\right)\right]}{\left(1+i^{(t)}\right)}.$$

For convenience, we also define

$$\alpha_{jt} \equiv \exp\left(-u^h_{jt} - u^b_{jt} - u^l_{jt}\right) \tag{A1}$$

and note that $\alpha_{0t} = 1$ for all t.

After making all its discrete choices before period T, the household chooses its remaining lifetime consumption profile $\{c_t\}_{t=T+1}^{\infty}$ to maximize

$$\alpha_{jt} \equiv \exp\left(-u^h_{jt} - u^b_{jt} - u^l_{jt}\right) \tag{A2}$$

subject to a sequence of budget constraints:

$$(1+i_t)^{-1}W_{t+1} \leq W_t - c_t.$$

The indirect utility function for this Lagrangian problem is

$$V_{T+1}(W_{T+1}) = -\widetilde{B}_{T+1}\exp\left(\frac{\widetilde{Q}_{T+1}}{\widetilde{B}_{T+1}} - \frac{\rho W_{T+1}}{\left(1+i^{(T+1)}\right)\widetilde{B}_{T+1}}\right).$$

Suppose a household with state variables z_T makes choice j at age T for one period and then retires. Let y_{jT} denote net income for the last period in which the household makes discrete choices; it includes wage income for the last period and the discounted sum of all future rents:

$$y_{jT} = l^*_{jT} w_T - \left[1 + i^{(T)}\right] \sum_{t=T+1}^{\infty} \frac{R_t(s_t^{(j)})}{\left(1 + i^{(t)}\right)}.$$

Note that future rents payable depend on the final housing choice. After selecting choice j, and receiving income y_{jT}, she chooses consumption and next period's endowment (c_T, W_{T+1}) optimally to maximize:

$$\text{(A3)} \qquad -\beta^T \alpha_{jT} \exp(-\varepsilon_{jT}) \exp(-\rho c_T) - \widetilde{B}_{T+1} \exp\left(\frac{\widetilde{Q}_{T+1}}{\widetilde{B}_{T+1}} - \frac{\rho W_{T+1}}{\left(1 + i^{(T+1)}\right)\widetilde{B}_{T+1}}\right)$$

subject of her budget constraint:

$$\frac{W_T}{1 + i^{(T)}} + \frac{y_{jT}}{1 + i^{(T)}} = \frac{W_{T+1}}{1 + i^{(T+1)}} + \frac{c_T}{1 + i^{(T)}}.$$

Denoting by $V_{jT}(W_T)$ the discounted sum of expected utility for a householder of age T onward with wealth W_T who chooses j and makes optimal consumption choices thereafter, we can apply Lagrangian methods to show

$$\begin{aligned} V_{jT}(W_T) &= -\widetilde{B}_T \alpha_{jT}^{1/\widetilde{B}_T(1+i^{(T)})} \exp\left\{\frac{\widetilde{Q}_T}{\widetilde{B}_T} - \frac{\varepsilon_{jT}}{\widetilde{B}_T\left[1 + i^{(T)}\right]} - \frac{\rho(W_T + y_{jT})}{\widetilde{B}_T\left[1 + i^{(T)}\right]}\right\} \\ \text{(A4)} \qquad &= \frac{-B_T}{\left(1 + i^{(T)}\right)} \alpha_{jT}^{\frac{1}{B_T}} \exp\left[\frac{Q_T}{B_T} - \frac{\varepsilon_{jT}}{B_T} - \frac{\rho(W_T + y_{jT})}{B_T}\right], \end{aligned}$$

where the second line exploits the relationships $B_T = \widetilde{B}_T(1 + i^{(T)})$ and $Q_T = \widetilde{Q}_T(1 + i^{(T)})$.

Appealing to the definition of $A_t(z_t)$ given in the text, we can now prove by an induction argument that, conditional on choosing j, the value function at t discounted back to date zero is

$$\text{(A5)} \qquad V_{jt}(W_t, z_t, \varepsilon_{jt}) = \frac{-B_t}{\left(1 + i^{(t)}\right)} \alpha_{jt}^{\frac{1}{B_t}} \exp\left[\frac{Q_t}{B_t} - \frac{\varepsilon_{jt}}{B_t} - \frac{\rho(W_t + y_{jt})}{B_t}\right] A_{t+1}\left(z_{t+1}^{(j)}\right)^{1-\frac{1}{B_t}}.$$

At time t, the household chooses j to maximize $V_{jt}(W_t, z_t, \varepsilon_{jt})$. Since maximizing an objective function is equivalent to minimizing the logarithm of its negative, the maximum can be found by minimizing

$$\ln \frac{B_t}{\left(1 + i^{(t)}\right)} + \frac{\ln \alpha_{jt}}{B_t} + \frac{Q_t}{B_t} - \rho \frac{W_t + y_{jt}}{B_t} - \frac{\varepsilon_{jt}}{B_t} + \left(1 - \frac{1}{B_t}\right) \ln A_{t+1}\left(z_{t+1}^{(j)}\right).$$

The proof is completed by multiplying the expression above by B_t, subtracting terms that do not depend on j, appealing to $(A1)$ and rearranging. □

PROOF OF THEOREM 2. It is helpful to define the date zero price of a bond that pays a consumption unit each from date t onward as

$$\text{(A6)} \qquad \widetilde{B}_t \equiv \sum_{s=t}^{\infty} \left(\frac{1}{1 + i^{(s)}}\right) = \widetilde{B}_{t+1} + \frac{1}{1 + i^{(t)}},$$

where $i^{(t)} \equiv \prod_{s=0}^{t}(1+i_s)-1$ is the compound interest rate over the first t periods, and that

$$\text{(A7)} \qquad \frac{\widetilde{B}_{t+1}}{\widetilde{B}_t} = 1 - \frac{1}{\widetilde{B}_t\left[1+i^{(t)}\right]} = 1 - \frac{1}{B_t}.$$

Note that if ε_{jt} is independently and identically distributed as a Type I extreme value with location and scale parameters (0,1), then from Theorem 1:

$$\ln\left[\frac{p_{0t}(z_t)}{p_{jt}(z_t)}\right] = \rho y_{0t} - (B_t-1)\ln A_{t+1}\left(z_{t+1}^{(0)}\right) - \left[\rho y_{jt} - \ln(\alpha_{jt}) - (B_t-1)\ln A_{t+1}\left(z_{t+1}^{(j)}\right)\right]$$

$$= \rho(y_{0t}-y_{jt}) + \ln(\alpha_{jt}) + (B_t-1)\ln\left[\frac{A_{t+1}\left(z_{t+1}^{(j)}\right)}{A_{t+1}\left(z_{t+1}^{(0)}\right)}\right].$$

Exponentiating the result and raising to the power $1/B_t$, we obtain:

$$\text{(A8)} \qquad \left[\frac{p_{0t}(z_t)}{p_{jt}(z_t)}\right]^{\frac{1}{B_t}} = \alpha_{jt}^{\frac{1}{B_t}}\exp\left[-\frac{\rho(y_{jt}-y_{0t})}{B_t}\right]\left[\frac{A_{t+1}\left(z_{t+1}^{(j)}\right)}{A_{t+1}\left(z_{t+1}^{(0)}\right)}\right]^{1-\frac{1}{B_t}}.$$

Rearranging Equation ($A8$), we obtain:

$$\alpha_{jt}^{\frac{1}{B_t}}\exp\left(-\frac{\rho y_{jt}}{B_t}\right)A_{t+1}\left(z_{t+1}^{(j)}\right)^{1-\frac{1}{B_t}} = \left[\frac{p_{0t}(z_t)}{p_{jt}(z_t)}\right]^{\frac{1}{B_t}}A_{t+1}\left(z_{t+1}^{(0)}\right)^{1-\frac{1}{B_t}}\exp\left(-\frac{\rho y_{0t}}{B_t}\right).$$

From the definition of $A_t(z_t)$:

$$\text{(A9)} \qquad A_t(z_t) = \sum_{j=0}^{J} p_{jt}(z_t)\alpha_{jt}^{\frac{1}{B_t}} E\left[\exp\left(-\frac{\varepsilon_{jt}^*}{B_t}\right)\right]\exp\left(-\frac{\rho y_{jt}}{B_t}\right)A_{t+1}\left(z_{t+1}^{(j)}\right)^{1-\frac{1}{B_t}}.$$

Substituting the left-hand side into the recursion for A_t given in Equation ($A9$) yields:

$$A_t(z_t) = \sum_{j=0}^{J} p_{jt}(z_t)E\left[\exp\left(-\frac{\varepsilon_{jt}^*}{B_t}\right)\right]\exp\left(-\frac{\rho y_{0t}}{B_t}\right)\left[\frac{p_{0t}(z_t)}{p_{jt}(z_t)}\right]^{\frac{1}{B_t}}A_{t+1}\left(z_{t+1}^{(0)}\right)^{1-\frac{1}{B_t}}.$$

But from the online appendix of Gayle et al. (2015):

$$E\left[\exp\left(-\frac{\varepsilon_{jt}^*}{B_t}\right)\right] = p_{jt}(z_t)^{\frac{1}{B_t}}\Gamma\left(\frac{B_t+1}{B_t}\right),$$

where $\Gamma(\cdot)$ is the complete gamma function. Substituting for the left-hand side in the expression derived for $A_t(z_t)$ above it thus yields:

$$A_t(z_t) = p_{0t}(z_t)^{\frac{1}{B_t}}\Gamma\left(\frac{B_t+1}{B_t}\right)\sum_{j=0}^{J} p_{jt}(z_t)\exp\left(-\frac{\rho y_{0t}}{B_t}\right)A_{t+1}\left(z_{t+1}^{(0)}\right)^{1-\frac{1}{B_t}}$$

$$= \Gamma\left(\frac{B_t+1}{B_t}\right)p_{0t}(z_t)^{\frac{1}{B_t}}\exp\left(-\frac{\rho y_{0t}}{B_t}\right)A_{t+1}\left(z_{t+1}^{(0)}\right)^{1-\frac{1}{B_t}},$$

or:

$$\ln A_t(z_t) = \ln \Gamma\left(\frac{B_t + 1}{B_t}\right) + \frac{1}{B_t} \ln p_{0t}(z_t) - \frac{\rho y_{0t}}{B_t} + \left(1 - \frac{1}{B_t}\right) \ln A_{t+1}\left(z_{t+1}^{(0)}\right).$$

Using this expression to difference $\log A_{t+1}(z_{t+1}^{(j)})$ with $\log A_{t+1}(z_{t+1}^{(0)})$ gives

$$\begin{aligned}\ln\left[\frac{A_{t+1}(z_{t+1}^{(j)})}{A_{t+1}(z_{t+1}^{(0)})}\right] &= \frac{1}{B_{t+1}}\left\{\ln\left[\frac{p_{0,t+1}(z_{t+1}^{(j)})}{p_{0,t+1}(z_{t+1}^{(0)})}\right] - \rho(y_{t+1}^{(j,t)} - y_{t+1}^{(0,t)})\right\} + \left(1 - \frac{1}{B_{t+1}}\right)\ln\left[\frac{A_{t+2}(z_{t+2}^{(j)})}{A_{t+2}(z_{t+2}^{(0)})}\right] \\ &= \frac{1}{B_{t+1}}\left\{\ln\left[\frac{p_{0,t+1}(z_{t+1}^{(j)})}{p_{0,t+1}(z_{t+1}^{(0)})}\right] - \rho(y_{t+1}^{(j,t)} - y_{t+1}^{(0,t)})\right\} + \frac{\widetilde{B}_{t+2}}{\widetilde{B}_{t+1}}\ln\left[\frac{A_{t+2}(z_{t+2}^{(j)})}{A_{t+2}(z_{t+2}^{(0)})}\right],\end{aligned}$$

where the second line follows from $(A7)$. Telescoping to period T and appealing to the fact that $A_{T+1}(z_{T+1}^{(j)}) = 1$ yields

$$\begin{aligned}\ln\left[\frac{A_{t+1}\left(z_{t+1}^{(j)}\right)}{A_{t+1}\left(z_{t+1}^{(0)}\right)}\right] &= \sum_{s=t+1}^{T}\frac{1}{B_s}\prod_{r=t+1}^{s-1}\frac{\widetilde{B}_{r+1}}{\widetilde{B}_r}\left\{\ln\left[\frac{p_{0s}\left(z_s^{(j)}\right)}{p_{0s}\left(z_s^{(0)}\right)}\right] - \rho\left(y_s^{(j,t)} - y_s^{(0,t)}\right)\right\} \\ &= \frac{1}{\widetilde{B}_{t+1}}\sum_{s=t+1}^{T}\frac{\widetilde{B}_s}{B_s}\left\{\ln\left[\frac{p_{0s}\left(z_s^{(j)}\right)}{p_{0s}\left(z_s^{(0)}\right)}\right] - \rho\left(y_s^{(j,t)} - y_s^{(0,t)}\right)\right\} \\ &= \frac{1}{\widetilde{B}_{t+1}}\sum_{s=t+1}^{T}\frac{1}{1+i^{(s)}}\left\{\ln\left[\frac{p_{0s}\left(z_s^{(j)}\right)}{p_{0s}\left(z_s^{(0)}\right)}\right] - \rho\left(y_s^{(j,t)} - y_s^{(0,t)}\right)\right\}. \qquad \text{(A10)}\end{aligned}$$

Taking the logarithm of $(A8)$, multiplying by $-B_t$ and substituting the expression for $A_{t+1}(z_{t+1}^{(j)})/A_{t+1}(z_{t+1}^{(0)})$, obtained in $(A10)$, yields

$$\begin{aligned}\ln\left[\frac{p_{jt}(z_t)}{p_{0t}(z_t)}\right] &= \rho(y_{jt} - y_{0t}) - \ln(\alpha_{jt}) + (1 - B_t)\ln\left[\frac{A_{t+1}\left(z_{t+1}^{(j)}\right)}{A_{t+1}\left(z_{t+1}^{(0)}\right)}\right] \\ &= \rho(y_{jt} - y_{0t}) - \ln(\alpha_{jt}) + \frac{(1 - B_t)}{\widetilde{B}_{t+1}}\sum_{s=t+1}^{T}\frac{1}{1+i^{(s)}}\left\{\ln\left[\frac{p_{0s}(z_s^{(j)})}{p_{0s}(z_s^{(0)})}\right] - \rho(y_s^{(j,t)} - y_s^{(0,t)})\right\}.\end{aligned}$$

But from $(A7)$:

$$\widetilde{B}_{t+1} = \widetilde{B}_t - \frac{\widetilde{B}_t}{B_t} = \frac{\widetilde{B}_t(B_t - 1)}{B_t}$$

implying

$$\frac{(1 - B_t)}{\widetilde{B}_{t+1}} = (1 - B_t)\frac{B_t}{\widetilde{B}_t(B_t - 1)} = -\frac{B_t}{\widetilde{B}_t} = -\left[1 + i^{(t)}\right].$$

Therefore

$$\ln\left[\frac{p_{jt}(z_t)}{p_{0t}(z_t)}\right] = \rho(y_{jt} - y_{0t}) - \ln(\alpha_{jt}) - \sum_{s=t+1}^{T} \frac{1+i^{(t)}}{1+i^{(s)}} \left\{ \ln\left[\frac{p_{0s}\left(z_s^{(j)}\right)}{p_{0s}\left(z_s^{(0)}\right)}\right] - \rho\left(y_s^{(j,t)} - y_s^{(0,t)}\right) \right\}$$

$$= \rho(y_{jt} - y_{0t}) - \ln(\alpha_{jt}) + \sum_{s=t+1}^{T} \prod_{r=t+1}^{s} \frac{1}{1+i_r} \left\{ \rho(y_s^{(j,t)} - y_s^{(0,t)}) + \ln\left[\frac{p_{0s}(z_s^{(0)})}{p_{0s}(z_s^{(j)})}\right] \right\}.$$

Appealing to $(A1)$ and definition of $y_s^{(j,t)}$, the theorem is proved. □

A.1 *Simulation Details.* First we describe the elements of the state vector. Let t denote the age of a female. Household fixed characteristics include education and race. Education is divided into four categories, which correspond to "less than high school," "high school," "some college," and "college degree." Race includes two categories: White and non-White. Marital status is modeled as stochastic exogenous shock, conditional on demographic characteristics. Aggregate factors include the level of house prices and interest rates. Such elements of state vector, as homeowner indicator, labor-force participation indicator, children and their ages arise through decision-making process within the model.

We solve the model by computing conditional choice probabilities for each combination of the state vector. The participation ratios $p_{j,t}$, $j = 0, \ldots J$ are computed by solving the model backward, starting from the termination condition. Termination condition is set to occur at age 65 after which a household retires and terminates. A household may enjoy a period 64 payoff, however, no future decisions are possible, which results in the ratio of conditional choice probabilities being set to one: $p_{0,65}(z_{65}^{(0)})/p_{0,65}(z_{65}^{(j)}) = 1$, so that we have

$$\text{(A11)} \qquad \ln \frac{p_{j,64}(z_{64})}{p_{0,64}(z_{64})} = \rho(y_{j,64} - y_{0,64}) + u_{j,64}^h + u_{j,64}^b + u_{j,64}^l.$$

Equation (A11) allows us to evaluate $p_{j,64}$, $j = 0, \ldots J$, which are then being fed into an equation for age 63:

$$\ln \frac{p_{j,63}(z_{63})}{p_{0,63}(z_{63})} = \rho(y_{j,63} - y_{0,63}) + u_{j,63}^h + u_{j,63}^b + u_{j,63}^l + \left(\frac{1}{1+i}\right) \ln\left[\frac{p_{j,64}(z_{64})}{p_{0,64}(z_{64})}\right]$$
$$-\left(\frac{1}{1+i}\right)\rho\left[\widetilde{R}_t(s_{63}) - R_t(s_{63})\right].$$

The procedure is continued recursively until the age 22:

$$\ln\left[\frac{p_{j,22}(z_{22})}{p_{0,22}(z_{22})}\right] = \rho(y_{j,22} - y_{0,22}) + u_{j,22}^h + u_{j,22}^b + u_{j,22}^l$$
$$+ \sum_{\tau=23}^{22+17} \left(\frac{1}{1+i}\right)^{\tau-22} \ln\left[\frac{p_{0\tau}(z_\tau^{(0)})}{p_{0\tau}(z_\tau^{(j)})}\right]$$
$$\text{(A12)} \qquad - \sum_{\tau=23}^{22+17} \left(\frac{1}{1+i}\right)^{\tau-22} \rho\left[\widetilde{R}_t(s_{22}) - R_t(s_{22})\right].$$

From Equation (A12), one can notice that the planning horizon cannot exceed 17 years. If a female gives birth to a child, she expects to care for this child until the child turns 18, when, according to our assumption, the child leaves the parent family and forms her own household.

Once the youngest child reaches age of 18 and leaves a household, no more children are born to the household as the probability of such cases is very small. The planning horizons for three decisions, which we consider in this article, do not have to coincide. For decision to work, we can rely on finite dependence (shown in Altug and Miller (1998), and further formalized in Arcidiacono and Miller (2011)), which occurs in two periods in our model specification.

Having the conditional choice probabilities computed for each combination of the state vector, we have simulated outcomes ready. To account for potential pre-existing conditions, the initial distribution by the education, race, marital status, homeownership status, labor-force participation indicator, children, and the age of the youngest child, as well as home size and hours of work supplied by the household at ages 20–22 are drawn from the joint empirical distribution in the PSID data.

A.2 *Estimation of Wage Equation.* The summary statistics in Table 1 show homeowners and renters differ in their labor force participation, average hours worked, and labor income. Our first set of estimates shed light on why those differences emerge. The estimated wage equation is for the most part standard, including basic demographic characteristics, such as age, education, and marital status, along with lagged labor force participation and working hours (see Miller and Sanders, 1997; Altug and Miller, 1998; Gayle and Miller, 2006, for a similar wage equation specification). In view of the last two rows of Table 1, which imply homeowners earn a higher wage rate than tenants, we control for home ownership to investigate the direct effects of ownership status on the wage rate.

Column (2) of Table A1 reports the estimated coefficients on demographic and labor input variables interacted with the homeownership dummy. All the coefficients on variables related to labor supply history interacted with the homeownership dummy are insignificant. Therefore, we do not reject the maintained null hypothesis that home ownership does not directly affect the wage rate. If the model is to explain differences in the wage rate between homeowners and renters, they must arise from differences either in their labor supply behavior that feed into the determination of the wage rate, or in the background variables of age, education, and marital status.

The results from Table A1 provide mechanisms that might reconcile these differences. As education interacted with age has a positive effect on wages, part of the positive correlation between home ownership and the wage rate is due to the fact that homeowners are more educated than tenants (shown in the second row in Table 1). Similarly, we find marriage magnifies the effect of past hours worked on the current wage rate, a result that resonates with similar conclusions reached by Killewald and Gough (2013) and Eckstein et al. (2019), and

TABLE A1
WAGE EQUATION

$\ln(wage_{it}) = B_1 X_{it} + B_2(O_{it} X_{it}) + \mu_t + \eta_i + \epsilon_{it}$,
where O_{it} is a dummy for homeowner

X_t	B_1 (1)	B_2 (2)
ΔHours worked at $t-1$	0.113	0.007
	(0.006)	(0.005)
ΔWork at $t-1$	−0.049	0.014
	(0.009)	(0.011)
Δ(Age×Education)	0.639	0.048
	(0.119)	(0.059)
ΔAge^2	−0.241	−0.031
	(0.044)	(0.022)
ΔMarital*Hours worked at $t-1$	0.039	
	(0.007)	

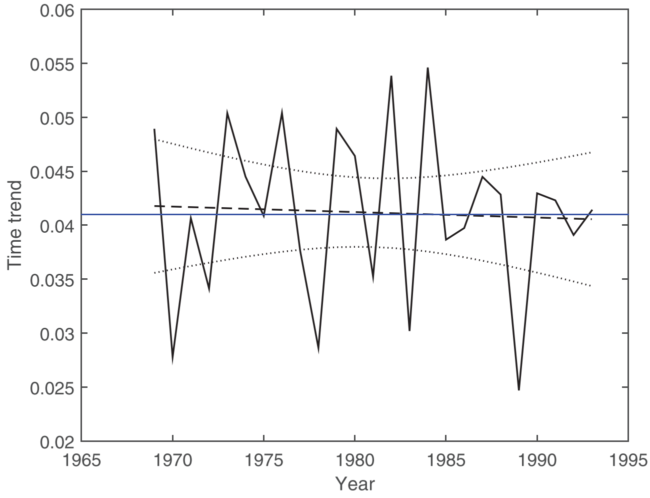


FIGURE A1

TRANSITION FROM HOMEOWNERSHIP TO RENTING

homeowners are more likely to be married (see the third row of Table 1). Apparently, these two factors dominate the negative effect on wages of homeowners working fewer hours than tenants.

A.3 *Additional Evidence from the Data.* Figure A1 shows that homeowners rarely revert to renting permanent accommodation and the rate of reverting to renting is fairly stable over the period between the 1970s and the 1990s.

Table A2
LOGIT REGRESSIONS FOR HOUSING TRANSITIONS ON A DUMMY FOR HIGH LIQUIDITY (TWO-MONTHS SAVINGS) AND DEMOGRAPHIC DETERMINANTS

	Rent to Own	Buy a new home	Own to Rent	Rent to Own	Buy a new home	Own to Rent
Female age	−0.0252	−0.0438*	−0.0982***	−0.00739	−0.0427***	−0.0800***
	(0.0173)	(0.0183)	(0.0266)	(0.00763)	(0.00842)	(0.0115)
Female education	−0.0102	0.0334	0.0426	0.00283	0.0294	0.0175
	(0.0363)	(0.0364)	(0.0564)	(0.0164)	(0.0165)	(0.0251)
Husbands age	0.00588	−0.00444	0.000340	−0.00806	−0.00776	−0.00684
	(0.0138)	(0.0149)	(0.0217)	(0.00645)	(0.00695)	(0.0101)
Husbands education	0.0700*	0.0390	0.0550	0.0304*	0.0494***	0.0247
	(0.0324)	(0.0307)	(0.0498)	(0.0137)	(0.0141)	(0.0222)
Female earnings ($'000)	0.0225	0.0102	−0.0196	0.0213***	−0.00936	−0.0263**
	(0.0127)	(0.0140)	(0.0238)	(0.00579)	(0.00634)	(0.00988)
Female earnings ($'000) $t-1$	0.00946	−0.00681	−0.0245	0.00564	0.00966	0.00956
	(0.0161)	(0.0168)	(0.0284)	(0.00729)	(0.00742)	(0.0114)
Husbands earnings ($'000)	0.0213***	−0.00399	−0.0222	0.0184***	0.00367	−0.0101
	(0.00617)	(0.00642)	(0.0130)	(0.00317)	(0.00234)	(0.00539)
Husbands earnings ($'000) $t-1$	0.00859	0.00568	−0.0120	0.0129***	−0.000540	−0.00524
	(0.00645)	(0.00683)	(0.0133)	(0.00341)	(0.00257)	(0.00557)
Single	0.0437	0.425	1.679	−0.840**	0.191	1.226*
	(0.663)	(0.766)	(1.090)	(0.300)	(0.360)	(0.493)
Non-White	−0.785**	−0.253	0.194	−0.577***	−0.343*	−0.197
	(0.248)	(0.277)	(0.348)	(0.107)	(0.137)	(0.203)
Single*Non-White	−0.0153	0.319	−0.116	−0.151	0.0840	−0.198
	(0.545)	(0.716)	(0.650)	(0.251)	(0.393)	(0.361)
Children at $t-1$	0.295*	0.0151	−0.0163	0.155*	−0.0995	−0.0440
	(0.141)	(0.151)	(0.181)	(0.0610)	(0.0584)	(0.0876)
Children sq. at $t-1$	−0.0703*	−0.0377	0.0379	−0.0348*	0.0104	0.0119
	(0.0355)	(0.0396)	(0.0351)	(0.0140)	(0.0129)	(0.0187)
Age of last child	−0.0149	0.0166	0.0172	−0.0168	−0.000543	−0.00205
	(0.0198)	(0.0159)	(0.0259)	(0.00919)	(0.00749)	(0.0119)
Employed at $t-1$	−0.144	−0.0538	−0.192	0.157	−0.127	−0.0206
	(0.188)	(0.178)	(0.269)	(0.0895)	(0.0865)	(0.130)
Work time at $t-1$	0.213	−1.296	1.291	−0.00114	0.189	−0.0738
	(1.050)	(1.149)	(1.584)	(0.482)	(0.505)	(0.734)
Two-month savings	−0.125	0.0649	−0.187			
	(0.133)	(0.118)	(0.190)			
Constant	−2.656***	−1.855**	−0.862	−2.563***	−1.922***	−0.775
	(0.582)	(0.579)	(0.902)	(0.304)	(0.314)	(0.478)
Observations	2883	4862	4862	13888	23917	23917

The variable "Two-month savings" is a dummy equal to one for whether household savings are equal to more than two months of household income.
Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

TABLE A3

LOGIT REGRESSIONS FOR HOUSING TRANSITIONS ON A DUMMY FOR HIGH LIQUIDITY (TWO-MONTHS SAVINGS) AND REDUCED DEMOGRAPHICS SET

	Rent to Own	Buy a new home	Own to Rent	Rent to Own	Buy a new home	Own to Rent
Female age	−0.0259	−0.0358*	−0.0939***	−0.00973	−0.0430***	−0.0809***
	(0.0162)	(0.0172)	(0.0249)	(0.00727)	(0.00808)	(0.0110)
Female education	−0.0106	0.0336	0.0294	0.00642	0.0300	0.0201
	(0.0351)	(0.0353)	(0.0553)	(0.0160)	(0.0161)	(0.0245)
Husbands age	0.00458	−0.00422	0.00160	−0.00810	−0.00732	−0.00690
	(0.0136)	(0.0147)	(0.0216)	(0.00635)	(0.00694)	(0.0100)
Husbands education	0.0723*	0.0411	0.0486	0.0321*	0.0494***	0.0225
	(0.0321)	(0.0305)	(0.0493)	(0.0136)	(0.0141)	(0.0221)
Female earnings ($'000)	0.0246**	−0.00839	−0.0302*	0.0268***	−0.00250	−0.0189***
	(0.00803)	(0.00741)	(0.0132)	(0.00361)	(0.00329)	(0.00556)
Husbands earnings ($'000)	0.0272***	0.000891	−0.0322***	0.0265***	0.00350*	−0.0140***
	(0.00497)	(0.00365)	(0.00783)	(0.00232)	(0.00144)	(0.00338)
Single	−0.0210	0.447	1.691	−0.917**	0.235	1.207*
	(0.652)	(0.752)	(1.082)	(0.296)	(0.355)	(0.490)
Non-White	−0.796***	−0.251	0.165	−0.612***	−0.333**	−0.260
	(0.221)	(0.254)	(0.296)	(0.0970)	(0.128)	(0.169)
Children at $t-1$	0.0342	−0.0764	0.159*	−0.000405	−0.0632*	−0.00350
	(0.0553)	(0.0543)	(0.0794)	(0.0253)	(0.0247)	(0.0372)
Two-month savings	−0.112	0.0655	−0.200			
	(0.132)	(0.118)	(0.190)			
Constant	−2.553***	−2.124***	−0.950	−2.357***	−1.992***	−0.795
	(0.545)	(0.545)	(0.860)	(0.290)	(0.298)	(0.456)
Observations	2883	4862	4862	13888	23917	23917

The variable "Two-month savings" is a dummy equal to 1 for whether household savings are equal to more than two months of household income.
Standard errors in parentheses. * $p < 0.05$, ** $p < 0.01$, and *** $p < 0.001$

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