

Skill-Biased Technological Change and Homeownership

Alexis Anagnostopoulos, Orhan Erem Atesagaoglu, Eva Carceles-Poveda

SUNY - Stony Brook

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Abstract

In the United States, the residential housing market went through important changes over the period of the 1970s to the mid-1990s. Although the aggregate homeownership rate was relatively constant during that period, the distribution of homeownership rates by age changed in remarkable ways. While younger households saw substantial declines in homeownership rates, the opposite happened for older households. In this paper, we argue that the skill-biased technological change (SBTC) that occurred during the 1970s has been an important factor behind the observed change in the distribution of homeownership rates by age. We build a life cycle model in which skills are accumulated on-the-job through experience: learning by doing. Early in life, households have lower levels of skills and therefore lower earnings. Accordingly, SBTC increases the returns to skill, widening the wage gap between young and old ages. As a consequence, it takes more time for young households to accumulate down payments and become homeowners, in line with consumption smoothing behaviour. On the other hand, older households that could not afford a house before may now have sufficient funds to become homeowners, given higher returns to skill. Our analysis confirms this conjecture, namely, the SBTC shifts the distribution of homeownership from the young to the old.

Keywords: Skill-Biased Technological Change, Homeownership.

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1. Introduction

In the United States, the residential housing market went through important changes over the period of the 1970s to the mid-1990s. Although the aggregate homeownership rate was relatively constant during that period, the distribution of homeownership rates by age changed in remarkable ways.¹ While younger households saw substantial declines in homeownership rates, the opposite happened for older households (Figure 1, Figure 2).

In this paper, we argue that the skill-biased technological change (SBTC) that occurred during the 1970s has been an important factor behind the observed change in the distribution of homeownership rates by age. Accordingly, we investigate the extent to which the observed changes can be accounted for by the SBTC.

Traditionally, technological change was viewed as factor-neutral. However, a common consensus has recently formed around the idea that, beginning in the 1970s, technological change in the U.S. has been skill-biased. In particular, the latent SBTC has been considered as the main factor behind the observed changes in the U.S. labor market since the 1970s.² The premise of this paper is that the two events (SBTC and changes in distribution of homeownership) are interrelated. Specifically, we argue that the observed increase in the relative returns to skill and the fact that skills are accumulated over the life cycle generated an increase in the income of the old relative to the income of the young. Moreover, the decrease in demand for low-skilled workers generated a decline in the income of the young, widening the wage gap between young and old ages. Accordingly, it became increasingly hard for young households to accumulate substantial savings early in life. In the absence of complete financial markets, and given the requirement of a substantial down payment when buying a house, this led younger households to delay their decision to buy a house. As a

¹In the United States, the aggregate homeownership rate was roughly constant at 64% from the 1970s up to the mid-1990s (See Figure 1). This stylized fact is documented by several studies in the literature, such as: Segal and Sullivan (1998), Li (2005) and Chambers, Garriga and Schlagenhauf (2010).

²In the United States, the labor market has experienced substantial changes since the 1970s, such as (i) rise in wage inequality, (ii) rise in college premium and (iii) rise in experience premium, among others. See Heathcote-Perri-Violante (2010) for a detailed documentation of these facts.

result, homeownership decreased at those early stages of the life cycle. On the other hand, to the extent that the increase in the demand for skills raises wages for older households, more of these households find themselves having sufficient funds to own a house. Overall, the effect of SBTC is to steepen the life cycle profile of homeownership, delivering lower homeownership for the young and higher homeownership for the old. Hence, we propose an interpretation of observed homeownership dynamics in which SBTC plays a key role.

In order to analyze this conjecture, we build a life-cycle model with housing and human capital accumulation. First, our model explicitly takes into account the following key characteristics of the housing market: (i) housing is held for the purpose of consumption and saving (ii) housing can be either owned or rented (iii) ownership is preferred over renting (iv) if owned, housing can be used as a collateral for mortgage loans (v) to buy a house, a household must satisfy a minimum down payment requirement which is equal to a fraction of the value of the house. Secondly, we assume the following characteristics for the human capital accumulation process: (i) individuals have both "raw labor" (health, strength, etc.) and "human capital" (skills) which earn separate wages in the labor market (ii) while raw labor is fixed over the life cycle, human capital is accumulated on-the-job through labor market experience with learning by doing, as in Jeong et al (2008).³

Using the framework above, we examine the response of the model to SBTC, which is modelled as an increase in the relative price (wage) of human capital to raw labor. We find that SBTC increases the wage gap between young and old ages, since households have lower levels of human capital early in life. Accordingly, it takes more time for young households to accumulate down payments and become homeowners, in line with consumption smoothing over the life cycle. Moreover, we find that older households that could not afford a house

³Note that a similar argument can be made if the decision to accumulate human capital is endogenous: on-the-job training. In this case, the rise in the return to human capital increases the incentives to accumulate skills at a younger age. However, this leads to a decline in labor income and savings early in life, which delays the homeownership decision for young households. On the contrary, the additional human capital accumulated pays off later in life through higher wages and it potentially allows the old to afford more houses.

In our sensitivity analysis, we find that the alternative setup (on-the-job training) generates similar results to those of our benchmark setup (learning-by-doing). [See 'Sensitivity Analysis' for a more detailed discussion].

before may now have sufficient funds to become homeowners, given higher returns to skill. In conclusion, our numerical results confirm the conjecture above, namely, the SBTC shifts the distribution of homeownership from the young to the old.

Recently, there has been an explosion of articles addressing the dynamics of aggregate homeownership. The literature has proposed a battery of mechanisms through which aggregate homeownership could be affected: tax policies, government regulation and homeowner-ship assistance programs, financial innovation in mortgage markets as well as demographic changes. Chambers, Garriga and Schlagenhauf (2009) find that financial innovations, such as the introduction of combo loans, seem to be important for the rise in homeownership after 1995, but these changes came too late to matter for the period we are interested in. The same is true for the Tax Payer Relief Act of 1997 and the affordable housing programs introduced by the Clinton and Bush administrations. The Tax Relief Act of 1986, which ended the tax deductibility of consumer loan interest payments but not of mortgage loan interest payments, falls within the period of interest. However, Glaeser and Shapiro (2002) argue that this act affects wealthy households who are already homeowners and thus has negligible effects on aggregate homeownership. In addition, we show that the steepening of life cycle homeownership profiles has been a continuous process that started in the 70s and was already underway by the mid 80s. Segal and Sullivan (1998) provide an illuminating discussion of the effects of various demographic trends and their effects on aggregate homeownership. The prominent one is the change in the age composition resulting from the baby boom generation.⁴ Although these could have an effect on the aggregate homeownership, they do not directly affect the distribution of homeownership by age.

Crucially, the overwhelming majority of research focuses on aggregate homeownership rather than the disaggregated aspect we are aiming to explain. An important exception is the work of Fisher and Gervais (2010). They document the steepening of home ownership profiles by age and provide a theoretical explanation for the decrease in homeownership for

⁴The other important change relates to marriage. We discuss this below.

the young. Their explanation is based on two factors: increased idiosyncratic risk and a trend towards later marriage. They argue forcefully that there is a clear empirical relation between homeownership and both risk and marriage. Their calibrated model closely matches the experience of young households observed in the data. Our explanation through the SBTC is, in this sense, complementary to their work. However, our analysis differs in a crucial way: the SBTC provides a mechanism that simultaneously decreases homeownership for the young *and increases* homeownership for the old. Accordingly, our proposed mechanism can capture the observed shift in the distribution of homeownership rates for all ages.

The paper is organized as follows. Section 2 presents empirical evidence on the changes in the homeownership distribution between the 1970s and the 1990s. Section 3 presents the model and defines the recursive competitive equilibrium. Section 4 presents the calibration and quantitative results. Section 5 provides the outline of future work. Section 6 summarizes and concludes.

2. Changes in the Homeownership Distribution

Figure 1 depicts the aggregate homeownership rate between 1968 and 2005 using data from the United States Statistical Abstract. As mentioned above, the figure reflects that the overall homeownership has been relatively stable during our period of interest, with an average of around 64% for that period. However, examination of the data at a more disaggregated level reveals an interesting pattern that is masked by aggregate data.

Table 1 summarizes the changes in aggregate and distribution of homeownership rates between the 1970s and 1990s using data from the March Current Population Survey (CPS).⁵ As documented by Segal and Sullivan (1998), the CPS homeownership data start in 1976 and are problematic for the years 1979 to 1982. We therefore ignore the latter years and only include an average of the years 1976-1978 for the 1970s. Similarly, we use an average of the years 1994-1997 for the 1990s. Our rates are closely in line with those reported by Segal

⁵More details about the data are provided in Appendix B.

and Sullivan (1998) and by Fisher and Gervais (2010), who also use the CPS dataset. The last row of the Table 1 displays the aggregate homeownership rate, which is 65.7% during the 1970s and 64.4% during the 1990s, with an average rate of 64.3% for the period between 1976 and 1997.

As claimed earlier, looking at homeownership rates by age reveals a substantial change in the age composition of homeownership. As we see, the homeownership has decreased substantially for younger households, especially for those less than 45 years old, while it has substantially increased for older households, specially for those above 59 years old. The same pattern can be seen in Figure 2, which is the graphical representation of Table 1.⁶

3. The Model

The economy is populated by households, firms, a real estate sector and a government. Households make the investment decisions and are subject to uninsurable idiosyncratic income and mortality shocks. Firms produce output and are owned by households. The government sets payroll taxes for the workers and it provides social security benefits to the retirees. Real estate firms work as the intermediaries for households who rent housing.

The model takes into account the following key characteristics of the housing market: (i) housing is held for the purpose of consumption and saving, (ii) housing can be either owned or rented, (iii) ownership is preferred over renting, (iv) if owned, housing can be used as a collateral for mortgage loans and (v) to buy a house, a household must satisfy a minimum down payment requirement which is equal to a fraction of the value of the house.⁷ We assume the following characteristics for the human capital accumulation process: (i) individuals have both raw labor and human capital which earn separate wages in the labor market and (ii) individuals accumulate human capital over the life cycle through learning by doing.

⁶For documentation of this fact, see Segal and Sullivan (1998), Li (2005), Garriga, Gavin and Schlagenhauf (2006), and Fisher and Gervais (2010).

⁷For quantitative models of housing see, for example, Yang (2009), Fisher and Gervais (2009), Gervais (2002), Nakajima (2008) and Chambers et al (2009).

Demographics. Time is discrete. In each period, there are I overlapping generations of agents and population grows at the rate of n . Agents are born at age 1 and can live up to age I . Retirement is mandatory at age I_r , with $1 < I_r < I$. Agents of age $i \leq I_r$ are called *workers* and those with age $i > I_r$ are called *retirees*. Each agent faces a positive probability of early death which is exogenous and independent of other household characteristics. The probability of surviving from age $i - 1$ to age i is denoted by $s_i \in (0, 1)$, with $s_{I+1} = 0$. Due to the probability of death, there are accidental bequests, which are distributed (as assets) among the members of all generations in the amount t_r .

Preferences. Agents maximize expected discounted lifetime utility

$$E \sum_{i=1}^I \beta^{i-1} (\Pi_{k=1}^i s_k) u(c_i, \varphi_i d_i)$$

where c_i is consumption of non-housing goods, d_i is consumption of housing services (either rented or owned), β is the time-discount factor, E is the expectation operator and φ is a parameter governing the preference for owning a house. When the household rents $\varphi_i < 1$ and when the household owns $\varphi_i = 1$. The instantaneous utility function $u(., .)$ is strictly increasing and strictly concave in both arguments.

Labor Endowments. Agents have two labor factors of production. They begin their life with endowments of "raw labor" (strength, health, etc.) and human capital (skills, knowledge, etc.). The endowment of raw labor is fixed over the life cycle. On the other hand, agents are able to accumulate skills on-the-job through learning-by-doing. This implies that differences in productivity by age can be attributed to skill accumulation. Raw labor and human capital earn separate wages in the labor market and each individual supplies the two factors of production at the competitive market wage rates.

Individual face stochastic productivity shocks e to the efficiency of the labor supplied to the market. The productivity shocks $e \in E = \{e_1, e_2, \dots, e_n\}$ are generated by a stationary Markov transition matrix Π that is identical across agents and over the life cycle. We assume that idiosyncratic risk in uninsurable and markets are therefore incomplete.

The total wage income of an individual of age i is given by:

$$w_i = \begin{cases} e(w_u u + w_h h_i) & \text{if } i \leq I_r \\ 0 & \text{if } i > I_r \end{cases}$$

where w_u and w_h are the market prices of raw labor and skill respectively, u is the raw labor endowment and h_i is the stock of skills at age i .

Government Policy. The government runs a pay-as-you-go social security program in order to provide retirement income. We assume that the retirement system is self-financed. In order to finance retirement benefits, the government collects payroll taxes τ_s from the labor earnings of workers. The social security funds are distributed to all retirees in equal amounts. The benefit for an individual of age i is given by:

$$b_i = \begin{cases} 0 & \text{if } i \leq I_r \\ b & \text{if } i > I_r \end{cases}$$

Real Estate Sector. The real estate sector acts as an intermediary for agents who want to rent houses. Firms in this sector borrow financial assets from households and use all of them to buy residential houses. They rent these houses to interested households at a price of q and use the rental income to pay their debt obligations at an interest rate of r . The problem of an intermediary is:

$$\max_{D_r} \{(1 - \delta_d) D_r + q D_r - (1 + r) D_r\}$$

where D_r denotes aggregate rental housing and δ_d is the rate of depreciation of houses. Optimization by intermediaries relates rental prices q to interest rates r according to

$$q = r + \delta_d$$

Asset Structure. Households own financial assets a , which represent both non housing capital and mortgage loans. More precisely, financial assets represent claims to non-housing

capital when they are positive and they capture mortgage debt when they are negative. Non housing capital depreciates at the constant rate δ_k . Apart from financial assets, households can save in housing assets, which are held for both savings and consumption purposes.

As for the housing assets, agents can either own or rent housing assets but the choice is mutually exclusive. As mentioned earlier, the cost of renting is equal to q , which is paid to the real estate intermediaries. When owning, the house size must be chosen from a finite grid $d_o \in \Omega = \{0\} \cup \{d_{\min}, \dots, d_{\max}\}$. Accordingly, owners have a different set of options than renters, who may choose both a continuous quantity of houses and houses smaller than $d_{\min}$.

We assume that only collateralized credit is available and no other form of credit is allowed. Collateralized credit represents mortgage loans and we assume that the borrowing interest rate, the mortgage rate and the deposit interest rate are all equal. To buy a house, a household must satisfy a minimum down payment requirement which is equal to a fraction χ of the value of the house. In addition, housing also serves as collateral for loans up to a fraction $(1 - \chi)$.⁸ This implies that financial assets must satisfy:

$$a \geq -(1 - \chi) d_o$$

For renters, the condition reduces to:

$$a \geq 0$$

Production Technology. There is a representative firm that produces output with the constant returns to scale technology:

$$Y = AK^\alpha L^{1-\alpha}$$

where A is total factor productivity (TFP), K is aggregate non-housing capital, $L = \gamma U + (1 - \gamma) H$ is the total "labor" supplied, which is composed of aggregate raw labor U and

⁸We follow Yang (2009) in assuming this close relationship between downpayment requirements and collateral values. This significantly simplifies the computational problem at hand by reducing downpayment and collateral constraints to a single inequality constraint.

the aggregate stock of skill H . The firm solves a static problem by hiring factors from the households to maximize period profits:

$$\max_{\{H,U,K\}} AK^\alpha L^{1-\alpha} - w_u U - w_h H - (r + \delta_k) K$$

$$\text{where } L = \gamma U + (1 - \gamma) H$$

The optimality conditions determine the factor prices w_u , w_h and r competitively.

Household Problem. In what follows, we write the problem of the household recursively, with primes denoting a variable next period. An agent is characterized by the individual set of state variables $s = (i, e, x)$, with $s' = (i + 1, e', x')$, where i is the age, e is stochastic productivity and x is total wealth (housing and financial assets). Households face the following optimization problem:

$$V(s) = \max \{V_o(s), V_r(s)\} \quad (1)$$

The maximization problem of homeowners can be written recursively as follows:

$$\begin{aligned} V_o(s) &= \max_{\{c \geq 0, d_o \in \Omega, a, x'\}} \{u(c_i, \varphi d_o) + \beta s_{i+1} EV(s')\} \text{ s.t.} \\ x &= d_o + a \\ c_i + x' &= (1 - \tau_s)w_i + (1 + r)(a + t_r) + (1 - \delta_d)d_o + b_i \\ a &\geq -(1 - \chi)d_o \end{aligned} \quad (2)$$

The maximization problem of renters can be written recursively as follows:

$$\begin{aligned} V_r(s) &= \max_{\{c \geq 0, d_r \geq 0, a, x'\}} \{u(c_i, \varphi d_r) + \beta s_{i+1} EV(s')\} \text{ s.t.} \\ x &= a \\ c_i + x' + qd_r &= (1 - \tau_s)w_i + (1 + r)(x + t_r) + b_i \\ a &\geq 0 \end{aligned} \quad (3)$$

Equation (1) represents the tenure decision, where V_o and V_r are the values of owning and renting respectively. The Bellman equation (2) is the problem of a homeowner. A homeowner chooses consumption c , financial assets a , owned housing assets d_o and wealth carried over to the next period x' . As mentioned earlier, when a household owns housing assets, they cannot rent and $d_r = 0$.

The first constraint is the asset allocation constraint, implying that total wealth x is allocated into housing assets d_o and financial assets a . If an agent is using mortgage loans ($a < 0$), the size of housing d_o will be larger than the total wealth x . The second constraint is the budget constraint. The first term on the right hand side is the net income from providing raw labor and skills to the market, multiplied by the idiosyncratic productivity shock e and net of payroll taxes. The second term is the asset income from financial assets, which earns a return of r . The third term is the owned housing assets net of depreciation. We assume that owners have to pay a depreciation cost to keep the value of housing as a proxy for maintenance costs. The fourth term denotes the social security benefits b_i and the last term is the transfer from accidental bequests. The last constraint is the collateral constraint.

The Bellman equation (3) is the problem of a renter. A renter chooses $d_r \geq 0$ instead of d_o . A renter does not make an asset allocation decision because all the wealth is invested in financial assets. The second constraint is the budget constraint. The term qd_r denotes the cost of renting the property d_r . For a renter, $d_o = 0$ because of the exclusivity assumption. On the right hand side, we again have the labor income, accidental bequests, social security benefits and the asset income, which is equal to the financial assets for a renter.

The solution to the dynamic programming problem above yields optimal decision rules $c_i = g_c(s)$, $d_o = g_{d_o}(s)$, $d_r = g_{d_r}(s)$, $a = g_a(s)$ and $x' = g_x(s)$. If an agent is an owner then $d_r = g_{d_r}(s) = 0$ and $d_o = g_{d_o}(s) > 0$ and the opposite if the agent is a renter.

3.1. Recursive Competitive Equilibrium

In what follows we define the stationary recursive competitive equilibrium. To do this, let M be the space of individual state variables and let μ be the probability measure defined over the Borel σ -algebra generated by M . Households perceive that the distribution evolves according to the law of motion:

$$\mu' = \Gamma(\mu)$$

Definition. Given the social security tax τ_s and initial conditions K_0, D_0, μ_0 , a recursive competitive equilibrium are value functions $V(s)$, optimal decision rules $g_c(s), g_{d_o}(s), g_{d_r}(s), g_a(s)$ and $g_x(s)$, aggregate stocks of non-housing capital K , housing capital D , skills H and raw labor U , prices r, w_u, w_h and q , transfers t_r , social security benefits b_i and a measure μ such that:

1. The value function $V(s)$ is the solution to the household's problem defined above and $g_c(s), g_{d_o}(s), g_{d_r}(s), g_a(s)$ and $g_x(s)$ are the associated policy functions.

2. The representative firm maximizes profits, leading to the competitive factor prices

$$\begin{aligned} r &= \alpha Z \left(\frac{K}{L} \right)^{\alpha-1} - \delta_k \\ w_u &= (1 - \alpha) \gamma A \left(\frac{K}{L} \right)^{\alpha} \\ w_h &= (1 - \alpha) (1 - \gamma) A \left(\frac{K}{L} \right)^{\alpha} \end{aligned}$$

3. The real estate sector is competitive, namely $q = r + \delta_h$.

4. The following market clearing conditions are satisfied (all the integrals are over M):

$$\begin{aligned} 1 &= \int e d\mu \\ U &= \int u d\mu \end{aligned}$$

$$\begin{aligned}
H &= \int h_i d\mu \\
D &= \int g_{d_o}(s) d\mu + \int g_{d_r}(s) d\mu \\
K &= \int g_a(s) d\mu - \int g_{d_r}(s) d\mu
\end{aligned}$$

5. The transition function Γ is generated by the optimal decisions for households and by the law of motion for the shocks.

6. The social security program is self financed:

$$\tau_s \int w_i d\mu = \int b_i d\mu$$

7. The total amount of accidental bequests is equal to the total amount of transfers plus the initial assets of the entering cohorts:

$$\int (1 - s_{i+1}) g_x(s) d\mu = \int t'_r d\mu' + a$$

where a are the total initial assets distributed to the young cohorts.

Using the market clearing conditions, it is easy to show that the aggregate resource constraint of the economy is:

$$C + K' + D' = (1 - \delta_d) D + (1 - \delta_k) K + Y$$

$$\text{where } D' = D'_o + D_r, C = \int g_c(s) d\mu, D_o = \int g_{d_o}(s) d\mu \text{ and } D_r = \int g_{d_r}(s) d\mu$$

4. Numerical Results

This section presents a numerical example that analyzes the impact of SBTC on the homeownership distribution. The first subsection presents the calibration and the second subsection discusses the numerical results.

4.1. Calibration

To choose the parameter values for our numerical experiment, we focus on the period between 1977 and 1997. The ending year is consistent with the slowdown of the SBTC in the second half of the 1990s. Moreover, the shift in the homeownership distribution mentioned earlier happened mostly during the period of study, after which the housing market experienced the recent boom and bust.

In the model, one period represents five years. Age 1 in the model corresponds to the actual age group of 20-24. I is set to 12, corresponding to the actual age group of 75-79 and I_r is set to 9, implying that agents retire at the actual age group of 65-69. The annual population growth n is set at 1.2%, corresponding to the average annual population growth in the US over the last 50 years. The survival probabilities s_i are taken from the Life Tables of the Social Security Administration.

Following Nakajima (2008), the social security tax is set to $\tau_s = 5.1\%$ to match a replacement ratio θ of 34% over the average wage income. The initial assets for the new entrants a are assumed to be distributed uniformly with an upper bound of $\bar{a}$. This upper bound, together with the minimum size of housing $\underline{h} = 0.165$ and the disutility from renting $\varphi = 0.96$ are chosen jointly to match an initial aggregate homeownership rate of 0.64, a ratio of owned housing assets to total housing assets of 0.7 and an initial homeownership rate for the 20-24 year olds of 24%. As for the downpayment fraction χ , we follow the literature on housing in assuming that $\chi = 0.2$.

Regarding the preferences, the instantaneous utility function takes the following form:

$$u(c, \varphi d) = \frac{\left(c^\lambda (\varphi d)^{1-\lambda}\right)^{1-\sigma}}{1-\sigma}$$

which is common in the literature on housing. The risk aversion parameter σ is set to 2, which is also common in the housing literature. The parameters δ^h , δ^k , β , λ and α are calibrated to match long run ratios computed from NIPA data to ensure that our economy before SBTC

conforms to the following ratios $\frac{I_h}{Y} = 0.047$, $\frac{I_k}{Y} = 0.19$, $\frac{K}{Y} = 1.65$ and $\frac{H}{Y} = 1.08$, as well as to a capital income share of 0.32. Appendix C describes in detail the computation of these ratios. Adjusting for a population growth rate of $n = 0.012$, $\delta_h = 0.0317$ and $\delta_k = 0.10$ lead to the desired investment to GDP ratios. The discount factor $\beta = 0.937$ and the preference parameter $\lambda = 0.842$ are used to match the non housing and housing capitals to GDP $\frac{K}{Y}$ and $\frac{H}{Y}$ respectively. The latter parameter implies a ratio of non-housing consumption over total consumption expenditures equal to 0.84, which is roughly in line with the 0.86 we find in the data. The parameter A is chosen to be 1, just as a normalization.

In the present model, the relative price of skill is equal to $\frac{w_h}{w_u} = \frac{1-\gamma}{\gamma}$. The initial and the final levels of γ are chosen to match a US experience earnings premium of around (i) 1.18 before SBTC and (ii) 1.35 after the SBTC. The earnings experience premium is the ratio of annual earnings of the 45-55 year-olds over the annual earnings of the 25-35 year olds. The US experience earnings premium for the period 1968-2006 is displayed in Figure 3. To calculate the earnings experience premium in the data, we have used the March CPS data set and closely follow Heathcote et al (2010). More details about the computation are provided in Appendix B. As Figure 3 reflects, the experience earnings premium increases from around 1.18 to 1.35 between 1977 and 1997, while it stabilizes towards the end of the sample period.

The stock of raw labor u is normalized to 1 and the evolution of human capital stock over the life cycle is calibrated to replicate the deterministic life cycle profile for earnings in the 1970s. In contrast, the life cycle profile for earnings in the 1990s is generated endogenously by the model, given the stocks of raw labor and human capital. To calculate the deterministic earnings profiles, we have used CPS data for both the 1970s and the 1990s. First, we construct hourly earnings data following the same procedure as Heathcote et. al (2010), which is explained in more detail in appendix B, but we focus on ages 20-65. Subsequently, we follow Hansen's (1993) procedure to obtain life cycle productivity profiles for each year. We average over all years between 1970 and 1979 to produce the 70's profile and over all

years between 1990 and 1999 to produce the 90's profile.⁹ The resulting profiles for the two periods are depicted in Figure 4.

While the deterministic life cycle process for earnings is taken from the data, we also introduce a stochastic component to earnings. The process is calibrated following Storesletten et al (2004). Specifically, the authors estimate an ARMA(1,1) process, obtaining an autocorrelation of $\rho = 0.95$, a standard deviation of 0.25 for the transitory innovation and a standard deviation of 0.17 for the innovation of the persistent AR(1) component. We discretize the AR(1) component into a five state Markov chain and the resulting transition matrix is:

$$\Pi = \begin{bmatrix} 0.3912 & 0.3354 & 0.1841 & 0.0714 & 0.0179 \\ 0.2640 & 0.3006 & 0.2393 & 0.1398 & 0.0563 \\ 0.1383 & 0.2283 & 0.2668 & 0.2283 & 0.1383 \\ 0.0563 & 0.1398 & 0.2393 & 0.3006 & 0.2640 \\ 0.0179 & 0.0714 & 0.1841 & 0.3354 & 0.3912 \end{bmatrix}$$

with an implied stationary distribution given by $\pi = [0.1703 \ 0.2163 \ 0.2268 \ 0.2163 \ 0.1703]$.

4.2. Numerical Results

In this section we study the impact of SBTC on the homeownership distribution using a calibrated version of the model. The average life cycle income profiles generated by the model are depicted in Figure 5. As explained earlier, the life cycle profile for the 1970s is calibrated from data, while the profile for the 1990s is generated endogenously by the model.

We find that the model is successful at replicating the life cycle income profile observed after the SBTC. In particular, the model is able to generate the crossing of the life cycle income profile that we see in the data. The relative pattern of the income profiles is clearly

⁹Using individual years leads to life cycle profiles that can vary significantly from one age to another. An alternative approach would be to fit smooth polynomials to the life cycle profiles. We have tried this approach and obtained very similar results to what we report here.

a result of SBTC. More specifically, SBTC increases the return to skill, which increases over the life cycle. In turn, this leads to a higher wage income for the old relative to the wage income of the young, who experience both a decrease in relative and total labor income. This will clearly have a direct effect on the homeownership profiles generated by the model, which are depicted in Figure 6.

As we see, the model is able to generate homeownership profiles with the same properties as in the data. First, we see an increase in homeownership over the life cycle with a decrease around the retirement age. The second observation is that the model is able to generate the crossing of homeownership profiles that we see in the data. As discussed earlier, this is a consequence of SBTC and the change in the income profiles. On the one hand, the younger generations face tighter borrowing constraints and are able to save less to buy homes. On the other hand, the older generations have a higher income and can afford to buy more housing. While the qualitative properties of the homeownership profiles conform to the data, we see that the crossing of the two profiles in the model occurs later than in the data.

This fact can also be observed in Table 2, which displays the homeownership rates by age in the model and in the data. Table 2 reflects that the model overpredicts the decrease in homeownership for the younger generations and it underpredicts the increase in homeownership for the older generations. For this reason, the crossing of the two profiles (distribution of homeownership rates) in the model occurs later than in the data.

As a consequence of this observation, the model generates a decline in aggregate homeownership rate after the SBTC. While the actual value of aggregate homeownership rate was 65.7% in the 1970s and 64.4% in the 1990s, the model's prediction's for aggregate homeownership rate are 65.7% and 58.3% respectively.

Finally, Figure 7,8,9,10 display the average asset holdings over the life cycle. As a consequence of SBTC, the average asset holdings decrease for younger households, while the opposite happens for older households.

Overall, we conclude that the model generates the same qualitative behavior as in the data, validating the explanation that SBTC was an important factor contributing towards the changes in the homeownership distribution between the 1970s and the 1990s. However, the model overpredicts the decrease in homeownership of the young, underpredicts the increase for the old and generates a decline in the aggregate homeownership rate. In the next section, we propose a mechanism, reconciling our findings with the observations in the data.

4.3. *Future Work*

As discussed in the previous section, the model generates the same qualitative behavior as in the data, validating the explanation that SBTC was an important factor contributing towards the change in the homeownership distribution between the 1970s and the 1990s. However, the model (i) overpredicts the decrease in homeownership for young generations (ii) underpredicts the increase in homeownership for old generations (iii) generate a decline in aggregate homeownership rate after SBTC.

Here, it is important to note that even though our model investigates the factors that affected the ‘*distribution of homeownership rates by age*’, our framework does not study the possible factors that affected the ‘*aggregate homeownership rate*’ during the period 1970s-1990s. Interestingly, Fisher and Gervais (2010) identify a potential factor that affected the aggregate homeownership rate during this period of study. Specifically, they argue that the increased participation of females in the labor force led to an increase in the aggregate homeownership rate. In particular, they model this fact as a uniform increase in productivity level, which is interpreted as higher effective supply of labor per household.

Preliminary qualitative results show that, introducing this factor in our framework increases homeownership at all ages and thus provides the best candidate for the additional force missing from our benchmark model. *Preliminary quantitative results* show that, when we introduce this additional factor in our framework, (i) the model matches the decrease in homeownership for young generations (ii) the model matches the increase in homeownership

for old generations (iii) aggregate homeownership rate stays roughly constant after SBTC, and (iv) the distribution of homeownership rates by age look remarkably similar to the data.

5. Conclusion

This paper has studied the relationship between the changes in the US homeownership distribution throughout the period 1970s-1990s and the SBTC that occurred during the same period. During the period of study, we conjecture that (i) the increase in the returns to skills generated an increase in the income of the old relative to the income of the young (ii) the decrease in demand for low-skilled workers generated a decline in the income of the young, widening the wage gap between young and old ages. This, in turn, reduced the ability of young households to accumulate savings at an early age. In the absence of complete financial markets, and given the requirement of a substantial down payment when buying a house, this led younger households to delay their decision to buy a house. In addition to this, the increased returns to skills allowed the older aged to be able to invest more heavily in homes.

To analyze the validity of these conjectures we study a model with housing and skill accumulation. Our results show that the model is able to reconcile our conjectures above. Namely, we see a decrease in homeownership at those early stages of the life cycle. At the same time, later in life, when the additional skills accumulated starts to payoff in terms of higher wages, more households can afford to buy houses.

While the model is able to generate these patterns qualitatively, it generates a decline in the aggregate homeownership rate and the crossing of the homeownership profiles in the model occurs later than in the data. As documented by other authors, there is evidence that other factors, such as the increased female labor force participation, also contributed to an increase in the aggregate homeownership rate during our period of study. When we introduce these additional factors into our model, we find that it is able to generate a roughly constant aggregate homeownership rate after SBTC as well as homeownership profile changes that are remarkably close to the ones in the data.

Appendix A: Derivation of the Resource Constraint

To derive the resource constraint, we can sum up the budget constraints of households.

The two budget constraints can be written as:

$$\begin{aligned} c + d'_o + a' &= e(w_u u_o + w_h h_o)(1 - l_o) + (1 + r)(a + tr) + (1 - \delta_d) d_o \\ c + a' + qd_r &= e(w_u u_r + w_h h_r)(1 - l_r) + (1 + r)(a) + tr \end{aligned}$$

Adding them up, we obtain:

$$\begin{aligned} & \int g_c(s) d\mu + \int g_a(s') d\mu + \int g_{d_o}(s') d\mu + q \int g_{d_r}(s) d\mu \\ &= (1 + r) \int g_a(s) d\mu + (1 - \delta_d) \int g_{d_o}(s) d\mu \\ & \quad + \int e(w_u u_r (1 - g_{l_r}(s)) + w_h g_{h_r}(s) (1 - g_{l_r}(s))) d\mu \\ & \quad + \int e(w_u u_o (1 - g_{l_o}(s)) + w_h g_{h_o}(s) (1 - g_{l_o}(s))) d\mu \end{aligned}$$

Note also that:

$$\begin{aligned} & \int e(w_u u_r (1 - g_{l_r}(s)) + w_h g_{h_r}(s) (1 - g_{l_r}(s))) d\mu \\ & \quad + \int e(w_u u_o (1 - g_{l_o}(s)) + w_h g_{h_o}(s) (1 - g_{l_o}(s))) d\mu \\ &= w_u \int [u_r (1 - g_{l_r}(s)) + u_o (1 - g_{l_o}(s))] d\mu \\ & \quad + w_h \int [g_{h_r}(s) (1 - g_{l_r}(s)) + g_{h_o}(s) (1 - g_{l_o}(s))] d\mu \\ &= w_u U + w_h H \\ &= (1 - \rho) AK^\rho (\gamma U + (1 - \gamma) H)^{-\rho} \gamma U + (1 - \rho) AK^\rho (\gamma U + (1 - \gamma) H)^{-\rho} (1 - \gamma) H \\ &= (1 - \rho) Y \end{aligned}$$

Using this, the conditions above and the fact that $q = r + \delta_d$, the resource constraint can be rewritten as:

$$\begin{aligned} & C + K' + D' + r \int g_{d_r}(s) d\mu + \delta_d \int g_{d_r}(s) d\mu \\ = & (1 + r) K + (1 + r) \int g_{d_r}(s) d\mu + (1 - \delta_d) \int g_{d_o}(s) d\mu + (1 - \rho) Y \end{aligned}$$

This implies that:

$$C + K' + D' = (1 + r) K + (1 - \delta_d) D + (1 - \rho) Y$$

We also know that:

$$(1 + r) K = \rho A K^\rho (\gamma U + (1 - \gamma) H)^{1-\rho} + 1 - \delta_k = \rho Y + (1 - \delta_k) K$$

so that the resource constraint becomes:

$$C + K' + D' = (1 - \delta_k) K + (1 - \delta_d) D + Y$$

Appendix B: CPS Data Appendix

We use the March CPS survey data for the period 1970 to 1999 to construct both the earnings profiles and the homeownership-by-age profiles. In this section we describe the construction of these profiles in more detail.

Earnings Profiles and Experience Premium

To calculate the earnings experience premium and the earnings profiles, we first construct annual earnings and hourly earnings following an almost identical procedure to the one used by Heathcote et. al (2008). In terms of cleaning the data, their approach is intended to clean miscoded or apparently miscoded observations. Thus they clean households with no (or more than one) reference person and households with any members that are assigned negative weights or that report positive earnings but zero weeks worked or that report less than half the minimum wage earned or that report less than 260 hours per year. We do the same and therefore include both genders, all races and both full and part time workers. The only additional cleaning they do is in focusing on ages 25 to 60. In order to capture the entire life cycle we instead focus on ages 20-65. This leaves us with 30 years of data on individuals by age.

To calculate annual earnings and hourly earnings, we follow their approach in defining annual earnings as labor income plus two thirds of self employment income and construct hourly earnings by dividing annual earnings by annual hours worked. We also deal with topcoded observations in a manner very similar to their approach. Before 1995, for each type of income, we fit a Pareto density to the top 10% of non-topcoded observations and use extrapolation to forecast the mean value for the top coded observations. All top coded observations are then replaced by that extrapolated mean value. After 1995, the CPS actually reports mean values for topcoded observations so we use directly those.¹⁰ The resulting hourly earnings are averaged for every year and every age using individual weights.

¹⁰Here, we differ from Heathcote et al. (2008), who use the extrapolation procedure also for the years after 1995. They do not report significant differences from doing so.

After constructing the hourly earnings, we follow Hansen's (1993) procedure to obtain life cycle productivity profiles for each year. In particular, for a given year, we divide the average hourly earnings for each age by the average hourly earnings over all ages. This leaves us with 30 life-cycle productivity profiles, one for each year from 1970 up to 1999. Finally, we average over all years between 1970 and 1979 to produce the "70's" profile and over all years between 1990 and 1999 to produce the "90's" profile.¹¹

It is important to note that our life cycle profiles are based on cross sections of individuals since we are attempting to explain cross sectional observations and focusing on steady states. In view of Kambourov and Manovskii's (2009) shrewd observation that looking at cross sections could be misleading, we also obtain estimates of life cycle profiles by looking at cohorts. Although the CPS does not contain enough information to do this on a panel, we can still track the average hourly earnings of different cohorts over time. For this analysis, we actually extend our sample back to 1967 and up to 2009, so that we have as much information about the early and late cohorts as possible. We find that life cycle profiles have steepened when one compares the cohorts entering the labor market in the 1970s and those entering in the 1990s.

There are several reasons why this is different than Kambourov and Manovskii's result. First, we include more recent data (they use data up to 1997) which allows the life cycle profile of those in the 1990's to be better captured. As discussed in Guvenen and Kuruscu (2009), it could be that life cycle profiles are flatter in the beginning of the life cycle and then turn sharply steeper later on. In this case, missing the latter part of the profile tends to bias the result towards finding a flattening. Secondly, they exclude females, non-whites and part timers, all of which seem to contribute to the steepening of life cycle profiles. Finally, perhaps more importantly, the approach of Kambourov and Manovskii (2009) bunches together different cohorts, starting as early as 1949 and going all the way to 1997. Finding

¹¹Using individual years leads to life cycle profiles that can vary significantly from one age to another. An alternative approach would be to fit smooth polynomials to the life cycle profiles. We have tried this approach and obtained very similar results to what we report here.

that when one averages over all those cohorts, earnings profiles have flattened over time is consistent with steeper profiles for the 70s cohorts compared to the 90s. All that is needed is sufficient flattening from the 50s to the 70s or from the 70s to the 80s. This is compounded by the lack of significant amounts of data for the 90s cohorts (when only data up to 1997 is used) which are the ones that actually face steeper profiles.

Homeownership Profiles

We use the same CPS data to obtain homeownership rates by age and we include ages 20 to 79. Since we ignore the data for years 1979 to 1982 and homeownership is reported in the CPS only starting in 1976, we are left with three years of homeownership data in the 70s (1976-1978). We use an average over these three years to represent the life cycle profile of homeownership for the 1970s. Similarly, we use an average for years 1994-1997 for the homeownership profile after the skill biased technological change. We consider different age groups and report the homeownership for each group before and after in figure 2 of the main text. Our rates are closely in line with those reported by Fisher and Gervais (2009) and by Segal and Sullivan (1998). In addition, aggregate homeownership exhibits the same level of stability close to 64% that is reported in Garriga et al (2009)¹².

¹²Since the data is of low quality for the years 1979-1982, we have reproduced the aggregate homeownership over time graph of Garriga et al (2009). in Figure 1.

Appendix C: NIPA Data Appendix

As stated in the calibration section, the parameters δ^h , δ^k , α , β and λ are calibrated to match long run ratios computed from NIPA data, specifically to ensure our economy before skill biased technological change conforms to the following numbers $\frac{K}{Y} = 1.65$, $\frac{H}{Y} = 1.08$, $\frac{I_k}{Y} = 0.19$ and $\frac{I_h}{Y} = 0.047$ and capital income share of 0.32. Here we describe the construction of these ratios.

We look at averages for the years 1947 to 2008. We define the capital stock K to include private non-residential fixed assets, the stock of inventories and the stock of consumer durables. Accordingly, I_k includes private non-residential investment, changes in inventories, consumer durable spending and net exports. On the housing side, the housing stock H is defined as private residential fixed assets and I_h as private residential investment.

Our definition of Y in the above ratios captures GDP produced in the non-housing sector. To construct Y , we therefore subtract expenditures on housing services from GDP.¹³ Given our treatment of consumer durables as capital stock, we also need to add the flow of services from consumer durables to our measure of Y . These flows are imputed in a manner identical to Cooley and Prescott (1995), explained below.

The above calculations determine the four ratios mentioned above. For the computation of the capital share in the production function of the non-housing sector, we follow Cooley and Prescott's (1995) approach closely. In particular, we first look at GDP minus the housing services (HS). Using *Gross Domestic Income* Table 1.10, we define Labor Income (LI) to be compensation of employees, Unambiguous Capital Income (UCI) to be rental income, corporate profits, interest and business current transfers and Ambiguous Capital Income to include all the rest (i.e. proprietor's income, taxes on production and imports less subsidies and the current surplus of government enterprises). We assume housing income is all unambiguously capital income. We also define depreciation (DEP) to be the consumption of fixed capital. A preliminary share of capital income in private income excluding housing θ_p can

¹³These are taken from Table 2.4.5 *Personal Consumption Expenditures by Type of Product*.

then be calculated as

$$\theta_p = \frac{UCI - HS + DEP}{GDP - HS - ACI}$$

Using this share we calculate capital income in measured GDP excluding housing as $\theta_p(GDP - HS)$ and use this to impute the return to capital as

$$i = (\theta_p(GDP - HS) - DEP) / K$$

For the years in question this yields an average return of 7.9%. We then look at consumer durables and estimate their depreciation rate by computing the investment to stock ratio and subtracting the growth rate of real GDP (an average of 3.3%). The average is approximately 23%. The return i and the individual depreciation rates are then used to impute the value of service flows from consumer durables.

The imputed flow is added to our measure of Y . The capital share is then recomputed by adding this flow to capital income and to GDP excluding housing, which yields a share $\alpha = 0.32$. This share is lower than the Cooley Prescott calculation (0.4) because we do not include government capital in calculations and because we look at shares in *non-housing* GDP.

Given that we do not explicitly model a government, we have to choose how to deal with the government sector in the data. In our model, it is important to capture the relative sizes of housing and non-housing capital for the private sector, since the latter is used as downpayment for the latter and the strength of the downpayment constraint depends on the relative sizes of the two. In this sense, it would be misleading if we were to include government capital as part of private capital. Our treatment implicitly assigns all government expenditures (consumption and investment) to private consumption. An alternative approach would be to only focus on private GDP and completely exclude the government sector from our calculations.¹⁴ Following this approach, and assuming that capital and labor shares are the

¹⁴Pedro Silos (2005) takes this approach.

same in the government and in the private sector, has a negligible effect on our calibrated parameters.

Adjusting for a population growth rate of 0.012, $\delta_h = 0.0317$ and $\delta_k = 0.10$ lead to the desired investment to GDP ratios. The discount factor β and the preference parameter λ are used to match $\frac{K}{Y}$ and $\frac{H}{Y}$ respectively. The latter also implies a ratio of non-housing consumption over total consumption expenditures equal to 0.81, which is roughly in line with the 0.86 we find in the data.

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FIGURE 1: AGGREGATE HOMEOWNERSHIP RATE

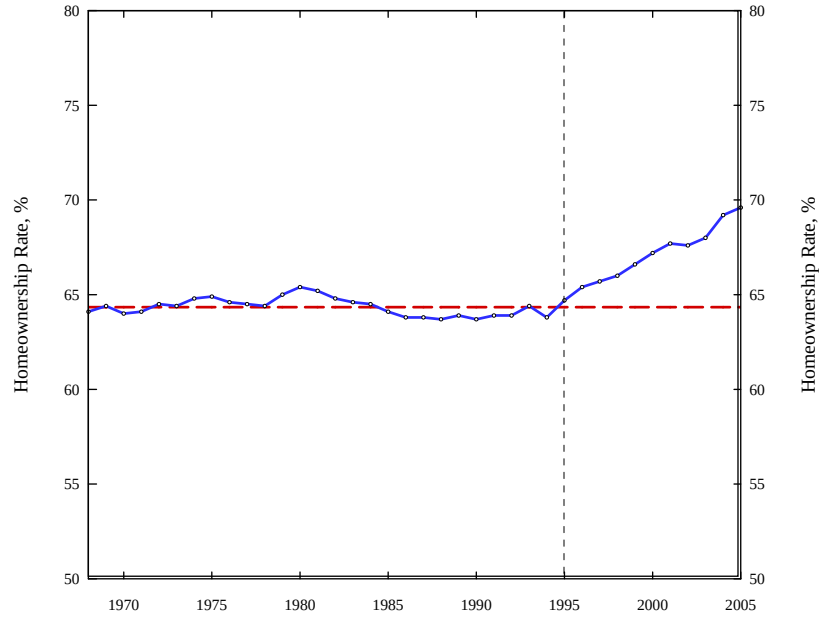


Table 1: Homeownership rates by age (Data)

Age of Household Head	1970s	1990s	1970s – 1990s
20-24	23.9	17.6	-6.3
25-29	45.4	37.1	-8.3
30-34	64.3	55.0	-9.3
35-39	71.9	64.8	-7.1
40-44	75.9	71.7	-4.2
45-49	78.8	76.8	-2.0
50-54	79.7	80.0	0.3
55-59	80.2	82.0	1.8
60-64	78.9	83.4	4.5
65-69	76.3	84.1	7.8
70-74	72.9	83.7	10.8
75-79	69.2	80.1	10.9
Overall	65.7	64.4	-1.4

FIGURE 2: HOMEOWNERSHIP RATES BY AGE (DATA)

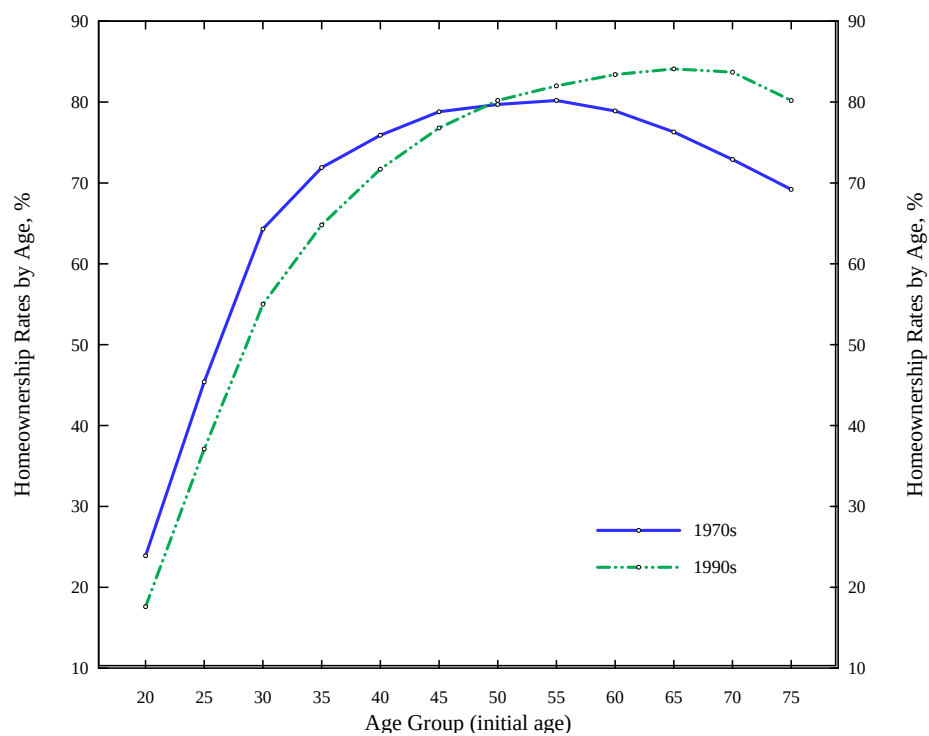


FIGURE 3: U.S. EXPERIENCE PREMIUM

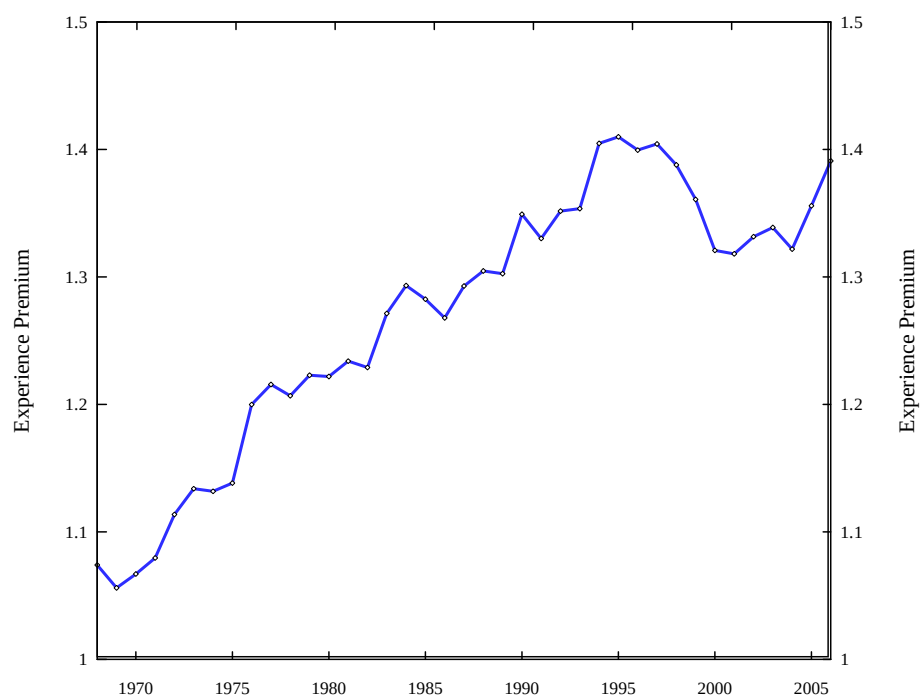


FIGURE 4: INCOME PROFILES OVER THE LIFE CYCLE (DATA)

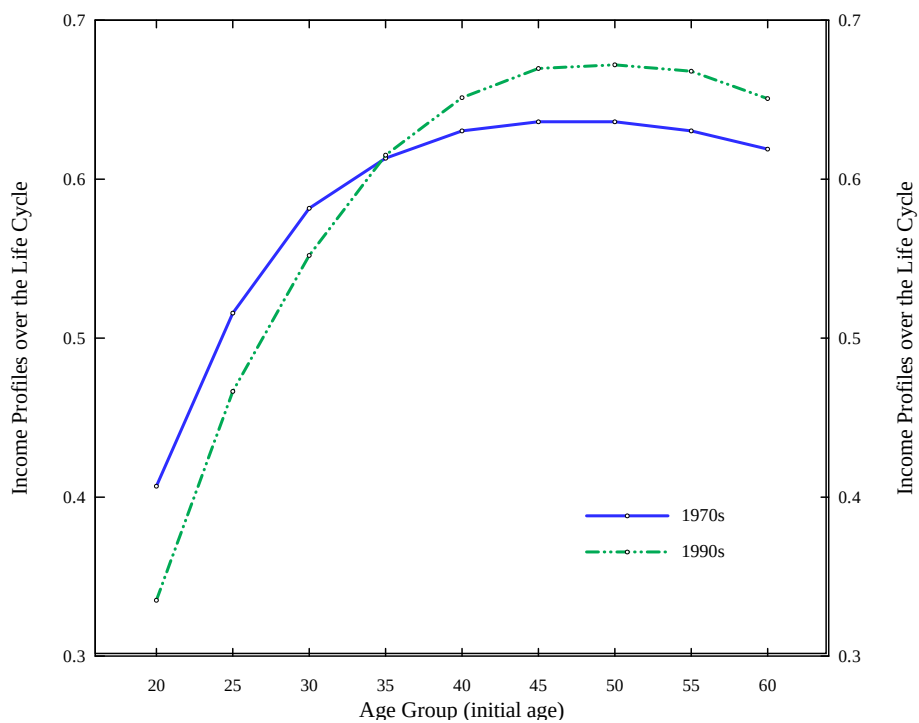


FIGURE 5: INCOME PROFILES OVER THE LIFE CYCLE (MODEL)

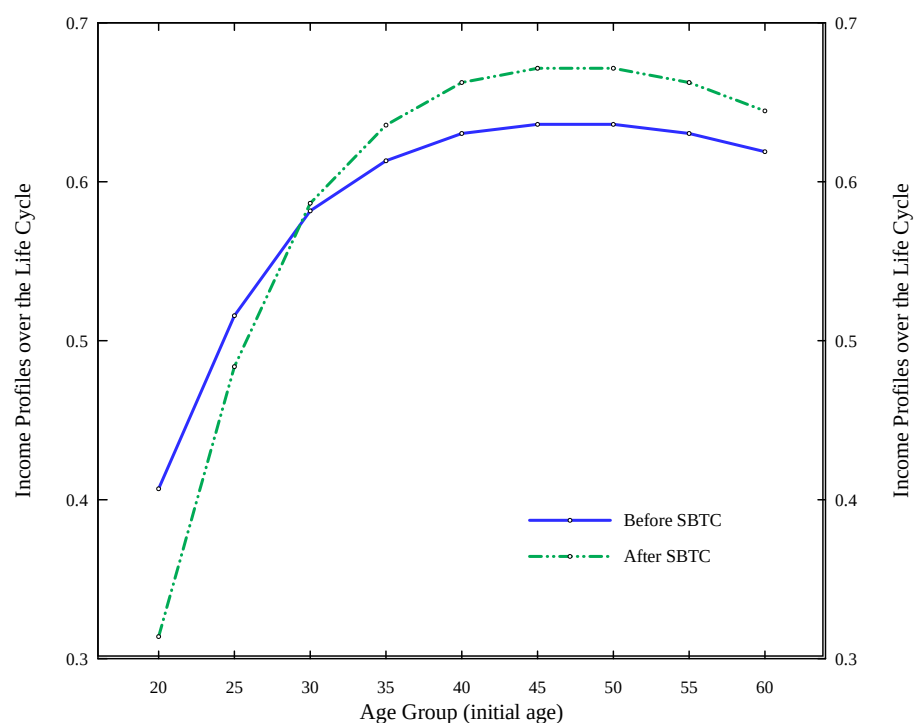


FIGURE 6: HOMEOWNERSHIP RATES BY AGE (MODEL)

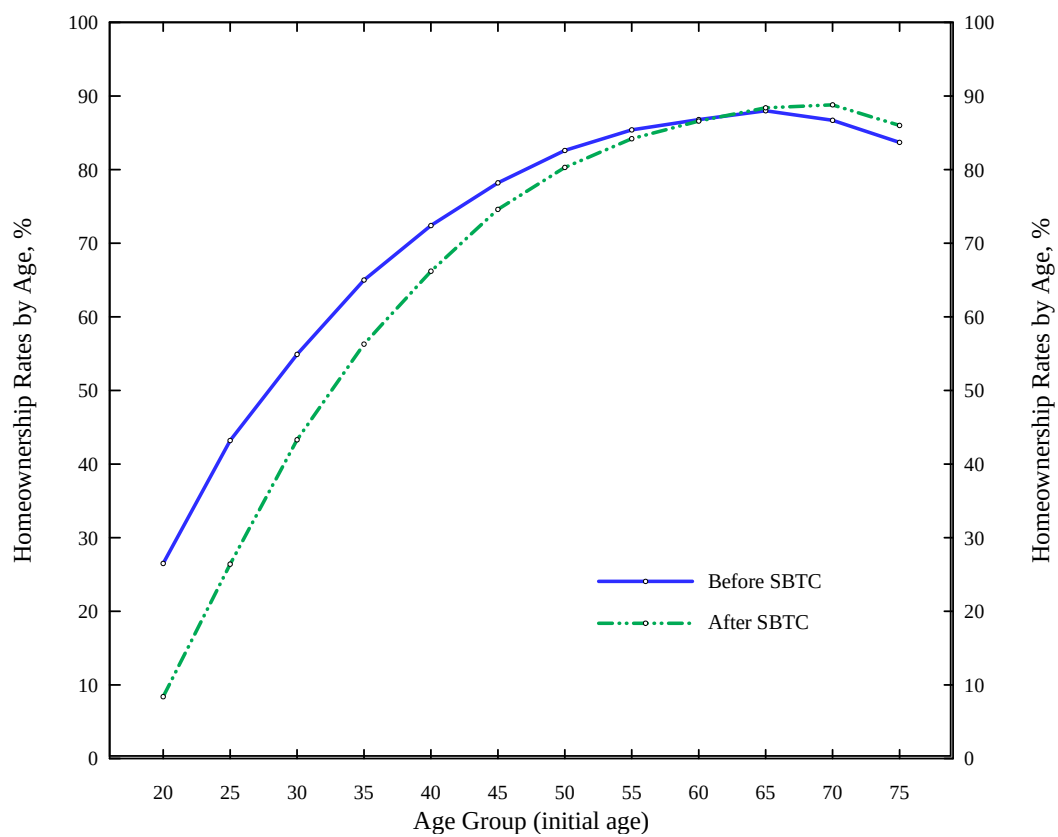


Table 2: Homeownership rates by age (Model vs. Data)

Age of Household Head	1970s	1990s	1970s-1990s	1970s	1990s	1970s-1990s
	Data	Data	Data	Model	Model	Model
20-24	23.9	17.6	-6.3	24.1	8.6	-15.5
25-29	45.4	37.1	-8.3	43.2	26.4	-16.8
30-34	64.3	55.0	-9.3	54.9	43.3	-11.6
35-39	71.9	64.8	-7.1	65.1	56.3	-8.8
40-44	75.9	71.7	-4.2	72.4	66.2	-6.2
45-49	78.8	76.8	-2.0	78.2	74.6	-3.6
50-54	79.7	80.0	0.3	82.6	80.3	-2.3
55-59	80.2	82.0	1.8	85.4	84.2	-1.2
60-64	78.9	83.4	4.5	86.8	86.6	-0.2
65-69	76.3	84.1	7.8	87.9	88.4	0.5
70-74	72.9	83.7	10.8	86.7	88.8	2.1
75-79	69.2	80.1	10.9	83.7	86.0	2.3

FIGURE 7: AVERAGE ASSET HOLDINGS OVER THE LIFE CYCLE

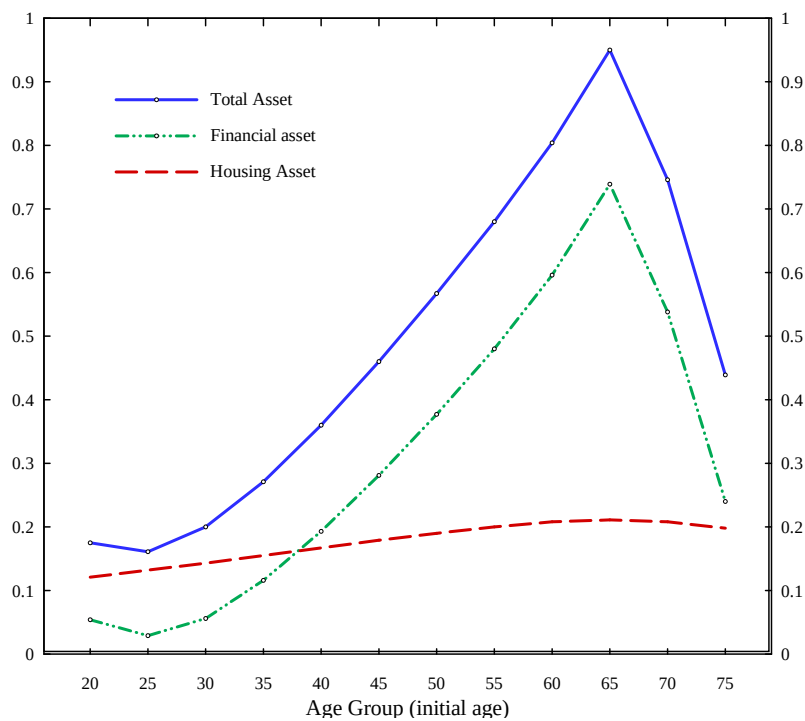
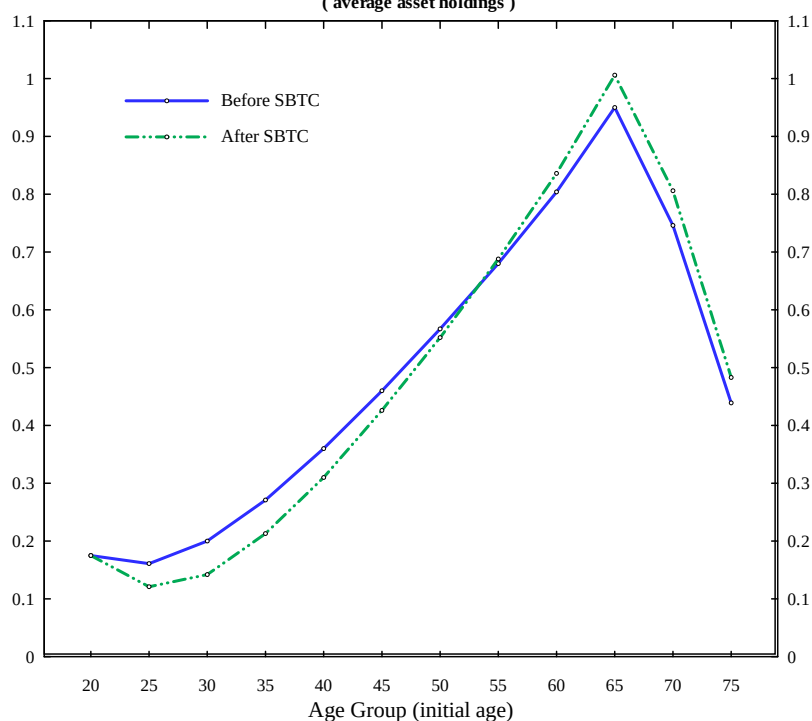
FIGURE 8: TOTAL ASSETS OVER THE LIFE CYCLE
(average asset holdings)

FIGURE 9: FINANCIAL ASSETS OVER THE LIFE CYCLE
(average asset holdings)

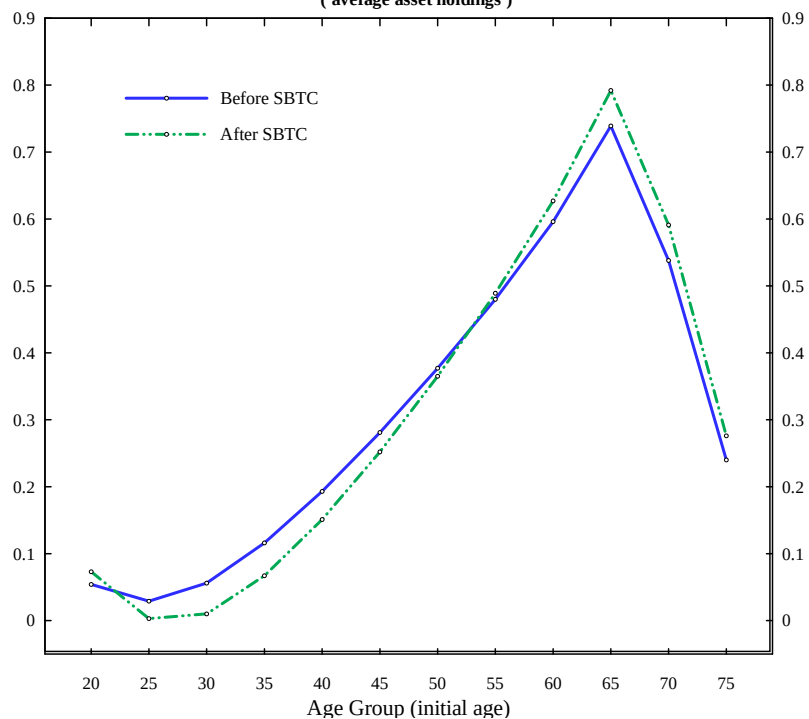


FIGURE 10: HOUSING ASSETS OVER THE LIFE CYCLE
(average asset holdings)

