



# Moving costs, nondurable consumption and portfolio choice

Nancy L. Stokey<sup>\*,1</sup>

*Department of Economics, University of Chicago, 1126 E. 59th Street, Chicago, IL 60637, USA*

Received 27 September 2007; final version received 28 February 2009; accepted 5 May 2009

Available online 21 October 2009

---

## Abstract

The substantial adjustment cost for housing affects nondurable consumption and portfolio allocations, as well as the frequency of housing transactions. A simple theoretical model, roughly calibrated, is used to assess the quantitative impact of adjustment costs on those decisions. The impact on portfolios is found to be significant, suggesting that housing wealth should be useful in empirical studies of portfolio choice. The welfare loss from the transaction cost is also substantial. The effect on nondurable consumption is small, however, so adjustment costs can explain only a small part of the equity premium puzzle.

© 2009 Elsevier Inc. All rights reserved.

*JEL classification:* D11; D14; D91; E21; G11

*Keywords:* Adjustment cost; Housing; Durable goods; Portfolio choice; Equity premium puzzle

---

For most individuals housing accounts for large fractions of both consumption and wealth. But housing is important for another reason as well. Moving typically entails substantial adjustment costs. These include direct financial costs, such as agents' commissions, legal fees, transfer taxes, and shipping/transportation costs, as well as the time cost of searching, transacting, and executing the move, and the psychic cost of changing school districts, broken emotional ties, and other disruptions.

---

\* Fax: +1 773 702 8490.

*E-mail address:* [nstokey@uchicago.edu](mailto:nstokey@uchicago.edu).

<sup>1</sup> I am grateful to Narayana Kocherlakota, Robert Lucas, Monika Piazzesi, Robert Shimer, and the editor and referee of this journal for helpful comments.

Consequently individuals adjust their consumption of housing services infrequently. As age, wealth, family size, and other household characteristics change, the consumer must decide whether and when to sell her current house and buy a new one, incurring the adjustment cost. She must also make decisions about nondurable consumption and her portfolio of financial assets. Between moves the size and direction of the latter adjustments are influenced by the fact that housing is fixed, and when she sells one house and buys another her nondurable consumption and portfolio take discrete jumps.

This paper uses a simple theoretical model to assess the impact of adjustment costs on those two aspects of the consumer's behavior, her portfolio decisions and her nondurable consumption. The model focuses on changes in the consumer's wealth as the driving variable, ignoring life cycle effects. This approach, which allows the use of a time-invariant Bellman equation, highlights the main forces at work, while at the same time keeping the problem theoretically tractable. The model is calibrated, roughly, so that quantitative effects can be calculated. The main conclusions are that the adjustment cost has a significant impact on portfolios but little effect on consumption of nondurables.

The consumer's portfolio of financial assets displays broad swings between moves and large jumps at the time of a move. Portfolio choice in the model depends on the local risk aversion of the consumer's value function for wealth, and the shape of this function is distorted by the presence of the transaction cost. Thus, with a transaction cost, risk aversion depends on the consumer's ratio of total wealth to housing wealth, although absent the transaction cost it is constant. As in Grossman and Laroque [7], risk aversion in the value function is lower when the ratio of housing wealth to total wealth is near a threshold that triggers a move and higher when that ratio is at the level chosen just after a move. Thus, the share of wealth held in the risky asset changes as the consumer's wealth rises or falls, increasing substantially between its post-transaction level and its level just before a move to a bigger (or smaller) house. It then jumps down when the new house is purchased.

These wide swings suggest that including the ratio of total wealth to housing will be useful in empirical studies using cross-section or panel data on portfolios. The way that housing affects these decisions is subtle—it is not monotonic—but the calibrated model suggests that the effects are substantial.

The adjustment cost imposes a large welfare loss on the consumer, even at fairly low values. For small adjustment costs, transactions are frequent so the cost is paid frequently. For large adjustment costs, transactions occur less often but the cost of the distortion in the consumption mix is substantial.

Between moves nondurable consumption rises and falls with the consumer's wealth, with the size of the change depending on the elasticity of substitution between housing and nondurables and on the elasticity of intertemporal substitution. But nondurable and total consumption are remarkably similar to what they would be in the absence of a transaction cost. They are also remarkably insensitive to the value assumed for the elasticity between nondurables and housing. This insensitivity may explain why empirical estimates of that parameter vary over such a wide range: it simply has very little effect on behavior.

The hypothesis that adjustment costs for housing may help to explain the equity premium puzzle is also examined. Given the insensitivity of total consumption to the transaction cost, the conclusion here is not surprising: the adjustment cost works in the right direction, but for reasonable parameter values the effect is small. Even with a very low elasticity of substitution, the most favorable case, the transaction cost explains only a modest fraction of the puzzle.

Finally, it is interesting to note that the theoretical model here produces a value function that is strictly concave. Thus, the non-concavities found in other models arise from additional features, not from adjustment costs alone.

The rest of the paper is organized as follows. Section 1 contains a brief review of the related literature. Preferences are described in Section 2 and a frictionless version of the model is studied briefly in Section 3. The model with transaction costs is set out in Section 4, the calibration is described in Section 5, and the simulations are presented in Section 6. Section 7 deals with the equity premium puzzle, and Section 8 concludes.

## 1. Related literature

There is a sizable literature, going back two decades, asking whether including durable goods can improve the fit of asset pricing models. Early attempts assumed that consumption of durables is flexible in the sense that there are no adjustment costs. In this group are the papers by Dunn and Singleton [4] and Eichenbaum and Hansen [5]. They found that including durables does little to help the model fit unconditional moments of financial returns, and hence does little to explain the equity premium puzzle.

The theoretical paper by Grossman and Laroque [7] provided a framework for studying the behavior of an individual who consumes only one good, housing services, and faces adjustment costs for changing her level of consumption. They showed that the adjustment cost affects the consumer's portfolio choice in a systematic way. Specifically, consumers who have recently adjusted their housing stock, and hence anticipate a long interval of time before another adjustment, are more risk averse than those who anticipate making an adjustment in the near future. Their model does not include nondurable consumption, however, so it is difficult to calibrate and provides no predictions about the behavior of standard Euler equations.

Several subsequent papers have further explored the implications of adjustment costs. Marshall and Parekh [13] study a model in which the adjustment cost applies to total consumption, not just housing. They find that even small values for this adjustment cost induce much smoother consumption behavior, and hence are quite successful in explaining the equity premium puzzle. However, it is not clear what those adjustment costs represent.

Flavin and Nakagawa [6] study a model similar to the one here that also includes life cycle effects and house price risk, and nests a habit persistence model as well. Using PSID data, they find that while the habit persistence model can be rejected, the adjustment cost model cannot be. Siegel [18] studies a similar model using aggregate (NIPA) data, and also finds evidence that adjustment costs are important.

Martin [14] looks at nondurable consumption around the time of a housing adjustment. Using PSID data, he distinguishes households that are likely to make upward and downward adjustments in their housing from those that are unlikely to adjust. He finds evidence that those likely to move to a larger house reduce their consumption of nondurables, and those likely to move to a smaller house raise their consumption of nondurables.

Finally, Kullmann and Siegel [10] find evidence of state-dependent risk aversion. Using a sample of homeowners from the PSID, the authors find that lower ratios of net worth to housing wealth are correlated with lower stock market participation and reduced holdings of stocks and other risky assets.<sup>2</sup>

---

<sup>2</sup> In addition, many papers have studied other channels—like house price risk—through which housing affects portfolio choice and nondurable consumption.

## 2. Preliminaries

There are two consumption goods, housing services  $H$  and a single composite nondurable  $C$ . The flow of housing services  $H$  reflects both size and quality, including features like location, lot size, and other attributes. The consumer has CES preferences over the two goods,

$$U(C, H) = \begin{cases} [\omega C^{(\varepsilon-1)/\varepsilon} + (1-\omega)H^{(\varepsilon-1)/\varepsilon}]^{\varepsilon/(\varepsilon-1)}, & \varepsilon \neq 1, \\ C^\omega H^{1-\omega}, & \varepsilon = 1, \end{cases}$$

where  $\omega \in [0, 1)$  is the relative weight on nondurables, and  $\varepsilon$  is the elasticity of substitution. Her intertemporal utility function is

$$E_0 \left[ \int_0^\infty e^{-\rho t} \frac{\{U[C(t), H(t)]\}^{1-\theta}}{1-\theta} dt \right], \quad (1)$$

where  $\theta > 0$ ,  $\theta \neq 1$  is the coefficient of relative risk aversion and  $\rho > 0$  is the rate of time preference. (The case  $\theta = 1$ , which represents logarithmic utility, can be treated along similar lines.)

The consumer's only income is the return on her portfolio. She holds two assets, a safe one with a constant rate of return  $r > 0$ , and a risky one with mean return  $\mu > r$  and variance  $\sigma^2 > 0$ . For simplicity the mortgage rate is assumed to be the same as the rate on the safe asset. The market 'price' of risk is the ratio

$$\gamma \equiv (\mu - r)/\sigma^2 > 0.$$

The price of the nondurable is normalized to one. The purchase price of housing is constant, and housing units can be chosen so that this price is also one. The direct cost of housing then has two components, non-interest costs and interest. Both are proportional to the value of the house. The non-interest costs, which will be denoted by  $m \geq 0$ , include maintenance and repairs (to offset depreciation), property taxes, and utilities. The (flow) cost of housing services is then  $p_h = r + m$ . Housing may also have an indirect cost because it enters the portfolio constraint. That constraint will be discussed below.

Let  $W$  denote the consumer's total wealth,  $A$  her wealth in the risky asset, and  $H$  the value of her house. Then  $W - A$  is her wealth in the safe asset, including housing. For  $\gamma > 0$  the consumer always chooses  $A > 0$ : she never shorts the risky asset. But if she is sufficiently risk tolerant she may want to short the safe asset, to buy the risky asset on margin. We allow her to do so but limit the size of such holdings, in effect imposing a margin requirement. The constraint has two parts.

First, there is an exogenously given minimal equity  $q \in (0, 1]$  that an owner must hold in her house. Since the mortgage interest rate is (by assumption) the same as the return on the safe asset, this is equivalent to requiring that the owner hold safe assets equal to  $qH$ . For  $q = 0$  the consumer can be interpreted as a renter. We then require

$$A \in [0, a_{ss}(W - qH)], \quad (2)$$

where  $a_{ss} \geq 1$  reflects the size of the margin requirement. If  $a_{ss} = 1$ , the consumer cannot buy the risky asset on margin.

Given  $C, H, A, W$ , the change in the consumer's total wealth over a short interval of time  $dt$  is

$$dW = [r(W - A) + \mu A - p_h H - C] dt + \sigma A dz, \quad (3)$$

where  $z$  is a Wiener process. If  $W - A \geq H$  the consumer owns her house outright, and if the inequality is strict she has additional wealth invested at the risk-free rate.

### 3. The frictionless model

A useful benchmark for comparisons is the model with no transaction cost. In this case the consumer’s problem is to choose  $(C, H, A)$  to maximize (1) subject to the portfolio constraint (2) and the budget constraint (3), given initial wealth  $W_0 > 0$ .

Since the objective function is homogeneous of degree  $(1 - \theta)$  in  $(C, H, A, W)$  and the constraints are homogeneous of degree one, the optimal ratios  $H/W, A/W$ , etc. are constant over time. Hence the consumer’s problem can be written as

$$V^*(W_0) = \max_{\substack{c \geq 0, h \in [0, 1/q] \\ a \in [0, a_{ss}(1-qh)]}} E_0 \left[ \int_0^\infty e^{-\rho t} \frac{[u(c)hW(t)]^{1-\theta}}{1-\theta} dt \right]$$

$$\text{s.t. } \frac{dW}{W} = [r + (\mu - r)a - (p_h + c)h] dt + \sigma a dz, \tag{4}$$

where  $c \equiv C/H$  is the ratio of nondurable consumption to housing services,  $h \equiv H/W$  is the ratio of housing to wealth,  $a \equiv A/W$  is the portfolio share in the risky asset, and  $u(c) \equiv U(c, 1)$  is the intensive form of the CES aggregator.

For any fixed  $(c, h, a)$ , total wealth  $W$  is a geometric Brownian motion with constant drift and variance. In particular,  $E_0[W(t)^{1-\theta}] = W_0^{1-\theta} e^{\Gamma(c,h,a)t}$ , where

$$\Gamma(c, h, a) \equiv (1 - \theta) \left[ r + (\mu - r)a - (p_h + c)h - \theta \frac{1}{2} (\sigma a)^2 \right].$$

Consequently, if  $\rho > \Gamma$  the value function in (4) has the form  $V^*(W_0) = W_0^{1-\theta} v^*$ , where

$$v^* \equiv \max_{\substack{c \geq 0, h \in [0, 1/q] \\ a \in [0, a_{ss}(1-qh)]}} \frac{[u(c)h]^{1-\theta}}{1-\theta} \frac{1}{\rho - \Gamma(c, h, a)}. \tag{5}$$

The following assumption, which insures that  $\Gamma$  satisfies the required condition, will be maintained throughout.

**Assumption 1.** If  $0 < \theta < 1$ ,

$$\rho > (1 - \theta) \times \begin{cases} [r + (\mu - r)a_{ss} - \theta(\sigma a_{ss})^2/2], & \text{if } \theta < \gamma/a_{ss}, \\ [r + (\gamma/\theta)(\mu - r)/2], & \text{if } \theta \geq \gamma/a_{ss}. \end{cases}$$

It is straightforward to show that for renters, consumers with  $q = 0$ , the solution to (5) is

$$a_R = \min \left\{ \frac{\gamma}{\theta}, a_{ss} \right\},$$

$$c_R = \left( \frac{\omega p_h}{1 - \omega} \right)^\varepsilon,$$

$$h_R = \frac{1}{c_R + p_h \theta} \frac{1}{\theta} \left\{ \rho - (1 - \theta) \left[ r + \sigma^2 \gamma a_R - \theta \frac{1}{2} \sigma^2 a_R^2 \right] \right\}. \tag{6}$$

For a renter the short sale constraint does not involve her housing choice. Hence there is a separation between the portfolio decision  $a_R$  and her consumption mix  $c_R$ , even if the portfolio constraint binds.

For an owner, a consumer with  $q > 0$ , the solution is the same as the renter’s if the (tighter) portfolio constraint is satisfied for the renter’s choices, if  $a_R = \gamma/\theta \leq a_{ss}(1 - qh_R)$ . Otherwise, for the owner housing services have an extra cost at the margin, the incremental portfolio distortion. In this case the owner chooses a higher ratio of nondurables to housing,  $c^* > c_R$ , a lower ratio of housing to total wealth,  $h^* < h_R$ , and a smaller portfolio share for risky assets,  $a^* = a_{ss}(1 - qh^*) < a_R$ . Let  $w^* = 1/h^*$  denote the ratio of total wealth to housing for an owner in a frictionless world.

**4. The model with transaction costs**

In a world with a positive transaction cost,  $\lambda > 0$ , the consumer must pay  $\lambda H$  when she adjusts her housing. Consequently she will adjust only occasionally, by discrete amounts, and her budget constraint has two parts. At dates when she adjusts her housing, her wealth falls by the amount of the transaction cost. At all other times her wealth grows continuously but stochastically.

In addition to voluntary housing adjustments, it is easy to incorporate moves that are required for exogenous reasons. Job changes that involve relocating to a new city and changes in family size are two possible interpretations of these moves. Assume that this shock is Poisson, with a constant arrival rate  $\kappa$ .

Define the stopping times  $T_X$ , the arrival of the next exogenous relocation shock, and  $T_A$ , the time the consumer chooses for the next adjustment in case the exogenous shock has not occurred. The consumer’s next housing adjustment occurs at the minimum of these two,  $T' \equiv T_A \wedge T_X$ .

With a transaction cost for housing, two state variables are needed,  $W$  and  $H$ . But the consumer’s value function  $V(W, H)$  is, as before, homogeneous of degree  $(1 - \theta)$  in the state variables, and the policy functions for  $C, A$ , and  $H'$  are homogeneous of degree one. Hence a normalized form of the problem can be written in terms of a single state variable, a ratio. It is convenient to use  $w = W/H = 1/h$ . The Bellman equation is then

$$\begin{aligned}
 v(w_0) &= \sup_{\{c(t), a(t)\}, T_A, w'} E_0 \left\{ \int_0^{T'} e^{-\rho t} \frac{u[c(t)]^{1-\theta}}{1-\theta} dt + e^{-\rho T'} \left( \frac{w(T') - \lambda}{w'} \right)^{1-\theta} v(w') \right\} \\
 \text{s.t. } dw &= \{[r + (\mu - r)a]w - (p_h + c)\} dt + \sigma aw dz, \\
 a &\in \left[ 0, a_{ss} \left( 1 - \frac{q}{w} \right) \right], \quad t \in [0, T'), \\
 T' &= T_A \wedge T_X, \\
 w' &\geq q,
 \end{aligned}
 \tag{7}$$

where  $v(w) \equiv V(w, 1)$ , and as before  $c = C/H$  and  $a = A/W$ . Note that depreciation is assumed to be completely offset by spending on maintenance and repairs (one component of  $m$ ), so consumption of housing services remains constant between moves. A solution consists of a value function  $v(w)$  defined on  $\mathbf{R}_+$  satisfying (7), and policy functions  $\{c(t), a(t)\}, T_A, w'$  that attain the maximum.

Two properties of the solution are immediate from (7). First, the optimal choice for  $w'$ , the ratio of total wealth to housing immediately after a transaction, does not depend on the state  $w(T')$  just prior to the transaction. Define

$$M \equiv \max_{w'} \frac{v(w')}{w'^{1-\theta}}, \tag{8}$$

and let  $S$  denote the return point, the maximizing value for  $w'$ . Thus,  $M = S^{-(1-\theta)}v(S) = V(1, 1/S)$  is the optimized value for an individual with net wealth  $W = 1$  (after paying the transaction cost on her old house) when she buys a new house, and  $S$  is the wealth/house ratio she chooses.

In addition, the stopping time chosen by the consumer has the form  $T_A = T(b) \wedge T(B)$ , where  $T(\beta)$  denotes the first time the stochastic process  $w$  reaches  $\beta$ , and  $0 \leq b < B < +\infty$  are optimally chosen thresholds. Thus, the state has an *inaction region*, the open interval  $(b, B)$ . While the state remains inside this interval the consumer does not sell her house voluntarily, although the exogenous shock may force her to do so. The consumer immediately adjusts her housing if  $w$  is outside the interval  $(b, B)$ . Hence the value function outside the inaction region has the form

$$v(w) = (w - \lambda)^{1-\theta} M, \quad w \notin (b, B). \tag{9}$$

After an initial transaction, if required, the state remains inside the interval  $(b, B)$ .

To characterize the value function  $v$ , the policy functions  $c$  and  $a$ , and the critical points  $b, S, B$ , we can use the fact that inside the inaction region the value function satisfies the Bellman-type equation

$$\begin{aligned} (\rho + \kappa)v(w) = & \max_{\substack{a \in [0, a_{ss}(1-q/w)] \\ c \geq 0, w' \geq q}} \left\{ \frac{u(c)^{1-\theta}}{1-\theta} + m(w)v'(w) \right. \\ & \left. + \frac{1}{2}s^2(w)v''(w) + \kappa(w - \lambda)^{1-\theta} \frac{v(w')}{(w')^{1-\theta}} \right\}, \end{aligned} \tag{10}$$

where

$$\begin{aligned} m(w) &\equiv [r + (\mu - r)a(w)]w - [p_h + c(w)], \\ s^2(w) &\equiv [\sigma a(w)w]^2, \end{aligned}$$

are the instantaneous drift and variance for  $w$  under the optimal policies  $a(w)$  and  $c(w)$ . (See Stokey [20, Chapter 9] for a more detailed discussion.)

The interpretation of (10) is fairly standard. The first term on the right is the current utility flow from consumption. The second and third, which come from an application of Ito’s lemma, are the expected ‘capital gain’ from changes in the state variable. To interpret the final term, subtract  $\kappa v(w)$  from both sides. The resulting expression multiplying  $\kappa$  on the right, which is negative, is the expected net loss from the exogenous moving shock.

For any ratio  $w$  inside the inaction region, the optimal portfolio maximizes the right side of (10). Hence

$$a(w) = \min \left\{ \frac{\gamma}{-wv''/v'}, a_{ss} \left( 1 - \frac{q}{w} \right) \right\}, \quad w \in (b, B). \tag{11}$$

The first expression in braces in (11) is exactly analogous to the one in (6) for the problem in the frictionless world. The only difference is that here the relative risk aversion of the value function,  $-wv''/v'$ , varies with  $w$ . In the frictionless world it is constant at  $\theta$ .

The condition for nondurable consumption  $c(w)$  is simply  $u(c)^{-\theta}u'(c) = v'$ , so the marginal utility of nondurable consumption, with housing fixed, must equal the marginal value of wealth.

Nondurable consumption increases with wealth, and the slope of the function depends on the substitution elasticity  $\varepsilon$  and the intertemporal elasticity  $1/\theta$ . Higher elasticities imply a stronger response for nondurable consumption.

The optimal thresholds  $b$  and  $B$  satisfy the value matching and smooth pasting conditions. That is, both  $v$  and  $v'$  must be continuous at  $b$  and  $B$ . From (9) we see that this requires

$$\begin{aligned} \lim_{w \downarrow b} v(w) &= (b - \lambda)^{1-\theta} M, & \lim_{w \downarrow b} v'(w) &= (1 - \theta)(b - \lambda)^{-\theta} M, \\ \lim_{w \uparrow B} v(w) &= (B - \lambda)^{1-\theta} M, & \lim_{w \uparrow B} v'(w) &= (1 - \theta)(B - \lambda)^{-\theta} M. \end{aligned}$$

Finally, it follows from (8) that the optimal return point  $S$  satisfies

$$v(S) = S^{1-\theta} M, \quad v'(S) = (1 - \theta)S^{-\theta} M.$$

Although a closed form solution is not available, it is not difficult to compute solutions numerically. The next sections describe the calibration and simulations.

## 5. Calibration

The model has twelve parameters:  $(\mu, \sigma, r, a_{ss}, q)$  describing asset markets,  $(\lambda, m, \kappa)$  for housing, and  $(\rho, \theta, \varepsilon, \omega)$  describing preferences. Parameters about which there is better information are fixed throughout the analysis. For the others, sensitivity experiments are conducted around the benchmark values. The model is very stylized, so the numbers should be viewed as illustrative.

The return parameters for the risky asset are fixed throughout at  $\mu = 0.070$  and  $\sigma = 0.1655$ , the values for real returns on the S&P 500 for the period 1889–1978, and the return on the safe asset is fixed at  $r = 0.01$ , the rate for short-term government securities over the same period.<sup>3</sup>

The short sale parameter is fixed at  $a_{ss} = 1.20$  throughout, which allows some scope for the consumer to buy the risky asset on margin. Down payments for traditional mortgages are typically 10–15%. The upper end of this range is used here,  $q = 0.15$ . In the simulations below the portfolio constraint involving these two parameters almost never binds.

Smith, Rosen, and Fallis [19] estimate the monetary cost of selling a house to be 8%–10% of the value of the unit. This figure includes agents' commissions, legal fees, transfer taxes and other transaction costs, and moving costs. In addition there are costs that are harder to measure, such as the time cost of search, the psychic cost of disruption, and so on. A conservative figure,  $\lambda = 0.08$ , is used for the benchmark and sensitivity experiments conducted for other values.

A key variable in the model is the ratio of total wealth to housing wealth. The model includes only tangible wealth, while in fact the bulk of 'total wealth'—in the sense of what generates income—is intangible wealth, human capital. Residential structures are about 40% of total private fixed capital,<sup>4</sup> so total physical capital is about 2.5 times the housing stock. In addition, physical capital's share in national income is about 1/3. Thus, if we impute the same rate of return to intangible and tangible wealth, total wealth is about 3 times the stock of physical capital. Multiplying these two ratios suggests a figure of  $2.5 \times 3 = 7.5$  for the ratio of total wealth to housing wealth.

<sup>3</sup> See Kocherlakota [9, Table 1]. Piazzesi et al. [16, Table 1] report similar figures for the periods 1936–2001 and 1947–2001.

<sup>4</sup> See Davis and Heathcote [3, Table 7], who use NIPA data for 1948–2001.



In the model this ratio is sensitive to the hazard rate  $\kappa$  for exogenous moves and the maintenance cost  $m$ , as well as the transaction cost  $\lambda$ . Lacking direct evidence on exogenous moves,  $\kappa = 0$  is used for the benchmark, and experiments conducted with a positive value.

The maintenance cost is set at  $m = 0.031$ , a value that produces an average ratio of total wealth to housing wealth of about 7.0 in the benchmark calibration. A small positive value for  $\kappa$  raises the ratio closer to the target. The benchmark figure for maintenance does not seem unreasonable, since it includes property taxes and utilities, as well as maintenance and repairs. It must also compensate for the fact that the interest cost is probably understated, since mortgage rates are higher than the safe rate of return used here.

There are four preference parameters,  $\rho$ ,  $\theta$ ,  $\omega$ , and  $\varepsilon$ . The rate of time preference is set at  $\rho = 0.025$  throughout. This figure is fairly standard.

There is less agreement about the risk aversion parameter  $\theta$ . With asset returns fixed at their market values, this parameter is important in determining the allocation of income between consumption and savings, the allocation of the portfolio between safe and risky assets, and—as a consequence—the average growth rate.

Since much of the capital stock here stands in for human capital, it is not obvious what the target figure for the portfolio allocation should be. For calibrating  $\theta$ , this leaves a choice between the savings rate and the growth rate. Between these two, the growth rate is more important here, since it influences the frequency of moves. The value  $\theta = 3.5$  produces a growth rate of about 2.0%, which is close to the historical average for the last century, so it will be used as a benchmark. The associated savings rate is high, but this is inevitable. Since the model has no labor income, a high savings rate is required to produce the target rate of income growth. Experiments are performed with other values for  $\theta$ .

There is even less consensus about the elasticity of substitution between housing and non-durables. Using data from a policy experiment that involved low-income renters in two cities, Hanushek and Quigley [8] estimate price elasticities of  $\varepsilon = 0.45$  and 0.64. Siegel [18] obtains two estimates based on homeowners in the PSID over the period 1978–1997, using the self-reported value of the owner occupied house. Aggregating across households and using only the time series information, the estimated elasticity is 0.47. Using the household level information and limiting the sample to households that own stocks, it is in the range [1.23, 1.67].

Flavin and Nakagawa [6] also use data from the PSID, for 1975–1985, but they employ a different measure of housing to sidestep the problem of price variation across cities. They obtain an elasticity of substitution of  $\varepsilon = 0.13$ . Using NIPA data on real rents and the aggregate expenditure share of housing over the period 1936–2001, Piazzesi et al. [16] estimate the elasticity to be in the range [1.05, 1.25]. Using CEX data for 27 cities in 2003, a simple regression involving expenditure shares and the relative price of housing leads to an estimated elasticity of  $\varepsilon = 0.45$ . (See Appendix A for details.)

The value  $\varepsilon = 0.5$  is used as the benchmark, and sensitivity experiments conducted with values of  $\varepsilon = 0.15$ , 1.0, and 1.25.

The weight parameter  $\omega$  is calibrated using the expenditure share of housing. In the model, the cost of housing has two parts,  $r$  and  $m$ . Take  $m$  to include utilities, fuel, insurance, and property taxes, as well as maintenance and repairs. With this definition, aggregate data from NIPA for 1990–2007 shows a mild but steady decline in the expenditure share, from 19.3% to 16.0%. Data from the CEX suggests a substantially higher figure, around 28%. An intermediate value will be used here. Specifically, except where noted  $\omega$  is calibrated in each simulation so that the expenditure share of housing is 23%.

The benchmark parameters are shown in Table 1.

Table 1  
Baseline parameters.

$\mu = 0.070$	$r = 0.010$	$\rho = 0.025$	$\varepsilon = 0.50$
$\sigma = 0.1655$	$\kappa = 0$	$\theta = 3.5$	$\omega = 0.255$
$q = 0.15$	$a_{ss} = 1.20$	$m = 0.031$	$\lambda = 0.08$

Another figure that can be used to check the predictions of the model (or to calibrate  $\kappa$ ) is the cross-sectional average for tenure (length of residence) in the current house. For persons 15 years and older who live in owner occupied housing, this figure is 11.3 years.<sup>5</sup>

## 6. Quantitative results

### 6.1. Benchmark model

Fig. 1 displays the value and policy functions for the benchmark calibration. For comparison, results are also shown for a frictionless consumer, one who faces no transaction cost. In each panel the horizontal axis measures total wealth. For the benchmark consumer housing wealth (and services) are fixed at unity as total wealth varies. For the frictionless consumer housing varies (optimally) with total wealth. The same value for the preference parameter  $\omega$  is used for both consumers, so the comparison represents the effect of eliminating the transaction cost. The portfolio constraint never binds, for either consumer.

Fig. 1a shows the value functions, which are smooth and concave. Their first derivatives (not shown) are smooth and convex. The transaction cost does not create kinks or nonconvexities.<sup>6</sup>

The adjustment thresholds for the benchmark consumer, indicated by dotted lines, are total wealth/housing ratios of  $b = 3.4$  and  $B = 10.9$ , and the ratio chosen when a new house is purchased, indicated with a small open circle, is  $S = 6.8$ . Thus, an upward adjustment is made when wealth has increased by about 60% and a downward adjustment when it has fallen by 50%.

The long run average for this ratio is calculated using the distribution for  $w$  following a start at  $w = S$ . This value,  $E[w] = 7.0$ , is higher than the (constant) ratio  $w^* = 5.8$  chosen by the consumer in the frictionless world. The transaction cost makes housing more expensive so less is consumed, producing a higher ratio of total wealth to housing.

Fig. 1b shows the share of wealth held in the risky asset. For the benchmark consumer this function is U-shaped, reflecting the fact—first noted by Grossman and Laroque [7]—that she is more risk tolerant when she is close to the adjustment thresholds, and more risk averse in the middle of the inaction region. The fairly high risk aversion coefficient used here,  $\theta = 3.5$ , means that the consumer puts only 59%–69% of her wealth in the risky asset. The long run average,  $E[a] = 0.61$ , is a little lower than the (constant) share  $a^* = 0.63$  chosen by the frictionless consumer. The average rate of return on the portfolio is 4.7% for the benchmark consumer and 4.8% for the frictionless consumer. The average growth rate of consumption, income and wealth (they are all the same) is 2.0% for both.

Fig. 1c shows the ratio of expenditures on nondurables to housing expenditures. For the benchmark consumer this ratio is approximately linear in wealth, rising 72% or falling 54% relative to its level just after the most recent housing adjustment. Its long run average,  $E[c(w)]/p_h = 3.5$ ,

<sup>5</sup> From Fig. 4 in J.P. Schachter and J.J. Kuenzi [17], which is based on Census (SIPP) data for 1996.

<sup>6</sup> See Chetty and Szeidl [2] for a model where it does.

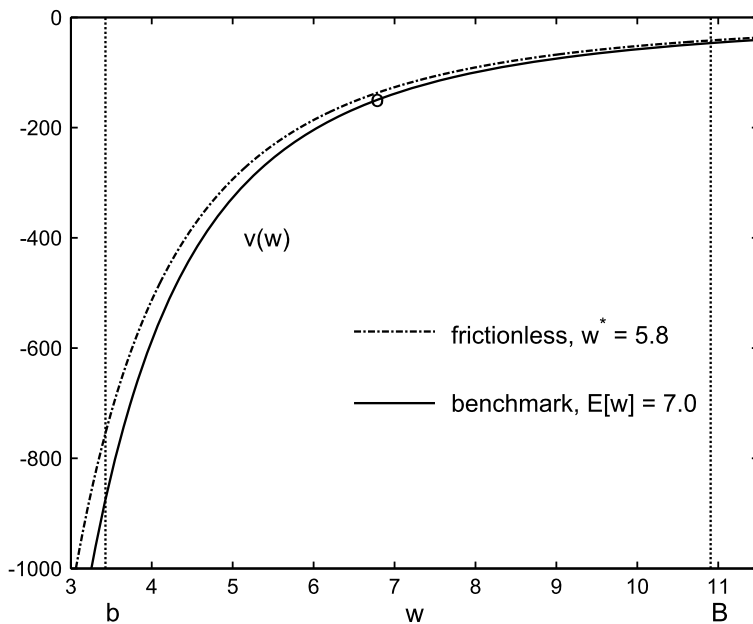


Fig. 1a. Value function.

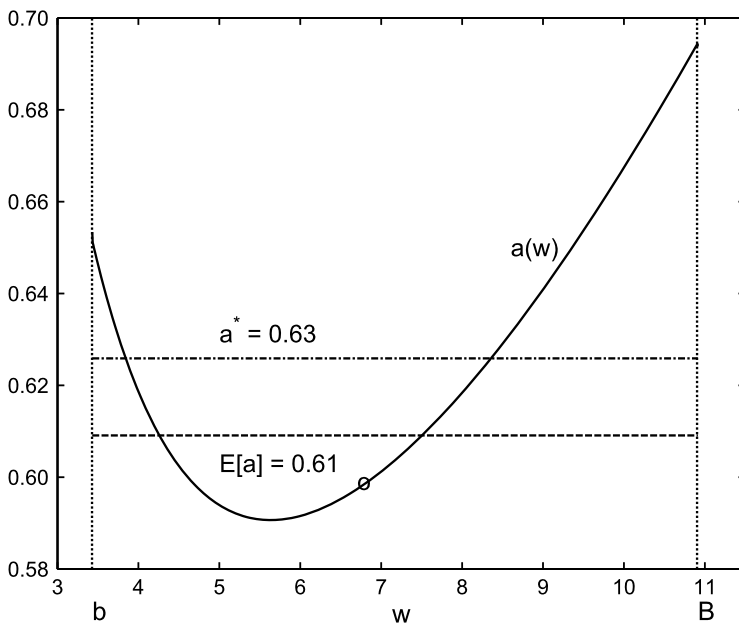


Fig. 1b. Portfolio share of the risky asset.

is somewhat higher than the constant ratio  $c^*/p_h = 2.9$  chosen by the frictionless consumer. The transaction cost makes housing more expensive, inducing the consumer to shift her consumption mix toward nondurables.

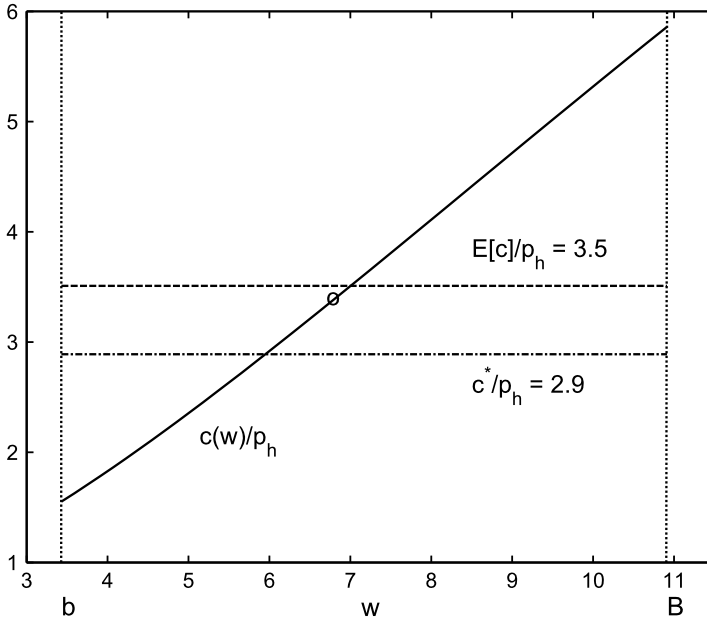


Fig. 1c. Expenditure ratio, nondurables/housing.

For the benchmark consumer the housing share of total expenditure  $p_h/(c + p_h)$  falls from 39% at the lower threshold to 15% at the upper threshold. The long run average value, by construction 23%, is slightly lower than the (constant) 26% for the frictionless consumer with the same preferences.

For the benchmark consumer total expenditure is on average 57% of income, and for the frictionless consumer it is 58%, so the savings rates are very high. As noted above, calibrating the model to produce a more realistic expenditure share reduces the growth rate, which in turn produces very long durations between moves.

Fig. 2 shows how total expenditure and its two components vary with wealth inside the inaction region. Since preferences here are homothetic, the frictionless consumer’s expenditures on housing and nondurables—and hence their sum—increase in proportion to her wealth. Thus the three broken lines, which represent the two components of her expenditures and their sum, are rays from the origin.

For the benchmark consumer housing expenditure is constant at  $p_h = r + m$  inside the inaction region. This consumer can increase her total consumption only by shifting her consumption mix toward nondurables, and indeed her nondurable consumption increases more strongly with wealth than that of the frictionless consumer. Nevertheless, the low intratemporal substitution elasticity assumed here ( $\epsilon = 0.50$ ) discourages such behavior, and her total expenditure increases less strongly with wealth than the total for the frictionless consumer.

Table 2 describes the changes when a housing transaction occurs. The first row shows changes for downward adjustments in house size (from  $b$  to  $S$ ) and the second row for upward adjustments (from  $B$  to  $S$ ).

The first column shows the probabilities of the two events, conditional on a starting wealth-to-house ratio of  $S$ . The fraction of downward adjustments is small, only 11%. Since the consumer’s

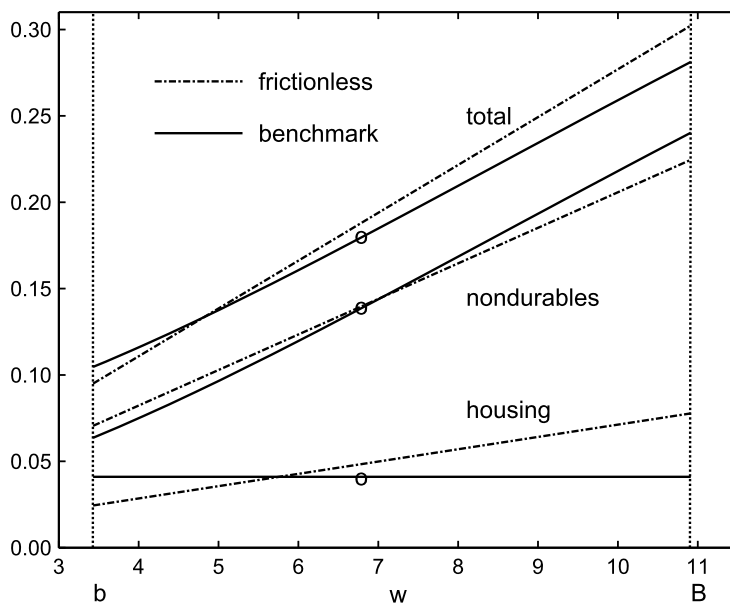


Fig. 2. Total expenditure and its components.

Table 2

For adjustments from  $b$  and  $B$ : probabilities and changes in housing, nondurables, total expenditure, and the portfolio share.

	Prob	$\hat{H}/H$	$\hat{C}/C$	$\hat{E}/E$	$\hat{a} - a$
$b$	0.11	0.49	1.08	0.85	-0.054
$B$	0.89	1.58	0.92	1.02	-0.095

wealth grows, on average, only a (relatively rare) sequence of bad portfolio returns induces her to downsize her house.

The next three columns show the ratios of the new to old house values  $\hat{H}/H$ , nondurable consumption  $\hat{C}/C$ , and total expenditures  $\hat{E}/E$ , and the last column shows the change in the portfolio share in the risky asset  $\hat{a} - a$ . For transactions at the lower threshold the value of the new house is 49% of the value of the one being sold, nondurable consumption rises by 8%, total expenditure falls by 15%, and the portfolio share in the risky asset falls by 5.4 percentage points. For transactions at the upper threshold, the value of the new house is 58% higher than the value of the one being sold, nondurable consumption falls by 8%, total expenditure rises by 2%, and the portfolio share in the risky asset falls by 9.5 percentage points.

For a consumer who has just transacted, one with  $w = S$ , the expected duration (expected time to the next adjustment) is  $E[D] = 22.9$  years. The cross-sectional average for tenure in the current house is  $\bar{T} = 15.0$  years, somewhat higher than the 11.3 years in the data.

### 6.2. Sensitivity analysis: $\varepsilon$

As noted above, there is conflicting (or little) evidence about some of the parameters. To assess the effect of changing these parameters, the model was simulated with alternative values.

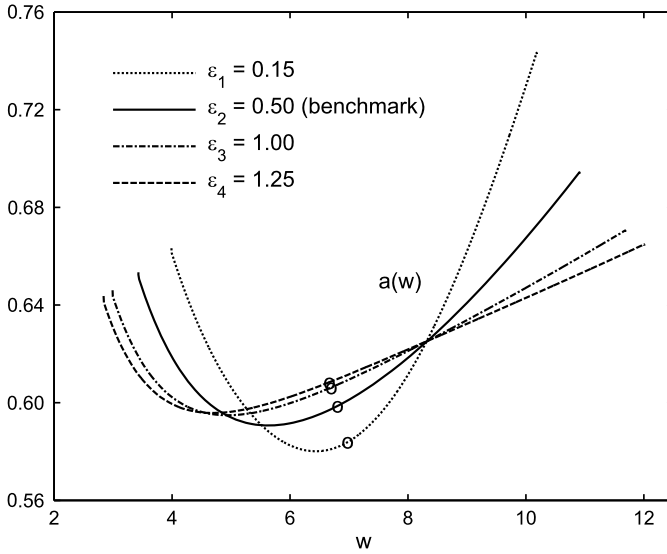


Fig. 3a. Portfolio share of the risky asset, for various substitution elasticities.

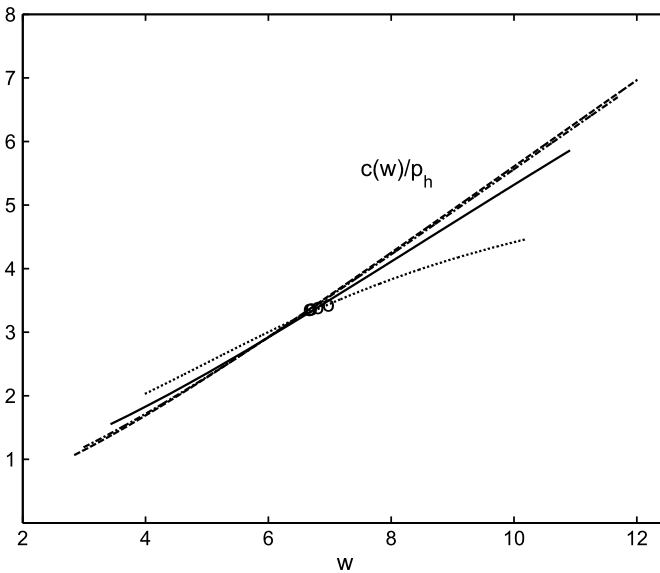


Fig. 3b. Expenditure ratio, nondurables/housing, for various substitution elasticities.

In each case  $\omega$  was adjusted to keep the average expenditure share for housing at 23%. In all these experiments the qualitative nature of the solution is as in the benchmark case: the value function is smooth and concave, the portfolio policy is U-shaped, and the policy function for nondurables is increasing and roughly linear in wealth. The results of some of these experiments are reported below.

For the elasticity of substitution, alternative values of  $\epsilon = 0.15, 1.0,$  and  $1.25$  were used. Fig. 3 shows the policy functions for these experiments. The U-shaped portfolio policy is flatter for

Table 3

For various substitution elasticities  $\varepsilon$ : thresholds ( $b$ ,  $B$ ), expected duration  $E[D]$ , average tenure in cross section  $\bar{T}$ , and changes for adjustments from  $B$  in housing, nondurables, and the portfolio share.

$\varepsilon$	$b$	$B$	$E[D]$	$\bar{T}$	adjustments from $B$		
					$\hat{H}/H$	$\hat{C}/C$	$\hat{a} - a$
0.15	4.0	10.2	16.0	11.4	1.44	1.12	-0.158
0.50	3.4	10.9	22.9	15.0	1.58	0.92	-0.095
1.00	3.0	11.7	29.8	18.0	1.72	0.87	-0.063
1.25	2.8	12.0	32.4	19.0	1.78	0.86	-0.056

higher elasticities, but the functions are quite similar except for the lowest elasticity,  $\varepsilon = 0.15$ , for which it displays more pronounced fluctuations. The approximately linear policy for nondurable consumption is steeper for higher elasticities, but the differences are small for the three higher elasticities. Only for  $\varepsilon = 0.15$  is the function significantly flatter. These results suggest why the elasticity of substitution has been difficult to estimate: within a broad range it has remarkably little effect on behavior.

Table 3 shows additional effects of changing the substitution elasticity. A higher elasticity allows the consumer to substitute more easily into nondurables as her wealth increases, reducing the incentive to pay the transaction cost associated with a housing adjustment. Thus, the inaction region gets wider as the elasticity of substitution increases:  $b$  falls and  $B$  rises. The wider inaction region leads to longer expected times between adjustments, with the expected duration rising from 16.0 to 32.4 years, and average tenure rising from 11.4 to 19.0 years. It also reduces the probability of a sequence of low returns sufficiently long and severe to induce a downward housing adjustment. Thus, the probability of an adjustment at the lower threshold (not displayed) falls from 0.14 to 0.07.

The last three columns of Table 3 show changes when a transaction is made at the upper threshold, where most adjustments occur. The increase in house value,  $\hat{H}/H$ , is larger for higher elasticities, increasing from 44% to 78% for the range here. This pattern is a straightforward result of the widening of the inaction region.

The change in nondurable consumption,  $\hat{C}/C$ , can be in either direction. Here the very low elasticity,  $\varepsilon = 0.15$ , leads to a 12% increase. For the higher elasticities, nondurable consumption falls by 8%, 13%, and 14%. Recall that when the intra- and intertemporal elasticities are the same, when  $\varepsilon = 1/\theta$ , preferences are additively separable between housing and nondurables. In this case (here it is  $\varepsilon = 1/3.5 = 0.286$ ), nondurable consumption is unchanged after a housing transaction,  $\hat{C}/C = 1$ . For lower values of  $\varepsilon$  there is an increase in nondurables at the time of an upward adjustment in housing, and for higher values of  $\varepsilon$  there is a decrease. Thus, for substitution elasticities exceeding  $1/\theta$  the consumer behaves like someone who is ‘house poor,’ even though she is not liquidity constrained, as that term suggests. As noted in Section 1, Martin [14] finds evidence for this type of behavior.

The change in the consumer’s portfolio when a transaction occurs simply reverses, in a single jump, the cumulative increase in the share of risky assets since the last housing adjustment. The change is larger for lower elasticities. For  $\varepsilon = 0.15$ , the consumer reduces her risky asset holdings by 15.8 percentage points, while for  $\varepsilon = 1.25$ , the reduction is only 5.6 percentage points.

The average ratio of total wealth to housing  $E[w]$  (not displayed) does not change much in these experiments, remaining at 7.0–7.1, and the long run growth rate  $g$  remains at 2.0%.

### 6.3. Sensitivity analysis: $\lambda$ , $\kappa$ , $\theta$

The transaction cost of  $\lambda = 0.08$  used in the benchmark calibration is modest, probably covering only the direct financial costs. Adding taxes, time costs, psychic costs, and so on, argues for a higher figure, and the model was simulated with  $\lambda = 0.12$ . Increasing the transaction cost has two effects. It increases the overall cost of housing, and it also makes adjustments less attractive. The first effect shifts the inaction region to the right and the second widens it at both ends. Here the second effect dominates, and an increase in  $\lambda$  widens the inaction region at both ends.

The increase in  $\lambda$  makes the portfolio swings in Fig. 1b wider, with the portfolio share in the risky asset adjusting by 12 percentage points when a larger house is purchased. It has almost no effect on the position or slope of nondurable policy function in Fig. 1c, however, instead simply widening its range at both ends. The average wealth-house ratio and average growth rate do not change much, but the expected duration between adjustments increases from  $E[D] = 22.9$  to 26.5 years, and the cross-sectional average for tenure increases from  $\bar{T} = 15.0$  to 16.6 years.

Moves are not always voluntary. To assess the impact of moves forced by geographic relocation and other factors, the hazard rate for exogenous moves was set at  $\kappa = 0.01$ . A higher hazard rate has the same two effects as a higher transaction cost: it increases the overall cost of housing and makes (voluntary) adjustments less attractive. Here the first effect dominates, and increasing the hazard rate from 0% to 1% produces a small increase in  $b$  and a larger one in  $B$ . The policy functions in Figs. 1b and 1c shift to the right with little change in their shapes. The average wealth-house ratio increases from  $E[w] = 7.0$  to 7.8, and the average growth rate increases to 2.3%. The biggest effects are on the expected duration between moves, which falls to  $E[D] = 18.2$  years, and the cross-sectional average for tenure, which falls to  $\bar{T} = 12.1$  years. The latter figure is not far from the empirical average of 11.3 years.

Finally, alternative values of  $\theta = 2.0$ , 2.7, and 5.0 for risk aversion were used. Changes in  $\theta$  have dramatic effects on the portfolio policy, with more risk tolerant consumers holding a larger share of risky assets. For  $\theta = 2$  the short sale constraint comes into play, constraining the consumer when she is near either transaction threshold. More risk tolerant consumers also display wider portfolio swings, and for  $\theta = 2$  the portfolio share in the risky asset adjusts by 14 percentage points when a larger house is purchased.

Reductions in  $\theta$  also increase nondurable consumption for any wealth-house ratio: the policy function in Fig. 1c shifts upward as  $\theta$  falls. Thus, reductions in  $\theta$  increase average income, since the riskier portfolio has a higher average rate of return, and also increase expenditures, through the effect on nondurables. The former dominates, and reductions in  $\theta$  increase the average growth rate, which rises to 4.1% for  $\theta = 2$ . This fact in turn leads to a shorter expected duration, only  $E[D] = 14.8$  years, and a lower average tenure in cross section, only  $\bar{T} = 8.7$  years.

### 6.4. Welfare cost

As noted above, housing is about 40% of total private capital, and the transaction cost for selling a house is 8%–10% (and perhaps more) of the value of the unit sold. Thus, the consumer's direct loss from the adjustment cost is clearly substantial. In addition, the consumer suffers a welfare loss from the distortion in her consumption mix between housing and nondurables.

The model can be used to calculate the total magnitude of these welfare costs. Specifically, it is easy to calculate the share of her current wealth the consumer would be willing to pay to move from the environment with the adjustment cost to a frictionless world (the economy in Section 3). This calculation is done for each wealth-house ratio  $w$  inside the inaction region, and



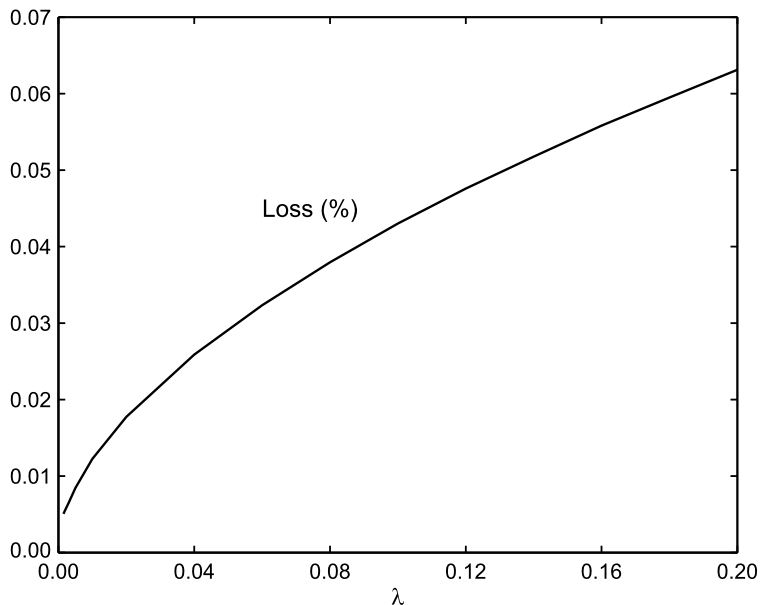


Fig. 4. Welfare loss from the transaction cost, as a share of initial wealth.

the resulting figures are averaged using the stationary distribution for that ratio. Fig. 4 displays the results of this exercise, for adjustment costs  $\lambda \in [0.0015, 0.20]$ , with the other parameters fixed at their benchmark values.

The loss is strongly concave near the origin. For the smallest transaction cost considered here,  $\lambda = 0.0015$ , the welfare cost is about 1/2% of wealth. For this small transaction cost, the consumer adjusts frequently—the average duration between moves is only 4.6 years. Thus, although the cost is small, it is paid frequently. At the benchmark value for the transaction cost,  $\lambda = 0.08$ , the welfare cost is 3.8% of total wealth. Note that in each case the costs are measured as shares of total wealth, which here represents both tangible and intangible assets.

The stylized nature of the model means that these welfare figures should be interpreted as rough estimates. Nevertheless, the model suggests that for the consumer, the welfare loss from the transaction cost is large. To the extent that the transaction cost represents transfer taxes or monopoly rents collected by real estate agents, the “loss” is simply a transfer from one party to another. To the extent that the cost is real, technologies like internet search capabilities that reduce it would produce substantial real savings.

### 7. The equity premium puzzle

A standard exercise in finance<sup>7</sup> uses the Euler equation

$$E_t \left[ \frac{U'(X_{t+s})}{U'(X_t)} e^{-\rho s} (1 + r_{t+s}^j) \right] = 1, \tag{12}$$

which hold for any asset  $j$ , to conclude that

<sup>7</sup> See Mankiw and Zeldes [12] for more detail.

$$\mu^j - r = \theta \text{Cov}\left(\frac{dX_t}{X_t}, r_t^j\right), \tag{13}$$

where  $X_t$  is total consumption,  $r_{t+s}^j$  is the instantaneous return on asset  $j$  at  $t + s$ ,  $\mu^j$  is the expected return on asset  $j$ ,  $r$  is the risk-free rate, and  $\theta$  is the coefficient of relative risk aversion. This is the equation commonly used to back out an estimate of the risk aversion parameter  $\theta$ , using data on consumption growth and asset returns.

The equity premium puzzle noted by Mehra and Prescott [15] is a puzzle because the covariance of consumption growth with asset returns is low, while the excess return on risky assets is high. Thus, a large value of  $\theta$  is needed to justify the excess return on the left side of (13). Much of the work attempting to explain this puzzle has involved constructing more sophisticated models of risk aversion. Most have had limited success. Thus, as Lucas [11] noted “we need to look beyond high estimates of risk aversion” to resolve it. Adjustment costs offer a possibility.

The relationship in (12) is derived in a frictionless model. Moreover, while it is usually labeled as a puzzle about the excessively high return on equity, it can as well be viewed as a puzzle about the excessive smoothness of consumption. If some components of consumption are costly to adjust, they will vary less than predicted by the frictionless model, and hence the covariance of consumption growth and asset returns will be lower. Thus, a transaction cost for housing offers a potential explanation for smooth consumption. Housing consumption is constant over long intervals, and for substitution elasticities  $\varepsilon < 1/\theta$  nondurable consumption is also smoother. The question then is quantitative: are these effects large enough to explain the puzzle? Using the model here we can calculate the magnitude of the error an econometrician would make if he estimated  $\theta$  using the (misspecified) frictionless model.

Let  $r_t^a = \mu dt + \sigma dz_t$  denote the instantaneous return on the model’s risky asset. First note that in the frictionless model of Section 3, total consumption expenditure is proportional to wealth, so

$$\frac{dX_t}{X_t} = \frac{dW_t}{W_t} = [r + (\mu - r)a^* - x^*] dt + \sigma a^* dz_t,$$

where  $a^* = (\mu - r)/\sigma^2\theta$  is the (constant) portfolio share in the risky asset and  $x^* = (p_h + c^*)h^*$  is the (constant) ratio of total consumption expenditure to wealth. The first term is not stochastic, so

$$\text{Cov}\left(\frac{dX_t}{X_t}, r_t^a\right) = \frac{1}{dt} E[(\sigma a^* dz_t)(\sigma dz_t)] = \sigma^2 a^* = (\mu - r)/\theta.$$

Thus, Eq. (13) is correctly specified, and the econometrician using it would obtain the correct estimate of  $\theta$  (neglecting sampling error).

Now suppose there is a transaction cost, and consider a consumer who is using the thresholds  $b, S, B$  and the policy functions  $c(w)$  and  $a(w)$ . To compute the covariance that would be obtained using long time series, we must average over wealth/house ratios inside the interval  $(b, B)$  using the stationary density and also take into account the discrete jumps that occur at the boundaries.

First consider expenditure growth inside the inaction region. If the consumer’s wealth is  $w_t$ , then her consumption expenditure is

$$X_t = p_h + c(w_t),$$

and the increment to her wealth is

$$dw_t = m(w_t) dt + a(w_t)w_t\sigma dz_t,$$

where

$$m(w_t) \equiv [r + (\mu - r)a(w_t)]w_t - [p_h + c(w_t)]$$

is the expected return on her portfolio less consumption expenditures. Thus, inside the inaction region expenditure growth is

$$\frac{dX_t}{X_t} = \frac{c'(w_t)}{p_h + c(w_t)} [m(w_t) dt + a(w_t)w_t\sigma dz_t].$$

As before the first term is not stochastic. Thus, averaging across wealth levels with the stationary distribution  $\psi(w)$ , we obtain

$$\text{Cov}\left(\frac{dX_t}{X_t}, r_t^a\right) = \sigma^2 \int_b^B \frac{c'(w)}{p_h + c(w)} a(w)w\psi(w) dw + J, \tag{14}$$

where  $J$  is the contribution of the jump terms.

Next consider jumps. In the benchmark calibration, total expenditure rises after a jump at  $B$  and falls after a jump at  $b$  (cf. Table 2). Since a jump at  $B$  occurs only if  $dz > 0$ , and a jump at  $b$  only if  $dz < 0$ , it follows that  $J \geq 0$ . That is, the jump terms can only add to the (positive) first term in (14). Thus, setting  $J = 0$  in (14) gives a lower bound on the covariance and an upper bound  $\hat{\theta}_B$  on the value  $\hat{\theta}$  that an econometrician using (13) would obtain.

For the benchmark calibration, with  $\theta = 3.5$ , the calculated bound is  $\hat{\theta}_B = 4.0$ . Changes in  $\lambda$ ,  $\kappa$ , and  $m$  have virtually no effect on this bound, and the error  $\hat{\theta}_B - \theta$  falls slightly for higher  $\theta$  values. A lower elasticity of substitution between housing and nondurables increases the size of the error, and for the very low elasticity  $\varepsilon = 0.15$  (and  $\theta = 3.5$ ) the calculated bound is  $\hat{\theta}_B = 5.7$ . Thus, while the effect is in the right direction it is too small to explain much of the equity premium puzzle.

Fig. 5 displays total expenditure as a function of wealth, for various scenarios. In each case  $\omega$  is calibrated to give housing an average share of 23% in total consumption. The dashed line is for the frictionless consumer, who chooses a constant ratio  $c^*$  of nondurables to housing and a constant ratio  $h^*$  of housing to wealth. The substitution elasticity does not matter for this consumer. The other three curves describe consumers who face a transaction cost of 8% and have elasticities as indicated. Each of these consumers has housing wealth fixed at unity, and the curves are displayed for wealth  $w$  inside the inaction region for that consumer. Even for the very low elasticity,  $\varepsilon = 0.15$ , the transaction cost has a modest effect on total expenditure.

## 8. Conclusions

Adjustment costs for housing are large, and it is not surprising that they affect other consumer decisions. In the model studied here they produce substantial effects on portfolios, with the consumer making large adjustments as the ratio of her total wealth to housing changes. The swings are wide in the benchmark calibration, and get even wider with a higher adjustment cost, a lower elasticity between housing and nondurables, or higher risk tolerance (a higher intertemporal elasticity). Thus, the model suggests that the ratio of housing wealth to total wealth should be useful in explaining household portfolios. It also suggests that the welfare loss from the transaction cost is large.

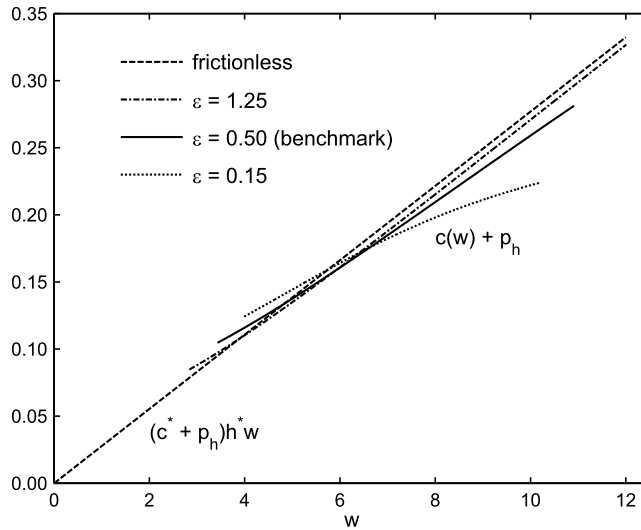


Fig. 5. Total expenditure, for various substitution elasticities and in the frictionless economy.

Adjustment costs for housing have surprisingly little impact on consumption of nondurables, however, and hence they provide little help in resolving the equity premium puzzle. Increasing the expenditure share for ‘housing,’ by including transportation, furniture, and other consumption components that are closely linked to housing, would produce larger effects, but it would then be difficult to justify a low substitution elasticity between the broader ‘housing’ good and the remaining set of nondurables.

It is also interesting that, over a wide range of moderate and high values, the elasticity of substitution between housing and nondurables has so little effect on consumption behavior. This fact may explain why that parameter has been difficult to estimate, in the sense that empirical studies have reported such a wide range of point estimates.

The model here excludes several important features: labor income, life cycle considerations, and house price risk. Extending the model to include them is an interesting avenue for further research.

## Appendix A

The estimate of the intratemporal substitution elasticity uses the simple regression equation appropriate for CES utility when there is no transaction cost,

$$\ln(x_h/(1-x_h)) = a_0 + (1-\varepsilon)\ln p_h,$$

where  $x_h$  and  $1-x_h$  are the expenditure shares for housing and nondurables. The expenditure shares, from Tables 21–24 of the Consumer Expenditure Survey (including Utilities, but excluding Household Operation, Housekeeping Supplies and Household Furnishings), are for 2003–2004. The price data, from Aten [1, Tables 3 and 4], are for 2003. The relative price of housing is computed as a ratio of the price of housing to the price of all other goods. The latter is calculated by subtracting the housing price index, weighted by Aten’s expenditure weight for housing (42%), and renormalizing.

The estimate excludes Anchorage, which has an expenditure share for housing that is 3.4–4.0 standard deviations from the sample mean, depending on what is included in the expenditure share. Including Anchorage reduces the estimate to  $\varepsilon = 0.29$ .

The data used in the regression are available at  
<http://www.bea.gov/papers/pdf/InterareaPriceLevels.pdf>,  
<http://www.bls.gov/cex/csxmsa.htm# y0304>.

## References

- [1] B.H. Aten, Report on interarea price levels, working paper 2005-11, Bureau of Economic Analysis, November 2005.
- [2] R. Chetty, A. Szeidl, Consumption commitments and risk preferences, *Quart. J. Econ.* 122 (2007) 831–877.
- [3] M.A. Davis, J. Heathcote, Housing and the business cycle, *Int. Econ. Rev.* 46 (2005) 751–784.
- [4] K. Dunn, K. Singleton, Modeling the term structure of interest rates under non-separable utility and durability of goods, *J. Finan. Econ.* 17 (1986) 27–55.
- [5] M.S. Eichenbaum, L.P. Hansen, Estimating models with intertemporal substitution using aggregate time series data, *J. Bus. Econ. Statist.* 8 (1990) 53–69.
- [6] M. Flavin, S. Nakagawa, A model of housing in the presence of adjustment costs: A structural interpretation of habit persistence, *Amer. Econ. Rev.* 98 (2008) 474–495.
- [7] S. Grossman, G. Laroque, Asset pricing and optimal portfolio choice in the presence of illiquid durable consumption good, *Econometrica* 58 (1990) 25–51.
- [8] E.A. Hanushek, J.M. Quigley, What is the price elasticity of housing demand? *Rev. Econ. Statist.* 62 (1980) 449–454.
- [9] N. Kocherlakota, The equity premium: It's still a puzzle, *J. Econ. Lit.* 34 (1996) 42–71.
- [10] C. Kullman, S. Siegel, Real estate and its role in household portfolio choice, working paper, Business School, University of Washington, November 2005.
- [11] R.E. Lucas Jr., Macroeconomic priorities, *Amer. Econ. Rev.* 93 (2003) 1–14.
- [12] N.G. Mankiw, S.P. Zeldes, The consumption of stockholders and nonstockholders, *J. Finan. Econ.* 29 (1991) 97–112.
- [13] D.A. Marshall, N.G. Parekh, Can costs of consumption adjustment explain asset pricing puzzles? *J. Finance* 54 (1999) 623–654.
- [14] R.F. Martin, Consumption, durable goods, and transaction costs, International Finance Discussion Paper No. 756, Federal Reserve Board, Washington, DC, 2003.
- [15] R. Mehra, E.C. Prescott, The equity premium: A puzzle, *J. Monet. Econ.* 15 (1985) 145–161.
- [16] M. Piazzesi, M. Schneider, S. Tuzel, Housing, consumption and asset pricing, *J. Finan. Econ.* 83 (2007) 531–569.
- [17] J.P. Schachter, J.J. Kuenzi, Seasonality of moves and the duration and tenure of residence: 1996, Population Division working paper 69, US Census Bureau, Washington, DC, December 2002.
- [18] S. Siegel, Consumption-based asset pricing: Durable goods, adjustment costs, and aggregation, working paper, Graduate School of Business, Columbia University, November 2005.
- [19] L.B. Smith, K.T. Rosen, G. Fallis, Recent developments in economic models of housing markets, *J. Econ. Lit.* 26 (1988) 29–64.
- [20] N.L. Stokey, *The Economics of Inaction*, Princeton Univ. Press, Princeton, NJ, 2008.