ELSEVIER

Journal of Econometrics 97 (2000) 117–144

JOURNAL OF Econometrics

www.elsevier.nl/locate/econbase

The demand for risky assets: Sample selection and household portfolios

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Received 1 May 1996; received in revised form 1 July 1999; accepted 1 October 1999

Abstract

We estimate a microeconomic model of household asset demands that allows for the fact that households typically have zero holdings of most assets. The adjustments for non-observed heterogeneity generalize methods developed by Dubin and McFadden (1984. Econometrica 52, 345–362). Simulating our model using a random sample of US households, we examine distributional and demographic effects on macroeconomic demands for money, stocks and bonds. © 2000 Elsevier Science S.A. All rights reserved.

JEL classification: C35; E41; G11

Keywords: Discrete-continuous model; Consumer finances; Monitoring costs; Incomplete portfolios; Logit model

1. Introduction

This paper applies discrete-continuous econometric techniques to microeconomic data on household portfolio composition in order to estimate individual asset demands from the 1983 Survey of Consumer Finances (SCF). Since

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PII: S0304-4076(99)00069-X

the data set we study includes a random sample of the US population, by simulating our model, we obtain estimates of economy-wide money, stock and bond demand elasticities that fully allow for the non-linearities in asset demand generated by the combination of a discrete choice of asset portfolio with a continuous choice of quantities demanded for given portfolio composition.

Early research using cross-sectional, household-level data to investigate portfolio choices includes Uhler and Cragg (1971), Friend and Blume (1975) and King and Leape (1984). Recently, research in this field has become very active and several studies directly complement our own. Ioannides (1992) utilizes the panel data structure of the 1983 and 1986 SCFs, focusing particularly on changes in individual portfolios between these two dates. Hochguertel and van Soest (1996) examine how housing wealth affects total liquid financial wealth,[1] and Poterba and Samwick (1997) use several waves of the SCF but focus exclusively on age versus cohort effects. Hochguertel et al. (1997) examine tax effects, Guiso et al. (1996) consider the relation between labor income risk and portfolio choice, and Heaton and Lucas (1997) study the effect of entrepreneurial risk on portfolio composition. Agell and Edin (1990) estimate a model resembling that of King and Leape on Swedish data, stressing tax effects in particular. Bertaut (1998) estimates bivariate probits on the 1983 and 1989 SCFs to investigate what determines whether households directly own stocks.[2] All the above studies, however, adopt reduced-form specifications and do not link discrete and continuous choices through utility maximization as is done in the present paper.

To cope with the fact that a large number of individuals hold only a subset of the assets available, we make the plausible assumption that households face monitoring costs, either in terms of time or money, of holding various portfolios. Such an assumption is consistent with the observation that hardly anyone holds, say, $1's worth of stocks. Past attempts at modeling incomplete portfolios have employed the assumption of non-negativity constraints that prevent investors from short selling particular assets as they would ideally choose to do. See, for example, Auerbach and King (1983). The assumption of fixed portfolio monitoring costs adopted in the present study provides a simple and flexible alternative. Similar assumptions might well prove useful in coping with zero consumption levels in studies of deterministic consumer demand.[3]

[1] Flavin and Yamashita (1998) argue that housing wealth cannot be easily adjusted, but that the amount of housing wealth is likely to affect the choice between bond and stock holdings.

[2] Related papers which use household data to parameterize portfolio simulation models include Bertaut and Haliassos (1997) and Haliassos and Hassapis (1998).

[3] There is a large econometric literature on consumption demand with zero consumption of certain commodities. An early paper which uses censored regression models is Tobin (1958). See also Wales and Woodland (1983), Hanemann (1984), Lee and Pitt (1986) and Blundell and Meghir (1987).

In the presence of fixed monitoring costs, one may decompose a household's optimal portfolio choice into (i) the choice of which assets to include in the portfolio and, (ii) the decision of how much of those assets to hold. The first stage involves comparing the maximum amount of utility attainable given different incomplete portfolios, while the second stage may be viewed as a 'continuous' decision as to how much of each asset or liability to demand. Just as in standard consumer theory, Roy's identity implies demand functions for risky assets that are ratios of partial derivatives of the indirect utility function. Sandmo (1977) seems to have been the first to apply this technique in portfolio theory, but the present paper is the first to combine such an approach with discrete-continuous econometric methods.

The techniques applied in this paper, and in particular the selectivity adjustments, may be viewed as an extension of the methods developed for different purposes by Dubin and McFadden (1984) (building on previous work by Heckman (1978)). Dubin and McFadden use discrete-continuous econometric methods to examine household consumption of different forms of energy. While Dubin and McFadden only estimate a single demand function using limited information procedures, our study estimates the whole system simultaneously, imposing the cross-equation restrictions implied by the theoretical model. Extending Dubin and McFadden's selectivity adjustments to a multivariate system is non-trivial and may be regarded as one of the contributions of this paper.

The SCF provides detailed information on the asset holdings, income and demographic characteristics of a sample of 4262 US families. To estimate the model, we aggregate asset and liability holdings into stocks (S), bonds (B) and money (M). These categories are more highly aggregated than one might wish but including more assets is difficult given the computational requirements of the estimation. Agents are all assumed to hold some quantity of money so investors may choose to hold any one of four different sets of assets (SBM, SM, BM, M). Households in the SM category comprised less than 1% of the sample and were not included in the study since it would not be feasible to obtain estimates of the parameters relating to this regime with any precision.

Our model sheds light on two sets of issues. The first is the impact of demographic effects and non-traded assets on financial markets.[4] Our study allows an explicit role for such factors by permitting the parameters of the indirect utility and demand equations to depend linearly on dummy variables describing demographics and on continuous variables such as housing equity, mortgage debt, etc. Second, our model provides evidence on the validity of the standard aggregation assumptions frequently made in financial economics.

[4] The importance of non-marketed or illiquid assets for capital market equilibrium was stressed by Mayers (1972), Grossman and Laroque (1990) and Svensson and Werner (1993). Jones (1995) estimates the demand for home mortgage debt.

Commonly adopted assumptions such as Hyperbolic Absolute Risk Aversion (HARA) preferences[5] or normally distributed rates of return imply individual and aggregate asset demands that are linear functions of initial wealth. To assess the importance of wealth distribution for aggregate portfolio demand, one may examine the extent to which individual demand functions are non-linear in wealth.[6]

We simulate our model for the actual dataset and for various perturbations to wealth distribution and demographics. The simulations allow for endogenous regime switching as households not only change their asset demands but also switch from holding one basket of assets to another. Our general finding is that some forms of distributional shocks are very significant. For example, redistributing wealth from poor to rich significantly raises the demand for bonds. A proportionate rise in the wealth of all households, however, raises the demand for stocks. Some demographic changes are also important for aggregate asset demands. For example, a shift from married to single household heads raises the demand for bonds at the expense of that for stocks.

The paper is arranged as follows. Section 2 reviews our basic model of portfolio choice and describes its econometric implementation. Section 3 gives a brief account of the data used. Section 4 presents the results and reports on some tests of model specification. Section 5 concludes.

2. The parametric model

2.1. Portfolio choice and Roy's identity

We begin by deriving the version of Roy's identity that forms the basis for our econometric model. Our approach follows that taken by Sandmo (1977) and Dalal (1983) in studying the comparative statics of risky asset demands. Suppose that an agent faces the following portfolio optimization decision:

$$\max_{D_n} \left\{ EU\left(\sum_{n=0}^{N} D_n(1 + r_n) \right) \text{ such that } \sum_{n=0}^{N} D_n = W \right\},$$

where D_n is the holding of asset n, r_n is the rate of return on asset n, and W is current wealth. Assume that the asset subscripted zero yields a safe return. One

[5] HARA utility functions are of the form: $U(x) = (A + x)^B$ for fixed parameters A and B.

[6] Stoker (1986) discusses the link between non-linearities and income distribution effects in aggregate equations. Lewbel (1996) and Jorgenson et al. (1982) examine the impact of aggregation effects in aggregate commodity demands.

may parameterize the rates of return as: $1 + r_0 \equiv \theta_0$, and $1 + r_n \equiv \theta_n + \zeta_n$ for $n = 1, \ldots, N$, where $\theta_n \equiv E(1 + r_n)$ and ζ_n is a random variable with zero mean.[7]

The first-order conditions to this problem are:

$$E[U'(W^*_{+1})(1 + r_n)] = \mu \quad \text{for } n = 0,1,\ldots,N \quad \text{and} \quad \sum_{n=0}^{N} D_n = W, \tag{1}$$

where μ is a Lagrange multiplier and W^*_{+1} is the optimal, random future wealth. For given returns, one may regard the first-order conditions as implicit functions of μ and the asset demands D_n. Applying the implicit function theorem, one may solve for the optimal demands, D_n, and substitute $W^*_{+1} \equiv \sum D_n(1 + r_n)$ into $EU(.)$ to derive an indirect utility function $V = V(\theta, W)$.[8] From the Envelope Theorem:

$$\frac{\partial V}{\partial \theta_n} = E[U'(W^*_{+1})\theta_0]\frac{D_n}{\theta_0} \quad \text{and} \quad \frac{\partial V}{\partial W} = \mu = E[U'(W^*_{+1})\theta_0], \tag{2}$$

where the last equality follows from the first-order condition for the safe asset. Combining equations in (2) gives

$$\frac{\partial V}{\partial \theta_n}\left(\frac{\partial V}{\partial W}\right)^{-1} = \frac{D_n}{\theta_0} \quad n = 1, \ldots, N. \tag{3}$$

The relation in (3) is the counterpart to Roy's identity in deterministic consumer theory.

2.2. Modeling zero holdings

A notable feature of household portfolios is the fact that only a small proportion of households possess non-zero holdings of available asset categories, even if the latter are highly aggregated. It seems reasonable to presume that this lack of diversification reflects frictional costs of various kinds.[9] Among such

[7] The approach here described in a static setting may be generalized to a fully dynamic portfolio problem. In that case, the value functions described below become the maximized lifetime utility of an agent facing a multiperiod savings and portfolio problem. Since such value functions still depend on mean rates of return over the next period, the partial differential equations obtained below continue to hold.

[8] Parameterizing returns as we do is useful not because the θ_n parameters explicitly enter the econometric model but because it enables us to derive restrictions that must hold between demand and value functions.

[9] As noted in the Introduction, an alternative explanation of zero holdings is that agents face binding short-selling constraints as in Auerbach and King (1983). It appears unlikely, however, that the majority of households (and especially those with low wealth levels) have optimal, unconstrained portfolios which involve short selling stocks. It therefore seems to us worth exploring the alternative hypothesis that the large number of zero holdings reflects costs of investing.

costs, one may distinguish between (i) those (either fixed or proportional) incurred at the time when assets are bought or sold, and (ii) those (denoted 'monitoring costs') associated with holding particular asset combinations. Haliassos and Bertaut (1995) discuss the latter type of costs and suggest they may explain why large numbers of households do not directly own stocks.

Theoretical studies of investors facing type (i) costs by Grossman and Laroque (1990), Dumas and Luciano (1991), and Davis and Norman (1990) show that such agents do not change their illiquid asset holdings if wealth changes by small amounts but adjust when wealth hits particular trigger levels. There is, however, no presumption with type (i) costs that zero holdings will be common. Type (ii) (monitoring-) costs appear a quite likely explanation of zero holdings. If they contain a fixed element, then such costs could also explain why low-wealth investors are particularly likely to have zero holdings of broad asset classes. For these reasons we explicitly model type (ii) costs in our empirical implementation below. Type (i) costs are implicitly included in that we analyze households' portfolio choices over liquid assets, conditioning on holdings of illiquid assets such as housing or mortgage debt for which transactions costs are large.

To derive our model, let V_i^j denote the value function of household i when it only invests in a subset j of the total set of assets available. Here, $j \in sbm, bm, m$ according to whether the household is in regime SBM, BM, or M, respectively. One can then express the household's unconstrained value function, V_i, as

$$V_i = \max\{V_i^{sbm}, V_i^{bm}, V_i^{m}\}. \tag{4}$$

The value function, $V_i^j \equiv V_i^j(\theta, W_i, X_i)$, depends on household wealth, W_i, and a vector of variables describing the individual's demographic characteristics, X_i. Suppose that V_i^j may be written as

$$V_i^j = v_i^j + e_i^j \equiv H_x^j(\theta)\ X_i'\beta^j + H_w^j(\theta)(W_i + w_0^j)^{1-\rho} + X_i'\alpha^j + e_i^j \tag{5}$$

for $j = sbm, bm, m$. Here, H_x^r and H_w^r are functions of the mean asset returns,[10] and the monitoring cost is $X_i\alpha^j + e_i^j$. w_0^j is a constant which equals minus the minimum amount of financial wealth for which Eq. (5) is well-defined. We assume that w_0^j is a linear function of the mean asset returns: $w_0^j = \gamma^{j\prime}\theta$. α^j, β^j, and γ^j are regime-specific parameters and e_i^j is the residual component of the monitoring cost which varies across individuals with identical observable characteristics.[11] We allow the parameters (apart from ρ) to vary from portfolio to portfolio. If the indirect utility functions had been derived from a single

[10] These functions are not entirely arbitrary since the demand functions must satisfy Slutsky symmetry, additivity and homogeneity restrictions as in standard deterministic consumer theory.

[11] This amounts to assuming that part of the utility function is independent of wealth and mean asset returns. A monitoring cost is a simple interpretation of this term but it may also reflect the fact that, for whatever reason, the household prefers to avoid certain portfolios.

underlying utility function, we might expect to find restrictions across the parameters of the different portfolios, but we do not impose such restrictions in the present study.[12,13]

The functional form in Eq. (5) is well-defined for positive wealth and represents a monotonic transformation of the Price Independent Generalized Linear (PIGL) class of functional forms investigated by Muellbauer (1975) and (1976) in the context of consumer demand. The PIGL functional form in consumer theory may be written as $V = F\{(Y^{1-\rho} - a(p)^{1-\rho})/(b(p)^{1-\rho} - a(p)^{1-\rho})\}$ where Y is total expenditure, p is a vector of prices, $b(.)$ and $a(.)$ are homogeneous and concave functions, and F is an arbitrary monotone function. The so-called Almost Ideal Demand System of Deaton and Muellbauer (1980) is a special case of this class of functions. For a survey of these and other functional forms commonly used in the context of consumer theory, see Blundell (1988).

Inverting the value function in (5) to obtain initial wealth as a function of utility and mean returns yields the agent's expenditure function, i.e., the minimum cost of attaining a particular level of utility for given asset return distributions. Lewbel and Perraudin (1995) show that separability of the expenditure function in prices is closely linked to mutual fund separation.[14] The PIGL form in (5) implies an expenditure function which is separable in functionals of the distribution of asset returns and, as we shall see below, yields mutual fund separation of order three.

For each conditional indirect utility function, V^j, one may use Roy's identity, as in Eq. (3), to derive conditional asset demand functions. Taking partial derivatives of Eq. (5) and substituting into Roy's identity yields

$$\begin{aligned} D^j_{ni} &= D^j_n(\theta, W_i, X_i) \\ &= \theta_0 \gamma^j_n + \frac{\theta_0 \partial H^j_x / \partial \theta_n}{(1-\rho) H^j_w} X'_i \beta^j (W_i + w^j_0)^\rho + \frac{\theta_0 \partial H^j_x / \partial \theta_n}{(1-\rho) H^j_w} (W_i + w^j_0), \end{aligned}$$

where D^j_{ni} is the demand for asset n (for $n = 0, \ldots, N_j$) of individual i holding asset combination j. Normalizing parameters which are not identified, we may write the stock (s) and bond (b) demand functions in the different regimes (*sbm*

[12] It may be seen as a drawback of the present approach that it is not more parsimonious in the parameterization it allows, but cross-sectional estimations of portfolio demands are typically conducted on large data sets (like the SCF used here), so parsimony is less of a concern.

[13] The indirect utility function in (5) may be taken to a power without changing the results, in which case (5) generalizes HARA by introducing a second power parameter, ρ. As Cass and Stiglitz (1970) show, HARA direct utility implies indirect utility functions that are themselves HARA in form. When ρ is zero, it will turn out that demand functions are linear as they are for HARA preferences (see Cass and Stiglitz, 1970).

[14] If mutual fund separation holds, asset demands satisfy a rank restriction in that agents with different initial wealths wish to hold different combinations of a small number of mutual funds.

and bm) as

$$D_{si}^{sbm} = \gamma_s^{sbm} + X_i'\beta^{sbm}(W_i + w_0^{sbm})^\rho + h_{sw}^{sbm} W_i \tag{6}$$

$$D_{bi}^{sbm} = \gamma_b^{sbm} + \pi^b X_i'\beta^{sbm}(W_i + w_0^{sbm})^\rho + h_{bw}^{sbm} W_i$$

$$D_{bi}^{bm} = \gamma_b^{bm} + X_i'\beta^{bm}(W_i + w_0^{bm})^\rho + h_{bw}^{bm}\, W_i. \tag{7}$$

Since there is no price variation in our cross-sectional dataset,[15] we treat h_{nw}^j as fixed parameters to be estimated.

To implement the discrete choice model empirically, note first that an individual will select portfolio r if and only if: $v^r - v^j \geqslant e^j - e^r$ for all possible combinations of the available assets, $j = sbm, bm, m$. Thus, if we regard the e^j's as random variables distributed across the population, and normalize the unidentified constants H_x^r to one, it follows that

$$\begin{aligned} P_i^j &\equiv \Pr\{\text{household with wealth } W_i \text{ and characteristics } X_i \\ &\qquad \text{chooses portfolio } j\} \\ &= \Pr\ \{v_i^j - v_i^k \geqslant e_i^k - e_i^j \text{ for all } k \neq j\} \\ &= \Pr\ \{X_i'(\beta^j + \alpha^j - \beta^k - \alpha^k) + H_{\mathrm{w}}^j(W_i + w_0^j)^{1-\rho} \\ &\qquad - H_{\mathrm{w}}^k(W_i + w_0^k)^{1-\rho} \geqslant e_i^j - e_i^k \text{ for all } k \neq j\} \end{aligned} \tag{8}$$

for all $j = sbm, bm, m$, where we treat H_{w}^j and $(\alpha^j + \beta^j)$, $j = sbm, bm, m$ as parameters to be estimated.[16]

Eq. (8) is known as the strict utility model. We assume that the e^j are iid, independent of wealth and demographic variables, and possess Type I extreme value distributions.[17] In this case, the strict utility model is equivalent to a multinomial logit.[18]

The logistic formulation does not permit some portfolios to be closer substitutes than others. In this respect, the use of multivariate probit techniques might appear preferable. However, we decided not to use probit models since this would have increased the computational demands of the model markedly. King and Leape (1984), Agell and Edin (1990), and Ioannides (1992) all estimate less aggregated portfolio models but restrict themselves to using binary probit models for estimating the probability of holding a specific portfolio.

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[15] Apart from possible differences in taxes.

[16] Since the β^j parameters are identified from the continuous demand part of the model, it would be simple to estimate the actual α^j parameters, but our interest is not focused on the parameter value per se.

[17] Basic references for such models are Maddala (1983) and McFadden (1984).

[18] McFadden (1973) shows that the assumption of iid Type I extreme valued e^j is necessary and sufficient for the probabilities in the strict utility model to be logit, i.e., of the form $P^j = [\exp(v^j)]/[\sum_k \exp(v^k)]$.

2.3. Endogenous selection

Suppose that the vector of demographic variables takes the form $X_i \equiv (Z_i, U_i)$ where Z_i is a $(K-1)$-dimensional vector of observable demographic characteristics and U_i is a scalar demographic variable not observable to the econometrician.[19] Furthermore, decompose the parameter vector into sub-vectors corresponding to observed and unobserved demographic characteristics as $\alpha^j = (\alpha^j_{\rm o}, \alpha^j_{\rm u})$ and $\beta^j = (\beta^j_{\rm o}, \beta^j_{\rm u})$. The indirect utility function of a household in regime j may be written as:

$$V^j_i = Z'_i(\alpha^j_{\rm o} + \beta^j_{\rm o}) + H^j_{\rm w}(W_i + w^j_0)^{1-\rho} + u^j_i, \tag{9}$$

where $u^j_i \equiv (\alpha^j_{\rm u} + \beta^j_{\rm u})U_i + e^j_i$, and e^j is defined as in the previous subsection. We now adopt the following assumption:

Assumption. Suppose that u^j for $j = 1, 2, \dots, J$ are independent, extreme-valued random variables satisfying: $\mathrm{E}(U_i \,|\, u^{sbm}_i, u^{bm}_i, u^m_i) = \sum_{j=sbm,bm,m} \lambda^j u^j_i$, where the λ^j are constant parameters.

By an argument in Dubin and McFadden (1984), the expectation of the unobserved demographic conditional on the chosen portfolio of assets being j, is proportional to[20]

$$\begin{aligned} \mathrm{E}_j\{U_i\} &\equiv \mathrm{E}\{U_i \,|\, j = \text{chosen portfolio}\} \\ &= -\lambda^j \frac{\log P^j_i}{(1-P^j_i)} + \sum_{k=sbm,bm,m} \lambda^k \frac{P^k_i \log P^k_i}{(1-P^k_i)}, \end{aligned} \tag{10}$$

where P^j_i is the logit probability that household i holds portfolio j.

Now, adding the unobserved demographic term to the demand function derived in the previous subsection, we obtain portfolio-j specific demand equation

$$D^j_{ni} = \gamma^j_b + X'_i\beta^j(W_i + w^j_0)^\rho + h^j_{bw}W_i + U_i\alpha^j_{\rm u}(W + w^j_0)^\rho, \tag{11}$$

which, with an obvious definition of the error term gives our final form

$$D^j_{ni} = \gamma^j_b + X'_i\beta^j(W_i + w^j_0)^\rho + h^j_{bw}W_i\alpha^j_{\rm u}\mathrm{E}_j\{U_i\}(W + w^j_0)^\rho + v^j_n. \tag{12}$$

D^j_n is identical to the demand with no unobserved heterogeneity, except for the addition of a parameterized adjustment term, $\alpha^j_{\rm u}\mathrm{E}_j\{U_i\}(W + w^j_0)^\rho$, plus an error term.[21] This model corresponds to the approach that Dubin and McFadden

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[19] One may easily extend the argument to include a vector of unobserved demographics but this would make no difference to the estimation.

[20] The factor of proportionality is not identified and is here normalized to unity.

[21] To identify the model, we set $\alpha^{sbm}_u = -1$ in the estimation.

(1984) refer to as the 'Conditional Expectation Correction Method'. The adjustment terms in the demand equations introduce a large number of cross-equation restrictions between the discrete and continuous parts of the model.

2.4. Implementation

We assume that the error terms in the demand systems, v_n, are independently distributed across households, but correlated across different asset demands for a given household. Our specification (see (11)) implies that error terms are heteroskedastic. Examination of the residuals from preliminary estimations indeed suggested pronounced heteroskedasticity, with the spread of the errors apparently proportional to liquid wealth, W. We, therefore, divided the estimation equations for the asset demands by $(1+W)$ to achieve homoskedasticity. We found that inclusion of a constant such as unity was necessary since, otherwise, households with liquid wealth close to zero received excessive weight and the algorithm failed to converge.

We define $v_{sb} = (v_s^{sbm}, v_b^{sbm})$ and $v_b = (v_b^{bm})$, and assume that v_{sb} is bivariate normal with zero means and covariance matrix Σ_{SB} while v_b is an independent normal random variable with a zero mean and scalar variance Σ_B. Finally, define 1_j for $j = sbm, bm$ to be functions that equal unity if the household in question holds the jth combination of assets.

The likelihood function for the complete model for each individual household is then:[22]

$$\left[1_{sbm}\frac{\exp(v^{sbm}-v^m)}{\exp(v^{sbm}-v^m)+\exp(v^{bm}-v^m)+1}\;\frac{1}{\Sigma_{sb}{}^{1/2}}\exp\left(-\frac{1}{2}v_{sb}'\Sigma_{sb}^{-1}v_{sb}\right)\right]$$
$$+\left[1_{bm}\frac{\exp(v^{bm}-v^m)}{\exp(v^{sbm}-v^m)+\exp(v^{sbm}-v^m)+1}\;\frac{1}{\Sigma_b^{1/2}}\exp\left(-\frac{1}{2}\frac{v_b^2}{\Sigma_b}\right)\right]$$
$$+\left[(1-1_{sbm}-1_{bm})\frac{1}{\exp(v^{sbm}-v^m)+\exp(v^{bm}-v^m)+1}\right] \tag{13}$$

where $v^j \equiv Z_i'(\alpha_o^j+\beta_o^j)+H_w^j(W_i+w_0^j)^{1-\rho}$ and the v_k are defined as in Eq. (12). We estimate the total discrete-continuous model, including the 'Dubin-McFadden correction terms', simultaneously by substituting the parametric expressions for the v^j and the v_k into Eq. (13).

As we argued above, households cannot instantaneously adjust holdings of such illiquid assets as human capital or the value of the family home. We, therefore, model households' portfolio choice as the allocation of liquid wealth among a small number of marketed assets, given their holdings of illiquid or

[22] We omit inconsequential constants.

non-marketed assets.[23] The illiquid asset holdings (including human capital, property value and mortgage debt) were introduced into the estimating equations in the same way as the demographic variables.

The assumption implicit in this approach that holdings of non-traded or illiquid assets are exogenous as far as the estimation is concerned, is quite strong. The error terms in our model in part reflect unobserved demographics which could possibly influence choices that investors have made in prior periods which result in their current holdings of house equity, mortgage debt, etc. If the influence were important, our approach would induce bias in our estimates, particularly of the non-traded asset parameters. Browning and Meghir (1991) estimate conditional commodity demand systems and comment on the assumptions involved.

3. The data

We estimated the model using cross-sectional data drawn from the 1983 Federal Reserve Survey of Consumer Finances (SCF). The SCF includes both a random sample of 3,824 US families and a special additional sample of 438 high-income individuals selected from tax returns. The inclusion of this special high-income group makes the dataset well-suited for examining the demand for assets such as stocks which are held by only a small proportion of the population. Of the larger, random sample, we dropped 159 observations which had many missing variables. The sample contained some clear outliers. After experiencing significant convergence problems when these were included in the sample, we chose to restrict our analysis to households for which liquid wealth was less than one million dollars.[24] Our estimating sample (after leaving out the extremely small number of households that only held stocks and money) was 3353 observations.

The SCF contains much information about households' assets and liabilities as well as detailed data on demographic characteristics. The large number of zero holdings for different asset types made it advisable to work with highly aggregated asset categories. We therefore supposed that individual investment decisions could be reduced at any one moment to the allocation of liquid wealth among stocks, bonds and money.

Aggregation of individual assets into these three broad categories required that we be explicit about what factors influenced portfolio choice. (In principle,

[23] In this respect, our demand functions can be considered as 'short-run' demand functions conditioned upon the 'quasi-fixed' portfolios of property, etc. This approach parallels the notion of quasi-fixed inputs, such as the capital stock, in producer theory (see Nadiri, 1982).

[24] This was not particularly restrictive since liquid wealth includes just direct holdings of stocks, bonds and money and is much less than total net worth.

our dual approach to portfolio decisions is consistent with a range of possible motives for holding different portfolios.) We choose to think of the underlying utility function as depending on the total random monetary return (as described in Section 2).[25] Our focus is, therefore, on the riskiness of different assets and we aggregate assets that we perceive as having similar risk characteristics. Stocks are taken to equal traded equities, bonds are defined as the sum of savings bonds, government securities and corporate bonds and money is represented by sight deposits plus savings accounts. Liquid wealth is the sum of money, bond, as stock holdings as we define them.

Table 1 shows the proportions of investors with different demographic characteristics who held various possible combinations of assets. The table also gives the proportions of the basic random sample and of the high-income sample with particular characteristics. It is immediately apparent from the table that systematic relationships exist between demographics characteristics and portfolio composition. For example, households which own stocks tend to have household heads who are white, male, well-educated and in professional or administrative employment. The attitudes of respondents to risk and liquidity also appear to be important, with households who report aversion to risk and a liking for liquid investments apparently less likely to hold stocks. Meanwhile, the high income sample, all but 11 of which hold all three assets, is overwhelmingly composed of households whose heads are white, educated, married with a marked preference for risky, illiquid, high return investments.

4. Results

4.1. Value function parameters

Table 2 presents estimates from the discrete choice part of the model.[26] A crucial parameter is the non-linearity parameter, ρ. This appears in the first row of Table 2 and is estimated to be 1.09. The estimate differs in a statistically significant way from the value of unity which would imply linear demand functions. We investigate the economic significance of this degree of non-linearity below. The parameters, w_0^j, that capture the minimum allowable financial wealth converged towards zero, but the model did not actually converge when this parameter was included. Given that this parameter seems to be badly identified, it was set to zero in the estimations reported.

[25] An alternative might be to base portfolio selection on the liquidity services that households derive from asset holdings.

[26] The estimates are based on the model that includes selectivity adjustments in the demand functions. We also estimated a model without selectivity adjustments, obtaining broadly similar results.

Table 1
Demographic factors and portfolio choice. Descriptive statistics[a]

Variable		Basic sample				High income
		SBM	*BM*	*M*	Total	
Proportion	Proportion in sample	0.24	0.52	0.23	100.00	0.02
Age	Average age of head (yrs)	49	47	48	47	55
Race	Hshld head white	0.23	0.46	0.20	0.88	0.99
	Hshld head black,hisp.,other	0.01	0.07	0.04	0.12	0.01
Marital Status	Married	0.18	0.35	0.13	0.66	0.91
	Not married	0.06	0.17	0.11	0.34	0.09
Education	Up to high school, no diploma	0.02	0.11	0.10	0.23	0.01
	High school diploma	0.06	0.18	0.07	0.31	0.03
	Some college education	0.05	0.09	0.04	0.17	0.12
	College education	0.12	0.14	0.03	0.28	0.84
Occupation	Professional or technical	0.06	0.09	0.03	0.17	0.30
	Manager, self-employ., farmer	0.09	0.11	0.03	0.23	0.66
	Other	0.10	0.33	0.18	0.61	0.04
Household size	One	0.04	0.11	0.08	0.22	0.07
	Two	0.09	0.16	0.06	0.31	0.44
	Three	0.04	0.10	0.04	0.18	0.20
	Four or more	0.07	0.16	0.06	0.29	0.29
Sex of head	Male	0.20	0.41	0.17	0.78	0.97
	Female	0.04	0.11	0.07	0.22	0.03
Risk	Willing to take substantial risks	0.02	0.03	0.01	0.06	0.09
	Willing to take above avg. risks	0.04	0.05	0.02	0.11	0.21
	Willing to take average risks	0.10	0.21	0.08	0.38	0.19
	Not willing to take risks	0.08	0.23	0.13	0.44	0.51
Liquidity	Prefer illiquid-high yield	0.03	0.06	0.02	0.11	0.07
	Prefer less liquid-above avg. return	0.08	0.12	0.04	0.25	0.10
	Prefer quite liquid-average return	0.06	0.17	0.07	0.30	0.05
	Prefer very liquid	0.07	0.17	0.11	0.34	0.79
House equity	Avg. $ value times 10,000	6.31	3.87	2.53	4.14	3.74
Mortgage debt	Avg. $ value times 10,000	3.53	1.74	0.85	1.96	8.77
Wage income	Avg. $ value times 10,000	3.96	2.43	1.05	2.47	10.49
Stocks	Avg. $ value times 10,000	5.51	0.00	0.00	1.32	10.55
Bonds	Avg. $ value times 10,000	4.39	1.65	0.00	1.91	13.22
Money	Avg. $ value times 10,000	2.53	0.96	0.41	1.21	8.19
Liquid assets	Avg. $ value times 10,000	12.43	2.61	0.41	4.44	31.96

[a]Note: Columns in the table show percentages of households which hold stocks, bonds and money (*SBM*), bonds and money (*BM*), money alone (*M*), and all households. Entries in the table represent percentages of households in the category at the head of each column having the characteristic corresponding to the row. Entries in the lower part of the table are dollar amounts and are given in units of 10,000.

Table 2
Parameters of the discrete choice models

Variable	Description	Param.	Std.Er.	Param.	Std.Er.
ρ	The power parameter on wealth	1.09	0.02		
		Stock–bond		Bond	
Age	Age of head scaled by mean age (i.v.)	– 3.14	0.54	– 1.03	0.36
Race	Hshld head white (d.)	– 0.20	0.22	– 0.17	0.14
	Hshld head black,hisp.,other (o.d.)	—	—	—	—
Marital status	Married (d.)	0.29	0.28	0.09	0.19
	Not married (o.d.)	—	—	—	—
Education	Up to high school, no diploma (d.)	– 0.96	0.25	– 0.73	0.17
	High school diploma (d.)	– 0.29	0.21	– 0.32	0.16
	Some college education (d.)	– 0.30	0.21	– 0.40	0.16
	College education (o.d.)	—	—	—	—
Occupation	Professional or technical (d.)	– 0.31	0.22	– 0.19	0.16
	Managerial, self-employed, farmers (d.)	– 0.31	0.18	– 0.22	0.13
	Other (o.d.)	—	—	—	—
Household size	One (d.)	– 0.66	0.28	– 0.65	0.19
	Two (d.)	– 0.13	0.18	– 0.17	0.13
	Three (d.)	– 0.14	0.19	– 0.21	0.14
	Four or more (o.d.)	—	—	—	—
Sex of head	Male (d.)	– 0.59	0.24	– 0.38	0.16
	Female (o.d.)	—	—	—	—
Risk	Willing to take substantial risks (d.)	0.22	0.27	0.04	0.20
	Willing to take above avg. risks (d.)	0.60	0.24	0.34	0.19
	Willing to take average risks (d.)	0.12	0.16	0.07	0.11
	Not willing to take risks (o.d.)	—	—	—	—
Liquidity	Prefer illiquid-high yield (d.)	0.62	0.24	0.23	0.18
	Prefer less liquid-above avg. return (d.)	0.46	0.19	0.16	0.14
	Prefer quite liquid-average return (d.)	0.19	0.17	0.05	0.12
	Prefer very liquid (o.d.)	—	—	—	—
House equity	Dollar value scaled by 10,000	– 0.01	0.01	– 0.00	0.01
Mortgage debt	Dollar value scaled by 10,000	0.00	0.01	– 0.00	0.01
Wage income	Dollar value scaled by 10,000	0.13	0.04	0.14	0.04
Constant	Constant term	17.37	3.67	8.69	1.68
Wealth	Slope term on $W^{1-\rho}$	– 14.48	3.64	– 5.69	1.62

The estimates in Table 2 suggest that a number of demographic variables significantly affect portfolio composition.[27] Household size and the sex of the household head are important in that single individuals and households with male household heads are more likely to hold only cash. Educational level also

[27] The coefficients which appear in the table, e.g., for the stock–bond–money regime, represent $\alpha^{sbm} + \beta^{sbm} - (\alpha^m + \beta^m)$ in the notation of the theoretical model, except for the parameter in the bottom row which equals $H_w^{sbm} - H_w^m$.

appears to play a role since high school drop-outs are less likely and college graduates more likely to hold both stocks and bonds. Age appears strongly significant in that families with older heads seem to be less likely to have non-zero bond holdings and even less likely to have non-zero equity holdings. This result should be interpreted with caution, since age effects cannot be separated from cohort effects in a single cross-section. Poterba and Samwick (1997) document significant cohort effects using several waves of the SCF.

Of the variables which describe households' attitudes to different investments, those reflecting attitudes to liquidity affect portfolio composition in an intuitive fashion. Households which prefer illiquid high-yield investments are significantly more likely to hold stocks, while those which prefer less liquid investments are also more likely to hold stocks although to a lesser degree. The variables measuring attitudes towards risk yield less intuitive results. The estimates suggest that households which expressed willingness to 'take substantial financial risks' are not significantly different from individuals who claim to be 'not willing to take any financial risks'. On the other hand, individuals who 'take above average financial risks', are significantly more likely to holds stocks.

Variables which do not have a significant effect on portfolio composition include race, marital status and occupation, although in the case of occupation there is some evidence that households with heads in professional, technical, or managerial occupations or who are self-employed[28] are less likely to hold stocks. The fact that these variables have little impact may appear surprising, but one should recall that this is a marginal effect, holding education and risk- and liquidity-attitudes constant.

Of the continuous variables, wage income significantly influences portfolio composition in that households with higher income are more likely to hold bonds or stocks. Total liquid wealth also has a very strong influence on the probabilities of holding bonds and stocks. We do not find that holdings of house equity or mortgage debt affect portfolio composition.

4.2. Parameters of the conditional demand functions

Table 3 contains estimates of the conditional demand function parameters, excluding those of the selectivity adjustment terms. To interpret the results, recall that our theoretical model implies that if a variable has a marginal effect on stock holdings in the stock–bond regime of \$1, then the impact on bond holdings is $\$\pi^b$ which is estimated to be −1.63 (see the 3rd to last row of the table). Thus, a demographic effect which increases stock holdings, generates a 63% larger decrease in bond holdings and, hence, an increase in cash holdings.

[28] These categories were consolidated based on initial exploratory estimations, which showed similar coefficients for, e.g., heads in professional and technical occupations.

Table 3
Parameters from the continuous demand systems

Variable	Description	Stock–bond Param.	Stock–bond Std.Er.	Bond Param.	Bond Std.Er.
		Stock			
Age	Age of head scaled by mean age (i.v.)	– 45.89	11.13	11.01	9.60
Race	Hshld head white (d.)	– 2.33	3.43	0.09	3.20
	Hshld head black,hisp.,other (o.d.)	—	—	—	—
Marital status	Married (d.)	1.15	3.16	– 0.97	3.68
	Not married (o.d.)	—	—	—	—
Education	Up to high school, no diploma (d.)	– 3.79	2.80	– 0.12	3.33
	High school diploma (d.)	0.57	2.03	4.16	2.14
	Some college education (d.)	0.68	1.84	1.85	2.19
	College education (o.d.)	—	—	—	—
Occupation	Professional or technical (d.)	– 3.93	1.92	– 0.83	2.27
	Managerial, self-employed, farmers (d.)	– 2.03	1.63	– 5.49	1.94
	Other (o.d.)	—	—	—	—
Household size	One (d.)	2.10	3.52	– 8.71	3.97
	Two (d.)	2.52	1.67	0.05	1.99
	Three (d.)	0.41	1.87	– 4.43	2.19
	Four or more (o.d.)	—	—	—	—
Sex of head	Male (d.)	1.49	2.79	– 8.21	3.05
	Female (o.d.)	—	—	—	—
Risk	Willing to take substantial risks (d.)	0.68	2.36	2.37	2.89
	Willing to take above avg. risks (d.)	1.45	1.84	– 0.96	2.72
	Willing to take average risks (d.)	– 2.29	1.86	– 0.02	1.71
	Not willing to take risks (o.d.)	—	—	—	—
Liquidity	Prefer illiquid-high yield (d.)	– 1.64	2.24	6.32	2.64
	Prefer less liquid-above avg. return (d.)	0.13	2.03	– 1.76	2.29
	Prefer quite liquid-average return (d.)	– 2.09	2.10	0.87	2.03
	Prefer very liquid (o.d.)	—	—	—	—
House equity	Dollar value scaled by 10,000	0.01	0.04	– 0.03	0.05
Mortgage debt	Dollar value scaled by 10,000	0.02	0.08	– 0.15	0.11
Wage income	Dollar value scaled by 10,000	– 0.13	0.08	0.13	0.09
Constant	(Multiplies W^{ρ})	53.98	17.93	19.01	36.18
Wealth	Slope term on W	16.54	18.16	16.70	34.95
Constant	Constant	– 0.59	3.21	0.00	0.92
		Bond			
Constant	Proportionality term π^b	– 1.63	0.44		
Wealth	Slope term on W	108.20	34.86		
Constant	Constant	3.80	3.12		

The estimates suggest that asset demands are significantly influenced by age in that older households hold less stocks and more bonds. As noted above, this age effect may in fact reflect changes between cohorts. Occupation also has a significant impact. Households whose heads are in professional or technical occupations demand significantly less stocks, while managers and self-employed demand significantly less bonds in the bond regime. Attitudes towards risk and liquidity do not seem to have strong effects on the demand for risky assets in the stock–bond–money regime. In the bond regime, on the other hand, we observe a large and significant estimate of bond demand for individuals who prefer illiquid high-yield assets. Holdings of housing equity and mortgage debt do not have a significant impact on asset demands.

A high level of wage income may imply higher bond holdings in both the stock–bond–money regime and the bond–money regime, but in neither regime is the coefficient significant at the 5% level. Not surprisingly, the amount of liquid wealth has a strong impact on asset holdings. Since wealth changes in the model have non-linear effects which vary across demographic groups, they are best illustrated by simulations which we report below.

4.3. Selectivity adjustment

In Table 4, we report parameter estimates for the self-selection part of the model. Three out of four parameters are strongly significant, indicating that self-selection is an important feature of asset demand.[29] The λ^j parameters carry large t-values, indicating that unobserved heterogeneity is important and that unobserved heterogeneity has a strong impact on stock demand in the stock–bond–money regime.[30] The impact of unobserved heterogeneity on bond demand in the bond–money regime operates through the parameter α_{u}^{bm}. This point estimate is larger than the normalized value of $\alpha_{\mathrm{u}}^{sbm}$ of unity, but is not precisely estimated.

Table 4
Selectivity adjustment parameters

	Parameter	t-Stat.
λ^{sbm}	− 15.67	7.24
λ^{bm}	6.06	6.49
λ^{m}	− 47.07	24.37
α_u^{bm}	− 1.21	0.70

[29] The parameters are not identified non-parametrically and it is therefore possible that the parameter estimates reflect other mis-specification of the model.

[30] Recall that the coefficient β_{u}^{sbm} which measures the impact of the unobserved heterogeneity on stock demand is normalized to −1.

Table 5
Demographic factors and portfolio regime[a]

Variable	Description	Regime SBM Δ	BM Δ	M Δ
Age	Up 4 yr from mean (47 yr)	– 2.18	1.90	0.28
Race	Hshld head white	—	—	—
	Hshld head black hisp. other	1.14	– 0.59	– 0.55
Marital status	Married	—	—	—
	Not married	– 5.28	4.60	0.67
Education	Up to high school and no diploma	– 8.78	6.80	1.98
	High school diploma	– 1.48	1.62	– 0.14
	Some college education	—	—	—
	College education	– 2.02	2.97	– 0.96
Occupation of head	Professional or technical	—	—	—
	Manager self-employed farmers	0.76	– 0.80	0.04
	Other	3.35	– 2.62	– 0.74
Household size	One	– 1.78	– 1.11	2.89
	Two	0.84	– 1.36	0.52
	Three	1.22	– 1.82	0.60
	Four or more	—	—	—
Sex of head	Male	—	—	—
	Female	5.93	– 4.66	– 1.28
Risk	Willing to take substantial risks	3.25	– 3.13	– 0.12
	Willing to take above avg. risks	5.83	– 4.80	– 1.04
	Willing to take average risks	—	—	—
	Not willing to take risks	– 1.22	0.89	0.33
Liquidity	Prefer illiquid-high yield	6.61	– 5.74	– 0.88
	Prefer less liquid-above avg return	4.22	– 3.65	– 0.57
	Prefer quite liquid-average return	—	—	—
	Prefer very liquid	– 3.61	3.18	0.43
House owner	Zero house equity and mortgage	0.04	0.04	– 0.08
Wage income	Double sample average	– 0.13	1.08	– 0.95

[a]Note: Entries represent changes in regime probabilities multiplied by 100. Dashes indicate baseline categories. The baseline household has four or more members and has a white married household head with some college education, a professional occupation, is willing to take average risks, requires average liquidity holds house equity and mortgage debt equal to the sample averages and is of average age.

4.4. Simulations

To obtain a more transparent interpretation of the parameter estimates, in Tables 5 and 6, we report the impact of changes in dummy variables and in age, wage income, etc. on the probabilities of holding each portfolio, and on the demand for individual assets conditional on portfolio choice. Each row of the tables shows the predicted effects of changing the variable from a baseline case.

Table 6
Demographic factors and asset demands[a]

Variable	Description	Discrete-contin. model *SBM* Stock Δ	Bond Δ	*BM* Bond Δ	Reduced-form model *SBM* Stock Δ	Bond Δ	*BM* Bond Δ
Age	Up 4 yr from mean (47yr)	– 9.31	15.19	2.24	– 12.04	12.04	2.31
Race	Hshld head white	—	—	—	—	—	—
	Hshld head black hisp. other	11.81	– 19.26	– 0.44	25.53	– 24.65	– 2.73
Marital status	Married	—	—	—	—	—	—
	Not married	– 5.85	9.54	4.94	– 10.57	2.99	5.57
Education	Up to high school and no diploma	– 22.67	36.98	– 9.99	1.75	29.76	2.89
	High school diploma	– 0.55	0.90	11.73	7.74	– 4.95	10.31
	Some college education	—	—	—	—	—	—
	College education	– 3.44	5.61	– 9.40	– 16.71	– 10.21	– 18.88
Occupation of head	Professional or technical	—	—	—	—	—	—
	Manager, self-employed, farmers	9.65	– 15.74	– 23.62	– 0.98	– 13.25	– 22.33
	Other	19.93	– 32.50	4.23	9.39	– 29.71	2.78
Household size	One	10.64	– 17.35	– 44.17	34.19	– 4.07	– 27.33
	Two	12.79	– 20.87	0.26	19.44	– 14.34	5.88
	Three	2.07	– 3.37	– 22.48	12.74	1.50	– 17.48
	Four or more	—	—	—	—	—	—
Sex of head	Male	—	—	—	—	—	—
	Female	– 7.58	12.37	41.67	– 12.94	18.36	38.32
Risk	Willing to take substantial risks	15.05	– 24.55	12.12	24.96	– 15.01	16.04
	Willing to take above avg. risks	18.96	– 30.92	– 4.73	15.99	– 21.87	– 5.72
	Willing to take average risks	—	—	—	—	—	—
	Not willing to take risks	11.61	– 18.94	0.12	26.25	– 22.13	1.03
Liquidity	Prefer illiquid-high yield	2.30	– 3.75	27.64	8.61	4.23	26.20
	Prefer less liquid-above avg return	11.30	– 18.43	– 13.35	1.96	– 9.80	– 14.80
	Prefer quite liquid-average return	—	—	—	—	—	—
	Prefer very liquid	10.63	– 17.33	– 4.43	8.82	– 25.22	– 4.59
House owner	Zero house equity and mortgage	– 0.31	0.51	2.06	– 0.93	0.35	1.34
Wage income	Double sample average	– 1.62	2.65	1.60	– 2.42	– 0.25	0.25

[a]Note: Entries represent changes and percentage changes in asset demands expressed in units of $100. Dashes indicate baseline categories. The baseline household has four or more members and has a white married household head with some college education a professional occupation is willing to take average risks and requires average liquidity who holds household equity and mortgage debt equal to the sample averages and is of average age.

The baseline household contains four or more members, has a white, married household head with some college and a professional occupation, and is willing to take average risk while requiring average liquidity. House equity, mortgage debt, the wage income and age of the household head are set equal to the sample averages.

The economically most important effects on the probability of being in different regimes are age, marital status, education, sex of household head and risk and liquidity attitudes. If a household head is four years older, the likelihood of being in the *SBM* regime falls by 2.18%, with corresponding increases in *BM* and *M* probabilities of 1.90% and 0.28%. An unmarried household is a substantial 5.28% less likely to be in the *SBM* regime and 4.60% more likely to be in the *BM* regime. Female household heads are 5.93% more likely to be in the *SBM* regime, with the *BM* and *M* regime probabilities being 4.66% and 1.28% lower.

Those with some college education are the most likely to be in the *SBM* regime. Households whose heads have no high school diploma are between about 9% less likely to be in the *SBM* regime. Such households are 7% more likely to hold *BM* portfolios and 2% more likely to hold just money. Risk attitudes significantly affect regime probabilities in that those willing to take above average risks or greater are 3% to 6% more likely to be in the *SBM* regime than those unwilling to take any risks. Liquidity attitudes are even more important in that households preferring illiquid or less liquid investments with higher returns are 4% to 7% more likely to hold all three asset categories than households which favor very liquid investments.

Table 6 reports the impact on conditional asset demands of changes in the characteristics of the reference household described above. Changes in demand are expressed in units of $100. The left hand three columns give the changes in demands forecast by the discrete-continuous model while columns 4–6 show the changes implied by reduced form asset demands (explained more fully below).

The results based on our own discrete-continuous model suggest that a large number of factors can substantially affect asset demands conditional on being in one or other regime. Some variables such as race, occupation and household size which did not influence regime probabilities in an economically significant way do greatly affect continuous demands. In particular, those not in professional or managerial occupations are likely to hold $2000 more stocks and $3200 less bonds in the *SBM* regime. Households with only one member hold $1700 less in bonds in the *SBM* regime and a surprisingly $4200 less in bonds in the *BM* regime.

Risk attitudes are important in that households which are willing to take above average risks or greater hold $1500 to $1900 more in stocks and $2500 to $3100 less in bonds than the reference household in the *SBM* regime. Education is also influential since households in the *SBM* regime whose heads have no high school diploma hold $3700 more in bonds and $2300 less in stocks.

Columns 4–6 of Table 6 report simulations based on reduced form regressions in which the demand functions are estimated alone.[31] This permits us to see to what extent our simulations are influenced by the cross-equation constraints introduced by the selectivity adjustment and the restriction across parameters in the demand functions of the *SBM* regime. The signs and broad magnitudes of the effects in columns 4–6 of the table match up to a considerable degree with those in columns 1–3. As one might imagine, the effects which appear the most similar between the reduced form models and the discrete-continuous are those like age which are associated with parameters bearing low standard errors.

It is interesting to note that the effects of risk and liquidity attitudes appear even more ‘non-monotonic’ in the reduced form model. For example, categories of household which express preferences for high risk–high return investments and those which prefer to take no risks are both likely to hold more stocks than households willing to take average risks and the magnitudes of the effects are greater than in the discrete-continuous model.

4.5. Macroeconomic simulations

Since the SCF contains a randomly selected sample of the US population (for information on how the sample was constructed, see Avery and Elliehausen (1986)), we were able to simulate our model in such a way as to mimic the macroeconomic effects of changes in the demographic or wealth profile of the population as a whole. To do this, we calculated the aggregate asset demands by (i) for each household in the random sample, calculating the fitted regime-specific demands weighted by the fitted regime probabilities, (ii) sum these weighted household-level demands across the entire random sample. Having accomplished this for the random sample, we altered demographic or other characteristics of the random sample, recalculated the aggregate asset demands and then worked out the per capital change (measured in units of $100) in the aggregate demands.

The results of these calculations are contained in Table 7. The first four rows in the table show the percentage impacts on aggregate demands and fractions of the portfolio holding different asset combinations of changes in the population liquid wealth profile. A 10% proportionate rise in each household’s liquid wealth leads to a 1.3% increase in the fraction of the population in the *SBM* regime, of which 0.8% comes from a fall in the percentage of households holding

[31] We estimated these regressions by maximizing the part of the likelihood for the demand equations without imposing cross equation restrictions between the different demand functions in the *SBM* regime. We set ρ to 1.09 (the value we obtained in our estimation of the full model) rather than estimating it freely and omitted the selectivity terms.

Table 7
Macroeconomic simulations[a]

No.	Simulation	Changes in Stock demand	Bond demand	Money demand	*SBM* Prob.	*BM* Prob.	*M* Prob.
1.	10% proportional rise in wealth	3.50	4.72	– 48.22	1.31	– 0.51	– 0.81
2.	Lump sum rise in wealth	7.92	20.74	– 28.66	1.97	14.14	– 16.10
3.	Increase log wealth dispersion	10.60	2.39	– 12.98	– 4.06	– 9.33	13.39
4.	Switch wealth from poor to rich	4.22	14.41	– 18.63	0.69	15.21	– 15.90
5.	Increase age by 10%	– 18.03	21.83	– 3.80	– 1.85	1.22	0.63
6.	Increase age by 5% of mean age	– 7.20	11.42	– 4.21	– 0.72	0.42	0.30
7.	Raise educational level 1 category	1.33	3.47	– 4.80	0.42	2.24	– 2.65
8.	40% of households shrink in size	1.00	0.46	– 1.46	0.06	– 0.72	0.66
9.	40% hshlds. shift up occupation	– 5.68	11.10	– 5.42	– 0.27	– 0.30	0.57
10.	40% hshlds. shift married to single	– 7.51	7.54	– 0.03	– 1.76	1.67	0.09
11.	40% hshlds. shift male to female	– 2.13	16.12	– 13.99	1.76	– 1.43	– 0.33
12.	Fall in risk aversion by 1 category	– 4.44	12.82	– 8.38	0.36	0.30	– 0.66
13.	Fall in liquidity pref. by 1 category	– 4.56	14.44	– 9.88	0.54	– 0.18	– 0.36
14.	20% rise in house equity and mortgage	– 0.05	2.89	– 2.83	– 0.09	0.06	0.03
15.	20% rise in wage	– 0.05	2.89	– 2.83	– 0.09	0.06	0.03
16.	Raise educational level 1 category	– 12.77	27.81	– 15.04	– 0.03	2.95	– 2.92
17.	40% hshlds. shift married to single	– 4.03	– 20.42	24.45	– 5.85	5.13	0.72

[a]Note: entries are per capita changes in demands in units of $100 and changes in regime probabilities in percent. Changes in demands are 'total' in that they include the effects of regime switches by individual households. Notes on Simulations: 1. All wealths rise 10%. 2. All wealths rise by 10% of mean wealth. 3. The absolute deviation of log wealth from mean log wealth is increased by 10%. 4. 10% of wealth of those with wealth less than the mean is redistributed in equal lump sum amounts to those with wealth grater than the mean. 5. Ages of household heads rise by 10% of amount they exceed 16 y. 6. Ages of household head increase by 5% of mean age. 7. Educational categories increase by 1. 8. 40% of households shrink in size by 1 category. 9. 40% of households shift to higher status profession by 1 category. 10. 40% of household heads if male shift to female. 11. 40% of household heads if married shift to single. 12. Risk aversion falls by 1 category. 13. Illiquidity aversion falls by 1 category. 14. House equity and mortgage debt rises by 10%. 15. Wage rise by 10%. 16. Like 7 except risk and liquidity attitudes and occupations generated endogenously. 17. Like 10 except risk and liquidity attitudes and occupations generated endogenously.

just money and 0.5% from households which own bonds and money. Interestingly, the effect of the regime switches by households and the intra-regime substitutions lead to roughly equal increases in stocks and bonds at the expense of aggregate money holdings.

A lump-sum (rather than proportionate) increase in liquid wealth for all households in the population leads to substitution from money to bonds much more than to stocks, as one may see from the second row of Table 7. This suggests that to obtain large increases in stock demand, liquid wealth growth must be concentrated on the rich. This impression is confirmed by the two simulations we perform for increases in liquid wealth inequality (rows 3 and 4 of the table). Raising the dispersion of log wealth (which significantly raises the wealth of the very rich) boosts stock demand substantially whereas just switching wealth from those below to those above the mean wealth leads to more marked increases in aggregate bond demand.

Rows 5 to 15 of Table 7 contain simulations of shifts in population demographics. Age has a major impact (although as already noted, this is probably in large part a cohort effect). Raising educational levels has surprisingly little impact on aggregate asset demands although it does lead quite a few households to switch from the *M* to the *BM* regime. Changes in profession have a large impact on asset demands with shifts towards higher profession status[32] leading to a fall in stock demand and an increase in bond demand. In this case, most of the effect is intra-regime in that the fractions of the population holding different asset combinations are little changed. By contrast, the substitutions from stocks to bonds that occurs when more households have single and female rather than married and male household heads seems to operate mostly through regime switches. Lastly, rows 14 and 15 of Table 7 show that falls in risk aversion or liquidity preference, although they induce households to switch into the *SBM* regime, increase bond rather than stock demand, largely at the expense of demand for money.

The last two rows of Table 7 report the results of simulations in which we allow demographic changes (in this case increases in educational level and shifts from married to single household heads) to influence asset demands not just directly but also through changes they induce in other variables. The motivation for this is the fact that some other variables such as risk and liquidity attitudes may be regarded as endogenous, themselves being determined by the demographic characteristics of the household in question. We therefore estimated multinomial logit models to determine the 'endogenous' risk attitude, liquidity attitude and occupation dummies. The independent variables in these logit regressions were taken to be the educational level and marital status dummies and a constant. The logits were then used to forecast the dependent variables for each household in the sample. We then simulated the effect of educational level

[32] 'Professional and technical' is regarded as the highest and 'Other' as the lowest status profession.

and marital status on aggregate asset demand by (i) altering the 'exogenous' educational status and marital status dummies as they appear directly in the regime probabilities and the demand functions, and (ii) changing the forecast values of the 'endogenous' dummies by changing the 'exogenous' dummies in the logit forecasting model.

The results underline how effects may be altered by looking at 'total' rather than 'marginal' effects of demographic shifts. A rise in educational level now actually leads to a fall in stock demand because it generates not just a positive direct effect on stock demand but also negative indirect effects by pushing households into more professional occupational status and leading them to have less risk averse and less illiquidity averse attitudes. These latter indirect effects boost bond demand as we have already seen. The impact of a shift from married to single household head is again significantly different if one looks at the total rather than the marginal effect. In the total effect simulation, bond demand falls significantly rather than rising.

4.6. Specification tests

We spent some considerable time investigating the specification of the model. Thus, we examined if the parameters were multicolinear through a series of estimations where we varied the set of included demographic variables. We found that the variables in the tables above, seemed not to display excessive variation when other demographic variables were left out. In a previous version, we included a squared term in age, but we found the coefficient to this term to be highly correlated with other variables leading to estimates which were sensitive to specification. We therefore left out this term (with some regret since a non-linearity term in age appears desirable).

We experimented with different forms of heteroskedasticity correction. This proved to be quite a sink for CPU time, since with more complicated forms (especially if a parameter was included in the heteroskedasticity term), it was extremely difficult to obtain convergence. We therefore decided to adopt the simple form $1 + W$. With this adjustment, the fitted residuals from the demand equations showed no obvious dependence on wealth when plotted and we concluded that further attempts to reduce heteroskedasticity were probably not worthwhile.

To check our distributional assumption, we calculated the skewness and kurtosis coefficients of the three sets of demand function residuals (the stock and bond demands from the SBM regime and the bond demand from the BM regime). For these three cases, the skewness coefficients were -0.64, 0.31 and 0.53, respectively, and the kurtosis coefficients were 4.88, 2.75, and 3.13, respectively. Given the large number of observations, we could reject normality at conventional significance levels using powerful tests such as those suggested by D'Agostino et al. (1990). However, the kurtosis and skewness coefficients are not such as to imply that the data exhibited gross deviations from normality.

Finally, we split the sample into those with wealth less than and greater than the median level and performed a Chow test to see if the estimated coefficients differed across high and low wealth samples. The model clearly flunked this test. The estimates were, however, not very well determined on the sub-samples and we did not attempt to construct a larger more complicated model with further non-linearity to pass this hurdle. (Recall that all other work in this area, to our knowledge, estimates reduced form *linear* demand functions.) Rather we suggest further exploration of models of portfolio demand utilizing parsimonious parametric functions, consistent with utility optimization, as an open area for further research.

5. Conclusion

This paper has employed discrete-continuous econometric methods, allowing for sample selectivity, to model US households' portfolio decisions. Our major conclusions are:

1. Asset Engel curves are non-linear, generating significant increases in demands for stocks and bonds as wealth rises. In a simulation designed to replicate the impact on the portfolio choices of the US population, we find that a 10% proportional rise in wealth of all households leads to a 24% and a 25% increase in stock and bond demand, respectively. A 10% rise in the absolute dispersion of log wealth leads to a 11% rise in stock demand but only a 2% rise in the demand for bonds.
2. Household characteristics apart from wealth have important effects on portfolio decisions. For individual households, family size, sex of household head, education and attitudes to risk and liquidity significantly influence the basket of assets households end up possessing. Race, marital status, and occupation are less important.
3. Simulations of the impact of changes in household characteristics on the asset demands of the population as a whole suggest that shifts from married to single household heads, changes in educational level, occupation, liquidity and risk preference can lead to big percentage changes in bond demands, often with offsetting changes in both stock and money demands.
4. Selectivity adjustments are highly statistically significant. This suggests that the results of past studies which employed discrete-continuous methods but did not allow for selectivity may be hard to interpret.

Acknowledgements

We thank Yannis Ioannides, Jonathan Leape, Richard Blundell and three anonymous referees, as well as many seminar participants. The views expressed herein are solely those of the authors and do not necessarily reflect the views of the Bank of England, the Federal Reserve Bank of Kansas City or the Federal Reserve System.

Appendix A. Data: The survey questions

1. *Age of head*: Question: age by date of birth, at last birthday of head of household. All missing values imputed. (Range: 16–60).
2. *Race of household*: Variable is observed race of survey respondent. All missing values imputed using census data and other sources. Categories: (i) Caucasian except hispanic; (ii) black except hispanic; (iii) hispanic; (iv) American indian or Alaskan native; (v) Asian or pacific islander; (vi) NA.
3. *Marital status*: Question: marital status. Responses: (i) married (includes couples living together); (ii) separated; (iii) divorced; (iv) widowed; (v) never married; (v) married but spouse not present.
4. *Education of household head*: Question: education of household head. Responses: (i) 0–8 grades; (ii) 9–12 grades, no high school diploma; (iii) high school diploma or equivalent, no college; (iv) some college, no college degree; (v) college degree.
5. *Occupation of head*: Question: occupation of household head. Response: (i) professional, technical and kindred workers; (ii) managers and administrators (except farm); (iii) self-employed managers; (iv) sales, clerical and kindred workers; (v) craftsmen, protective service, and kindred workers; (vi) operatives, laborers, and service workers; (vii) farmers and farm managers; (viii) miscellaneous (mbrs. of armed service, housewives, students, never worked and other occupations).
6. *Household size*: Question: total number of persons in household. Responses: (i) 1; (ii) 2; (iii) 3; (iv) 4; (v) 5; (vi) 6; (vii) 7; (viii) 8; (ix) 9; (x) 11; (xi) 13.
7. *Sex of household head*: Question: sex of head of household. Responses: (i) male; (ii) female.
8. *Risk*: Question: which of the following statements on this card comes closest to the amount of financial risk you are willing to take when you save or make investments? Responses: (i) take substantial financial risks expecting to earn substantial returns; (ii) take above average financial risks expecting to earn above average returns; (iii) take average financial risks expecting to earn average returns; (iv) not willing to take any financial risks; (v) do not know, NA .
9. *Liquidity*: Question: which of the following statements on this card comes closest to how you feel about tying up your money in investments for long periods of time? Responses: (i) tie up money for a long period of time to earn substantial returns; (ii) tie up money for an intermediate period of time to earn above average returns; (iii) tie up money for a short period of time to earn average returns; (iv) not willing to tie up money at all; (v) do not know (vi) NA.

10. *Value of home*: Current value of home.
11. *House mortgage*: Sum of first and second mortgages on household's primary residence.

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