Estimating Nonseparable Preference Specifications for Asset Market Participants.

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Abstract

This paper uses panel data to estimate preference specifications that are nonseparable in consumption and leisure. Because the econometric analysis uses panel data, it differs from existing econometric studies that use a representative agent framework. Because the paper focuses on the nonlinear implications of the theory, it is different from most existing panel data studies that investigate linearizations. The evidence shows that we only obtain intuitively plausible estimates when using samples that contain households who own riskless and risky assets. For those samples, estimated parameter values are radically different from existing studies. The findings are therefore of interest to an extensive literature in macroeconomics and finance.

JEL Classification: G12, E2, D91

Keywords:

1 Introduction

The estimation of preference parameters is of interest to an extensive literature in economics and finance. The size and sign of these parameters is often used to address important policy questions and to judge the empirical performance of a certain model or a methodological approach. For instance, the ease with which economic agents trade off consumption or leisure over time determines the effectiveness of a given government design of social security programs. Also, following the work by Kydland and Prescott (1982), an extensive literature has debated the ability of "real business cycle models" to explain the data. For

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this debate, the level of the intertemporal rate of substitution is a critical issue. Available estimates of the rate of intertemporal substitution, and therefore assessments of the usefulness of these models, are determined by the choice of preference specification and the econometric methodology used in estimation.

Whereas the debate about real business cycle models has somewhat subsided, the use of dynamic models has become a cornerstone of modern macroeconomics. Many of these dynamic studies evaluate theoretical models by comparing actual data with data simulated from the model under study. These simulations require estimates of a wide variety of parameters, including preference parameters. For this literature, reliable estimates of parameters that describe intertemporal behavior are therefore very valuable. Such estimates are also of interest for more traditional econometric tests of dynamic models. Traditional econometric testing uses uses some model implications for testing, conditional on the estimated parameters. If the parameter estimates are unreliable, the resulting tests are not likely to be informative. In asset pricing a popular alternative approach to testing is often used (e.g. see Mehra and Prescott (1985) and Hansen and Jagannathan (1991)). The implications of the theory are evaluated for different values of the behavioral parameters. If parameter values can be found that can explain the theoretical implications, the researcher asks himself the question if those parameter values are intuitively plausible. Whereas the judgment of plausibility is presumably based on a wide range of available sources, including introspection, existing parameter estimates are useful as reference points.

This paper contributes to this literature by presenting estimates and test statistics obtained using nonlinear Euler equations. This estimation and test strategy is quite popular in the representative agent literature. Hansen and Singleton (1982) pioneered the approach using a time-separable constant relative risk aversion (TS-CRRA) utility function. The approach was later used to analyze other preference specifications, and Mankiw, Rotemberg and Summers (1985) (henceforth MRS) and Eichenbaum, Hansen and Singleton (1988) (henceforth EHS) provide an analysis of nonseparabilities between consumption and leisure in a representative agent context. This paper differs from those studies because it provides an analysis of nonseparable preferences using panel data. The available panel data literature on preference estimation is extensive. However, many panel data studies analyze separable preferences. Those that analyze nonseparable preferences almost always investigate linearizations of the nonlinear Euler equations, and therefore parameter estimates in those papers may be difficult to relate to the ones in this paper. Because there are so many studies that use linearizations, I provide an analysis of the linearized Euler equations below using the same datasets. I find that for the same dataset, the difference between parameter estimates from the linearized and the nonlinear equations is always substantial.

For each specification, estimation and test results are reported for three different samples. The first sample contains all households who fulfill certain selection criteria. The second and third samples contains households who participate in asset markets, with the selection criteria for these two samples slightly different. I find that whereas parameter estimates are always intuitively plausible for the second and third samples, this is almost never the case for the first sample. For those samples that yield intuitively plausible estimates, the results indicate that leisure enters the utility function in a statistically significant way, casting doubt on studies that use separable preference specifications. The parameter values are significantly different from those obtained by other panel data studies, and from the ones presented in MRS (1985) and EHS (1988). Also, point estimates are different from the estimates typically used in simulation studies in dynamic macroeconomics. The special case of logarithmic preferences, which is also often used in this literature, is rejected by the data. The rejection of separability is also of interest for the asset pricing literature, which almost without exception uses separable preferences. Statistical tests of overidentifying restrictions indicate less evidence against the model compared to similar tests obtained using a TS-CRRA specification in Jacobs (1999). It is therefore tempting to conclude that the asset pricing literature should adopt nonseparable preferences. However, it will be argued that additional analysis is needed to determine whether nonseparable preferences can solve a number of well-known asset-pricing puzzles.

The paper proceeds as follows. Section 2 provides a detailed motivation for this study and an extensive discussion of related research. Section 3 discusses the data and Section 4 discusses the estimation and testing methodology. Section 5 presents the empirical results. Section 6 provides a robustness analysis of the results obtained in Section 5. Section 7 relates the findings of the paper to the related literature and Section 8 provides a short conclusion.

2 Motivation

Estimation and testing are carried out with a minimum of auxiliary assumptions. We assume the existence of a large number of individuals with an identical per period utility function, specified as

$$u(c_{i,t}, l_{it}) = \frac{1}{\gamma} c_{i,t}^{\gamma} l_{i,t}^{\psi}. \tag{1}$$

where $c_{i,t}$ is the consumption of individual i in period t and $l_{i,t}$ is the leisure of individual i in period t. We present estimates of the parameters using the first-order condition with respect to consumption (assuming an interior solution)

$$u_c(c_{i,t}, l_{it}) - \lambda_{i,t} = 0. \tag{2}$$

where $\lambda_{i,t}$ is the Lagrange multiplier associated with individual i's time t budget constraint. One way to generate testable restrictions from the model is to specify the assets that the individual can invest in. Many existing panel data studies assume that the individual only has a riskless asset (a bond) to invest in. Here we assume that the individual can invest in risky assets (stocks) as well as in bonds. This yields the following two Euler equations

$$1 = \beta E_{t-1}\left(\frac{1}{q_{t-1}}\right)\left(\frac{c_{i,t}}{c_{i,t-1}}\right)^{\psi-1}\left(\frac{l_{i,t}}{l_{i,t-1}}\right)^{\gamma}. \tag{3}$$

$$1 = \beta E_{t-1}\left(\frac{p_t + d_t}{p_{t-1}}\right)\left(\frac{c_{i,t}}{c_{i,t-1}}\right)^{\psi-1}\left(\frac{l_{i,t}}{l_{i,t-1}}\right)^{\gamma}. \tag{4}$$

where p_t is the price of the risky asset in period t; d_t is the dividend on the risky asset in period t; q_t is the (normalized) price of the riskless asset in period t; β is the discount factor, and E_t is the mathematical expectation conditional on information available at time t.

Two important advantages of focusing on the estimation of (3) and (4) have to be emphasized at this point. First, it is clear that the derivation of (3) and (4) assumes that the household is at an interior sulution w.r.t. the holdings of the riskless and the risky asset and w.r.t. consumption. However, no assumption has been made about the existence of corner solutions or rigidities in the labor market. This is important for an empirical study, because many individuals are clearly at a corner solution for leisure choice, and it is difficult to tell from available data whether an individual is at a corner solution or not. It would of course be preferable to include information about leisure choice in the econometric analysis, because the extra information would generate more precise parameter estimates and more powerful test statistics. However, given that the extra power comes at a higher risk of classification error and inconsistent estimation, the focus in this paper is on (3) and (4) in isolation. Second, to derive (3) and (4) no assumptions about the structure of financial markets have to be made beyond the existence of a riskless and a risky asset. In particular, we do not have to make the complete markets assumption which underlies all of the representative agent studies of consumption and leisure choice (e.g. see EHS (1988) and MRS (1985). In view of the overwhelming evidence against complete markets in the literature (see Cochrane (1991), Mace (1991) and Hayashi, Altonji and Kotlikoff (1996)), the absence of this assumption is reassuring. Jacobs (1998b, 1999) shows that in the absence of a complete markets assumption, parameter estimates and test results are very different from the representative agent literature for a time-separable constant relative risk aversion (TS-CRRA) specification.

The importance of estimating preference parameters using elementary implications of dynamic equilibrium models can hardly be overstated. Whereas economists continue to disagree about many issues, the last two decades have witnessed the emergence of dynamic aspects of human behavior as one of the cornerstones of economics. Estimates of parameters characterizing intertemporal behavior are therefore of interest to almost every theory-based economic study, because often such parameters are of fundamental importance to assess the theory's policy implications or its empirical performance.

Besides pointing out the general relevance of this exercise, it is also instructive to provide a more detailed motivation of its importance by discussing its impact on different research areas. Such a more detailed discussion is necessary because the ostensibly simple issue of estimating behavioral parameters such as the ones in (3) and (4) has been tackled using different auxiliary assumptions in different areas of the economics and finance literature, each motivated by different questions and concerns. Perhaps unsurprisingly, these different approaches have given rise to different parameters estimates and widely varying assessments of their relevance and policy implications.

I discuss the importance of preference specification in three different (but related) areas: first, the literature on dynamic macroeconomics; second, the literature that unites macroeconomics and asset pricing; and third, the literature on consumption, savings and labor economics. This somewhat arbitrary division into research areas is motivated by the fact that within each group, the econometric and methodological tools used in the analysis are fairly similar. First, in macroeconomics an extensive literature has developed that investigates the implications of general equilibrium models by way of simulation. In principle, this literature does not depend on estimates of behavioral parameters, but the empirical implementation used in many studies requires estimates of behavioral parameters as model inputs. Therefore, specific values for behavioral parameters are mostly assumed as part of the primitives of the model. For instance, Kydland and Prescott (1982) use the Cobb-Douglas preference specification

$$u(c_{i,t}, l_{i,t}) = \frac{1}{\gamma\theta}\left(c_{i,t}^{\gamma} l_{i,t}^{1-\gamma}\right)^{\theta}. \tag{5}$$

Kydland and Prescott (1982) argue that it is straightforward to parameterize (6) by interpreting γ as the percentage of the agent's time allocated to consumption activities. Also, by interpreting $c_{i,t}^{\gamma} l_{i,t}^{1-\gamma}$ as a generalized version of a unit of consumption, they interpret $1-\theta$ as the rate of constant relative risk aversion. They therefore set γ equal to 1/3, based on the fact that households' allocation of time to nonmarket activities is about twice as large as the allocation to market activities, and they use three different values of the parameter θ in their simulations: -1, -0.5 and -0.1.

It is clear that (7) is simply a redefinition of (1) with $\theta = \psi + \kappa$ and $\gamma = \psi/\theta$. For our purposes, it is convenient to report on the parameters in equation (1), because inspection of the standard error on κ allows us to determine whether leisure enters the utility function in a significant manner and whether the underlying optimization problem is concave. However, for reasons of comparison with the real business cycle literature, all tables also list the point estimates of γ and θ that are implied by our estimates of ψ and κ. In this context, the parameter $1-\theta$ will be referred to as the rate of relative risk aversion in accordance with the terminology proposed by Kydland and Prescott (1982).

Several studies in dynamic macroeconomics employ the utility specification (7) used in Kydland and Prescott (1982) (e.g. see Backus, Kehoe and Kydland

(1992)).[1] A central question is therefore whether the range of estimates for μ proposed by Kydland and Prescott (1982) contains the parameter estimate from the data. Moreover, many existing studies use a logarithmic specification that is a special case of (7) for $\mu = 0$ (see Christiano and Eichenbaum (1992)).[2] It is therefore of interest to verify if this restriction holds in the data.[3]

The second area of interest that has studied the importance of leisure is the asset pricing literature. Following the work of Lucas (1978) and Breeden (1979), the asset pricing literature has focused on estimating and testing general equilibrium models of asset pricing. Parameter estimation is critically important in this context because the theory is usually evaluated conditional on parameter estimates obtained under the maintained hypothesis that the theory holds. After several studies demonstrated the inadequacy of the TS-CRRA specification to explain the volatility of asset returns (see Hansen and Singleton (1982,1983,1984), Mehra and Prescott (1985)), several authors proposed the inclusion of leisure in the utility function to remedy the problem (see MRS (1985) and EHS (1988)). However, the representative agent literature has concluded that the presence of leisure in the utility function is not likely to solve notorious asset pricing puzzles. Using the intuition captured by the work of Hansen and Jagannathan (1991), the problem with consumption based asset pricing is that the consumption series is not volatile enough to generate sufficient volatility in asset returns, given the available parameterization of the utility function. For the TS-CRRA specification, one needs an "implausibly large" risk aversion parameter to generate sufficient variability in the intertemporal marginal rate of substitution. Because the time series of monthly, quarterly or yearly aggregate leisure is also very smooth, it is not surprising that the parameters needed to generate sufficient variability in the IMRS are judged implausible as well (see also Campbell, Lo and MacKinlay (1997, p.326)).

More in general, the relationship between nonseparable preferences and asset prices has not attracted abundant interest in the finance literature.[4] Mayers

[1] The merits and criticisms of this literature are not the focus of this paper. Whereas the term "real business cycles" has been hotly debated, and the original methodology in Kydland and Prescott (1982) has also come under scrutiny (e.g. refer to the debate between Kydland and Prescott ( ) and Hansen and Heckman ( )), the analysis of dynamic models has become the state of the art in macroeconomics. Whereas much of this research in economic dynamics has little in common with the ideological battleground of real business cycles, many of these studies (but not all) use a simulation setup where parameter values from other studies are used as inputs into the analysis.

[2] Following the analysis in Kydland and Prescott (1982), many of the studies that use the Cobb-Douglas specification (7) specify time-nonseparabilities in leisure. Strictly speaking therefore, our estimates cannot be compared with the calibrated values used in these studies.

[3] The literature on dynamic general equilibrium models has recognized the importance of heterogeneity. The framework used in Rogerson (1988) and Hansen (1985) allows for the preferences of the representative agent to differ from those of the individual agents populating the economy. Nevertheless, estimates of the preferences of individual agents remain valuable.

[4] Besides the poor performance of leisure in an intertemporal pricing context, there are other explanations for this. First, the emergence of arbitrage pricing techniques (Ross (1976)) does not necessitate an elaborate description of the economic environment. Second, economic pricing factors such as consumption have not performed well in cross-sectional asset pricing (Breeden, Gibbons and Litzenberger (1989)).

(1972, 1973) emphasizes the importance of leisure and human capital accumulation at an early stage in the context of the Capital Asset Pricing Model. Cochrane and Hansen (1992) and Fama (1991, p. 1610) make a forceful point for establishing a theoretical and empirical connection between asset returns and intuitively plausible pricing factors emanating from general equilibrium models, such as leisure. In the theoretical literature, the importance of leisure choice has been analyzed among others by Bodie, Merton and Samuelson (1992) and Basak (1999).[5] The work of Jagannathan and Wang (1996) suggest that human capital accumulation could be of interest in cross-sectional asset pricing.

This paper argues that the perceived failure of nonseparable utility specifications to solve asset pricing puzzles may be due to the complete markets assumption that underlies these studies. If this assumption does not hold, it is the properties of the individual agent's consumption and leisure instead of aggregate consumption and leisure that determine asset prices. Mankiw and Zeldes (1991) and Jacobs (1998b,1999) show that these aggregation issues are critically important when evaluating the TS-CRRA specification. This paper investigates if similar arguments apply for the evaluation of preferences that are nonseparable in consumption and leisure.

Whereas the existence of nonseparabilities between consumption and leisure has not received a lot of attention recently, the specification of preferences has received ever more attention in the asset pricing literature. Most notably, the specification of preferences with time-nonseparabilities has become quite popular (e.g. see Abel (1990), Campbell and Cochrane (1995), Constantinides (1990), Detemple and Zapatero (1991) and Sundaresan (1989)). Whereas this paper does not deny that this type of specification is intuitively plausible, it explores how much leverage can be obtained from a specification without time-nonseparabilities once the complete markets assumption is relaxed.

This study is also related to a third important area of research. Empirical analyses of consumption choice, savings, and leisure choice are treated as one group mainly because this literature contains a large number of empirical studies that use panel data.[6] For purposes of comparison with this study, a

[5] The stochastic properties of leisure are also of interest in the literature on nontraded assets, even though leisure does not enter the utility function in many of the studies in that literature (e.g. see Detemple (1999) and Svensson and Werner (1993)).

[6] For panel data studies in the consumption literature, see Attanasio and Browning (1995), Attanasio and Weber (1995), Keane and Runkle (1992), Runkle (1991), Zeldes (1989) and the references in the excellent overview paper by Browning and Lusardi (1996). For panel data studies in the labor supply literature see Altonji (1986), Ham (1986), Heckman and MaCurdy (1980) and MaCurdy (1981). Whereas many studies in this literature use panel data, there is an equally extensive literature that relies on aggregate data (see Hall (1988) and the references in Deaton (1992) in the consumption and savings literature and Altonji (1982) and Altonji and Ham (1990) in the labor supply literature). It is hard to determine why this particular empirical literature has started relying relatively more on panel data compared to the other research areas discussed in this section. Several authors maintain that aggregation problems make it tenuous to use time series of consumption and leisure to draw conclusions about individual preferences (e.g. see Browning and Lusardi (1996 p.1799)). Perhaps another reason for the focus on panel data in this literature is the extensive literature on static demand systems which predates most dynamic studies. This literature relies almost exclusively on panel data (see Deaton and Muellbauer (1980) , Deaton (1992)).

potential problem is that most existing studies analyze linearized versions of Euler equations (3) and (4) as well as linearized versions of other intertemporal Euler equations such as those implied by optimal leisure choice.[7] The main motivation for using linearizations is probably that measurement error is an important problem with panel data (see Altonji (1986) and Altonji and Siow (1987)), and it is easier to deal with measurement error problems in a linear context. While this study does not deny the importance of measurement error, it takes the opposite view that it is worth investigating the original nonlinear Euler equations (3) and (4) directly.[8] If measurement error is a serious problem in this context and for this purpose, it will likely lead to implausible parameter estimates and a lack of robustness. It turns out that for most specifications this is not the case.

There are other reasons why it is not necessarily straightforward to compare parameter estimates obtained from the analysis of the nonlinear Euler equations (3) and (4) with the parameter estimates in the panel data studies mentioned above. First, the link with the labor supply literature is that we focus on the point estimate and the statistical significance of the parameter κ. However, whereas we obtain estimates of this parameter using the first order condition with respect for consumption, much of the labor supply literature uses the first order condition with respect to leisure (e.g. see MaCurdy (1981), Altonji (1986), Ham (1986)). Illustrating this methodology for our preference specification (1), consider the Euler equation obtained by combining the intertemporal optimality condition and the first order condition w.r.t. leisure

$$1 = \frac{\beta\kappa}{\psi} E_{t-1} R_t \left(\frac{w_{i;t}}{w_{i;t-1}}\right)\left(\frac{c_{i;t}}{c_{i;t-1}}\right)^{\psi}\left(\frac{l_{i;t}}{l_{i;t-1}}\right)^{\kappa-1}: \qquad (6)$$

where R_t is the return on the riskless or the risky asset. The intertemporal rate of substitution for labor supply can then be obtained from the following log-linearization of (5)

$$\Delta \ln l_{i;t} = \chi_1 + \chi_2 \ln R_t + \chi_3 \Delta \ln c_{i;t} + \chi_4 \Delta \ln w_{i;t} + u_{i;t}: \qquad (7)$$

The intertemporal rate of substitution for labor supply in this regression is defined as $-\chi_4$: It can be easily verified that this quantity can be related to our

[7] One can estimate and test a linear estimating equation without any extra assumptions, by combining the first order conditions for consumption and leisure, and neglecting the intertemporal optimality condition. This type of analysis is referred to as estimation of the intratemporal optimality condition (e.g. see MaCurdy (1983), Altonji (1986) and EHS (1988)).

[8] There are a few papers in the panel data literature that provide an analysis of nonlinear Euler equations. Hotz, Kydland and Sedlacek (1988) analyze a translog utility function. Because this utility specification is quite different from the ones traditionally analyzed in the literature, it is not straightforward to compare their results with other studies. Altug and Miller (1990) analyze a utility function that contains several nonseparabilities between consumption and the leisure of different members of the household. However, their estimates are obtained under the hypothesis of market completeness. Moreover, the econometric framework they use results in some instances in fairly imprecise estimates. The results in this paper therefore differ quite strongly from the ones in these two studies.

parameterization in (1) because $\chi_4 = 1/(\kappa - 1)$. Whereas our analysis focuses on different implications of the theory, we can therefore derive the intertemporal rate of substitution because our estimates identify preferences, if all the implications of the theory are correct. It may be that by focusing on implications of the theory that contain less interesting information on leisure choice, we end up with less precise estimates of the intertemporal rate of substitution. However, I want to emphasize again that an argument in favor of the analysis in this paper is that the first order conditions with respect to consumption are more likely to hold than those with respect to leisure. So from the perspectice of consistent parameter estimation a comparison with parameter estimates from the labor supply literature can be very instructive.

A final difficulty in comparing parameters estimated in this paper with those obtained in the labor supply literature is the testing method used in those studies. Whereas the labor supply literature is interested in the parameter that determines the intertemporal rate of substitution for labor supply in order to comment on its policy implications, the focus of those studies is primarily on tests of the underlying theory that agents trade off utility over time. Whereas the theory can be tested by focusing on overidentifying restrictions, often tests are executed by inspecting the significance of extra coefficients that are inserted into the Euler equation (see Ham (1986)). Presumably such tests are more powerful than tests of overidentifying conditions. With this approach, behavioral parameters are estimated consistently under the null that the theory is correct. However, when using this technique, rejection is the rule rather than the exception. The relevant question is therefore how to interpret the parameters if the extra variables enter significantly and the theory is rejected.[9]

The same caveat applies to the comparison between the estimates in this paper and the estimates of preference parameters obtained by several studies in the consumption literature. The object of interest in this literature is the intertemporal rate of substitution for consumption, which is usually obtained in panel data studies by estimating a log-linearization of the Euler equations (3) and (4). This gives

$$\Delta \ln c_{i,t} = \omega_1 + \omega_2 \ln R_t + \omega_3 \Delta \ln l_{i,t} + u_{i,t} \tag{8}$$

where the parameter ω_2 is the intertemporal rate of substitution for consumption, which can be related to the preference specification (1) as $\omega_2 = 1/(1 - \psi)$.

[9] Note that accepting this argument has far-reaching implications. If the theory is rejected by the presence of extra variables in the Euler equation, the resulting estimates of preference parameters are uninterpretable. So is the estimate from the Euler equation without the extra variables, because we know that the orthogonality conditions used in estimation are false. The temptation is to always interpret estimates from studies that simply test orthogonality conditions as valuable. However, using a similar argument, if the orthogonality conditions are rejected, estimates of preference parameters are no more valuable than those obtained in the studies that insert extra variables in the Euler equation. The difficulty with maintaining this argument is of course that given that the implications of the theory are mostly rejected, it would suggest that we know nothing about the rate of intertemporal substitution. It seems then that implicitly, many economists accept the legitimacy of available parameter estimates, even if they are obtained using orthogonality conditions that are statistically rejected.

However, instead of testing the overidentifying conditions, Euler equations are also often tested in this literature with extra variables included in the specification, to improve the power of the tests. The panel data literature on consumption and savings decisions suffers from another problem, because many studies estimate models that are additively separable between consumption and leisure.[10] It is clear from (7) that if the separability assmption is incorrect, the estimate of ω_2 will be biased. Dynamic studies of demand systems (see Browning, Deaton and Irish (1985)) do not make such assumptions, but they often focus on more detailed components of consumption. The work in this paper is of interest to the literature on consumption and savings because a statistically significant estimate of the parameter $\cdot$ would call into question some of its test results. To give an example, the life-cycle model is often questioned because several studies have documented a relationship between consumption patterns and variables such as age. This fact is often illustrated using regressions or a straightforward graphical analysis. However, if older people compensate for lower consumption by enjoying more leisure this rejection of the life-cycle model would be called into question. Without knowledge of the relative weights placed on consumption and leisure it is hard to appreciate the importance of this argument. If leisure enters the utility function significantly, this is likely to influence the point estimate of the rate of intertemporal substitution in consumption.

3 Data

The empirical investigation uses data from the Panel Study of Income Dynamics (PSID) for the period 1974-1987. The dataset is the same as the one used in Jacobs (1998b, 1999) and is described in the Appendix. The PSID does not contain a satisfactory measure of total consumption. Therefore, I follow existing studies that use the PSID by using household food consumption as the consumption measure. Alternatively one could use the Consumer Expenditure Survey (CEX) to investigate the preference specifications in (1) and (7). Unlike the PSID, the CEX contains data on total household consumption, and the frequency of the data is quarterly, therefore yielding more time series observations than the PSID. However, in the CEX data on leisure are only available on a yearly basis. Moreover, the CEX is not a genuine panel dataset because households are only followed for five consecutive time periods. One therefore has to resort to the construction of synthetic cohorts, and to investigate the impact of aggregation problems this approach is not necessarily appealing. In contrast, the PSID is a genuine panel dataset, even though not observations on a given household are not available in any given year.

[10] Table 5.1 in Browning and Lusardi (1996) presents an overview of available panel data studies in the consumption and savings literature. This table also indicates which studies control for leisure when analyzing the problem at hand. It can be seen from this table that there are not too many studies that do. Moreover, most of these follow the approach of Attanasio and Weber (1995), where variables are inserted to control for leisure without formally modeling leisure choice. As a result estimates in these studies are also hard to relate to the ones obtained in this paper.

The PSID allows the construction of samples of households who are at interior solutions with respect to asset choice. This allows us to assess the quantitative importance of including households at corners in the sample. To identify households at interior solutions, I use a 1984 question from the PSID which asks households for their holdings of liquid assets and stocks. This question is the same as that used by Mankiw and Zeldes (1991) and Jacobs (1998b,1999). It is discussed in more detail in the Appendix. The question allows the construction of five successively smaller samples: a sample including all households that satisfy the selection criteria; a sample including only households who fulfill the selection criteria and who have nonzero holdings of the relevant asset; and samples including only households who fulfill the selection critaria and who have holdings of the relevant asset larger than $1,000, $10,000, and $100,000 respectively. Unfortunately the two smallest samples are too small to yield reliable econometric results. Parameter estimates are imprecise and not very robust. Results are therefore only reported using the first three samples.

Returns on stock and bond markets are constructed as follows: yearly returns are computed as the average of twelve returns on one-year investments which expire at the end of every month of the year. This construction is motivated by the interpretation of consumption as yearly totals (flows) and not stocks at one point in time. The bond returns are returns on rolling over three-month treasury bills and are obtained from Moody's. The stock returns are returns on the Standard and Poor's 500 composite.

4 Estimation and Testing

As with most other available panel datasets, the household and not the individual is the unit of observation in the PSID. This complicates empirical testing because preferences are defined at the level of the individual. To resolve this issue, I include an exponential function of household size in periods t-1 and t in the Euler equation. Another issue of interest is that many available panel data studies, especially those in the labor economics and consumption literature, estimate preferences conditional on demographic variables such as age and marital status and some of the agent's decision variables such as education. For purposes of comparison with these earlier studies, I therefore estimate the Euler equations with and without an exponential function of such variables included as preference shifters. The most general specification of the Euler equations is therefore given by

$$1 = \beta E_{t-1} R_t \left(\frac{c_{i;t}}{c_{i;t-1}}\right)^{\psi-1} \left(\frac{l_{i;t}}{l_{i;t-1}}\right)^{\kappa} \exp[\pi_1\ fam_{i;t} + \pi_2\ fam_{i;t-1}] \exp[\sigma\ demo_{i;t}]. \quad (9)$$

where $fam_{i;t}$ stands for family size in period t, $demo_{i;t}$ stands for a vector of preference shifters at time t, π_1 and π_2 are scalar parameters and σ is a vector of parameters. As mentioned before, many studies in the consumption and labor economics literature use panel data to investigate linearizations of (8). The most general linearization investigated in this paper is

$$\Delta \ln c_{i,t} = \omega_1 + \omega_2 \ln R_t + \omega_3 \Delta \ln l_{i,t} + \pi_1 \, fam_{i,t} + \pi_2 \, fam_{i,t-1} + \sigma \, demo_{i,t} + u_{i,t}. \quad (10)$$

By estimating the parameters in (9), we can retrieve the parameters ψ and κ that characterize the utility function (1).[11]

Parameter estimates and test statistics are obtained using a generalized method of moments (GMM) framework (see Hansen (1982)). Regardless of whether one is estimating the nonlinear Euler equation (8) or the linearized equation (9), parameter estimates and test statistics can be obtained by exploiting the orthogonality between the Euler equation errors and variables in the agent's information set. Consider the error associated with the nonlinear Euler equation (8) or with the linearized Euler equation (9) and for simplicity label it e_{it}, where t is the time index and i is the household index. Theory specifies $E_{t-1} e_{it} = 0$. Consider a maximum of T observations on H households, and consider M instruments per household $z^1_{i,t-1}, \ldots, z^n_{i,t-1}, \ldots, z^M_{i,t-1}$. Then consider $v^n_{i,t} = e_{it} z^n_{i,t-1}$. Using the law of iterated expectations we know that $E v^n_{i,t} = 0$, for all n and i. Rather than using all $M \times H$ orthogonality conditions in estimation, we sum over the orthogonality conditions to obtain a more powerful test statistic. Denote the number of households in the sample at time t as H_t and consider the M orthogonality conditions $E\overline{v^n_t}; n = 1, \ldots, M$ where $\overline{v^n_t} = \frac{1}{H_t}\sum_{i=1}^{H_t} v^n_{i,t}$. The GMM estimator exploits the fact that if the theory is correct $\sum_1^T \overline{v^n_t}$ should be close to zero. Define the $M \times 1$ vector $\overline{v_t} = (\overline{v^1_t}, \ldots, \overline{v^M_t})'$ and consider minimizing

$$\left[\frac{1}{T}\sum_{t=1}^{T} \overline{v_t}(\phi)'\right] W \left[\frac{1}{T}\sum_{t=1}^{T} \overline{v_t}(\phi)\right]. \quad (11)$$

for an arbitrary $M \times M$ weighting matrix W. From Hansen (1982) we know that

$$J_T = T \left[\frac{1}{T}\sum_{t=1}^{T} \overline{v_t}(\hat{\phi})'\right] \hat{Q}^{-} \left[\frac{1}{T}\sum_{t=1}^{T} \overline{v_t}(\hat{\phi})\right]. \quad (12)$$

is distributed χ^2_{M-K}, where $\hat{Q} = \hat{P}\hat{\Omega}\hat{P}'$, $\hat{P} = I - \hat{G}(\hat{G}'W\hat{G})^{-1}\hat{G}'W$, and $\hat{Q}^{-}$ is the generalized inverse of Q. All matrices in (11) are evaluated at $\hat{\phi}$, the value

[11] Hansen and Singleton (1983) use time series data and a lognormality argument to estimate a linearized version of the Euler equation in structural as opposed to reduced form. This allows them to identify additional preference parameters such as the discount factor β. In this paper we follow the papers in the panel data literature and estimate the reduced form (9) to illustrate the differences in parameter estimates obtained from the nonlinear Euler equation (8) and the linearized equation (9).

of the parameters that minimizes (10). The covariance matrix $\hat{\Omega}$ is computed as

$$\hat{\Omega} = \frac{1}{T}\sum_{t=1}^{T}[\hat{v}_t - (\frac{1}{T}\sum_{t=1}^{T}\hat{v}_t)][\hat{v}_t - (\frac{1}{T}\sum_{t=1}^{T}\hat{v}_t)]'. \qquad (13)$$

The covariance matrix of $T^{1/2}(\theta - \hat{\theta})$ can be computed as

$$(\hat{D}' W \hat{D})^{-1}(\hat{D}' W \hat{\Omega} W \hat{D})(\hat{D}' W \hat{D})^{\prime -1}. \qquad (14)$$

The small-sample reliability of parameter estimates and test statistics depends on the weighting matrix W. Define for a given $1 \times M$ vector of instruments $Z_t = (\frac{1}{H_t})(z^1_{i,t-1}, \ldots, z^M_{i,t-1})$. The inverse of $\sum_{t=1}^{T} Z_t' Z_t$ is used as the weighting matrix W. This choice of W effectively reduces the minimization in (10) to NL2SLS.

Estimation and test results are reported for five different instrument sets. Family size in periods t and $t-1$ is included in every instrument set. The first instrument set used contains seven instruments: besides the family variables, it contains a constant, the riskless rate of return lagged once, the risky rate of return lagged once, the occupational unemployment rate lagged once and the occupational unemployment rate lagged once interacted with age and education of the household head. The second instrument set contains eleven instruments: besides the family variables there is a constant, the riskless rate of return lagged once and twice, the risky rate of return lagged once and twice, the occupational unemployment rate lagged once interacted with age and education of the household head, the occupational unemployment rate lagged twice interacted with age and education of the household head, the industry unemployment rate lagged once interacted with age and education of the household head and the industry unemployment rate lagged twice interacted with age and education of the household head. The third instrument set contains nine instruments: it includes family size in periods t and $t-1$, a constant, the riskless and risky rates of return lagged once, the occupational unemployment rate lagged once, the occupational unemployment rate lagged once interacted with age and education of the household head, the industry unemployment rate lagged once and the industry unemployment rate lagged once interacted with age and education of the household head. The fourth and fifth instrument sets are used to investigate the robustness of estimation and test results w.r.t. the inclusion of preference shifters. Both include eleven instruments: the nine instruments included in instrument set three, and the two demographic variables includede in the Euler equation. In instrument set four these demographic variables are age and age squared. In instrument set five the demographic variables are education and education squared.

5 Empirical Results

Tables 1 through 9 present results obtained using the five different instrument sets. Each table contains two parts, with the first part presenting estimation and test results for the riskless asset and the second part presenting estimation and test results for the risky asset. I first discuss the results in tables 1 through 3, which contain estimation and test results using instrument sets one, two and three. Subsequently I discuss the results in tables 4 through 9, which analyze a number of robustness issues, such as the specification of leisure time, the importance of linearization and the importance of preference shifters in the Euler equation.

Tables 1, 2 and 3 present estimation and test results for instrument sets one, two and three. Instrument set one in table 1 contains 7 instruments, instrument set two in table 2 contains 11 instruments, and instrument set three in table 3 contains 9 instruments. Each table presents results for three different samples: the first column presents results for a first sample, which contains all households who fulfill the selection criteria specified in the Appendix. This yields a sample with $H = 3555$ households. It must be noted that the panel is unbalanced, and that the number of observations we actually end up with in the sample is $N = 18813$. The second column in every table presents results for smaller samples: they include those households present in the first sample who have nonzero holdings of the riskless asset and nonzero holdings of the risky asset. This sample contains $H = 740$ households and $N = 5029$ observations. The third column contains only those households who have holdings of the riskless and the risky asset larger than \$1000, $H = 413$ households and $N = 2990$ observations respectively. For each sample we present parameter estimates and standard errors for the parameters based on the utility specification (1), as well as the implied point estimates of the parameters in utility specification (7) that can be derived by using $\theta = \psi + \kappa$ and $\gamma = \psi/\theta$.

A first important observation in table 1A is that the results in columns 2 and 3 are remarkably similar. The estimates of the discount rate β are 0.824 and 0.823, respectively, which are intuitively plausible magnitudes. For the optimization problem under study to be well defined, the estimate of $\psi - 1$ has to be negative. This is the case in both samples and the estimates are not very different. Note that we do not investigate the consumer's decision with respect to leisure, and therefore we do not need the estimate of κ to imply concavity in order for these estimates to make sense. However, the estimates of κ of -1.363 and -1.602 would guarantee that we were dealing with a concave problem, if we were to analyze leisure choice. Note also that the estimates of π_1 and π_2, indicating the importance of family size, have the expected sign. Finally, the significance level for the J statistics indicates that the statistical evidence against the theory is not very strong. Finally, each column lists the implication of the estimates of ψ and κ for the parameters γ and θ in utility specification (7). We obtain estimates of γ of 0.353 and 0.364 in columns 2 and 3 respectively and estimates of θ of -2.109 and -2.520 respectively. The estimate for γ is very close to the calibrated 1/3 first proposed by Kydland and Prescott and commonly used in the real business cycle literature. However, the value for θ, which determines the rate of relative risk aversion, is very different from the parameter values used in many simulation studies.

If corner solutions are important, one would expect the estimates in column 1 to differ from those in columns 2 and 3. A first observation is that the discount rate β in column 1 is significantly lower than the estimates reported in columns 2 and 3. However, most importantly, whereas the estimate of ψ is also quite different, the sign of η is different from that of the estimates in columns 2 and 3, even though the parameter is fairly precisely estimated. It must be emphasized that this is not necessarily a problem, because we are not analyzing leisure choice, but if we obtained a similar estimate from the first order condition for leisure it would indicate that our optimization problem was not well defined. It is perhaps more intuitively appealing to investigate the implications of these parameter estimates for the values of the parameters γ and θ in the utility specification (7). We see that the weight placed on consumption γ is 0.097, much smaller than in columns 2 and 3. Moreover, the parameter θ, which determines the rate of relative risk aversion, has the wrong sign. In summary, the parameter estimates for the large sample seem much less plausible that those for the smaller samples, which is reinforced by the observation that the parameters π_1 and π_2 also have the wrong sign. A final important observation is that the test statistic indicates little evidence against the theoretical specification. This is problematic, because we do not expect the theory to hold for households who are at corners and the parameter estimates indicate the importance of these corner solutions. It must therefore be concluded that the interpretation of these test statistics is likely to be problematic in this context.

Table 1B presents estimation and test results for the Euler equation associated with the risky asset, obtained using instrument set 1. The most important observation is that estimation and test results largely confirm the results reported in table 1A. Parameter estimates in columns 2 and 3 are dramatically different from those in column 1. Once again, the parameter estimate for η in column 1 would place us in the nonconcave region of the parameter space if we were to analyze the optimal leisure decision. Whereas parameter estimates for π_1 and π_2 have the expected sign in columns 2 and 3, they do not in column 1. In terms of the implied point estimates for parameters γ and θ in utility specification (7), the estimates in column 1 imply a negative weight on leisure ($\gamma = -0.027$) and again the parameter θ has the wrong sign. When comparing the estimates of and in columns 2 and 3 with those in table 1A, it must be noted that the weight γ on consumption is higher and that risk aversion is higher too. Finally, test statistics in columns 2 and 3 indicate more evidence against the model as compared to those in table 1A, but the test statistic in column 1 of table 1A is again surprisingly low.

The results in tables 2 and 3 investigate the robustness of the results in table 1 w.r.t. the choice of the instrument set. It is clear that most of the results obtained in table 1 are very robust. First, estimates for ψ and η in tables 2 and 3 situate us in the concave region of the parameter space, even if we were analyzing leisure choice. The implied values of γ and θ are fairly robust across estimation exercises, even though it must be noted that the values for γ obtained in table 2A (0.174 and 0.137) are much lower than those obtained in the other tables. Finally, in all tables the estimates of κ in column 1 are implausible, leading to implausible values of γ and θ. Whereas the estimates of π_1 and π_2 have the expected sign in all instances in columns 2 and 3, this is never the case in column 1. One aspect of the results that is not necessarily robust is the significance levels of the test statistics. Whereas we obtain statistical nonrejections in many cases, there are several exceptions. Also, the finding from table 1 that test statistics are lower in column 1 is not always confirmed. These results are indicative of the results for the large number of instrument sets that I have investigated and that are not reported: parameter estimates are very robust, test statistics are not.

It is instructive at this point to relate these parameter estimates and test statistics to the results for the time separable constant relative risk aversion (TS-CRRA) specification studied in Jacobs (1999). There are some interesting parallels. First, the differences between the parameter estimates obtained from the Euler equation for the riskless and the risky asset are in a certain sense similar to the ones in Jacobs (1999). For example, the estimates of the discount rate β obtained from the Euler equation for the risky asset in Jacobs (1999) are also smaller than those obtained from the Euler equation for the riskless asset. Second, if one interprets $1 - \theta$ as the rate of relative risk aversion for the composite good as in Kydland and Prescott (1982), then the finding that the rate of risk aversion is larger when estimating the Euler equation for the risky asset also obtains in Jacobs (1999). However, there are marked differences when estimating nonseparable preferences. First, the discount rate β estimated in this study is almost always lower than the one estimated in Jacobs (1999). Second, the test statistics in this study are markedly lower than those in Jacobs (1999). It must of course be remembered that we know very little about the performance of these test statistics in small samples in a panel data context. However, systematic overrejections or underrejections are equally likely to influence the results in a similar fashion in Jacobs (1999). The results therefore suggest that leisure is an important determinant in the utility function, a conclusion which is of course reinforced by the finding that the parameter κ is usually significantly estimated in columns 2 and 3 of the tables. Third, estimation and test results in Jacobs (1999) do not vary markedly across different columns, seemingly implying that corner solutions are not very important. When taking the presence of leisure in the utility function into account, the results in tables 1 through 3 clearly show that corner solutions are critically important and cause significant biases in estimated parameters.

6 Robustness

Inspection of tables 1 through 3 revealed that estimation results are robust with respect to the choice of instrument set. In this section we investigate robustness of estimation and test results in other dimensions. The unifying theme of this section is that the results are not robust to a number of important assumptions.

The first issue we investigate is the specification of leisure time. There is a certain arbitrariness that enters the setup, because we have to construct the leisure time that enters the utility function from available data on hours worked, . The results in tables 1 through 3 are obtained by specifying total time available to the consumer in the year as 5840 hours (16 hours per day multiplied by 365). Leisure time is then computed as 5840 hours minus hours of work reported for that year. This construction follows the work of EHS (1988) and MRS (1985). However, one can also justify including sleeping time in the available leisure time, or specifying that an individual has less than 16 hours available every day to divide between consumption and leisure. To investigate the dependence of parameter estimates and test statistics on this construction, table 4 presents results obtained using the second instrument set, where the total time endowment for a year is set at 8760 hours (24 hours x 365 days). When comparing the results to table 2, it is clear that the main impact of this change is that the estimated absolute value of the parameter · is larger in columns 2 and 3. As a consequence the implied point estimates of ° and µ in the utility specification (7) are different from the ones in table 2: ° is smaller and the rate of risk aversion µ is much larger. There is a second and less obvious difference which is nevertheless interesting. The impact of the change in the specification of leisure time on the results in column 1 is larger than on the results in columns 2 and 3. For the results in table 4A (the riskless asset), not only is the estimate · of very different from the one in table 2A, but also the estimate of Ã. Moreover, the test statistic is much higher. This suggests that the econometric analysis of the results in column 1 is perhaps less robust than the one for the samples that contain only households at interior conditions.

Table 5 investigates how estimation and test results are affected by estimating linearizations of the original nonlinear Euler equations. Strictly speaking this is not an investigation of the robustness of the results listed in tables 1 through 3, because we do not relax any of the assumptions used to obtain those results; on the contrary, to analyze the linearizations one has to make additional assumptions. A limited analysis of these linearized equations is nevertheless of interest for several reasons. First, many available studies in the consumption, savings and labor economics literature that use panel data analyze linearized Euler equations.[12] Also, to the best of my knowledge, analysis of linearized Euler equations has only been performed for the Euler equation associated with the riskless asset. Given that estimation and test results in tables 1, 2 and 3 differ between the rikless and the risky asset, it is worth investigating if this is also the case when analyzing these linearized equations. Finally, it is well known that measurement error problems can be solved in a linear context by an appropriate choice of instruments. When estimating nonlinear Euler equations, dealing with measurement error problems is much more problematic. To

[12] It is well known that estimation and test results for these analyses can differ dramatically dependent on the sample under investigation, and therefore it is difficult to compare the results in tables 1 through 3 with existing parameter estimates.

some extent, analysis of the linearized Euler equations can therefore be interpreted as an analysis of robustness of the nonlinear analysis to measurement error problems.[13]

Table 5A presents estimation and test results for the linearization of the Euler equation (9) associated with the riskless asset, obtained using instrument set three. Comparing the results to those in table 3A, it is clear that they are dramatically different. First, the test statistics indicate dramatically stronger evidence against the model. Second, when using the estimates of ω_2 and ω_3 to derive implied parameters ψ and η, it is clear that the absolute value of both parameters is much larger in columns 2 and 3 in table 5A compared to table 3A. Translating these parameters to the more intuitively appealing parameters γ and θ of utility specification (7), it is seen that the share of consumption in the utility function is roughly comparable to the one estimated in table 3A. However, the parameter θ, which indicates a higher rate of relative risk aversion is dramatically higher. A third interesting observation is that the implied estimates of the parameters γ and θ in column 1 are much more similar to those in columns 2 and 3 than is the case in table 3A. Also, the estimates for π_1 and π_2 in column 1 have the expected sign, just as in columns 2 and 3. Table 5B provides a similar analysis for the risky asset. The same observations as in table 5A apply. Interestingly, it is also the case that the estimates for the parameter of relative risk aversion are much larger than those obtained in table 5A, just as the estimates obtained in table 3B are higher than those obtained in table 3A.

A final important robustness analysis is performed with respect to the inclusion of demographics in the Euler equation. Most of the literature on consumption, savings and labor economics estimates (linearizations of) Euler equations or demand systems by conditioning on a number of demographic variables (preference shifters) such as age, education, marital status, race and others (see table 5.1. in Browning and Lusardi (1996)). Motivation for such analyses seems obvious, for instance by plotting consumption over the life cycle as a function of age. However, once one considers nonseparable preferences it is clear that such techniques may be misleading because other components of the utility function may change too. For instance, as people get older they may consume less but still confirm to intertemporal optimization theory because they enjoy more leisure. Exactly how much more leisure they have to enjoy to make the theory work is an open question, because it determines on the parameterization of the utility function, which should be determined from the data in the first place. It could

[13] It is clear though that this interpretation is potentially troublesome: if one can investigate the robustness to measurement error by investigating linearizations, there would be no motivation for investigating the nonlinear Euler equations in the first place. Just as there are costs to analyzing the nonlinear equations (higher probability of measurement error problems), there are costs to analyzing the linearized equations (is the linearization valid?). Moreover, there is no evidence indicating that linearization solves all potential measurement error problems in this context, nor that measurement error strongly biases parameter estimates for this particular estimation problem. The only thing we know for sure is that measurement error problems are potentially serious in these datasets (see Altonji (1986) and Altonji and Siow (1987)) and that the effects of these errors are much more likely to cause problems in a nonlinear environment.

then be the case that age enters signi…cantly in the utility function because it proxies for leisure, with which it is highly correlated. Therefore, his paper takes a di¤erent approach from much of the literature by …rst investigating the theory without preference shifters included, and then investigating the robustness of the results to the inclusion of demographics. Our results show that this may be a worthwhile approach, as the inclusion of demographics can seriously bias estimation and test results.

Table 6 presents results for the Euler equations augmented with two regressors: the age of the household head and the age of the household head squared. Table 7 augments the Euler equations with the education of the household head and the education of the household head squared. In both cases the instrument set used is instrument set three augmented with both regressors; these instrument sets are referred to as instrument sets four and …ve, respectively. Table 6A presents results using instrument set four for the Euler equation associated with the riskless asset. Comparing the results to table 3A, it is clear that the point estimates of Ã and · are very di¤erent. Translating this into the parameters ° and µ, it is seen that the share of leisure is very small in column 2 and negative in column 3. The estimates in column 1 are not very di¤erent from the ones in table 3A, but they were not intuitively plausible to start with. Why do these di¤erences occur? A serious problem with the estimates in column 2 and 3 is that the parameter · is estimated very imprecisely. Further inspection shows that d_1 and d_2 are also very imprecisely estimated.[14] Also, the parameters $¼_1$ and $¼_2$ are more imprecisely estimated than in table 3A and they di¤er more between columns 2 and 3 than is the case in table 3A. It can therefore be argued that the point estimates for Ã and · and the resulting point estimates for ° and µ have to be interpreted with caution. It is tempting to conclude that a likely reason for these imprecise estimates is that age and leisure are highly correlated. However, comparison of tables 6B and 3B shows that the problem is more complex: when analyzing the Euler equation for the risky asset, including age and age squared in the Euler equation does not signi…cantly bias the estimates of Ã and ·. This is interesting because just as in table 6A, the parameters d_1, d_2, $¼_1$ and $¼_2$ are not very precisely estimated.

Inspection of table 7 nevertheless shows that the properties of the age variable are part of the problem. When including education and education squared in the Euler equation, point estimates of Ã and ·, and resulting point estimates of ° and µ are not dramatically a¤ected. This …nding can partially be explained by the fact that the parameter · is estimated with similar standard errors as in table 3. Nevertheless, it must once again be noticed that the parameters d_1 and d_2 are very imprecisely estimated and that the J statistics in table 7 are in many cases higher than the corresponding ones in table 3.

The …nal question addressed is whether the problems with estimating utility parameters in the presence of preference shifters are speci…c to the analysis of nonlinear Euler equations. After all, almost all available studies estimate prefer-

[14] This …ndings is not due to the inclusion of too many regressors. Identical results obtain when only age and not age squared is included in the regression.

ence parameters in the presence of preference shifters from linearized equations. Because these studies typically report estimates in the presence of different sets of preference shifters, but not while excluding preference shifters, it is difficult to verify from those studies whether they also incur similar difficulties. Tables 8 and 9 investigate this issue by including age and age squared and education and education squared respectively in the linearized Euler equations. To ensure that the results are comparable with those for the nonlinear Euler equations, the instrument sets used are the same, namely instrument set three augmented with the regressors. These instrument sets are referred to as instrument sets 4 and 5 respectively. Table 8A shows that just as in the nonlinear case, problems occur when including the age variables in the Euler equation associated with the riskless asset. The parameter ω_3 is very imprecisely estimated and the resulting point estimates for are not intuitively plausible. Table 8B shows that problems also obtain when analyzing the Euler equation for the risky asset, but they are less serious, just as in the nonlinear case. Finally, table 9 shows that the problems are much less serious when including the education variables in the Euler equation as preference shifters.

7 Comparison With Existing Literature

This section presents a discussion of the relevance of the parameter estimates obtained in sections 5 and 6 for the existing literature. First, the implications for dynamic macroeconomics are discussed, with particular attention to those studies that employ the methodology in Kydland and Prescott (1982), and use parameter estimates as inputs into the model. It is clear that all of the estimates of the parameter θ in columns 2 and 3 of tables 1,2 and 3 fall outside the range of parameter values used by Kydland and Prescott (-1, -0.5 and -0.1). It may be argued that the differences with the parameter range obtained in tables 1, 2 and 3 (from -1.980 to -4.515) are insignificant. Indeed, when interpreting $1-\theta$ as the rate of relative risk aversion, it is clear that the differences between the parameter estimates in this paper and some of the parameters estimated or proposed in the representative agent literature are small. However, by the very nature of these models and the methodology used, it is often not clear how even modest changes in parameter values influence the results.

Many of the studies in the "real business cycle" literature and in dynamic macroeconomics in general use the preference specification (7) of Kydland and Prescott (1982) and several studies use similar parameter estimates. For instance, Backus, Kehoe and Kydland (1992) use $\theta = -1$: Another potential problem for many studies in this literature is that several authors use a logarithmic preference specification, which maintains additive separability between consumption and leisure (e.g. see Christiano and Eichenbaum (1992)). It is clear from inspecting the standard error on η in tables 1 through 3 that the data do not support this hypothesis. More precisely, the logarithmic utility function used in those studies can be formulated as a special case of (7) with $\theta = 0$: This hypothesis cannot be tested using the tables because we only report on the point estimates of ° and µ that are implied by the preference specification (1). However, for a limited number of specifications we repeated the estimation using (7). Whereas ° is sometimes imprecisely estimated, estimates for µ are always highly significant. Our findings therefore indicate that the logarithmic specification used in several studies is not supported by the data.

The parameter estimates and test statistics reported in this paper have important implications for for the asset pricing literature, yet they do not allow for a definitive conclusion on this topic. Following the work of Lucas (1978) and Breeden (1979), a voluminous literature has investigated the empirical performance of consumption-based asset pricing models, first using a TS-CRRA specification (see Hansen and Singleton (1982,1983,1984), Mehra and Prescott (1985) and Grossman, Melino and Shiller (1987)), and later using more general time-nonseparable specifications (see Abel (1990), Campbell and Cochrane (1995), Constantinides (1990), Heaton (1995)). The implication of our estimates for these studies, which all (implicitly) assume additive separability between consumption and leisure, seems to be that since the parameter · is significantly different from zero, test results in those papers are severely biased. This conclusion is reinforced by the finding that the test statistics in this paper are lower than the corresponding ones in Jacobs (1999). However, whereas the representative agent literature attaches great importance to this type of test statistics (see Hansen and Singleton (1982) and Epstein and Zin (1991)), recently attention has been focused on one particular dimension of the data, the so-called "unconditional restrictions" of the model. This dimension of the model is closely associated with the so called asset pricing puzzles, such as the equity premium puzzle and the riskfree rate puzzle.[15] The question is therefore to what extent the statistically significant presence of leisure in the utility function translates into different properties of the model in the dimension that matters for asset pricing puzzles.

This question cannot be readily answered using the test results in this paper.[16] However, at the very least, the statistically significant and intuitively

[15] Because to a certain extent this terminology is a misnomer, it is instructive to indicate exactly what is meant with unconditional information. In a GMM setup such as the one in this paper, this information can be thought of as exploiting the orthogonality between the Euler equation error and a constant. In contrast, the estimation and testing in this paper exploits orthogonality between the Euler equation and a constant as well as other variables in the agent's information set. To appreciate that this difference can be important, with a TS-CRRA specification unconditional information yields large estimates of the rate of risk aversion, whereas conditional information such as the one used in this paper yields much smaller estimates (see Hansen and Singleton (1982, 1983) and Grossman, Melino and Shiller (1987)).

[16] For nonseparable preferences such a test is less straightforward than in the separable case. In the TS-CRRA case, one can simply use the orthogonality condition associated with the riskless asset and a constant and the orthogonality condition associated with the risky asset and a constant to determine the two parameters of interest, the discount rate and the rate of relative risk aversion. In the nonseparable case we need to determine three parameters, so we need to add an orthogonality condition involving a third asset. If one adds a third asset that has different time series properties from the riskless and risky asset, the danger is that test results will be impacted by the choice of this asset. The best solution is probably to work with the riskless asset and two risky assets with properties similar to the market return.

plausible values of κ suggest that nonseparable utility functions are worth looking into to solve asset pricing puzzles. Also, it was mentioned previously that the representative agent finance literature has not focused on leisure in the utility function because aggregate leisure is too smooth to significantly affect the intertemporal rate of substitution, even though it enters the utility function significantly when estimating Euler equations for aggregate data (See EHS (1988)). Unlike aggregate leisure, household leisure is very variable over time. These findings, together with those of Jagannathan and Wang (1995), who show that human capital variables can play an important role in cross-sectional asset pricing, suggest that nonseparable utility functions are worth looking into to solve asset pricing puzzles.

A comparison with available estimates of preference parameters in the representative agent literature also shows that relaxing the assumptions necessary for aggregation may change the role of leisure in asset pricing models. MRS (1985) and EHS (1988) provide a representative agent analysis of nonlinear Euler equations.[17] However, their setup differs from ours in several respects. First, both studies use information from the first order condition for leisure as well as the first order condition for consumption. Second, whereas MRS (1985) study time-separable preferences, EHS (1988) exclusively study preferences with time-nonseparabilities modeled as in Kydland and Prescott (1982). Conditional on these interpretational difficulties, the differences between estimates in those studies and ours are striking. When MRS (1985) exclusively use the intertemporal optimality condition and the first order condition wrt consumption, they do not obtain statistically significant parameter estimates. Perhaps unsurprisingly, estimation results are also not robust. This contrasts with the estimates obtained by EHS. They report two estimates of θ; 0.85 and 0.8 respectively (their third estimate of -0.16 is obtained after adjusting for taxes). While these estimates are in the concave region of the parameter space, the implied value of the rate of relative risk aversion is much lower than the one obtained in this paper. Also, EHS's estimate of the share parameter γ is around 0.15, much lower than ours. Besides the obvious remark that this estimate may be strongly affected by the time-nonseparabilities in leisure, it must also again be noted that this estimate is affected by the definition of total available time. Using the alternative definition of leisure time in table 4, our estimates are much closer to those of EHS (1988). EHS also note (1988, p.67) that changes in their definition of leisure time could bring their estimates more in line with our estimate (and

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Another possible approach, following Hansen and Jagannathan (1991), is to evaluate the two orthogonality conditions obtained by combining Euler equations (3) and (4) with a constant for different values of β, κ and ψ. The question is then if given the data, we can find solutions for the Euler equations for a priori plausible values of the behavioral parameters.

[17] Note again that for this discussion studies are gouped together mainly according to methodology. The studies by MRS (1985) and EHS (1988) are intimately related to and motivated by the "real business cycle" methodology pioneered by Kydland and Prescott (1982). However, because they provide tests of Euler equations they are intimately related to the asset pricing tests of Hansen and Singleton (1982) and for that reason they are discussed here. This goes to prove once again that the results in this paper are of interest in several research fields, but these fields are intimately connected.

Kydland and Prescott's (1982) calibrated value).

Finally, estimates of the parameters ψ and κ obtained in tables 1 through 3 are of interest to the consumption and labor supply literature. The estimates are of interest to the consumption literature because of several reasons: first, in the consumption literature many tests are constructed using additive separability. The statistically significant estimates of κ in tables 1 through 3 show that this assumption is not supported by the data. Second, the estimate of $\omega_2 = -1/(\psi - 1)$ in (10) is of interest because it is the rate of intertemporal substitution in consumption. Because our estimates of ψ in columns 2 and 3 of tables 1 through 3 are between -1.347 and -2.749, our results imply a rate of intertemporal substitution of consumption between 0.266 and 0.426. It is not straightforward to compare these point estimates to the ones that are available in the literature, because a wide range of parameter estimates have been reported in existing research. Another caveat is that most available estimates of the rate of intertemporal substitution in consumption are obtained using an additively separable specification which is TS-CRRA in consumption. In this context the intertemporal rate of substitution in consumption is simply one divided by the rate of risk aversion. In the representative agent literature, most studies point towards a very large rate of risk aversion and therefore a small intertemporal elasticity (e.g. see Hall (1988), Mehra and Prescott (1985) and Hansen and Jagannathan (1991)). The exception is the evidence in Hansen and Singleton (1982, 1983): when using conditional information, their estimates of the intertemporal substitution elasticity are in line with ours. In the panel data literature, under additive separability different studies have reported a wide range of point estimates. Zeldes (1989) reports estimates in line with the small elasticities in the representative agent literature. The results in Runkle (1991) and Keane and Runkle (1992) are larger, but smaller than the estimates in this paper. Attanasio and Weber (1995), using synthetic cohorts, from the CEX find small elasticities and Attanasio and Browning (1995) using British data find a wide variety of estimates. In the representative agent literature that investigates nonseparable preferences, the study by EHS (1988) is a natural reference point, because the results in MRS (1985) are not very robust. Their estimates of the intertemporal rate of elasticity are actually larger than ours. Altonji and Ham (1990) present panel data evidence under nonseparabilities and also find small elasticities.

It is not the objective of this paper to attempt to reconcile these different estimates. They are determined, among other things, by differences in data selection and econometric methodology. However, comparison of the nonlinear results in table 3A and the estimation results for the linearized equation in table 5A suggests one potential explanatory factor. many elasticities estimated in the panel data literature are estimated using lineraized Euler equations, and they are far more in line with the results in table 5A than with those in table 3A. Whereas the existing literature does not investigate the Euler equation associated with the risky asset, inspection of the results in table 5B indicates intertemporal substitution elasticities even smaller than the ones reported in existing literature when using the riskless asset.

How do the results in tables 1 through 3 reflect on the labor economics literature? As outlined previously, the intertemporal elasticity of labor supply can be computed as $-1/(\eta - 1)$. Given that the estimates of η in columns 2 and 3 of tables 1 through 3 are between -1.267 and -3.188, this implies an elasticity of substitution between 0.238 and 0.441. This range of estimates is higher than most estimates available in the labor supply literature. This is of critical importance because the low estimates in the labor supply literature have traditionally been invoked to argue that intertemporal models did not stand a chance to explain the data.[18] There are several potential explanations for this difference between our estimates and those available in the literature. First, note that once again the definition of leisure plays a role. Table 4, with the alternative definition of leisure has estimates of η of -5.661 and -4.487 respectively, which leads to lower elasticity estimates. However, once again, a more striking difference obtains when we investigate linearizations of the Euler equations in table 5. In table 5A, where we investigate the Euler equation associated with the riskless asset, the estimates of η imply estimates of the substitution elasticity of approximately 0.1, more in line with estimates in the literature. In table 5B implied values of the substitution elasticity are actually much smaller than most estimates available in the literature! (Note again that the Euler equations associated with the risky asset are not investigated in the labor supply literature). It therefore seems that some of the differences between the estimates in this paper and those in the literature seem to be determined by the difference in estimation methodology (linearized versus nonlinear Euler equation), and not by which first order condition is being studied (consumption versus leisure).

Finally, what is the role of preference shifters? As mentioned in Section 6, for some Euler equations the presence of preference shifters yields imprecise parameter estimates. For those that are estimated precisely, the implied estimate of the parameter η and ψ in tables 6 and 7 are not too much affected. The same conslusion holds for the estimates of the linearized Euler equations in tables 8 and 9. The differences in intertemporal elasticities with the existing literature are therefore most likely not due to the rich array of preference shifters that is estimated in many available studies.

8 Conclusion

This paper estimates and tests nonlinear intertemporal Euler equations using a preference specification that is nonseparable in consumption and leisure. It finds that for samples that only contain households at interior solutions, parameter estimates are intuitively plausible. Parameter estimates indicate that the optimization problems under study are concave, which is reassuring. Further, for Cobb-Douglas preferences, the implied point estimates for the share

[18] A convexification argument devised in Rogerson (1988) and used in Hansen (1985) can reconcile low intertemporal substitutability of individual agents with high intertemporal substitutability of the representative agent.

of consumption in the utility function and the rate of relative risk aversion are intuitively appealing. For a sample that also contains households at corner solutions, parameter estimates are almost always hard to interpret. This finding indicates that participation in asset markets is of critical importance when estimating preference parameters. As a result studies of representative agent models are likely to be severely biased. This finding contrasts with the findings in Jacobs (1999), who studies a TS-CRRA preference specification. Whereas estimation results differ dependent on whether one analyzes the Euler equation associated with the riskless or the risky asset, these differences are relatively minor.

A critical difference between the methodology used in this paper and the approach of most of the existing panel data literature is that almost all available papers investigate linearizations of the original nonlinear Euler equations. It is shown that when investigating linearizations, parameter estimates are dramatically different. Most importantly, the implied rate of relative risk aversion is much higher than the one obtained using nonlinear analysis. Interestingly, this finding matches the findings of Jacobs (1998) for a TS-CRRA utility function. Even though it may be tempting to conclude from this that linearization biases parameter estimates, this is not necessarily the case. Another possible interpretation is that parameter estimates obtained from the nonlinear analysis are biased because of measurement error problems. Another difference between this paper and many others is that besides controls for family size, no other preference shifters are included in the Euler equations. When including preference shifters, it is shown that the presence of age variables in the Euler equations leads to imprecise estimates and a lack of robustness when analyzing the Euler equation for the riskless asset.

Because preference specification lies at the basis of most economic analysis, these findings are of substantial interest. I discuss in detail the importance of the findings in this paper for three different but interconnected research areas: 1) intertemporal asset pricing; 2) the literature on consumption, savings and intertemporal labor supply; and 3) the "real business cycle" literature and more generally the intertemporal macroeconomics literature. For the asset pricing literature, the findings in this paper suggest that nonseparabilities may substantially affect the performance of equilibrium asset pricing models. However, because of the nature of the restrictions that are investigated in this paper, estimation and test results do not give a definitive answer to the potential of nonseparabilities to solve asset pricing puzzles, such as the equity premium puzzle and the risk-free rate puzzle. The results are of great interest for the literature on consumption, savings and intertemporal labor supply. First and foremost, the results indicate that many test results in the consumption literature are invalid because of a separability assumption. Moreover, when estimating the intertemporal elasticity of consumption, our estimates are much higher than most of the ones available in the literature. A similar finding holds for our estimates of the intertemporal elasticity of labor supply. It is shown that some of the lower estimates in the literature may obtain because of log-linearization, although it must be emphasized that this paper does not offer convincing arguments to prefer one type of estimation method over the other. Finally, the high estimates of intertemporal substitution elasticities are in principle good news for an extensive literature which investigates dynamic general equilibrium models by simulation. However, our estimates show that the parameters calibrations used in many of these studies are subject to criticism. It is difficult to judge to what extent these findings invalidate the conclusion reached by those models.

These findings suggest a number of questions and extensions. First, it is clear that the use of the PSID, which forces us to use food consumption, may be a problem. The CEX offers data on total consumption, but is not a panel. Perhaps investigation of datasets from countries other than the United States will be helpful here, but such analysis may not be instructive to explain phenomena that are typical to the United States, such as the low savings rate. Second, some of the comparisons made with other studies in the literature are imperfect, because many existing studies use time-nonseparabilities. This observation suggests an analysis of those more general utility functions. Finally, the patterns of the test-statistics are sometimes difficult to understand. A detailed study of the performance of the test statistics used here in a panel data context is desirable.

9 Appendix: Data Selection

This appendix describes the data selection procedure for the Panel Study of Income Dynamics (PSID) data used in the empirical analysis. I use data from the PSID for the years 1974 to 1987. The data is taken from the 1987 respondent and non-respondent files of the PSID and includes all data on families headed by a male, including single males. Observations on individuals in the poverty subsample are included in the sample if they fulfill the selection criteria.

The central issue is the construction of the consumption measure. The most important problem is that the PSID allows only the construction of a measure of food consumption. I therefore follow the existing literature by using food consumption as the consumption measure. Another problem is that this food consumption measure is defined at the household level, and the theory is at the level of an individual agent. The latter problem is solved by working with household consumption and including a function of family size in the Euler equation. All consumption measures in the PSID are in nominal terms. They are converted to real terms by deflating by the food consumption price index, which is obtained from the Economic Report of the President.

The measure of consumption is constructed by aggregating i) money spent on food in restaurants; ii) money spent on food in the home which is not purchased with food stamps; and iii) the monetary value of food obtained through food stamps. The expenditure information on food in and outside the house in interview year $t+1$ is interpreted as referring to year t. Other authors have assumed that expenditure on food consumed in the home and restaurants in year t is a weighted average of the responses from interview year t+1 and interview year t, usually with the respective weights being .75 and .25. It must be noted that this construction of the consumption measure interprets the relevant PSID questions as referring to a flow variable, as opposed to a stock at a point in time. The reason that different studies have not treated this information in a consistent way is that the questions asked are not without ambiguity (See Altug and Miller (1990), Hall and Mishkin (1982), Mankiw and Zeldes (1991), Runkle (1991) and Zeldes (1989) on this issue). Stock and bond returns are constructed to match the construction of the consumption series.

For each Euler equation, results are reported for three different samples. A first sample is the same regardless of the Euler equation under investigation and includes all observations for which the following data selection criteria are satisfied:

- the household head has to be between 25 and 60 years of age.
- yearly hours worked by the household head have to be between 100 and 4160.
- total real food consumption in 1987 dollars has to be less than $12,000 per person and more than $720 per person and total real family food consumption has to be less than $30,000.
- there can be no missing data on the demographic information used in the estimation exercises. The different demographic variables used as regressors are: age of the head, age of the head squared, family size in period t, family size in period t-1, dummies indicating whether the head is married or not in periods t and t-1, and the race of the head. Also, the educational achievement of the household head is used as a selection criterion because it is used in the construction of the instrument set. It must be noted that some estimation exercises using these demographics are not reported in the paper.

This first sample has 18813 observations. For all Euler equations under investigation, estimation and test results are reported for two other samples, which are meant to include only households with strictly positive holdings of the relevant assets. The samples are created by including only households who state that they have nonzero holdings of the relevant asset, or holdings larger than $1,000. To select these households, a series of 1984 questions from the PSID are used. These questions essentially ask households whether they have positive holdings of a relatively riskless and/or a risky asset at that time. Specifically, for the riskless asset the questions (questions # V10917 through # V10921) ask:

- "Do you (or anyone else in your family living there) have any money in checking or savings accounts, money market funds, certificates of deposit, government savings bonds, or Treasury bills, including IRA's?"

- if affirmative answer to i)
- "If you added up all such accounts for all of your family living there, about how much would they amount to right now?"
- iii) if no answer to ii)
- "Would it amount to $10,000 or more?" and dependent on this answer
- "$1,000 or more?" or "$100,000 or more?"

For the risky asset, questions # V10912 through # V10916 are:

- "Do you (or anyone in your family living there) have any shares of stock in publicly held corporations, mutual funds, or investment trusts, including stocks in IRAs?"
- if affirmative answer to i)
- "If you sold all that and paid off everything you owed on it, how much would you have?"
- if no answer to ii)
- "Would it amount to $10,000 or more?" and dependent on this answer
- "$1,000 or more?" or "$100,000 or more?"

The main purpose of using these questions is a comparison of estimation and test results between the sample that only includes households at interior conditions and the sample that also includes households at corner solutions. The analysis of the sample that only include households with asset holdings larger than $1,000 is interesting from two perspectives. First, this sample is less likely to contain classification errors (households at corner solutions), and therefore it is interesting to compare them to the sample that also includes households at corner solutions. Also, a comparison of estimation and test results between the different samples with positive asset holdings can indicate whether they have different characteristics. It must be noted that the questions listed above also allow construction of a sample of households with asset holdings larger than $10,000 and $100,000. However, these samples are not used in the analysis because they do not yield robust estimation results.

It must also be noted that the selection criterion used in this paper is potentially problematic. The most important problem is that for every year that a household is included in the sample, it is classified as an assetholder or a non-assetholder on the basis of this 1984 question. This may obviously give rise to misclassifications. Also, a potential problem with the interpretation of the results is that the difference between the second and the first sample for the analysis of a given Euler equation is not necessarily totally made up by households who are non-assetholders in 1984. A household may simply not be present in the sample in 1984, yet be an assetholder in every other year. For a more detailed discussion of the 1984 PSID question see Mankiw and Zeldes (1991).

References

[1] Abel, Andrew B., 1990, Asset prices under habit formation and catching up with the Joneses, American Economic Review Papers and Proceedings 80, 38-42.

[2] Altonji, Joseph G., 1982, The intertemporal substitution model of labour market ‡uctuations: an empirical analysis, Review of Economic Studies 49, 783-824.

[3] Altonji, Joseph G., 1986, Intertemporal substitution in labor supply: evidence from micro data, Journal of Political Economy 94, S176-S215.

[4] Altonji, Joseph G. and Aloysius Siow, 1987, Testing the response of consumption to income changes with (noisy) panel data, Quarterly Journal of Economics 102, 293-328.

[5] Altonji, Joseph G. and John C. Ham, 1990, Intertemporal substitution, exogeneity and surprises: estimating life cycle models for Canada, Canadian Journal of Economics 23, 1-43.

[6] Altug, Sumru and Robert A. Miller, 1990, Household choices in equilibrium, Econometrica 58, 543-570.

[7] Attanasio, Orazio P. and Martin Browning, 1995, Consumption over the life cycle and over the business cycle, American Economic Review 85, 1118-1137.

[8] Attanasio, Orazio P. and Guglielmo Weber, 1995, Is consumption growth consistent with intertemporal optimization? Evidence from the consumer expenditure survey, Journal of Political Economy 103, 1121-1157.

[9] Backus, David K., Patrick J. Kehoe and Finn E. Kydland, International real business cycles, Journal of Political Economy 100, 745-775.

[10] Basak, Suleyman, 1999, On the ‡uctuations in consumption and market returns in the presence of labor and human capital: an equilibrium analysis, Journal of Economic Dynamics and Control 23, 1029-1064.

[11] Bodie, Zvi, Robert C. Merton and William F. Samuelson, 1992, Labor supply ‡exibility and portfolio choice in a life cycle model, Journal of Economic Dynamics and Control 16, 427-449.

[12] Breeden, Douglas T., 1979, An intertemporal asset pricing model with stochastic consumption and investing opportunities, Journal of Financial Economics 7, 265-296.

[13] Breeden, Douglas T., Michael Gibbons and Robert Litzenberger, 1989, Empirical tests of the consumption-based CAPM, Journal of Finance 44, 231-262.

[14] Browning, Martin and Annamaria Lusardi, 1996, Household saving: micro theories and micro facts, Journal of Economic Literature 34, 1797-1855.

[15] Browning, Martin, Angus S. Deaton and Margaret Irish, A profitable approach to labor supply and commodity demands over the life-cycle, Econometrica 53, 503-544

[16] Campbell, John Y. and John Cochrane, 1995, By force of habit: A consumption-based explanation of aggregate stock market behaviour, NBER working paper no. 4995, National Bureau of Economic Research, Cambridge, MA.

[17] Campbell, John Y., Andrew W. Lo, and A. Craig MacKinlay (1997), "The Econometrics of Financial Markets," Princeton University Press.

[18] Christiano, Lawrence J. and Martin Eichenbaum, 1992, Current real business cycle theories and aggregate labor-market fluctuations, American Economic Review 82, 430-450.

[19] Cochrane, John, 1991, A simple test of consumption insurance, Journal of Political Economy 99, 957-976.

[20] Cochrane, John and Lars Peter Hansen, 1992, Asset pricing lessons for macroeconomics, in O. Blanchard and S. Fischer, eds.: 1992 NBER Macroeconomics Annual (National Bureau of Economic Research, Cambridge, MA).

[21] Constantinides, George M., 1990, Habit formation: A resolution of the equity premium puzzle, Journal of Political Economy 98, 519-543.

[22] Deaton, Angus S., 1992, Understanding consumption (Oxford University Press, New York, NY).

[23] Deaton, Angus S. and John Muellbauer, 1980, Economics and consumer behavior, New York, Cambridge University Press.

[24] Detemple, Jerome, 1996, Intertemporal asset pricing with incomplete markets and nontraded assets, working paper, McGill University.

[25] Detemple, Jerome and Fernando Zapatero, 1991, Asset prices in an exchange economy with habit formation, Econometrica 59, 1633-1657.

[26] Eichenbaum, Martin, Lars Peter Hansen, and Kenneth Singleton, 1988, A time series analysis of representative agent models of consumption and leisure choice under uncertainty, Quarterly Journal of Economics 103, 51-78.

[27] Epstein, Larry G. and Stanley E. Zin, 1991, Substitution, risk aversion, and the temporal behavior of asset returns: an empirical analysis, Journal of Political Economy 99, 263-287.

[28] Fama, Eugene, 1991, Efficient capital markets: II, Journal of Finance 46, 1575-1618.

[29] Grossman, Sanford J., Melino, Angelo and Robert J. Shiller, 1987, Estimating the continuous-time consumption-based asset pricing model, Journal of Business and Economics Statistics 5, 315-327.

[30] Hall, Robert E., 1988, Intertemporal substitution in consumption, Journal of Political Economy 96, 339-357.

[31] Hall, Robert E., and Frederic S. Mishkin, 1982, The sensitivity of consumption to transitory income: Estimates from panel data on households, Econometrica 50, 461-482.

[32] Ham, John, 1986, Testing whether unemployment represents intertemporal labour supply behaviour, Review of Economic Studies 53, 559-578.

[33] Hansen, Gary, 1985, Indivisible labor and the business cycle, Journal of Monetary Economics 16, 309-327.

[34] Hansen, Lars Peter, 1982, Large sample properties of generalized method of moments estimators, Econometrica 50, 1029-1054.

[35] Hansen, Lars Peter and Ravi Jagannathan, 1991, Implications of security market data for models of dynamic economies, Journal of Political Economy 99, 225-262.

[36] Hansen, Lars Peter and Kenneth Singleton, 1982, Generalized instrumental variables estimation of nonlinear rational expectations models, Econometrica 50, 1269-1286.

[37] Hansen, Lars Peter and Kenneth Singleton, 1983, Stochastic consumption, risk aversion and the temporal behavior of asset returns, Journal of Political Economy 91, 249-265.

[38] Hansen, Lars Peter and Kenneth Singleton, 1984, Errata, Econometrica 52, 267-268.

[39] Hayashi, Fumio, Joseph Altonji and Laurence Kotlikoff, 1994, Risk sharing across and within families, Econometrica 64, 261-294.

[40] Heaton, John, 1993, The interaction between time-nonseparable preferences and time aggregation, Econometrica 61, 353-385.

[41] Heaton, John, 1995, An empirical investigation of asset pricing with temporally dependent preference specifications, Econometrica 63, 681-717.

[42] Heaton, John and Deborah Lucas, 1996, Evaluating the effects of incomplete markets for risk sharing and asset pricing, Journal of Political Economy 104, 443-487.

[43] Heckman, James J. and Thomas E. MaCurdy, A life-cycle model of female labour supply, Review of Economic Studies 47, 47-74.

[44] Hotz, V. Joseph, Finn E. Kydland and Guilherme L. Sedlacek, 1988, Intertemporal preferences and labor supply, Econometrica 56, 335-360.

[45] Jacobs, Kris, 1998a, Estimating the rate of relative risk aversion: interpreting the evidence from panel data, working paper, McGill University.

[46] Jacobs, Kris, 1998b, Asset market data do not imply high risk aversion: reassessing the evidence on asset pricing puzzles, working paper, McGill University.

[47] Jacobs, Kris, 1999, Incomplete markets and security prices: do asset-pricing puzzles result from aggregation problems?, Journal of Finance 54, 123-164.

[48] Jagannathan, Ravi and Zhenyu Wang, 1996, The conditional CAPM and the cross-section of expected returns, Journal of Finance 51, 3-53

[49] Keane, Michael P. and David E. Runkle, 1992, On the estimation of panel data models with serial correlation when instruments are not strictly exogenous, Journal of Business and Economic Statistics 10, 1-9.

[50] Kydland, Finn and Edward Prescott, 1982, Time-to-build and aggregate ‡uctuations, Econometrica 50, 1345-1370.

[51] Lucas, Robert, 1978, Asset prices in an exchange economy, Econometrica 46, 1429-1445.

[52] Mace, Barbara, 1991, Full insurance in the presence of aggregate uncertainty, Journal of Political Economy 99, 928-956.

[53] MaCurdy, Thomas E, 1981, An empirical model of labor supply in a life-cycle setting, Journal of Political Economy 89, 1059-1086.

[54] MaCurdy, Thomas E., 1983, A simple scheme for estimating an intertemporal model of labor supply and consumption in the presence of taxes and uncertainty, International Economic Review 24, 265-289.

[55] Mankiw, N. Gregory and Stephen P. Zeldes, 1991, The consumption of stockholders and nonstockholders, Journal of Financial Economics 29, 113-135.

[56] Mankiw, N. Gregory, Julio Rotemberg and Lawrence Summers, 1985, Intertemporal substitution in macroeconomics, Quarterly Journal of Economics 100, 225-252.

[57] Mayers, David, 1972, Non-marketable assets and capital market equilibrium under uncertainty, in: M. Jensen, ed.: Studies in the Theory of Capital Markets (Praeger, New York, NY), 223-248.

[58] Mayers, David, 1973, Nonmarketable assets and the determination of capital asset prices in the absence of a riskless asset, Journal of Business 46, 258-276.

[59] Mehra, Rajnish and Edward C. Prescott, 1985, The equity premium: A puzzle, Journal of Monetary Economics 15, 145-161.

[60] Rogerson, Richard, 1988, Indivisible labor, lotteries and equilibrium, Journal of Monetary Economics 21, 3-16.

[61] Ross, Steven, 1976, The arbitrage theory of capital asset pricing, Journal of Economic Theory 13, 341-360.

[62] Runkle, David E., 1991, Liquidity constraints and the permanent-income hypothesis: Evidence from panel data, Journal of Monetary Economics 27, 73-98.

[63] Sundaresan, Suresh, 1989, Intertemporally dependent preferences and the volatility of consumption and wealth, Review of Financial Studies 2, 73-88

[64] Svensson, Lars and Ingrid Werner, 1993, Nontraded assets in incomplete markets, European Economic Review 37, 1149-1168.

[65] Telmer, Chris I., 1993, Asset pricing puzzles and incomplete markets, Journal of Finance 48, 1803-1832

[66] Zeldes, Stephen P., 1989, Consumption and liquidity constraints, Journal of Political Economy 97, 305-346

Table 1A

Estimation and test results for the nonlinear Euler equation associated with the riskless asset. Results obtained using instrument set one.

Estimation and test results obtained by GMM estimation of the Euler equation

$$1 = b\left(\frac{c_{i,t+1}}{c_{i,t}}\right)^{y-1}\left(\frac{l_{i,t+1}}{l_{i,t}}\right)^{k}\left(\frac{1}{q_t}\right)\exp[\,p_1\, fam_{i,t+1} + p_2\, fam_{i,t}\,] + e_{i,t+1}$$

where $c_{i,t}$ is consumption of household i at date t, $l_{i,t}$ is the leisure time of household head i at date t, q_t is the (normalized) price of the riskless asset in period t, $fs_{i,t}$ is the size of household i in period t and $e_{i,t+1}$ is an econometric error term. Results for f_1 and f_2 are not reported.

	All Households	Asset Holdings > 0	Asset Holdings > 1000
b	0.676	0.824	0.823
(Standard Deviation)	(0.095)	(0.093)	(0.077)
$y-1$	-0.428	-1.745	-1.602
(Standard Deviation)	(0.0.482)	(0.468)	(0.834)
k	5.298	-1.363	-1.602
(Standard Deviation)	(0.586)	(0.624)	(0.834)
p_1	-0.020	0.051	0.048
(Standard Deviation)	(0.032)	(0.035)	(0.029)
p_2	0.024	-0.038	-0.042
(Standard Deviation)	(0.027)	(0.027)	(0.024)
Number of instruments	7	7	7
Degrees of Freedom	2	2	2
J statistic	0.247	2.066	1.674
(Significance Level)	(0.883)	(0.355)	(0.433)
Implied g	0.097	0.353	0.364
Implied J	5.870	-2.109	-2.520
H	3555	740	413
N	18813	5029	2990

Table 1B

Estimation and test results for the nonlinear Euler equation associated with the risky asset. Results obtained using instrument set one.

Estimation and test results obtained by GMM estimation of the Euler equation

$$1 = b\left(\frac{c_{i,t+1}}{c_{i,t}}\right)^{y-1}\left(\frac{l_{i,t+1}}{l_{i,t}}\right)^{k}\left(\frac{p_{t+1}+d_{t+1}}{p_t}\right)\exp[p_1\, fam_{i,t+1} + p_2\, fam_{i,t}] + e_{i,t+1}$$

where $c_{i,t}$ is consumption of household i at date t, $l_{i,t}$ is the leisure time of household head i at date t, p_t is the price of the risky asset in period t, d_t is the dividend of the risky asset in period t , $fs_{i,t}$ is the size of household i in period t and $e_{i,t+1}$ is an econometric error term. Results for f_1 and f_2 are not reported.

	All Households	Asset Holdings > 0	Asset Holdings > 1000
b	0.382	0.560	0.679
(Standard Deviation)	(0.053)	(0.208)	(0.238)
$y-1$	-1.176	-2.724	-2.409
(Standard Deviation)	(0.692)	(0.831)	(1.086)
k	6.672	-1.850	-2.199
(Standard Deviation)	(0.637)	(0.804)	(1.239)
p_1	0.010	0.010	0.062
(Standard Deviation)	(0.087)	(0.067)	(0.055)
p_2	0.023	-0.058	-0.050
(Standard Deviation)	(0.067)	(0.049)	(0.039)
Number of instruments	7	7	7
Degrees of Freedom	2	2	2
J statistic	0.451	6.950	6.831
(Significance Level)	(0.798)	(0.030)	(0.032)
Implied g	-0.027	0.482	0.390
Implied J	6.496	-3.575	-3.608
H	3555	740	413
N	18813	5029	2990

Table 2A

Estimation and test results for the nonlinear Euler equation associated with the riskless asset. Results obtained using instrument set two.

Estimation and test results obtained by GMM estimation of the Euler equation

$$1 = b\left(\frac{c_{i,t+1}}{c_{i,t}}\right)^{y-1}\left(\frac{l_{i,t+1}}{l_{i,t}}\right)^{k}\left(\frac{1}{q_t}\right)\exp[p_1\, fam_{i,t+1} + p_2\, fam_{i,t}] + e_{i,t+1}$$

where $c_{i,t}$ is consumption of household i at date t, $l_{i,t}$ is the leisure time of household head i at date t, q_t is the (normalized) price of the riskless asset in period t, $fs_{i,t}$ is the size of household i in period t and $e_{i,t+1}$ is an econometric error term. Results for f_1 and f_2 are not reported.

	All Households	Asset Holdings > 0	Asset Holdings > 1000
b	0.760	0.783	0.894
(Standard Deviation)	(0.062)	(0.085)	(0.076)
$y-1$	-2.770	-1.674	-1.347
(Standard Deviation)	(0.536)	(0.495)	(0.414)
k	4.624	-3.188	-2.182
(Standard Deviation)	(0.699)	(0.633)	(1.101)
p_1	-0.019	0.043	0.033
(Standard Deviation)	(0.029)	(0.030)	(0.025)
p_2	0.021	-0.033	-0.035
(Standard Deviation)	(0.025)	(0.026)	(0.021)
Number of instruments	11	11	11
Degrees of Freedom	6	6	6
J statistic	6.509	2.450	4.561
(Significance Level)	(0.368)	(0.874)	(0.601)
Implied g	-0.620	0.174	0.137
Implied J	2.854	-3.863	-2.530
H	3555	740	413
N	18813	5029	2990

Table 2B

Estimation and test results for the nonlinear Euler equation associated with the risky asset. Results obtained using instrument set two.

Estimation and test results obtained by GMM estimation of the Euler equation

$$1 = b\left(\frac{c_{i,t+1}}{c_{i,t}}\right)^{y\ -1}\left(\frac{l_{i,t+1}}{l_{i,t}}\right)^{k}\left(\frac{p_{t+1} + d_{t+1}}{p_t}\right)\exp[p_1\ fam_{i,t+1} + p_2\ fam_{i,t}] + e_{i,t+1}$$

where $c_{i,t}$ is consumption of household i at date t, $l_{i,t}$ is the leisure time of household head i at date t, p_t is the price of the risky asset in period t, d_t is the dividend of the risky asset in period t , $fs_{i,t}$ is the size of household i in period t and $e_{i,t+1}$ is an econometric error term. Results for f_1 and f_2 are not reported.

	All Households	Asset Holdings > 0	Asset Holdings > 1000
b	0.536	0.592	0.649
(Standard Deviation)	(0.139)	(0.156)	(0.240)
$y\ -1$	-1.410	-2.538	-2.483
(Standard Deviation)	(0.762)	(0.626)	(1.009)
k	5.181	-2.270	-3.032
(Standard Deviation)	(0.833)	(1.213)	(1.887)
p_1	0.015	0.089	0.069
(Standard Deviation)	(0.059)	(0.053)	(0.051)
p_2	0.009	-0.051	-0.059
(Standard Deviation)	(0.033)	(0.043)	(0.079)
Number of instruments	11	11	11
Degrees of Freedom	6	6	6
J statistic	15.610	8.605	19.470
(Significance Level)	(0.016)	(0.197)	(0.003)
Implied g	-0.086	0.403	0.328
Implied J	4.770	-3.809	-4.515
H	3555	740	413
N	18813	5029	2990

Table 3A

Estimation and test results for the nonlinear Euler equation associated with the riskless asset. Results obtained using instrument set three.

Estimation and test results obtained by GMM estimation of the Euler equation

$$1 = b\left(\frac{c_{i,t+1}}{c_{i,t}}\right)^{y-1}\left(\frac{l_{i,t+1}}{l_{i,t}}\right)^{k}\left(\frac{1}{q_t}\right)\exp[p_1\, fam_{i,t+1} + p_2\, fam_{i,t}] + e_{i,t+1}$$

where $c_{i,t}$ is consumption of household i at date t, $l_{i,t}$ is the leisure time of household head i at date t, q_t is the (normalized) price of the riskless asset in period t, $fs_{i,t}$ is the size of household i in period t and $e_{i,t+1}$ is an econometric error term. Results for f_1 and f_2 are not reported.

	All Households	Asset Holdings > 0	Asset Holdings > 1000
b	0.790	0.828	0.869
(Standard Deviation)	(0.098)	(0.084)	(0.057)
$y - 1$	-0.437	-1.731	-1.645
(Standard Deviation)	(0.421)	(0.420)	(0.374)
k	4.245	-1.267	-1.436
(Standard Deviation)	(1.045)	(0.670)	(0.735)
p_1	-0.011	0.050	0.038
(Standard Deviation)	(0.022)	(0.034)	(0.022)
p_2	0.013	-0.038	-0.035
(Standard Deviation)	(0.018)	(0.027)	(0.019)
Number of instruments	9	9	9
Degrees of Freedom	4	4	4
J statistic	3.091	13.235	6.768
(Significance Level)	(0.542)	(0.010)	(0.148)
Implied g	0.117	0.360	0.309
Implied J	4.808	-1.980	-2.081
H	3555	740	413
N	18813	5029	2990

Table 3B

Estimation and test results for the nonlinear Euler equation associated with the risky asset. Results obtained using instrument set three.

Estimation and test results obtained by GMM estimation of the Euler equation

$$1 = b\left(\frac{c_{i,t+1}}{c_{i,t}}\right)^{y-1}\left(\frac{l_{i,t+1}}{l_{i,t}}\right)^{k}\left(\frac{p_{t+1}+d_{t+1}}{p_t}\right)\exp[p_1\, fam_{i,t+1} + p_2\, fam_{i,t}] + e_{i,t+1}$$

where $c_{i,t}$ is consumption of household i at date t, $l_{i,t}$ is the leisure time of household head i at date t, p_t is the price of the risky asset in period t, d_t is the dividend of the risky asset in period t , $fs_{i,t}$ is the size of household i in period t and $e_{i,t+1}$ is an econometric error term. Results for f_1 and f_2 are not reported.

	All Households	Asset Holdings > 0	Asset Holdings > 1000
b	0.404	0.555	0.720
(Standard Deviation)	(0.068)	(0.191)	(0.225)
$y-1$	-1.253	-2.749	-2.193
(Standard Deviation)	(0.707)	(0.767)	(1.103)
k	6.445	-1.815	-2.085
(Standard Deviation)	(0.667)	(1.213)	(1.085)
p_1	0.013	0.010	0.054
(Standard Deviation)	(0.008)	(0.069)	(0.049)
p_2	0.019	-0.059	-0.045
(Standard Deviation)	(0.006)	(0.053)	(0.035)
Number of instruments	9	9	9
Degrees of Freedom	4	4	4
J statistic	2.456	9.664	13.228
(Significance Level)	(0.652)	(0.046)	(0.010)
Implied g	-0.040	0.490	0.363
Implied J	6.192	-3.564	-3.278
H	3555	740	413
N	18813	5029	2990

Table 4A

Estimation and test results for the nonlinear Euler equation associated with the riskless asset. Results obtained using instrument set two. Time endowment set to 8760 hours.

Estimation and test results obtained by GMM estimation of the Euler equation

$$1 = b\left(\frac{c_{i,t+1}}{c_{i,t}}\right)^{y-1}\left(\frac{l_{i,t+1}}{l_{i,t}}\right)^{k}\left(\frac{1}{q_t}\right)\exp[p_1\, fam_{i,t+1} + p_2\, fam_{i,t}] + e_{i,t+1}$$

where $c_{i,t}$ is consumption of household i at date t, $l_{i,t}$ is the leisure time of household head i at date t, q_t is the (normalized) price of the riskless asset in period t, $fs_{i,t}$ is the size of household i in period t and $e_{i,t+1}$ is an econometric error term. Results for f_1 and f_2 are not reported.

	All Households	Asset Holdings > 0	Asset Holdings > 1000
b	0.758	0.793	0.882
(Standard Deviation)	(0.090)	(0.079)	(0.075)
$y - 1$	-0.125	-1.644	-1.379
(Standard Deviation)	(0.656)	(0.472)	(0.391)
k	8.642	-5.661	-4.487
(Standard Deviation)	(1.780)	(1.265)	(1.870)
p_1	-0.022	0.040	0.034
(Standard Deviation)	(0.032)	(0.028)	(0.025)
p_2	0.028	-0.029	-0.034
(Standard Deviation)	(0.031)	(0.024)	(0.020)
Number of instruments	11	11	11
Degrees of Freedom	6	6	6
J statistic	17.455	3.096	4.019
(Significance Level)	(0.007)	(0.796)	(0.674)
Implied g	-0.014	0.102	0.077
Implied J	8.517	-6.306	-4.866
H	3555	740	413
N	18813	5029	2990

Table 4B

Estimation and test results for the nonlinear Euler equation associated with the risky asset. Results obtained using instrument set two. Time endowment set to 8760 hours.

Estimation and test results obtained by GMM estimation of the Euler equation

$$1 = b\left(\frac{c_{i,t+1}}{c_{i,t}}\right)^{y-1}\left(\frac{l_{i,t+1}}{l_{i,t}}\right)^{k}\left(\frac{p_{t+1}+d_{t+1}}{p_t}\right)\exp[\,p_1\ fam_{i,t+1} + p_2\ fam_{i,t}\,] + e_{i,t+1}$$

where $c_{i,t}$ is consumption of household i at date t, $l_{i,t}$ is the leisure time of household head i at date t, p_t is the price of the risky asset in period t, d_t is the dividend of the risky asset in period t , $fs_{i,t}$ is the size of household i in period t and $e_{i,t+1}$ is an econometric error term. Results for f_1 and f_2 are not reported.

	All Households	Asset Holdings > 0	Asset Holdings > 1000
b	0.556	0.589	0.638
(Standard Deviation)	(0.159)	(0.158)	(0.222)
$y-1$	-1.490	-2.555	-2.514
(Standard Deviation)	(0.790)	(0.653)	(0.924)
k	9.065	-4.146	-5.930
(Standard Deviation)	(1.756)	(2.558)	(3.398)
p_1	0.019	0.090	0.069
(Standard Deviation)	(0.052)	(0.054)	(0.046)
p_2	0.010	-0.051	-0.057
(Standard Deviation)	(0.028)	(0.043)	(0.034)
Number of instruments	11	11	11
Degrees of Freedom	6	6	6
J statistic	14.151	8.115	21.848
(Significance Level)	(0.027)	(0.229)	(0.001)
Implied g	-0.057	0.272	0.203
Implied J	8.575	-5.702	-7.445
H	3555	740	413
N	18813	5029	2990

Table 5A

Estimation and test results for the linearized Euler equation associated with the riskless asset. Results obtained using instrument set three.

Estimation and test results obtained by GMM estimation of

$$\Delta \ln(c_{i,t+1}) = w_1 + w_2 \ln(\frac{1}{q_t}) + w_3 \Delta \ln(l_{i,t+1}) + p_1 \, fam_{i,t+1} + p_2 \, fam_{i,t} + u_{i,t+1}$$

where $c_{i,t}$ is consumption of household i at date t, $l_{i,t}$ is the leisure time of household head i at date t, p_t is the price of the risky asset in period t, d_t is the dividend of the risky asset in period t , $fs_{i,t}$ is the size of household i in period t and $e_{i,t+1}$ is an econometric error term. Results for f_1 and f_2 are not reported.

	All Households	Asset Holdings > 0	Asset Holdings > 1000
w_1	0.035	0.032	0.038
(Standard Deviation)	(0.012)	(0.010)	(0.018)
w_2	0.148	0.224	0.178
(Standard Deviation)	(0.212)	(0.193)	(0.209)
w_3	-0.877	-1.659	-1.722
(Standard Deviation)	(0.549)	(0.426)	(0.885)
p_1	0.018	0.010	0.011
(Standard Deviation)	(0.005)	(0.006)	(0.012)
p_2	-0.027	-0.017	-0.020
(Standard Deviation)	(0.005)	(0.007)	(0.011)
Number of instruments	9	9	9
Degrees of Freedom	4	4	4
J statistic	43.187	53.327	16.724
(Significance Level)	(0.000)	(0.000)	(0.002)
Implied y	-5.756	-3.464	-4.617
Implied k	-5.925	-7.406	-9.674
Implied g	0.492	0.318	0.323
Implied J	-11.682	-10.870	-14.292
H	3555	740	413
N	18813	5029	2990

Table 5B

Estimation and test results for the linearized Euler equation associated with the risky asset. Results obtained using instrument set three.

Estimation and test results obtained by GMM estimation of

$$\Delta \ln(c_{i,t+1}) = w_1 + w_2 \ln\left(\frac{p_{t+1}+d_{t+1}}{p_t}\right) + w_3 \Delta \ln(l_{i,t+1}) + p_1\, fam_{i,t+1} + p_2\, fam_{i,t} + u_{i,t+1}$$

where $c_{i,t}$ is consumption of household i at date t, $l_{i,t}$ is the leisure time of household head i at date t, p_t is the price of the risky asset in period t, d_t is the dividend of the risky asset in period t , $fs_{i,t}$ is the size of household i in period t and $e_{i,t+1}$ is an econometric error term. Results for f_1 and f_2 are not reported.

	All Households	Asset Holdings > 0	Asset Holdings > 1000
w_1	0.032	0.033	0.039
(Standard Deviation)	(0.011)	(0.010)	(0.017)
w_2	0.071	0.059	0.036
(Standard Deviation)	(0.061)	(0.059)	(0.076)
w_3	-1.052	-1.797	-1.795
(Standard Deviation)	(0.446)	(0.470)	(0.847)
p_1	0.018	0.010	0.011
(Standard Deviation)	(0.005)	(0.006)	(0.012)
p_2	-0.028	-0.017	-0.020
(Standard Deviation)	(0.005)	(0.007)	(0.011)
Number of instruments	9	9	9
Degrees of Freedom	4	4	4
J statistic	481.434	41.537	16.375
(Significance Level)	(0.000)	(0.000)	(0.002)
Implied y	-13.084	-15.949	-26.777
Implied k	-14.816	-30.457	-49.861
Implied g	0.468	0.343	0.349
Implied J	-27.901	-46.406	-76.638
H	3555	740	413
N	18813	5029	2990

Table 6A

Estimation and test results for the nonlinear Euler equation associated with the riskless asset. Results obtained using instrument set four.

Estimation and test results obtained by GMM estimation of the Euler equation

$$1 = b\left(\frac{c_{i,t+1}}{c_{i,t}}\right)^{y\ -1}\left(\frac{l_{i,t+1}}{l_{i,t}}\right)^{k}\left(\frac{1}{q_t}\right)\exp[\,p_1\ fam_{i,t+1} + p_2\ fam_{i,t}\,] + e_{i,t+1}$$

where $c_{i,t}$ is consumption of household i at date t, $l_{i,t}$ is the leisure time of household head i at date t, q_t is the (normalized) price of the riskless asset in period t, $fs_{i,t}$ is the size of household i in period t and $e_{i,t+1}$ is an econometric error term. Results for f_1 and f_2 are not reported.

	All Households	Asset Holdings > 0	Asset Holdings > 1000
b	0.895	0.953	1.014
(Standard Deviation)	(0.141)	(0.095)	(0.119)
$y\ -1$	-0.376	-1.163	-0.942
(Standard Deviation)	(0.371)	(0.233)	(0.339)
k	3.984	-0.202	-0.362
(Standard Deviation)	(1.085)	(1.201)	(1.533)
p_1	-0.010	0.021	0.009
(Standard Deviation)	(0.021)	(0.018)	(0.017)
p_2	0.013	-0.014	-0.008
(Standard Deviation)	(0.017)	(0.015)	(0.018)
d_1	-0.005	0.0003	-0.001
(Standard Deviation)	(0.010)	(0.0040)	(0.005)
d_2	0.0006	-0.00003	-0.067
(Standard Deviation)	(0.0013)	(0.00006)	(0.785)
Number of instruments	11	11	11
Degrees of Freedom	4	4	4
J statistic	5.521	10.049	27.387
(Significance Level)	(0.237)	(0.039)	(0.000)
Implied g	0.135	0.039	-0.190
Implied J	4.608	-4.179	-0.304
H	3555	740	413
N	18813	5029	2990

Table 6B

Estimation and test results for the nonlinear Euler equation associated with the risky asset. Results obtained using instrument set four.

Estimation and test results obtained by GMM estimation of the Euler equation

$$1 = b\left(\frac{c_{i,t+1}}{c_{i,t}}\right)^{y-1}\left(\frac{l_{i,t+1}}{l_{i,t}}\right)^{k}\left(\frac{p_{t+1}+d_{t+1}}{p_t}\right)\exp[p_1\ fam_{i,t+1} + p_2\ fam_{i,t}] + e_{i,t+1}$$

where $c_{i,t}$ is consumption of household i at date t, $l_{i,t}$ is the leisure time of household head i at date t, p_t is the price of the risky asset in period t, d_t is the dividend of the risky asset in period t , $fs_{i,t}$ is the size of household i in period t and $e_{i,t+1}$ is an econometric error term. Results for f_1 and f_2 are not reported.

	All Households	Asset Holdings > 0	Asset Holdings > 1000
b	1.472	0.442	0.758
(Standard Deviation)	(1.006)	(0.361)	(0.476)
$y-1$	-1.191	-2.540	-1.925
(Standard Deviation)	(0.734)	(0.946)	(1.315)
k	6.496	-1.030	-1.471
(Standard Deviation)	(0.668)	(2.558)	(1.418)
p_1	0.003	0.084	0.034
(Standard Deviation)	(0.077)	(0.075)	(0.047)
p_2	0.041	-0.051	-0.028
(Standard Deviation)	(0.054)	(0.055)	(0.039)
d_1	-0.071	0.021	0.003
(Standard Deviation)	(0.046)	(0.029)	(0.021)
d_2	0.090	-0.00029	-0.00007
(Standard Deviation)	(0.056)	(0.00038)	(0.00020)
Number of instruments	11	11	11
Degrees of Freedom	4	4	4
J statistic	6.133	11.754	16.639
(Significance Level)	(0.189)	(0.019)	(0.002)
Implied g	-0.030	0.599	0.386
Implied J	6.305	-2.570	-2.396
H	3555	740	413
N	18813	5029	2990

Table 7A

Estimation and test results for the nonlinear Euler equation associated with the riskless asset. Results obtained using instrument set five.

Estimation and test results obtained by GMM estimation of the Euler equation

$$1 = b\left(\frac{c_{i,t+1}}{c_{i,t}}\right)^{y-1}\left(\frac{l_{i,t+1}}{l_{i,t}}\right)^{k}\left(\frac{1}{q_t}\right)\exp[p_1\, fam_{i,t+1} + p_2\, fam_{i,t}] + e_{i,t+1}$$

where $c_{i,t}$ is consumption of household i at date t, $l_{i,t}$ is the leisure time of household head i at date t, q_t is the (normalized) price of the riskless asset in period t, $fs_{i,t}$ is the size of household i in period t and $e_{i,t+1}$ is an econometric error term. Results for f_1 and f_2 are not reported.

	All Households	Asset Holdings > 0	Asset Holdings > 1000
b	0.892	0.430	0.615
(Standard Deviation)	(0.087)	(0.337)	(0.303)
$y-1$	-0.994	-2.342	-1.972
(Standard Deviation)	(0.560)	(0.813)	(0.548)
k	0.146	-2.211	-2.225
(Standard Deviation)	(1.064)	(0.796)	(0.714)
p_1	0.027	0.079	0.053
(Standard Deviation)	(0.024)	(0.062)	(0.030)
p_2	-0.022	-0.047	-0.046
(Standard Deviation)	(0.016)	(0.042)	(0.025)
d_1	0.0018	0.050	0.024
(Standard Deviation)	(0.0040)	(0.078)	(0.091)
d_2	0.0007	-0.0012	-0.0004
(Standard Deviation)	(0.0019)	(0.0026)	(0.0033)
Number of instruments	11	11	11
Degrees of Freedom	4	4	4
J statistic	29.695	0.881	5.809
(Significance Level)	(0.000)	(0.927)	(0.213)
Implied g	0.039	0.377	0.304
Implied J	0.152	-3.553	-3.197
H	3555	740	413
N	18813	5029	2990

Table 7B

Estimation and test results for the nonlinear Euler equation associated with the risky asset. Results obtained using instrument set five.

Estimation and test results obtained by GMM estimation of the Euler equation

$$1 = b\left(\frac{c_{i,t+1}}{c_{i,t}}\right)^{y\ -1}\left(\frac{l_{i,t+1}}{l_{i,t}}\right)^{k}\left(\frac{p_{t+1} + d_{t+1}}{p_t}\right)\exp[\,p_1\ fam_{i,t+1} + p_2\ fam_{i,t}\,] + e_{i,t+1}$$

where $c_{i,t}$ is consumption of household i at date t, $l_{i,t}$ is the leisure time of household head i at date t, p_t is the price of the risky asset in period t, d_t is the dividend of the risky asset in period t , $fs_{i,t}$ is the size of household i in period t and $e_{i,t+1}$ is an econometric error term. Results for f_1 and f_2 are not reported.

	All Households	Asset Holdings > 0	Asset Holdings > 1000
b	0.458	1.006	0.567
(Standard Deviation)	(0.178)	(0.257)	(0.509)
$y\ -1$	-1.228	-3.556	-2.826
(Standard Deviation)	(0.631)	(0.900)	(1.394)
k	6.649	-2.777	-2.630
(Standard Deviation)	(0.737)	(1.416)	(1.359)
p_1	0.012	0.155	0.083
(Standard Deviation)	(0.077)	(0.101)	(0.076)
p_2	0.020	-0.064	-0.061
(Standard Deviation)	(0.062)	(0.089)	(0.049)
d_1	-0.020	0.153	-0.016
(Standard Deviation)	(0.049)	(0.299)	(0.192)
d_2	0.005	-0.0043	0.0012
(Standard Deviation)	(0.023)	(0.0102)	(0.0072)
Number of instruments	11	11	11
Degrees of Freedom	4	4	4
J statistic	1.964	2.543	11.063
(Significance Level)	(0.742)	(0.636)	(0.025)
Implied g	-0.035	0.479	0.409
Implied J	6.421	-5.333	-4.456
H	3555	740	413
N	18813	5029	2990

Table 8A

Estimation and test results for the linearized Euler equation associated with the riskless asset. Results obtained using instrument set four.

Estimation and test results obtained by GMM estimation of

$$\Delta \ln(c_{i,t+1}) = w_1 + w_2 \ln(\frac{1}{q_t}) + w_3 \Delta \ln(l_{i,t+1}) + p_1\, fam_{i,t+1} + p_2\, fam_{i,t} + u_{i,t+1}$$

where $c_{i,t}$ is consumption of household i at date t, $l_{i,t}$ is the leisure time of household head i at date t, p_t is the price of the risky asset in period t, d_t is the dividend of the risky asset in period t , $fs_{i,t}$ is the size of household i in period t and $e_{i,t+1}$ is an econometric error term. Results for f_1 and f_2 are not reported.

	All Households	Asset Holdings > 0	Asset Holdings > 1000
w_1	0.091	0.079	0.101
(Standard Deviation)	(0.038)	(0.073)	(0.115)
w_2	0.301	0.301	0.243
(Standard Deviation)	(0.295)	(0.211)	(0.243)
w_3	0.167	-0.155	-1.020
(Standard Deviation)	(0.893)	(0.867)	(2.251)
p_1	0.012	0.004	0.003
(Standard Deviation)	(0.004)	(0.008)	(0.020)
p_2	-0.019	-0.008	-0.009
(Standard Deviation)	(0.004)	(0.008)	(0.021)
d_1	-0.0014	-0.001	-0.0019
(Standard Deviation)	(0.0020)	(0.003)	(0.0054)
d_2	-0.000008	-0.000012	0.000002
(Standard Deviation)	(0.000026)	(0.000043)	(0.000068)
Number of instruments	11	11	11
Degrees of Freedom	4	4	4
J statistic	27.339	2.989	3.951
(Significance Level)	(0.000)	(0.559)	(0.412)
Implied y	-2.322	-2.322	-3.115
Implied k	0.544	-0.514	-4.197
Implied g	1.313	0.818	0.425
Implied J	-1.767	-2.837	-7.312
H	3555	740	413
N	18813	5029	2990

Table 8B

Estimation and test results for the linearized Euler equation associated with the risky asset. Results obtained using instrument set four.

Estimation and test results obtained by GMM estimation of

$$\Delta \ln(c_{i,t+1}) = w_1 + w_2 \ln(\frac{p_{t+1} + d_{t+1}}{p_t}) + w_3 \Delta \ln(l_{i,t+1}) + p_1\, fam_{i,t+1} + p_2\, fam_{i,t} + u_{i,t+1}$$

where $c_{i,t}$ is consumption of household i at date t, $l_{i,t}$ is the leisure time of household head i at date t, p_t is the price of the risky asset in period t, d_t is the dividend of the risky asset in period t , $fs_{i,t}$ is the size of household i in period t and $e_{i,t+1}$ is an econometric error term. Results for f_1 and f_2 are not reported.

	All Households	Asset Holdings > 0	Asset Holdings > 1000
w_1	0.070	0.063	0.094
(Standard Deviation)	(0.040)	(0.075)	(0.118)
w_2	0.088	0.068	0.050
(Standard Deviation)	(0.068)	(0.061)	(0.072)
w_3	-0.435	-0.611	-1.503
(Standard Deviation)	(0.525)	(0.780)	(1.974)
p_1	0.013	0.004	0.006
(Standard Deviation)	(0.004)	(0.007)	(0.020)
p_2	-0.021	-0.009	-0.013
(Standard Deviation)	(0.004)	(0.008)	(0.020)
Number of instruments	11	11	11
Degrees of Freedom	6	6	4
J statistic	20.212	16.620	30.239
(Significance Level)	(0.000)	(0.000)	(0.000)
Implied y	-10.363	-13.705	-19.000
Implied k	-4.943	-8.905	-30.060
Implied g	0.677	0.604	0.387
Implied J	-15.306	-22.691	-49.060
H	3555	740	413
N	18813	5029	2990

Table 9A

Estimation and test results for the linearized Euler equation associated with the riskless asset. Results obtained using instrument set five.

Estimation and test results obtained by GMM estimation of

$$\Delta \ln(c_{i,t+1}) = w_1 + w_2 \ln(\frac{1}{q_t}) + w_3 \Delta \ln(l_{i,t+1}) + p_1\, fam_{i,t+1} + p_2\, fam_{i,t} + u_{i,t+1}$$

where $c_{i,t}$ is consumption of household i at date t, $l_{i,t}$ is the leisure time of household head i at date t, p_t is the price of the risky asset in period t, d_t is the dividend of the risky asset in period t , $fs_{i,t}$ is the size of household i in period t and $e_{i,t+1}$ is an econometric error term. Results for f_1 and f_2 are not reported.

	All Households	Asset Holdings > 0	Asset Holdings > 1000
w_1	0.001	-0.186	-0.055
(Standard Deviation)	(0.029)	(0.138)	(0.325)
w_2	0.045	0.191	0.166
(Standard Deviation)	(0.187)	(0.198)	(0.230)
w_3	-1.672	-2.413	-2.484
(Standard Deviation)	(0.556)	(0.489)	(0.581)
p_1	0.019	0.009	0.014
(Standard Deviation)	(0.006)	(0.007)	(0.014)
p_2	-0.028	-0.016	-0.023
(Standard Deviation)	(0.006)	(0.008)	(0.013)
d_1	0.002	0.029	0.011
(Standard Deviation)	(0.004)	(0.020)	(0.046)
d_2	0.00002	-0.0009	-0.0003
(Standard Deviation)	(0.00016)	(0.0007)	(0.0016)
Number of instruments	11	11	11
Degrees of Freedom	4	4	4
J statistic	29.002	71.707	231.738
(Significance Level)	(0.000)	(0.000)	(0.000)
Implied y	-21.222	-4.235	-5.024
Implied k	-37.155	-12.633	-14.963
Implied g	0.363	0.251	0.251
Implied J	-58.377	-16.869	-19.987
H	3555	740	413
N	18813	5029	2990

Table 9B

Estimation and test results for the linearized Euler equation associated with the risky asset. Results obtained using instrument set five.

Estimation and test results obtained by GMM estimation of

$$\Delta \ln(c_{i,t+1}) = w_1 + w_2 \ln(\frac{p_{t+1} + d_{t+1}}{p_t}) + w_3 \Delta \ln(l_{i,t+1}) + p_1\, fam_{i,t+1} + p_2\, fam_{i,t} + u_{i,t+1}$$

where $c_{i,t}$ is consumption of household i at date t, $l_{i,t}$ is the leisure time of household head i at date t, p_t is the price of the risky asset in period t, d_t is the dividend of the risky asset in period t , $fs_{i,t}$ is the size of household i in period t and $e_{i,t+1}$ is an econometric error term. Results for f_1 and f_2 are not reported.

	All Households	Asset Holdings > 0	Asset Holdings > 1000
w_1	-0.001	-0.192	-0.055
(Standard Deviation)	(0.030)	(0.145)	(0.329)
w_2	0.062	0.059	0.039
(Standard Deviation)	(0.057)	(0.063)	(0.089)
w_3	-1.658	-2.510	-2.530
(Standard Deviation)	(0.501)	(0.587)	(0.582)
p_1	0.019	0.009	0.014
(Standard Deviation)	(0.006)	(0.007)	(0.014)
p_2	-0.027	-0.016	-0.023
(Standard Deviation)	(0.006)	(0.008)	(0.013)
Number of instruments	11	11	11
Degrees of Freedom	4	4	4
J statistic	32.623	12.393	25.492
(Significance Level)	(0.000)	(0.014)	(0.000)
Implied y	-15.129	-15.949	-24.641
Implied k	-26.741	-42.524	-64.871
Implied g	0.361	0.272	0.275
Implied J	-41.870	-58.491	-89.512
H	3555	740	413
N	18813	5029	2990