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Consumption and labor supply

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ABSTRACT

We present a new econometric model of aggregate demand and labor supply for the United States. We also analyze the allocation full wealth among time periods for households distinguished by a variety of demographic characteristics. The model is estimated using micro-level data from the *Consumer Expenditure Surveys* supplemented with price information obtained from the Consumer Price Index. An important feature of our approach is that aggregate demands and labor supply can be represented in closed form while accounting for the substantial heterogeneity in behavior that is found in household-level data. As a result, we are able to explain the patterns of aggregate demand and labor supply in the data despite using a parametrically parsimonious specification.

1. Introduction

The objective of this paper is to present a new econometric model of aggregate consumer behavior for the United States. The model allocates full wealth among time periods for households distinguished by demographic characteristics and determines the within-period demands for leisure, consumer goods, and services. An important feature of our approach is the development of a closed form representation of aggregate demand and labor supply that accounts for the heterogeneity in household behavior that is observed in micro-level data. Aggregate demand functions are important components of general equilibrium models that are used to analyze the macroeconomic consequences of a broad spectrum of public policies.

We combine expenditure data for over 150,000 households from the Consumer Expenditure Surveys (CEX) with price information from the Consumer Price Index (CPI) between 1980 and 2006. Following Slesnick (2002) and Kokoski et al. (1994), we exploit the fact that the prices faced by households vary across regions of the United States as well as across time periods. We use the CEX to construct quality-adjusted wages for individuals with different characteristics that also vary across regions and over time. In order to measure the value of leisure for individuals who are not employed, we impute the opportunity wages they face using the wages earned by employees.

Cross-sectional variation of prices and wages is considerable and provides an important source of information about patterns of consumption and labor supply. The demographic characteristics of households are also significant determinants of consumer expenditures and the demand for leisure. The final determinant of consumer behavior is the value of the time endowment for households. Part of this endowment is allocated to labor market activities and reduces the amount available for consumption in the form of leisure.

We employ a generalization of the translog indirect utility function introduced by Jorgenson et al. (1997) in modeling household demands for goods and leisure. This indirect utility function generates demand functions with rank two in the sense of Gorman (1981). The rank-extended translog indirect utility function proposed by Lewbel (2001) has Gorman rank three. We present empirical results for the original translog demand system as well as the rank-extended translog system and conclude that the rank three system more adequately represents consumer behavior although the differences are not large.

Our model of consumption and labor supply is based on two-stage budgeting and is most similar to the framework described and implemented by Blundell et al. (1994) for consumption goods alone. The first stage allocates full wealth, including assets and the value of the time endowment, among time periods using the standard Euler equation approach introduced by Hall (1978). Since the CEX does not provide annual panel data at the household level,

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we employ synthetic cohorts, introduced by Browning et al. (1985) and utilized, for example, by Attanasio et al. (1999), Blundell et al. (1994) and many others.

We introduce our model of consumer behavior in Section 2. We first consider the second stage of the model, which allocates full consumption among leisure, goods, and services. We subsequently present the first stage of the consumer model that describes the allocation of full wealth across time periods. In Section 3 we discuss data issues including the measurement of price and wage levels that show substantial variation across regions and over time. In Section 4 we present the estimation results for the rank-two and rank-three specifications of our second-stage model. We present estimates of price and income elasticities for goods and services, as well as leisure. We find that the wage elasticity of household labor supply is essentially zero, but the compensated elasticity is large and positive. Leisure and consumer services are income elastic, while capital services and nondurable goods are income inelastic. Perhaps most important, we find that the aggregate demands and labor supplies predicted by our model accurately replicate the patterns in the data despite the (comparatively) simple representation of household labor supply.

Finally, we estimate a model of the inter-temporal allocation of full consumption. We partition the sample of households into 17 cohorts based on the birth year of the head of the household. There are 27 time series observations from 1980 through 2006 for all but the oldest and youngest cohorts and we use these data to estimate the remaining unknown parameters of the Euler equation using methods that exploit the longitudinal features of the data.

2. Modeling consumption behavior

We assume that household consumption and labor supply are allocated in accord with two stage budgeting. In the first stage, full expenditure is allocated over time so as to maximize a lifetime utility function subject to a full wealth constraint. Conditional on the chosen level of full expenditure in each period, households allocate expenditures across consumption goods and leisure so as to maximize a within-period utility function.

To describe the second stage model in more detail, assume that households consume n consumption goods in addition to leisure. The within-period demand model for household k can be described using the following notation:

$\mathbf{x_k} = (x_{1k}, x_{2k}, \ldots, x_{nk}, \mathbf{R}_k)$ are the quantities of goods and leisure.

$\rho_\mathbf{k} = (\mathbf{p_k}, p_{Lk})$ are prices and wages faced by household k. These prices vary across geographic regions and over time.

$w_{ik} = p_{ik}x_{ik}/F_k$ is the expenditure share of good i for household k.

$\mathbf{w_k} = (w_{1k}, w_{2k}, \ldots, w_{nk}, w_{Rk})$ is the vector of expenditure shares for household k.

$\mathbf{A_k}$ is a vector of demographic characteristics of household k.

$F_k = \sum p_{ik}x_{ik} + p_{Lk}R_k$ is the full expenditure of household k where p_{Lk} is the wage rate and R_k is the quantity of leisure consumed.

In order to obtain a closed-form representation of aggregate demand and labor supply, we use a model of demand that is consistent with exact aggregation as originally defined by Gorman (1981). Specifically, we focus on models for which the aggregate demands are the sums of micro-level demand functions rather than the typical assumption that they are generated by a representative consumer. Exact aggregation is possible if the demand function for good i by household k is of the form:

$$x_{ik} = \sum_{j=1}^{J} b_{ij}(\rho)\psi_j(F_k).$$

Gorman showed that if demands are consistent with consumer rationality, the matrix $\{b_{ij}(\rho)\}$ has rank that is no larger than three.[1]

We assume that household preferences can be represented by a translog indirect utility function that generates demand functions of rank three. Lewbel (2001) has characterized such a utility function to be of the form:

$$(\ln V_k)^{-1} = \left[\alpha_0 + \ln\left(\frac{\rho_\mathbf{k}}{\mathbf{F_k}}\right)'\alpha_\mathbf{p} + \frac{1}{2}\ln\left(\frac{\rho_\mathbf{k}}{\mathbf{F_k}}\right)'B_{pp}\ln\left(\frac{\rho_\mathbf{k}}{\mathbf{F_k}}\right) + \ln\left(\frac{\rho_\mathbf{k}}{\mathbf{F_k}}\right)'B_{pA}\mathbf{A_k}\right]^{-1} - \ln\left(\frac{\rho_\mathbf{k}}{\mathbf{F_k}}\right)'\gamma_\mathbf{p} \tag{1}$$

where we assume $B_{pp} = B_{pp}'$, $i'B_{pA} = 0$, $i'B_{pp}i = 0$, $i'\alpha_\mathbf{p} = -1$ and $i'\gamma_\mathbf{p} = 0$.

To simplify notation, define $\ln G_k$ as:

$$\ln G_k = \alpha_0 + \ln\left(\frac{\rho_k}{\mathbf{F_k}}\right)'\alpha_\mathbf{p} + \frac{1}{2}\ln\left(\frac{\rho_k}{\mathbf{F_k}}\right)'B_{pp}\ln\left(\frac{\rho_k}{\mathbf{F_k}}\right) + \ln\left(\frac{\rho_k}{\mathbf{F_k}}\right)'B_{pA}\mathbf{A_k}. \tag{2}$$

Application of Roy's Identity to Eq. (1) yields budget shares of the form:

$$\mathbf{w_k} = \frac{1}{D(\rho_k)}\left(\alpha_\mathbf{p} + B_{pp}\ln\frac{\rho_k}{F_k} + B_{pA}\mathbf{A_k} + \gamma_\mathbf{p}[\ln G_k]^2\right) \tag{3}$$

where $D(\rho_\mathbf{k}) = -1 + i'B_{pp}\ln\rho_k$.

With demand functions of this form, aggregate budget shares, denoted by the vector $\mathbf{w}$, can be represented explicitly as functions of prices and summary statistics of the joint distribution of full expenditure and household attributes:

$$\mathbf{w} = \frac{\sum_k F_k\mathbf{w_k}}{\sum_k F_k} = \frac{1}{D(\rho)}\left[\alpha_\mathbf{p} + B_{pp}\ln\rho - i'B_{pp}\frac{\sum F_k\ln F_k}{\sum F_k} + B_{pA}\frac{\sum F_k\mathbf{A_k}}{F_k} + \gamma_\mathbf{p}\frac{\sum F_k(\ln G_k)^2}{\sum F_k}\right].$$

2.1. The inter-temporal allocation of consumption

In the first stage of the household model, full expenditure F_{kt} is allocated across time periods so as to maximize lifetime utility U_k for household k:

$$\max_{F_{kt}} U_k = E_t\left\{\sum_{t=1}^{T}(1+\delta)^{-(t-1)}\left[\frac{V_{kt}^{(1-\sigma)}}{(1-\sigma)}\right]\right\} \tag{4}$$

subject to:

$$\sum_{t=1}^{T}(1+r_t)^{-(t-1)}F_{kt} \le W_k$$

where r_t is the nominal interest rate, σ is an inter-temporal curvature parameter, and δ is the subjective rate of time preference. We expect δ to be between zero and one and the within-period utility function is logarithmic if σ is equal to one.

The first order conditions for this optimization yield Euler equations of the form:

$$(V_{kt})^{-\sigma}\left[\frac{\partial V_{kt}}{\partial F_{kt}}\right] = E_t\left[(V_{k,t+1})^{-\sigma}\left[\frac{\partial V_{k,t+1}}{\partial F_{k,t+1}}\right]\frac{(1+r_{t+1})}{(1+\delta)}\right]. \tag{5}$$

[1] See Blundell and Stoker (2005) for further discussion.

If the random variable η_{kt} embodies expectational errors for household k at time t, Eq. (5) becomes:

$$(V_{kt})^{-\sigma}\left[\frac{\partial V_{kt}}{\partial F_{kt}}\right] = \left[(V_{k,t+1})^{-\sigma}\left[\frac{\partial V_{k,t+1}}{\partial F_{k,t+1}}\right]\frac{(1+r_{t+1})}{(1+\delta)}\right]\eta_{k,t+1}. \quad (6)$$

We can simplify this equation by noting that, for the rank three specification of the indirect utility function given in Eq. (1), we obtain:

$$\frac{\partial V_{kt}}{\partial F_{kt}} = \frac{V_{kt}}{F_{kt}}(-D(\rho_{kt}))[1-(\gamma_{\mathbf{p}}'\ln\rho_{kt})^{*}G_{kt}]^{-2}.$$

The last term in the square bracket is approximately equal to one in the data, so that taking logs of both sides of Eq. (6) yields:

$$\Delta\ln F_{k,t+1} = (1-\sigma)\Delta\ln V_{k,t+1} + \Delta\ln(-D(\rho_{k,t+1})) + \ln(1+r_{t+1}) - \ln(1+\delta) + \ln\eta_{kt}. \quad (7)$$

Eq. (7) serves as the estimating equation for σ and the subjective rate of time preference δ.

3. Data issues

3.1. The CEX sample

In the United States, the only comprehensive sources of information on expenditure and labor supply are the CEX published by the Bureau of Labor Statistics. These surveys are representative national samples that are conducted for the purpose of computing the weights in the CPI. The surveys were administered approximately every ten years until 1980 when they were given every year. Detailed information on labor supply is provided only after 1980 and, as a result, we use the sample that covers the period from 1980 through 2006. Expenditures are recorded on a quarterly basis and our sample sizes range from between 4000 and 8000 households per quarter. To avoid issues related to the seasonality of expenditures, we use only the set of households that were interviewed in the second quarter of each year.[2]

In order to obtain a comprehensive measure of consumption, we modify the total expenditure variable reported in the surveys by deleting gifts and cash contributions as well as pensions, retirement contributions, and Social Security payments. Outlays on owner occupied housing such as mortgage interest payments, insurance, and the like are replaced with households' estimates of the rental equivalents of their homes. Durable purchases are replaced with estimates of the services received from the stocks of goods held by households.[3] After these adjustments, our estimate of total expenditure is the sum of spending on nondurables and services (a frequently used measure of consumption) plus the service flows from consumer durables and owner-occupied housing.

3.2. Measuring price levels in the US

The CEX records the expenditures on hundreds of items, but provides no information on the prices paid which makes it necessary to link the surveys with price data from alternative sources. While the BLS provides time series of price indexes for different cities and regions, they do not publish information on price levels. Kokoski et al. (1994) (KCM) use the 1988 and 1989 CPI database to estimate the prices of goods and services in 44 urban areas. We use their estimates of prices for rental housing, owner occupied housing, food at home, food away from home, alcohol and tobacco, household fuels (electricity and piped natural gas), gasoline and motor oil, household furnishings, apparel, new vehicles, professional medical services, and entertainment.[4] Given price levels for 1988 and 1989, prices both before and after this period are extrapolated using price indexes published by the BLS. Most of these indexes cover the period from December 1977 to the present at either monthly or bimonthly frequencies depending on the year and the commodity group.[5]

These prices are linked to the expenditure data in the CEX. Although KCM provide estimates of prices for 44 urban areas across the US, the publicly available CEX data do not report households' cities of residence in an effort to preserve the confidentiality of survey participants. This necessitates aggregation across urban areas to obtain prices for the four major Census regions: the Northeast, Midwest, South and West. Because the BLS does not collect nonurban price information, rural households are assumed to face the prices of Class D-sized urban areas.[6]

3.3. Measuring wages in efficiency units

The primitive observational unit in the CEX is a "consumer unit", and expenditures are aggregated over all members. We choose to model labor supply at the same level of aggregation by assuming that male and female leisure are perfect substitutes when measured in quality-adjusted units. The price of leisure (per efficiency unit) is estimated using a wage equation defined over "full time" workers, i.e. those who work more than forty weeks per year and at least thirty hours per week. The wage equation for worker i is given by:

$$\ln P_{Li} = \sum_j \beta_j^z z_{ji} + \sum_j \beta_j^s (S_i^* z_{ji}) + \sum_j \beta_j^{nw}(NW_i^* z_{ji}) + \sum_l \beta_l^g g_{li} + \varepsilon_{it} \quad (8)$$

where

p_{Li} — the wage of worker i.

z_i — a vector of demographic characteristics that includes the age, age squared, years of education, and years of education squared of worker i.

S_i — a dummy variable indicating whether the worker is female.

NW_i — a dummy variable indicating whether the worker is nonwhite.

g_i — a vector of region-year dummy variables.

The wage equation is estimated using the CEX from 1980 through 2006 using the usual sample selection correction, and the quality-adjusted wage for a worker in region-year s is given by $p_L^s = \exp(\hat{\beta}_s^g)$. The parameter estimates (excluding the region-year effects) are presented in Appendix Table A.1.

In Fig. 1a we present our estimates of quality-adjusted hourly wages in the urban Northeast, Midwest, South, West as well

[2] Surveys are designed to be representative only at a quarterly frequency. We use the second quarter to avoid seasonality of spending associated with the summer months and holiday spending at the end of the calendar year.

[3] The methods used to compute the rental equivalent of owner occupied housing and the service flows from consumer durables are described in Slesnick (2001).

[4] In 1988 and 1989 these items constituted approximately 75% of all expenditures.

[5] A detailed description of this procedure can be found in Slesnick (2002).

[6] These areas correspond to nonmetropolitan urban areas and are cities with less than 50,000 persons. Examples of cities of this size include Yuma, Arizona in the West, Fort Dodge, Iowa in the Midwest, Augusta, Maine in the Northeast and Cleveland, Tennessee in the South.

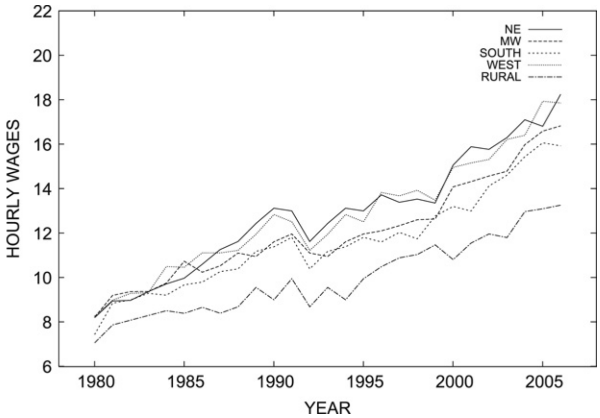

Fig. 1a. Regional wages (current dollars).

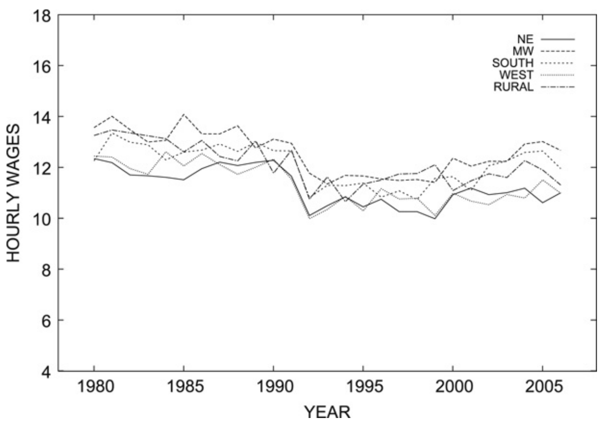

Fig. 1b. Regional real wages (NE 1989 dollars).

as rural areas from 1980 through 2006. The reference worker, whose quality is normalized to one, is a white male, age 40, with 13 years of education. The levels and trends of the wages are generally consistent with expectations; the highest wages are in the Northeast and the West and the lowest are in rural areas. Nominal wages increase over time with the highest growth rate occurring in the Northeast and the lowest is in rural areas. Perhaps more surprising is the finding that real wages, shown in Fig. 1b, have decreased over the sample period and exhibit substantially less variation across regions. This suggests that more accurate adjustments for differences in the cost of living across geographic regions reduce the between-region wage dispersion to a large degree.

3.4. Measuring quality-adjusted household leisure

For workers, estimates of the quantity of leisure consumed are easily obtained. The earnings of individual m in household k at time t are:

$$E_{kt}^{m} = p_{Lt} q_{kt}^{m} H_{kt}^{m},$$

where p_{Lt} is the wage at time t per efficiency unit, q_{kt}^{m} is the quality index of the worker, and H_{kt}^{m} is the observed hours of work. With observations on wages and the hours worked, the quality index for worker m is:

$$q_{kt}^{m} = \frac{E_{kt}^{m}}{p_{Lt} H_{kt}^{m}}.$$

If the daily time endowment is 14 h, the household's time endowment measured in efficiency units is $T_{kt}^{m} = q_{kt}^{m} * (14)$ and leisure consumption is $R_{kt}^{m} = q_{kt}^{m}(14 - H_{kt}^{m})$.

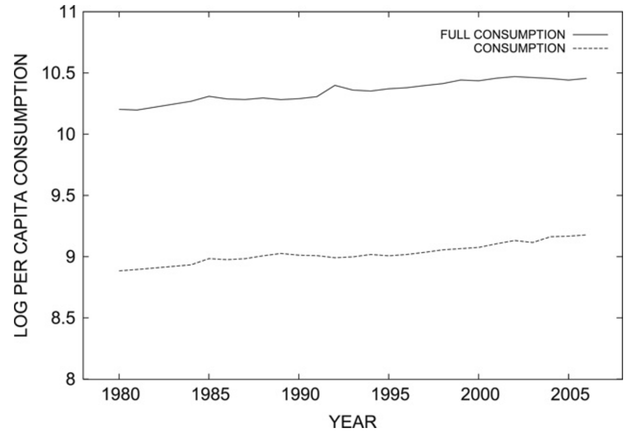

Fig. 2a. Log consumption per capita (constant dollars).

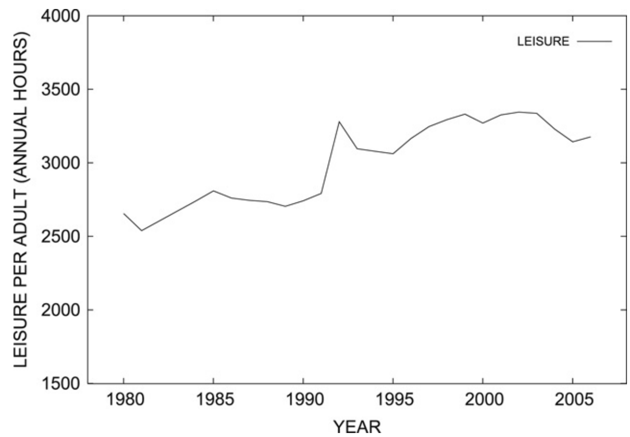

Fig. 2b. Quality-adjusted leisure per adult.

For nonworkers, we impute a nominal wage for individual m in household k, $\hat{p}_{Lkt}^{m}$, using the fitted values of a wage equation similar to Eq. (8). The estimated quality adjustment for nonworkers is:

$$\hat{q}_{kt}^{m} = \frac{\hat{p}_{Lkt}^{m}}{p_{Lt}},$$

and the individual's leisure consumption is calculated as $R_{kt}^{m} = \hat{q}_{kt}^{m} * (14)$. Given estimates of leisure for each adult in the household, full expenditure for household k is computed as:

$$F_{kt} = p_{Lt} R_{kt} + \sum_{i} p_{ik} x_{ik}$$

where $R_{kt} = \sum_{m} R_{kt}^{m}$ is total household leisure computed as the sum over all adult members.

In Fig. 2a we present tabulations of per capita full consumption (goods and household leisure) as well as per capita consumption (goods only). For both series, expenditures are deflated by price and wage indexes that vary over time and across regions. Over the period from 1980 through 2006, per capita consumption grew at an average annual rate of 1.1% per year compared to 1.0% per year for per capita full consumption. Fig. 2b shows the average level of quality-adjusted leisure consumed per adult. The average annual hours increased by approximately 18% over the 26 years from 2656 in 1980 to 3177 in 2006. Fig. 2c shows that the inclusion of household leisure has the effect of lowering the dispersion in consumption in each year. The variance of log per capita full consumption is approximately 25% lower than the variance of log per capita consumption. The trends of the two series, however, are similar.

Table 1
Sample summary statistics (Sample size: 154,180).

Variable	Mean	Standard error	Minimum	Maximum
Share NON	0.101	0.052	0.0009	0.695
Share CAP	0.133	0.076	0.0001	0.895
Share CS	0.072	0.054	0.00004	0.787
Share LEIS	0.694	0.123	0.0001	0.991
Log PNON	0.116	0.212	−0.510	0.877
Log PCAP	−0.090	0.280	−1.101	0.526
Log PCS	0.144	0.333	−0.828	0.702
Log wage	−0.304	0.234	−0.933	0.137
Log full exp.	11.547	0.605	8.241	15.281
No. children	0.717	1.121	0.000	12.000
No. adults	1.887	0.841	1.000	13.000
White dummy	0.844	0.363	0.000	1.000
Nonwhite dummy	0.156	0.363	0.000	1.000
Male dummy	0.715	0.451	0.000	1.000
Female dummy	0.285	0.451	0.000	1.000
Urban dummy	0.905	0.293	0.000	1.000
Rural dummy	0.095	0.293	0.000	1.000
NE dummy	0.198	0.398	0.000	1.000
MW dummy	0.249	0.433	0.000	1.000
South dummy	0.311	0.463	0.000	1.000
West dummy	0.242	0.428	0.000	1.000

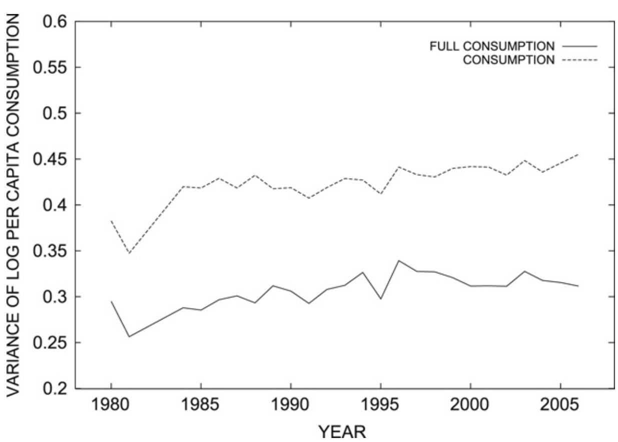

Fig. 2c. Variance of log per capita consumption.

4. Aggregate demands for goods and leisure

We estimate the parameters of the second stage model using a demand system defined over four commodity groups:

Nondurables—Energy, food, clothing and other consumer goods.

Consumer Services—Medical care, transportation, entertainment and the like.

Capital Services—services from rental housing, owner occupied housing, and consumer durables.

Household Leisure—the sum of quality-adjusted leisure over all of the adult members of the household.

The demographic characteristics that are used to control for heterogeneity in household behavior include:

Number of adults: A quadratic in the number of individuals in the household who are age 18 or older.

Number of children: A quadratic in the number of individuals in the household who are under the age of 18.

Gender of the household head: Male, female.

Race of the household head: White, nonwhite.

Region of residence: Northeast, Midwest, South and West.

Type of residence: Urban, rural.

In Table 1 we present summary statistics of the variables used in the estimation of the demand system. On average, household leisure comprises almost 70% of full expenditure although the dispersion is greater than for the other commodity groups. As expected, the price of capital (which includes housing) shows substantial variation in the sample as does the price of consumer services. The average number of adults is 1.9 and the average number of children is 0.7. Female headed households account for over 28% of the sample and almost 16% of all households have nonwhite heads.

We model the within-period allocation of expenditures across the four commodity groups using the rank-extended translog model defined in Eq. (3). We assume that the disturbances of the demand equations are additive so that the system of estimating equations is:

$$\mathbf{w_k} = \frac{1}{D(\rho_\mathbf{k})}\left(\alpha_\mathbf{p} + B_{pp}\ln\frac{\rho_\mathbf{k}}{F_k} + B_{pA}\mathbf{A_k} + \gamma_\mathbf{p}[\ln G_k]^2\right) + \varepsilon_\mathbf{k}$$

where the vector $\varepsilon_\mathbf{k}$ is assumed to be mean zero with variance–covariance matrix Σ. We compare these results to those obtained using the rank two translog demand system originally developed by Jorgenson et al. (1997):

$$\mathbf{w_k} = \frac{1}{D(\rho_\mathbf{k})}\left(\alpha_\mathbf{p} + B_{pp}\ln\frac{\rho_\mathbf{k}}{F_k} + B_{pA}\mathbf{A_k}\right) + \mu_\mathbf{k}.$$

Note that the two specifications coincide if the elements of the vector $\gamma_\mathbf{p}$ are equal to zero.

Both the rank two and rank three demand systems are estimated using nonlinear full information maximum likelihood with leisure as the omitted equation of the singular system. The parameter estimates of both models are presented in Appendix Tables A.2 and A.3. The level of precision of the two sets of estimates is high as would be expected given the large number of observations. Less expected is the fact that the rank two and rank three estimates are similar for all variables other than full expenditure. Note, however, that the parameters $\gamma_\mathbf{p}$ are statistically significant and any formal test would strongly reject the rank two model in favor of the rank three specification (i.e. the likelihood ratio test statistic is over 998).

In Table 2 we compute price and income elasticities for the three consumption goods and leisure. In all cases the elasticities are calculated for a particular type of household: two adults and two children, living in the urban Northeast, with a male, white head of the household with $100,000 of full expenditure in 1989. Both nondurables and consumer services are price inelastic while capital services have elasticities exceeding unity. The own compensated price elasticities are negative for all goods and the differences between the rank two and rank three models are small.

Table 2
Price and income elasticities (Reference household: Two adults, Two children, NE Urban, Male, White, Full expenditure = 100 K).

Good	Uncompensated price elasticity		Compensated price elasticity		Full expenditure elasticity	
	Rank 2	Rank 3	Rank 2	Rank 3	Rank 2	Rank 3
Nondurables	−0.918	−0.903	−0.822	−0.809	0.722	0.724
Capital services	−1.428	−1.432	−1.314	−1.319	0.926	0.930
Consumer services	−0.613	−0.614	−0.548	−0.548	1.088	1.096
Leisure	0.012	0.014	−0.323	−0.314	1.059	1.056
Labor supply	−0.026	−0.030	0.698	0.698	−2.289	−2.342

The uncompensated wage elasticity of household labor supply is negative but close to zero while the expenditure elasticity is quite high. The compensated wage elasticity is around 0.70 and, as with the consumption goods, the differences between the two types of demand systems are small.[7]

If the rank two and rank three models are to differ, they most likely differ in terms of their predicted effects of full expenditure on demand patterns. To assess this possibility, we present the fitted shares from both systems at different levels of full expenditure for the reference household in Table 3. The predicted shares for both models are similar for levels of full expenditure in the range between $25,000 and $150,000. They diverge quite sharply, however, in both the upper and lower tails of the expenditure distribution. For example, when full expenditure is $7500, the share of nondurables in the rank two model is 0.227 compared with 0.268 for the rank three model. At high levels of full expenditure ($350,000) the fitted share of household leisure is 0.734 in the rank two model and 0.711 in the rank three model.

[7] In the calculations of the wage elasticities, unearned income is assumed to be zero the value of the time endowment is equal to full expenditure.

Table 3
Full expenditure and household budget shares (Reference household: Two adults, Two children, NE Urban, Male, White).

Expenditure level	Rank 2	Rank 3	Rank 2	Rank 3
	Nondurables share		Capital services share	
7 500	0.227	0.268	0.147	0.183
25 000	0.183	0.192	0.136	0.145
75 000	0.143	0.140	0.126	0.125
150 000	0.117	0.116	0.120	0.119
275 000	0.095	0.100	0.114	0.119
350 000	0.086	0.095	0.112	0.120
	Consumer services share		Leisure share	
7 500	0.047	0.073	0.579	0.476
25 000	0.053	0.060	0.627	0.603
75 000	0.059	0.058	0.672	0.677
150 000	0.063	0.062	0.700	0.702
275 000	0.066	0.070	0.725	0.711
350 000	0.067	0.073	0.734	0.711

4.1. Aggregate demands

Both the rank two and rank three demand systems are consistent with exact aggregation and provide closed form

Table 4
Aggregate budget shares.

Year	Sample shares	Fitted shares	R-squared	Aggregation factors		
				Price	Expenditure	Demographics
Nondurables						
1980–1981	0.1145	0.1074	0.1273	0.3985	−0.3009	0.0098
1985–1986	0.0993	0.1003	0.1609	0.4009	−0.3090	0.0084
1990–1991	0.0967	0.0990	0.1793	0.4051	−0.3141	0.0080
1995–1996	0.0898	0.0892	0.2198	0.3996	−0.3181	0.0077
2000–2001	0.0846	0.0852	0.1910	0.4011	−0.3235	0.0076
2005–2006	0.0864	0.0845	0.1806	0.4055	−0.3279	0.0068
Capital services						
1980–1981	0.0956	0.1162	0.0296	0.2100	−0.0141	−0.0797
1985–1986	0.1134	0.1178	0.1003	0.2103	−0.0143	−0.0782
1990–1991	0.1186	0.1213	0.1292	0.2132	−0.0145	−0.0774
1995–1996	0.1222	0.1240	0.1161	0.2161	−0.0150	−0.0771
2000–2001	0.1306	0.1272	0.1226	0.2193	−0.0154	−0.0766
2005–2006	0.1403	0.1344	0.1134	0.2255	−0.0155	−0.0756
Consumer services						
1980–1981	0.0566	0.0561	0.0018	−0.0439	0.1202	−0.0202
1985–1986	0.0626	0.0668	0.0111	−0.0370	0.1236	−0.0199
1990–1991	0.0706	0.0678	0.0317	−0.0379	0.1258	−0.0201
1995–1996	0.0734	0.0750	0.0318	−0.0326	0.1270	−0.0193
2000–2001	0.0724	0.0747	0.0420	−0.0350	0.1289	−0.0192
2005–2006	0.0748	0.0678	0.0245	−0.0434	0.1308	−0.0195
Leisure						
1980–1981	0.7333	0.7203	0.1506	0.4354	0.1948	0.0902
1985–1986	0.7247	0.7151	0.1532	0.4257	0.1997	0.0897
1990–1991	0.7141	0.7119	0.1804	0.4197	0.2028	0.0895
1995–1996	0.7146	0.7117	0.1791	0.4170	0.2060	0.0887
2000–2001	0.7124	0.7129	0.1758	0.4147	0.2100	0.0882
2005–2006	0.6985	0.7133	0.1458	0.4124	0.2126	0.0883

Table 5
Group budget shares of leisure (Male household head with 2 or more adults).

Year	At least 1 child			No children		
	Sample share	Fitted share	R-Squared	Sample share	Fitted share	R-Squared
1980–1981	0.7347	0.7236	0.1144	0.7522	0.7412	0.0277
1985–1986	0.7221	0.7167	0.0774	0.7467	0.7391	0.0171
1990–1991	0.7171	0.7136	0.0730	0.7342	0.7366	0.0811
1995–1996	0.7161	0.7138	0.0799	0.7364	0.7343	0.0612
2000–2001	0.7115	0.7158	0.0633	0.7405	0.7358	0.0528
2005–2006	0.7029	0.7161	0.0421	0.7200	0.7360	0.0349

Table 6
Synthetic cohorts.

Cohort	Cohort birth year	Average no. observ.	Range of no. observ.	Years covered
1	1900–1904	108	52–169	1980–1989
2	1905–1909	158	78–229	1980–1994
3	1910–1914	195	92–305	1980–2000
4	1915–1919	261	176–347	1980–2000
5	1920–1924	284	53–415	1980–2005
6	1925–1929	337	234–417	1980–2006
7	1930–1934	337	272–469	1980–2006
8	1935–1939	354	289–446	1980–2006
9	1940–1944	437	341–554	1980–2006
10	1945–1949	546	432–705	1980–2006
11	1950–1954	622	457–817	1980–2006
12	1955–1959	650	382–910	1980–2006
13	1960–1964	580	120–870	1980–2006
14	1965–1969	484	103–768	1985–2006
15	1970–1974	464	83–742	1990–2006
16	1975–1979	397	71–594	1995–2006
17	1980–1984	331	45–473	2000–2006

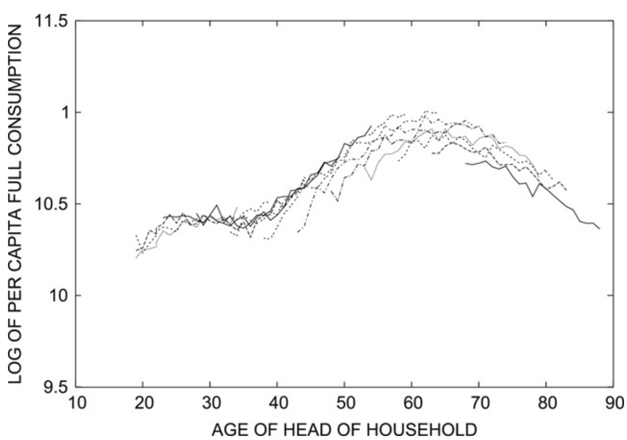

Fig. 3a. Age profile of per capita full consumption.

representations of aggregate demands for the four goods:

$$\mathbf{w} = \frac{\sum_k F_k \mathbf{w_k}}{\sum_k F_k} = P_t + Y_t + D_t$$

where P_t, Y_t, and D_t are summary statistics similar to the aggregation factors described by Blundell et al. (1993). Specifically, the price factor is the full expenditure weighted average of the price terms in the share equations in each time period:

$$P_t = \frac{\sum_k F_{kt} D(\rho_{\mathbf{kt}})^{-1}(\alpha_{\mathbf{p}} + B_{pp} \ln \rho_{\mathbf{kt}})}{\sum_k F_{kt}},$$

and Y_t and D_t are defined similarly for the full expenditure and demographic components of the aggregate demand system:

$$Y_t = \frac{\sum_k F_{kt} D(\rho_{\mathbf{kt}})^{-1}(\gamma_{\mathbf{p}} (\ln G_{kt})^2 - i' B_{pp} \ln F_{kt})}{\sum_k F_{kt}}$$

$$D_t = \frac{\sum_k F_{kt} D(\rho_{\mathbf{kt}})^{-1}(B_{pA} \mathbf{A_{kt}})}{\sum_k F_{kt}}.$$

How well do the fitted demands reflect aggregate expenditure patterns and their movements over time? In Table 4 we compare the fitted aggregate shares for the rank three system with sample averages tabulated for each of the four commodity groups. The rank three demand system provides an accurate representation of both the levels and movements of the aggregate budget shares over time. With few exceptions, the fitted shares track the sample averages closely in terms of both the absolute and relative differences. Table 4 also reports the R-squared statistic to assess the normalized within-sample performance of the predicted household-level budget shares. At this level of disaggregation, the nondurables and leisure demand equations fit better than the other two commodity groups in most years.

The aggregation factors show that essentially all of the movement in the aggregate shares was the result of changes in prices and full expenditure; the demographic factors showed very little movement over time for any of the four commodity groups. This is especially true of leisure where the effects of prices and full expenditure on the aggregate shares changed significantly (in opposite directions) while the influence of demographic variables showed little temporal variation.

As a final assessment of our within-period demand model, we examine the statistical fit of the leisure demand equations for subgroups of the population for whom our model might perform poorly. Recall that in order to develop a model of aggregate labor

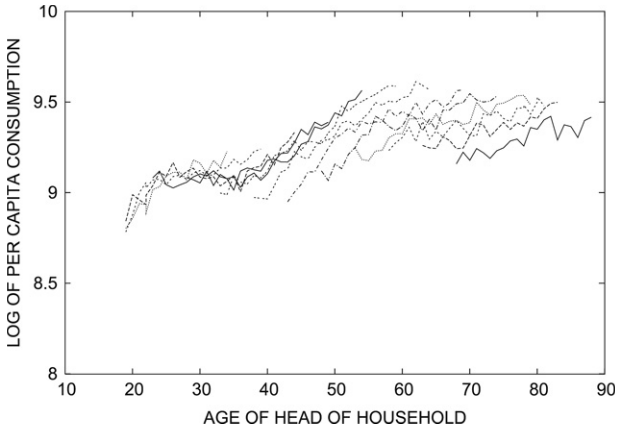

Fig. 3b. Age profile of per capita consumption.

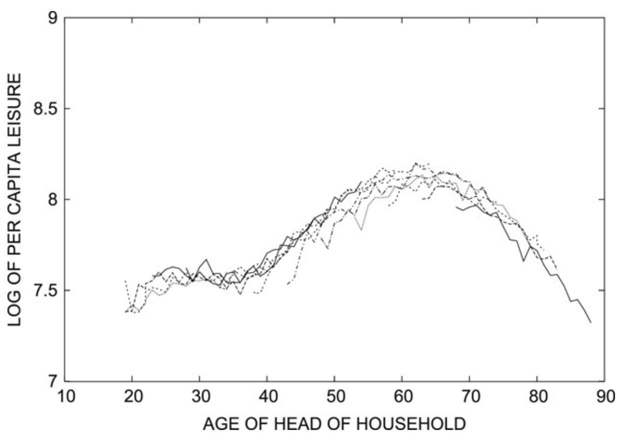

Fig. 3c. Age profile of per capita leisure.

supply, we have made the simplifying assumption that quality-adjusted male and female leisure are perfect substitutes within the household. If this turns out to be overly strong, we might expect the demand system to predict less well for groups for which this assumption is likely to be counterfactual.

In Table 5 we compare the aggregate leisure demands of households with at least two adults. It seems reasonable to expect that the presence of children almost certainly complicates the labor supply decisions of adults and, given that we do not explicitly model this interaction, our model might not fit the data well for this subgroup as for others. Instead, we find that for both types of households, the fitted aggregate demands for leisure are quite close to the sample averages for the subgroups. Moreover, the R-squared computed for households with children is actually higher than that computed for those without.

5. Inter-temporal allocation of full consumption

In this section we describe the inter-temporal allocation of full consumption. Eq. (7) serves as the basis for the estimation of the curvature parameter σ and the subjective rate of time preference δ. However, because we do not have longitudinal data on full consumption, we create synthetic panels from the CEX as described by Blundell et al. (1994) and Attanasio and Weber (1995). The estimating equation for this stage of the consumer model is:

$$\Delta \ln F_{c,t+1} = (1-\sigma)\Delta \ln V_{c,t+1} + \Delta \ln(-D(\rho_{c,t+1})) + \ln(1+r_{t+1}) - \ln(1+\delta) + \nu_{ct} \quad (9)$$

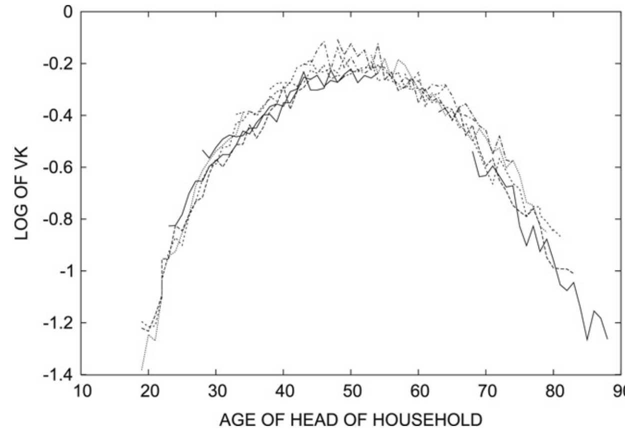

Fig. 4. Age profile of $\ln V_k$.

where

$$\Delta \ln F_{c,t+1} = \sum_{k\varepsilon c} \ln F_{k,t+1} - \sum_{k\varepsilon c} \ln F_{k,t}$$

$$\Delta \ln V_{c,t+1} = \sum_{k\varepsilon c} \ln V_{k,t+1} - \sum_{k\varepsilon c} \ln V_{k,t}$$

$$\Delta \ln(-D(\rho_{c,t+1})) = \sum_{k\varepsilon c} \ln(-D(\rho_{k,t+1})) - \sum_{k\varepsilon c} \ln(-D(\rho_{k,t}))$$

where the summations are over all households in cohort c at time t.

To create the cohorts, we partition the sample of households in the CEX into birth cohorts defined over five year age bands on the basis of the age of the head of the household. In 1982 and 1983 the BLS did not include rural households in the survey and, to maintain continuity in our sample, we use data from 1984 through 2006. The characteristics of the resulting panel are described in Table 6. The oldest cohort was born between 1900 and 1904 and the youngest cohort was born between 1980 and 1984. The cell sizes for most of the cohorts were typically several hundred households, although the range is substantial.

The age profiles of full consumption per capita, consumption per capita, and household leisure per capita are presented in Figs. 3a–3c for the cohorts in the sample. Not surprisingly, the profile of per capita full consumption is largely determined by the age profile of household leisure. Per capita full expenditure remains relatively constant until age 35, increases until age 60 and then decreases. Fig. 4 shows the age profile of the average within period utility levels ($\ln V_k$) which plays a critical role in the estimation of Eq. (9).

The statistical properties of the disturbances ν_{ct} in Eq. (9) that are used with synthetic panels are described in detail by Attanasio and Weber (1995). They note that the error term is the sum of expectational error as well as measurement error associated with the use of averages tabulated for each cohort. We present estimates of δ and σ using ordinary least squares, least squares weighted by the cell sizes of each cohort in each year, and a random effects estimator that exploits the panel features of our synthetic cohort data. The first panel in Table 7 shows that estimates of δ are consistently around 0.015 while the estimates of σ are approximately 0.1.

We re-estimate Eq. (9) using a variety of instruments to account for expectational and measurement error associated with synthetic cohorts. The results shown in the second panel of Table 7 are based on different sets of instruments. The first estimator, (IV1), uses a constant, the average age of the cohort, a time trend, and the two period lagged average marginal tax rate on earnings as instruments. The second estimator (IV2) uses, in addition, the two period lags of wages, interest rates, and prices of capital services and consumer services. The third estimator (IV3) also includes

Table 7
Parameter estimates — intertemporal model.

Least squares estimates						
	OLS		Weighted OLS		Random effects	
Variable	Estimate	SE	Estimate	SE	Estimate	SE
δ	0.01471	0.0011	0.01185	0.0011	0.01460	0.0016
σ	0.08226	0.0194	0.11280	0.0218	0.10183	0.0202
Instrumental variables estimators						
	IV1		IV2		IV3	
Variable	Estimate	SE	Estimate	SE	Estimate	SE
δ	0.01253	0.0012	0.01251	0.0012	0.01249	0.0011
σ	0.03414	0.0357	0.05521	0.0350	0.08150	0.0337

Table A.1
Parameter estimates of wage equation.

Variable	Estimate	SE
CONST	0.04507	0.0783
AGE	0.06014	0.0024
AGESQ	−0.00056	0.00003
EDUC	0.03609	0.0058
EDUCSQ	0.00118	0.0002
FEM ∗ AGE	−0.02322	0.0028
FEM ∗ AGESQ	0.00022	0.00003
FEM ∗ EDUC	−0.00808	0.0082
FEM ∗ EDUCSQ	0.00075	0.0003
NW ∗ AGE	−0.01340	0.0035
NW ∗ AGESQ	0.00014	0.00004
NW ∗ EDUC	−0.02971	0.0088
NW ∗ EDUCSQ	0.00127	0.0003
MAR	0.09257	0.0044
NW	0.38577	0.0882
FEM	0.30830	0.0772
INVMILLS	−0.21600	0.0204

Table A.2
Parameter Estimates– rank 2 Model.

Variable	Estimate	SE	Estimate	SE
	Nondurables		Capital services	
CONST	−0.53660	0.0027	−0.29696	0.0041
PNON	−0.01576	0.0014	−0.02430	0.0013
PCAP	−0.02430	0.0013	0.05172	0.0022
PSERV	0.05024	0.0009	−0.04291	0.0012
WAGE	−0.04689	0.0019	0.00632	0.0026
FULLC	0.03670	0.0002	0.00916	0.0004
CHILD	−0.01482	0.0002	−0.00256	0.0004
CHILDSQ	0.00152	0.0001	0.00066	0.0001
ADULT	0.00360	0.0006	0.04338	0.0007
ADULTSQ	−0.00048	0.0001	−0.00407	0.0001
REGMW	−0.00390	0.0004	0.00865	0.0007
REGS	−0.00824	0.0004	0.01163	0.0007
REGW	0.00057	0.0004	−0.00753	0.0005
NONWHITE	0.01115	0.0003	0.01341	0.0005
FEMALE	0.00823	0.0003	0.00285	0.0004
RURAL	−0.01264	0.0004	0.03158	0.0008
	Consumer services		Leisure	
CONST	−0.03032	0.0030	−0.13615	0.0063
PNON	0.05024	0.0009	−0.04689	0.0019
PCAP	−0.04291	0.0012	0.00632	0.0026
PSERV	−0.02309	0.0013	0.02110	0.0018
WAGE	0.02110	0.0018	0.05999	0.0045
FULLC	−0.00535	0.0003	−0.04052	0.0006
CHILD	−0.00077	0.0003	0.01815	0.0006
CHILDSQ	0.00053	0.0001	−0.00271	0.0002
ADULT	0.01814	0.0007	−0.06511	0.0011
ADULTSQ	−0.00139	0.0001	0.00594	0.0002
REGMW	−0.01280	0.0005	0.00805	0.0010
REGS	−0.01857	0.0005	0.01519	0.0010
REGW	−0.00216	0.0004	0.00913	0.0009
NONWHITE	0.01139	0.0004	−0.03594	0.0008
FEMALE	−0.00776	0.0003	−0.00333	0.0007
RURAL	−0.01141	0.0005	−0.00752	0.0011

Table A.3
Parameter estimates– rank 3 model (A0 = −12.1089, SE = 1.2657).

Variable	Estimate	SE	Estimate	SE
	Nondurables		Capital services	
CONST	−0.42468	0.2143	−0.20158	0.1835
PNON	−0.01508	0.0039	−0.02232	0.0043
PCAP	−0.02232	0.0043	0.05330	0.0039
PSERV	0.05108	0.0018	−0.04132	0.0034
WAGE	−0.04136	0.0086	0.00886	0.0053
FULLC	0.02768	0.0177	0.00148	0.0151
FULLCSQ	−0.00678	0.0002	−0.00590	0.0003
CHILD	−0.01474	0.0004	−0.00257	0.0004
CHILDSQ	0.00150	0.0001	0.00065	0.0001
ADULT	0.00112	0.0007	0.04090	0.0011
ADULTSQ	0.00003	0.0001	−0.00360	0.0001
REGMW	−0.00400	0.0004	0.00851	0.0007
REGS	−0.00816	0.0005	0.01151	0.0007
REGW	0.00054	0.0004	−0.00747	0.0006
NONWHITE	0.01079	0.0005	0.01306	0.0006
FEMALE	0.00848	0.0003	0.00312	0.0004
RURAL	−0.01274	0.0005	0.03112	0.0008
	Consumer services		Leisure	
CONST	0.03746	0.1305	0.41120	0.5281
PNON	0.05108	0.0018	−0.04136	0.0086
PCAP	−0.04132	0.0034	0.00886	0.0053
PSERV	−0.02203	0.0022	0.02310	0.0046
WAGE	0.02310	0.0046	0.02773	0.0608
FULLC	−0.01082	0.0107	−0.01833	0.0435
FULLCSQ	−0.00428	0.0002	0.01696	0.0005
CHILD	−0.00080	0.0003	0.01811	0.0008
CHILDSQ	0.00052	0.0001	−0.00267	0.0002
ADULT	0.01649	0.0008	−0.05851	0.0020
ADULTSQ	−0.00106	0.0001	0.00462	0.0002
REGMW	−0.01275	0.0005	0.00824	0.0011
REGS	−0.01847	0.0006	0.01512	0.0012
REGW	−0.00215	0.0004	0.00907	0.0009
NONWHITE	0.01113	0.0005	−0.03497	0.0013
FEMALE	−0.00748	0.0003	−0.00412	0.0007
RURAL	−0.01150	0.0005	−0.00687	0.0011

the third period lags. Regardless of the instrument set, the point estimates of the subjective rate of time preference remains around 0.0125 while the estimates of σ are in the range between 0.0341 and 0.0815.

6. Summary and conclusion

In this paper we have integrated twenty-seven years of repeated cross sections with information on the levels of prices and wages that vary across regions and over time. The resulting data set is comprised of over 150,000 households and allows us to model the joint determination of the allocation of full expenditure across goods and leisure. The large sample sizes and lengthy time series enable us to create synthetic cohorts that facilitate the estimation of the allocation of full wealth, including the assets and time endowment of each household, over time.

We find that the cross-sectional and inter-temporal variation of prices and wages is substantial which allows us to estimate the price and wage elasticities very precisely. We find that wage elasticities of labor supply are negative but close to zero while the price elasticities of demand for nondurables and consumer services are price inelastic. As important, household heterogeneity is important in explaining consumption patterns and these effects would be missed if micro-level data are not used to estimate the joint determination of labor supply and goods demand. For example, we find that the numbers of adults and children in each household have an important impact on the allocation of full consumption between leisure and goods.

The within-period model of consumer behavior has been extended by utilizing a less restrictive approach for representing income effects. We estimate a translog demand system of Gorman rank three and compare it with demand functions that are of rank two. We find that the average income and price elasticities of goods and services, as well as leisure, are very similar. However, over the entire range of full consumption, the new rank three translog demand system better describes the income effects than the earlier rank two system implemented by, for example, (Jorgenson and Slesnick, 1997).

The most important and novel feature of our model of the joint determination of leisure and goods demand is that it is consistent with exact aggregation. As illustrated by Jorgenson and Wilcoxen (1998), aggregate commodity demands and labor supply play crucial roles in general equilibrium models that are used to evaluate the macroeconomic consequences of energy and environmental policies. As noted by Browning et al. (1999), the challenge is to capture the heterogeneity of household behavior in a tractable way in developing aggregates that can be used for macroeconomic policy evaluation.

The exact aggregation framework presented in Section 4 incorporates this heterogeneity while also encompassing the price and income variation that is included in traditional models based on the highly over-simplified theory of a representative consumer. The aggregate demand functions can be represented in closed form and are obtained by simply summing over all of the households in the sample. We find that the aggregate expenditure patterns and leisure demands are largely determined by movements in prices and incomes. While demographic characteristics have significant impacts cross-sectionally, they show little movement over time and have little impact on temporal variations of aggregate demand.

Appendix

See Tables A.1–A.3.

References

Attanasio, O., Banks, J., Meghir, C., Weber, G., 1999. Humps and bumps in lifetime consumption. Journal of Business and Economic Statistics 17 (1), 22–35.

Attanasio, O., Weber, G., 1995. Is consumption growth consistent with intertemporal optimization? Evidence from the consumer expenditure survey. Journal of Political Economy 103 (6), 1121–1157.

Blundell, R., Browning, M., Meghir, C., 1994. Consumer demand and the life-cycle allocation of household expenditures. Review of Economic Studies 61, 57–80.

Blundell, R., Pashardes, P., Weber, G., 1993. What do we learn about consumer demand patterns from micro data?. American Economic Review 83 (3), 570–597.

Blundell, R., Stoker, T., 2005. Heterogeneity and aggregation. Journal of Economic Literature 43 (2), 347–391.

Browning, M., Deaton, A., Irish, M., 1985. A profitable approach to labor supply and consumer demands over the life cycle. Econometrica 53 (3), 503–543.

Browning, M., Hansen, L., Heckman, J., 1999. Micro data and general equilibrium models. In: Taylor, J., Woodford, M. (Eds.), Handbook of Macroeconomics, vol. 1A. North-Holland, Amsterdam.

Gorman, W., 1981. Some Engel curves. In: Deaton, A. (Ed.), Essays in the Theory and Measurement of Consumer Behavior. Cambridge University Press, Cambridge.

Hall, R., 1978. Stochastic implications of the life cycle-permanent income hypothesis: Theory and evidence. Journal of Political Economy 86 (6), 971–988.

Jorgenson, D., Lau, L., Stoker, T., 1997. Transcendental logarithmic model of aggregate consumer behavior. In: Jorgenson, D. (Ed.), Aggregate Consumer Behavior. The MIT Press, Cambridge, pp. 203–356.

Jorgenson, D., Slesnick, D., 1997. Aggregate consumer behavior and household equivalence scales. In: Jorgenson, D. (Ed.), Measuring Social Welfare. The MIT Press, Cambridge, pp. 219–252.

Jorgenson, D., Wilcoxen, P., 1998. Energy, the environment, and economic growth. In: Jorgenson, D. (Ed.), Energy, the Environment, and Economic Growth. The MIT Press, Cambridge, pp. 1–88.

Kokoski, M., Cardiff, P., Moulton, B., 1994. Interarea Price Indices for Consumer Goods and Services: An Hedonic Approach. BLS Working Paper 256.

Lewbel, A., 2001. The Rank Extended Translog, Boston, Department of Economics, Boston College.

Slesnick, D., 2001. Consumption and Social Welfare. Cambridge University Press, Cambridge.

Slesnick, D., 2002. Prices and regional variation in welfare. Journal of Urban Economics 51 (3), 446–468.