Part 2. Analyzing Environmental Policies with IGEM

Chapter 2. Estimating the demand side of the US economy

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2.1. Estimating household demands and labor supply

2.1.1 Introduction

This chapter describes our 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. The aggregate demand functions are then used to represent the household sector in IGEM.

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, Cardiff, and Moulton (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, Lau, and Stoker (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, Browning and Meghir (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, we employ synthetic cohorts, introduced by Browning, Deaton, and Irish (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 2.1.2. 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 2.1.3 we discuss data issues including the measurement of price and wage levels that show substantial variation across regions and over time. In Section 2.1.4 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 non-durable 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.

2.1.2. 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:

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

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

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

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

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

$F_k = \Sigma p_{ik} x_{ik} + p_{Lk} R_k$ 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 o f 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]

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

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:

$$(2.1)\qquad (\ln V_k)^{-1} = [\alpha_0 + \ln(\frac{\rho_k}{F_k})'\alpha_p + \frac{1}{2}\ln(\frac{\rho_k}{F_k})' B_{pp} \ln(\frac{\rho_k}{F_k}) + \ln(\frac{\rho_k}{F_k})' B_{pA} A_k]^{-1} - \ln(\frac{\rho_k}{F_k})'\gamma_p$$

where we assume $B_{pp} = B'_{pp}, \iota' B_{pA} = 0, \iota' B_{pp}\iota = 0, \iota'\alpha_p = -1$ and $\iota'\gamma_p = 0$.

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

$$(2.2)\qquad \ln G_k = \alpha_0 + \ln(\frac{\rho_k}{F_k})'\alpha_p + \frac{1}{2}\ln(\frac{\rho_k}{F_k})' B_{pp} \ln(\frac{\rho_k}{F_k}) + \ln(\frac{\rho_k}{F_k})' B_{pA} A_k$$

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

$$(2.3)\qquad w_k = \frac{1}{D(\rho_k)}(\alpha_p + B_{pp}\ln\frac{\rho_k}{F_k} + B_{pA}A_k + \gamma_p[\ln G_k]^2)$$

where $D(\rho_k) = -1 + \iota' B_{pp} \ln \rho_k$.

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

$$(2.3b)\qquad w = \frac{\sum_k F_k w_k}{\sum_k F_k}$$

$$= \frac{1}{D(\rho)}\left[\alpha_p + B_{pp}\ln\rho - \iota' B_{pp}\frac{\sum F_k \ln F_k}{\sum F_k} + B_{pA}\frac{\sum F_k A_k}{F_k}\gamma_p \frac{\sum F_k (\ln G_k)^2}{\sum F_k}\right].$$

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:

$$(2.4)\qquad \max_{F_{kt}} U_k = E_t\{\sum_{t=1}^{T}(1+\delta)^{-(t-1)}[\frac{V_{kt}^{(1-\sigma)}}{(1-\sigma)}]\}$$

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:

$$\max_{F_{kt}} U_k = E_t\{\sum_{t=1}^{T}(1+\delta)^{-(t-1)}\ln V_{kt}\}\ .$$

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

$$(2.5)\qquad (V_{kt})^{-\sigma}[\frac{\partial V_{kt}}{\partial F_{kt}}] = E_t[(V_{k,t+1})^{-\sigma}[\frac{\partial V_{k,t+1}}{\partial F_{k,t+1}}]\frac{(1+r_{t+1})}{1+\delta}]$$

If the random variable η_{kt} embodies expectational errors for household k at time t, equation (2.5) becomes:

$$(2.6)\qquad (V_{kt})^{-\sigma}[\frac{\partial V_{kt}}{\partial F_{kt}}] = [(V_{k,t+1})^{-\sigma}[\frac{\partial V_{k,t+1}}{\partial F_{k,t+1}}]\frac{(1+r_{t+1})}{1+\delta}]\eta_{k,t+1}$$

We can simplify this equation by noting that, for the rank three specification of the indirect utility function given in equation (2.1), we obtain:

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

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

$$(2.7)\qquad \Delta\ln F_{k,t+1} = (1-\sigma)\Delta\ln V_{k,t+1} + \Delta\ln(-D(\rho_{k,t+1})) + \ln(1+r_{t+1}) - \ln(1+\delta) + \eta_{kt}$$

Equation (2.7) serves as the estimating equation for σ and the subjective rate of time preference δ.

2.1.3. Data Issues

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.

Measuring Price Levels in the U.S.

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, Cardiff, and Moulton [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]

[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 1988-1989 these items constituted approximately 75 percent of all expenditures.

Given price levels for 1988-1989, 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 U.S., 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 non-urban price information, rural households are assumed to face the prices of Class D-sized urban areas.[6]

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:

$$(2.8) \quad \ln P_{Li} = \sum_j \beta_j^z z_{ji} + \sum_j \beta_j^z (S_i * z_{ji}) + \sum_j \beta_j^{nw} (NW_i * z_{ji}) + \sum_l \beta_l^g g_i + \varepsilon_{it}$$

where

P_{Li} -- the wage of worker *i*.

$\mathbf{z}_i$ -- a vector of demographic characteristics that includes age, age squared, years of education, and education squared of worker *i*.

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

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[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.

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

$\boldsymbol{g_i}$ -- a vector of region-year interaction 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 F1.

In figure 2.1A we present our estimates of quality-adjusted hourly wages in the urban Northeast, Midwest, South, West as well 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 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 rates occurring in the Northeast and the lowest is in rural areas. Perhaps more surprising is the finding that real wages, shown in figure 2.1B, 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 regions reduce the between-region wage dispersion to a large degree.

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:

$$(2.9) \quad E_{kt}^m = p_{Lt} q_{kt}^m H_{kt}^m$$

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:

$$(2.10) \quad q_{kt}^m = \frac{E_{kt}^m}{p_{Lt} H_{kt}^m}.$$

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

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 equation (2.8). The estimated quality adjustment for nonworkers is:

$$(2.11)\quad \hat{q}_{kt}^{m} = \frac{\hat{p}_{Lkt}^{m}}{p_{Lt}},$$

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:

$$(2.12)\quad F_{kt} = p_{Lt}R_{kt} + \sum_{i} p_{ik}x_{ik}$$

where

$$(2.13)\quad R_{kt} = \sum_{m} R_{kt}^{m}$$

is total household leisure computed as the sum over all adult members.

In figure 2.2A 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 percent per year compared to 1.0 percent per year for per capita full consumption. Figure 2.2B shows the average level of quality-adjusted leisure consumed per adult. The average annual hours increased by approximately 18 percent over the 26 years from 2656 in 1980 to 3177 in 2006. Figure 2.2C 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 percent lower than the variance of log per capita consumption. The trends of the two series, however, are similar.

2.1.4. 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 2.1 we present summary statistics of the variables used in the estimation of the demand system. On average, household leisure comprises almost 70 percent 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 percent of the sample and almost 16 percent 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 equation (2.3). We assume that the disturbances of the demand equations are additive so that the system of estimating equations is:

$$(2.14)\quad w_k = \frac{1}{D(\rho_k)}(\alpha_p + B_{pp}\ln\frac{\rho_k}{F_k} + B_{pA}A_k + \gamma_p[\ln G_k]^2) + \varepsilon_k$$

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, Lau and Stoker (1997):

$$(2.15)\quad w_k = \frac{1}{D(\rho_k)}(\alpha_p + B_{pp} \ln \frac{\rho_k}{F_k} + B_{pA} A_k) + \mu_k .$$

Note that the two specifications coincide if the elements of the vector γ_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 F2 and F3. 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 γ_p are statistically significant and that 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 2.2 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 \$100000 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. 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 2.3. The predicted shares for both

[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.

models are similar for levels of full expenditure in the range between \$25000 and \$150000. 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 (\$350000) the fitted share of household leisure is 0.734 in the rank two model and 0.711 in the rank three model.

Aggregate Demands

Both the rank two and rank three demand systems are consistent with exact aggregation and provide closed form representations of aggregate demands for the four goods:

$$(2.16) \quad w = \frac{\sum_k F_k w_k}{\sum_k F_k} = P_t + Y_t + D_t$$

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

$$(2.17) \quad P_t = \frac{\sum_k F_{kt} D(\rho_{kt})^{-1}(\alpha_p + B_{pp} \ln \rho_{kt})}{\sum_k F_{kt}},$$

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

$$(2.18) \quad Y_t = \frac{\sum_k F_{kt} D(\rho_{kt})^{-1}(\gamma_p (\ln G_{kt})^2 - \iota' B_{pp} \ln F_{kt})}{\sum_k F_{kt}}, \quad D_t = \frac{\sum_k F_{kt} D(\rho_{kt})^{-1}(B_{pA} A_{kt})}{\sum_k F_{kt}}.$$

How well do the fitted demands reflect aggregate expenditure patterns and their movements over time? In Table 2.4 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 2.4 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.

How well do the fitted demands reflect aggregate expenditure patterns and their movement's overtime? In Table 2.4 we compare the fitted aggregate shares for the rank 3 system with sample averages for each of the four commodity groups. To assess the relative importance of prices, full expenditure and demographic variables on aggregate shares, we also report summary statistics similar to the "aggregation factors" described by Blundell, Pashardes, and Weber (1993). The price factor (eq. 2.17) is the full expenditure weighted average of the fitted price terms on the budget shares in each time period.

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 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 2.5 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.

2.1.5. Inter-temporal Allocation of Full Consumption

In this section we describe the inter-temporal allocation of full consumption. Equation (2.7) 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:

$$(2.19)\qquad \Delta \ln F_{c,t+1} = (1-\sigma)\Delta \ln V_{c,t+1} + \Delta \ln(-D(\rho_{c,t+1})) + \ln(1+r_{t+1}) - \ln(1+\delta) + v_{ct}$$

where

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

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

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

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 2.6. 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 figures 2.3A, 2.3B and 2.3C 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. Figure 2.4 shows the age profile of the average within period utility levels ($\ln V_k$) which plays a critical role in the estimation of equation (2.19).

The statistical properties of the disturbances V_{ct} in equation (2.19) that are constructed from synthetic panels in the CEX 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. The expectational errors are likely correlated with the current values of the interest rate implying that standard least squares estimators are inconsistent. As a result, we estimate (2.19) using instrumental variable estimators (IV).

In table 2.7 we present OLS, simple IV and Generalized Method of Moments estimators (GMM) for δ and σ .For each type of estimator we present estimators where the data are weighted by the cell sizes of the each cohort in each year, and compare those estimates with the unweighted estimators. The instruments used for the IV and GMM estimators include a constant, age, age squared, a time trend, and two and three period lags of wages, interest rates, and the prices of nondurables, capital services and consumer services.

Regardless of the estimator, the estimate of the subjective rate of time preference, δ is essentially unchanged. The point estimate remains around 0.03 regardless of the type of estimator, or whether the observations are weighted or unweighted. The point estimate of σ shows more variation over the different sets of estimators but lies in the range between 0.16 and 0.30.

2.1.6. Summary and Conclusion

In this section 2.1 we have successfully exploited variation across households to characterize the allocation of full wealth, including the assets and time endowment of each household, overtime. We have also characterized the allocation of full consumption within each time period among goods and services and leisure, incorporating variations in prices and wages across households. We find that leisure and consumer services are income elastic, while non-durable goods and capital services are income inelastic. Leisure and capital services are price elastic, while non-durable goods and consumer services are price inelastic.

We have greatly extended our translog model of aggregate consumer expenditures by incorporating leisure and utilizing a less restrictive approach for representing income effects. We find that the average income and price elasticities of goods and services, as well as leisure, are very similar for translog demand systems of Gorman rank two and rank three. 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.

The allocation of full consumption among goods and services and leisure also depends on the composition of individual households. The share of leisure greatly predominates, accounting for around 70 percent of full consumption. This increases considerably with the number of adults in the household and declines slightly with the number of children for a given number of adults. The shares of goods and services decline with the number of adults, while the share of non-durable goods rises and the shares of capital and other consumer services fall with the number of children.

The challenge for general equilibrium modeling has been to capture the heterogeneity of behavior of individual households in a tractable way, as emphasized by Browning, Hansen, and Heck-man (1999). In this version of IGEM we have exact aggregation over these households that incorporates this heterogeneity, while also encompassing the variations in prices and income included in traditional models with a representative consumer.

2.2 Personal Consumption Expenditures and work hours, 1970-2005

Chapter 1, section 1.2, describes how the household model in IGEM consist of three stages: the first stage allocates full-income between savings and full-consumption; the second stage uses the consumption function estimated above in section 2.1 to allocate full-consumption among 5 sub-aggregates – non-durables, capital services, consumer services and leisure; and the third stage allocates these 4 sub-aggregates to the 35 detailed commodities identified in IGEM. Table 1.3 in Chapter 1 gave the value of consumption by these 35 (NIPA-PCE based) commodities in 2005. In this section we provide some historical trends in these consumption series. These are the time series that are used to estimate the consumption function subtiers, as described in the next section 2.3.

In the top tier, full consumption is allocated to non-durables (ND), capital services (K), consumer services (SV) and leisure (R) using the estimates derived from the CEX data described in section 2.1; the value of aggregate consumption derived from this CEX data was given in eq. (1.36) in Chapter 1 as:

$$(2.20) \quad MF^X = \sum_k n_k m_k = P_{ND}^{CX} C_{ND}^X + P_K^{CX} C_K^X + P_{SV}^{CX} C_{SV}^X + P_R^{CX} C_R^X$$

This CEX based series (denoted by the X superscript) is then linked to the Personal Consumption Expenditures in the National Accounts (described in eqs. 1.37-1.40); the value of expenditures on ND, K and SV in CEX terms are scaled to equal the value in NIPA terms:

$$(2.21) \quad P_t^{CC} CC_t = PN_t^{ND} N_t^{ND} + PN_t^K N_t^K + PN_t^{CS} N_t^{CS} = P_{ND}^{CX} C_{ND}^X + P_K^{CX} C_K^X + P_{SV}^{CX} C_{SV}^X$$

The N variables denote the NIPA-PCE based quantities and the PN's denote the prices. The value for leisure is not given in the NIPA and requires no rescaling:

$$(2.22) \quad PN_t^R N_t^R = P_{Rt}^{CX} C_{Rt}^X$$

Table 2.8 gives the values and shares of these full-consumption aggregates from the NIPA-PCE for various years, and Figure 2.5 plots the shares of these 4 sub-aggregates in full-consumption. The share of leisure fell from a high of 67.8% in 1971 to 64.1% in 1990 as the female work-force participation rate rose. Since then, this share has not moved persistently in any direction. To explain this further, in figure 2.6 we show how the labor supply and leisure grew differently from total population. Recall that our indices of labor input and leisure are not a simple sums of hours (hours worked or hours not working) but are Tornqvist indices with wage weights. The U.S. population grew at 1.08% per year between 1960 and 1990, but labor supply (i.e. index of hours worked) grew at 1.71% per year. The leisure quantity index grew much slower at 1.57% per year during this period, that is, there is a shift of the share of people going into the paid labor force. During 1990-2000 period when population growth accelerated to 1.21% per year, the leisure index growth decelerated to 1.46%. The rapid rise in labor supply during this period, however, is only due in small part to changes in the female participation rate, the participation rate and annual work hours rose for the population as a whole during this boom period. (Since 2000, we entered a period that is sometimes referred to as the "jobless growth" and the trends are reversed; the labor supply growth rate fell substantially.)

For the other non-leisure components of full consumption, the share of non-durables fell almost continuously from 16.4% in 1960 to 12.0% in 2000, while the share of consumer services rose from 10.1% to 18.8%. The share of capital services was volatile but showed no distinct trend. That is, over the entire 1960-2005 period, the leisure share first rose, then fell back close to the initial value and then rose during the 2000s; the rise in the services share mirrors the decline in the nondurables share (nondurables which include energy).

The allocation of these 3 consumption sub-aggregates (nondurables, capital, services) to the commodities identified in IGEM via a nested structure was given in Table 1.4 in Chapter 1. Table 2.9 gives the values for each node of the nested consumption functions for year 2005. The top node for full consumption is dominated by leisure (14.4 trillion out of 23.4), with consumer services contributing 4.30 trillion. Consumer Services has 5 components, the largest of which are Miscellaneous Services (1670 bil.) and Medical Services (1491 bil.). Miscellaneous Services include Business Services (646) and Education & Welfare (451).

The Nondurables group contributes 2715 billion, and consists of Energy, Food and Consumer Goods. The Energy node only comes to 503 billion and consists of – gasoline & oil (284 billion), coal and fuel-oil (21), electricity (133) and gas (65). Hired transportation services is energy intensive, and households purchased a substantial $62 billion in 200 (note the carbon emissions from hired services is counted as emissions from the Transportation sector, while emissions from household gasoline use is counted as Household emissions). "Own transportation" comes to 263 billion, and this refers to expenditures on repair, car rental, insurance and other services.

In Figure 2.7 we plot the energy share of the nondurables group and the energy share of total consumption (i.e. total Personal Consumption Expenditures excluding the leisure value). The share of energy expenditures rose dramatically with the oil shocks in the 1970s, rising from 14.8% of nondurables in 1972 to 21.7% in 1981. It then declined sharply in the mid 1980s and continued to fall, reaching the lowest share of only 14.5% in 1999 when oil prices were very low. By 2005, with the high oil prices, the share rose to 18.5%. In terms of total PCE, the energy share rose from 6.1% in 1972 to 8.9% in 1981, gradually declined to 4.3% in 1998, and then rose to 5.6% in 2005.

Within the energy group, gas consumption is relatively stable at about 12-13% of total energy expenditures, however the electricity share rose from 21.1% in 1960 to 35.6% in 1995 before falling back to 26.5% in 2005. The gasoline share fell from the 54.8% peak in 1981 to 46.4% in the low oil price year of 1998 and rose back to above 56% in 2005.

2.3 Estimating consumption function subtiers

In section 1.2 we described how the household model 3rd stage allocates the three consumption baskets – nondurables, capital services and consumer services – to the 35 detailed commodities. These aggregate consumption functions do not include demographic information like the top level function described in section 2.1 above. In this section we describe how these simpler functions are estimated.

The detailed commodities are based on the Personal Consumption Expenditures in the National Accounts which include items such as "purchased meals" and "road tolls". The classification of PCE goods is different from the commodities in the input-output table, and is based on purchaser values inclusive of trade and transportation margins. The demand model is first specified in terms of the PCE classification, and then bridged to the IO classification. For symmetry we group the detailed PCE items into 35 categories given in Table 1.3. The tier structure of the allocation to these 35 groups is given in Table 1.4, and we just described the dollar value allocations in year 2005 in Table 2.9.

The prices and quantities of aggregate consumption of group i are denoted as PN_i and N_i , where the letter N is used to remind us that these are classifications based on the NIPA. For consumption organized according to the input-output classification (the Consumption column in the IO tables) we use the notation P_i^C and C_i.

The allocation of the consumer nondurables, capital services, consumer services bundles is given as a price function derived from an aggregate indirect utility function (eq. 1.41). As explained in section 1.2.4, the utility from consumption of sub-aggregate *m* is a homothetic (unit income elasticity) function of the prices of the components and total expenditures, $V^m = V(P^{Hm}, M^m)$. For example, for *m*=3,

$P^{H3}=(PN_6,PN^{FC},PN_{18},PN_{19}) =(PN_{gasoline}, PN_{Fuel\text{-}Coal}, PN_{electricity}, PN_{gas})$ and

$M^{m=3} = PN_6 N_6 + PN^{FC} N^{FC} + PN_{18} N_{18} + PN_{19} N_{19}$.

There are trends in the consumption shares that cannot be explained by movements in relative prices and we include a latent variable (f^{Hm}) similar to that of the industry cost function (Chapter 3). The demand functions derived from this $V(P^{Hm}, M^m)$ homothetic utility function, are as though they are factor demands derived from a translog price function (eq. 1.45); this is reproduced here for node *m*:

(2.23) $\ln PN^m = \alpha^{Hm}{}' \ln P^m + \frac{1}{2} \ln P^m{}' B^{Hm} \ln P^m + \ln P^m{}' f^{Hm}$

The value of national expenditures at node *m* is:

(2.24) $M^m = PN^m N^m = PN_{m1} N_{m1} + \ldots + PN_{m,im} N_{m,im}$

From this value and the price in (2.23), we obtain the quantity index, N^m. For the energy node example, the value of aggregate expenditures on energy by households is:

(2.25) $PN^{EN} N^{EN} = PN_6 N_6 + PN^{FC} N^{FC} + PN_{18} N_{18} + PN_{19} N_{19}$

The share demands derived by differentiating this price function were given in eq. (1.43) for each node *m*. We add a stochastic term to it and estimate the following demand function with a first-order AR for the latent term:

(2.26) $SN^m = \begin{bmatrix} PN_{m1} N_{m1} / PN^m N^m \\ \cdots \\ PN_{m,im} N_{m,im} / PN^m N^m \end{bmatrix} = \alpha^{Hm} + B^{Hm} \ln PN^{Hm} + f^{Hm} + \varepsilon_t^{Hm}$

(2.27) $f_t^{Hm} = F^{Hm} f_{t-1}^{Hm} + v_t$

These share equations are the ones actually estimated, not the price function (2.23).

The results for estimating this system are given in Table 2.10. This system is used for the 35 items in nodes 2 through 17 given in Table 1.4. The coefficients are generally well estimated for the nodes with 2 or 3 inputs, the price elasticities for the nodes with 4 or 5 inputs unfortunately have large standard errors. Nodes 7 and 14 (Fuel-coal and Medical) could not be estimated and were set to fixed share functions with $B^{Hm} = 0$. The estimated share (own-price) elasticities range from -0.9 to 0.16, but most are between -0.1 and 0.1. The bigger values are from the nodes with 4 or 5 inputs that are poorly estimated. That is, most nodes are close to a Cobb-Douglas function which has a zero share elasticity (unit substitution elasticity). Of the 43 diagonal B_{ii}^{Hm} coefficients that are estimated, 22 are negative, i.e. with a price elasticity greater than one.

There are strong non-price trends in most items, that is, the latent terms, f_t^{Hm}, have noticeable trends in the sample period. These are projected using eq. (2.27). To illustrate these trends, Fig. 2.8 shows the latent term during the sample period, and in the projections, for node 3 which gives Energy as a function of gasoline, fuel-coal, electricity and gas. We can see that the latent term for electricity rising between the late 1960s and 1990 and flattening out since. The projection for the latent electricity share is thus a very modest increase in the next 50 years. The latent gasoline share was flat for most of the sample period and the projection is thus quite flat. The latent term for natural gas is mostly declining during the sample period and is projected to decline a tiny bit more. We must emphasize again that these are trends in the shares after taking into account the price effects.

This picture of a stabilization of the projected latent term within a short period is typical of almost all the other items in the consumer tier structure. The exception is the somewhat strong upward trend projected for purchased meals in the Food node (node 4) and a corresponding strong down trend for food purchased for off-premise consumption.

2.4 Estimating the aggregate intertemporal consumption function

Section 2.1.5 above describes the intertemporal function that allocates consumption over time. This is implemented in some version of IGEM. We also keep the option of using a simpler function derived from aggregate national consumption data. This is described in Chapter 1, where eq. (1.18) is the aggregate household intertemporal utility function as a discounted sum of log full consumption:

(2.28) $U = \sum_{t=1}^{\infty} N_0 \prod_{s=1}^{t} \left(\frac{N_t^{eq}}{1+\rho} \right) \ln F_t$

This gives the following Euler equation to be estimated:

(2.29) $\frac{F_t / N_t}{F_{t-1} / N_{t-1}} = \frac{(1+r_t)}{1+\rho} \frac{P_{t-1}^F}{P_t^F}$

We assume that the errors in this first stage of the household model can be expressed in the following stochastic form:

(2.30) $\ln \frac{F_t / N_t}{F_{t-1} / N_{t-1}} = \ln \frac{(1+r_t)}{1+\rho} + \ln \frac{P_{t-1}^F}{P_t^F} + \varepsilon_t^F$

The ε^F 's are serially uncorrelated by construction.

Equation (2.30) is estimated using non-linear three stage least squares using instruments described in section 3.2.2. The value of ρ is estimated to be 0.0263 with a standard error of 0.004. This estimated pure rate of time preference is fairly low given our deterministic approach (no risk premia) which leads to a slightly higher savings rate than other models.

2.5 Estimating investment function subtiers

In Chapter 1, Section 1.3.2 describes how aggregate investment, I_t^a, is built up from data on investment by detailed asset classes within the broad groups of structures, producer durable equipment, and consumer durables. It was also noted that the expenditures on each asset type are linked to the Input-Output commodity classification via a bridge table. For example, the $43.6 billion investment in "computers and peripheral equipment" in 1992 is made up of the following IO commodities at factory gate prices: 32.7 from machinery, 3.4 from services, 0.4 from transportation, and 7.1 from trade. Using such information we constructed a time series of investment classified by the 35 IGEM commodities based on the IO classification as described in Appendix B. The values for fixed investment by these IO commodities in 2000 and 2005 are given in Table 2.11, i.e. values at producer's price. Of the total $2538 billion worth of investment at the peak of the economic boom in 2000, the biggest type is Construction (634 bil.) followed by Motor Vehicles (331 bil.). Trade margins are significant for investment goods, and are valued at 446 billion. By 2005, at the end of the investment slump during the 2000s, the share of investment going to computers (Industrial Machinery and Equipment) has fallen substantially, offset by a rise going to Finance, Insurance and Real Estate, and Petroleum and Gas Mining.

In the historical data, aggregate investment (I_t^a) is the sum of fixed investment and changes in business inventory. Inventory is a cyclical variable and in IGEM this variable is only maintained to match the data, it is not modeled as a result of agent optimization. Here we concentrate on modeling fixed investment, I^{fixed}.

In the IGEM the demand for these 35 commodities by the investor is modeled in a way analogous to the demand for consumption described above in section 2.3. That is, aggregate fixed investment is a function of these commodities, $I^{fixed} = I(IF_1, IF_2, ...IF_{35})$, and this is implemented as a nested set of demand functions. The tier structure was given in Table 1.6 where node 1 allocates fixed investment to "long-lived" commodities and "short-lived" commodities, and node 15 allocates "mining" to "metal mining" and "petroleum mining" commodities. The set of nodes is denoted as $I_{INV} = \{1, 2, ...15\} =$ $\{\text{fixed, long, …, mining}\}$. Of the 35 commodities only 25 have positive contributions to fixed investment. We have noted that the main contributors are Construction ($634 billion) and Trade (446 bil.). The recent dominance of Information Technology investment is shown by the large $279 bn. from Industrial Machinery to total fixed investment in 2005.

We model the allocation of investment using translog price functions as given in eq. (1.78) for node *m* with components $IF_{m1}, \ldots, IF_{m,im}$:

$$(2.31) \quad \ln PII^m = \alpha^{Im} \ln P^{Im} + \frac{1}{2} \ln P^{Im}{}' B^{Im} \ln P^{Im} + \ln P^{Im}{}' f_t^{Im}$$

where $\ln P^{Im} \equiv \left(\ln PII_{m,1}, \ldots, \ln PII_{m,i}, \ldots, \ln PII_{m,im}\right)'$ is the vector of component prices. Since there are trends in the investment demands that cannot be explained by the price variation we also include a latent term f_t^{Im} just as in (2.23) for consumption:

$$(2.32) \quad f_t^{Im} = F^{Im} f_{t-1}^{Im} + v_t$$

The share demands at node *m* corresponding to this price function were given in eq. (1.79) in Chapter 1. We add a stochastic term to it and estimate the following share demands:

$$(2.33) \quad SI^{m} = \begin{bmatrix} PII_{m1}IF_{m1} / PII^{m}IF^{m} \\ \dots \\ PII_{m,im}IF_{m,im} / PII^{m}IF^{m} \end{bmatrix} = \alpha^{Im} + B^{Im} \ln PII^{Im} + f_t^{Im} + \varepsilon_t^{Im}$$

As an example, the Transportation Equipment sub-aggregate (node 4) is made of Motor Vehicles (I24) and Other Transportation Equipment (I25), and the share demand for Motor Vehicles is given by:

$$(2.34) \quad \frac{PII_{24}I_{24}}{PII^{m=4}IF^{m=4}} = \alpha_1^{I,m=4} + B_{11}^{I,m=4} \ln \frac{PII_{24}}{PII_{25}} + f_1^{I,m=4} + \varepsilon_t$$

$$f_{1,t}^{Im=4} = F_{1,1}^{Im=4} f_{1,t-1}^{Im=4} + v_{1,t}$$

The results of estimating the investment tiers are given in Table 2.12. Seventeen of the 39 own share elasticities (the B_{ii}'s) are negative, i.e. the substitution is more elastic than a Cobb-Douglas function. The remainder are positive, i.e. with an elasticity less than one. In absolute terms, almost all the B_{ij}'s are less than 0.2, with the most elastic parameters in the Textile-Apparel node (node 14), and the short-lived assets node (node 3).

Examples of the estimated latent variable and the projections are given in Figure 2.9 for the node 1 and node 5. Node 1 gives total fixed investment as a function of long-lived assets and short-lived assets. The plot marked by squares show how the long-lived share $f_{longlived,t}^{Im=1}$ is falling in the sample period and thus is projected to continue falling. Node 5 gives Machinery as a function of Industrial Machinery, Electrical Machinery and Other Machinery. The plot marked by diamonds show how the Industrial Machinery share show no particular long term trend in the sample period and thus is projected in a constant fashion. Most of the nodes show a pattern more similar to the plot for Industrial Machinery, that is, with no distinct sustained trend in the sample period unlike the obvious trend in Long-lived assets. As another example, in node 4 for Transportation equipment the share of motor vehicles in total transportation equipment fell from the early 1960s to hit bottom after the oil shocks and recovered.

2.6 Estimating export demand functions

In Section 1.5 we describe how the share of total supply allocated to the export market is written as a translog share function of domestic and world prices. We add a stochastic term to equation 1.103b and estimate the following function:

$$(2.35) \quad \frac{PS_{it} X_{it}}{PS_{it} QS_{it}} = \alpha_{xt} + \beta_{xx} \ln \frac{PM_{it}}{PC_{it}} + f_{it}^{X} + \varepsilon_{it}^{X}$$

The results are reported in Table 2.13. The fitted share for year 1996, when the prices are normalized to 1, would be given by the sum of the α_{xt} and f_{it}^{X} terms. The major exported commodities are Other Transportation Equipment, Instruments, Chemicals, Transportation services, Motor Vehicles, and Electrical Equipment. For six commodities with small exports the share elasticity could not be estimated. For the other 29 commodities, the share elasticity, β_{xx}, ranges from -0.27 to 0.04. Of these, only four are positive, i.e. inelastic supply. The most elastic exports are Other Transportation Equipment and Transportation Services.

The latent term captures the trend of rising export share between 1960 and 1980 for most commodities. The U.S. economic boom in the second half of the 1990s led to a decline in export shares as output is allocated more to the domestic market. These are illustrated in Figure 2.10 for three commodities – other transportation equipment, industrial machinery and electrical machinery.

The strong upward trend for Other Transportation Equipment (mainly aerospace) throughout the sample period is projected to continue, but at rate much slower than the sample period. The share of Electrical Machinery exports declined during the economic boom and the projection is a recovery to historical shares.

Exports of energy – crude oil, refined petroleum, electricity – are not very important. The most significant are coal exports which were more than 10% of total domestic output in the 1990s but have since dropped to about 5%.

Table 2.1 Sample summary statistics

Table 1
Sample Summary Statistics
(Sample Size: 109,356)

Variable	Mean	Standard Error	Minimum	Maximum
Share NON	0.105	0.0529	0.0013	0.695
Share CAP	0.128	0.073	0.00013	0.895
Share CS	0.071	0.0537	0.000037	0.792
Share LEIS	0.696	0.122	0.0022	0.991
Log PNON	0.0161	0.156	-0.510	0.366
Log PCAP	-0.178	0.256	-1.101	0.334
Log PCS	0.00286	0.287	-0.828	0.471
Log Wage	-0.0307	0.203	-0.543	0.353
Log Full	11.246	0.586	8.149	14.793
Children	0.728	1.130	0.0	12.0
Adults	1.885	0.840	1.0	13.0
White	0.852	0.355	0.0	1.0
Nonwhite	0.148	0.355	0.0	1.0
Male	0.717	0.450	0.0	1.0
Female	0.283	0.450	0.0	1.0
Urban	0.899	0.301	0.0	1.0
Rural	0.101	0.301	0.0	1.0
NE	0.209	0.407	0.0	1.0
MW	0.255	0.436	0.0	1.0
South	0.300	0.458	0.0	1.0
West	0.236	0.425	0.0	1.0

Table 2.2 Price and Income Elasticities

Table 2
Price and Income Elasticities

Good	Uncompensated Price Elasticity		Compensated Price Elasticity		Expenditure Elasticity	
	Rank 2	Rank 3	Rank 2	Rank 3	Rank 2	Rank 3
Nondurables	-0.727	-0.718	-0.651	-0.638	0.673	0.713
Capital Services	-1.192	-1.200	-1.084	-1.088	0.902	0.939
Consumer Services	-0.561	-0.558	-0.490	-0.485	1.067	1.110
Leisure	0.014	0.011	-0.305	-0.299	1.063	1.046
Labor Supply	-0.032	-0.026	0.713	0.709	-2.486	-2.478

Table 2.3. Full expenditure and household budget shares

Table 3
Full Expenditure and Household Budget Shares

	Nondurables		Capital Services	
Expenditure	Rank 2	Rank 3	Rank 2	Rank 3
7500	0.208	0.240	0.151	0.181
25000	0.164	0.169	0.137	0.142
75000	0.123	0.121	0.124	0.122
150000	0.098	0.100	0.116	0.117
275000	0.075	0.086	0.108	0.119
350000	0.066	0.082	0.106	0.120

	Consumer Services		Leisure	
Expenditure	Rank 2	Rank 3	Rank 2	Rank 3
7500	0.055	0.074	0.586	0.505
25000	0.060	0.063	0.639	0.626
75000	0.065	0.06	0.688	0.693
150000	0.068	0.069	0.718	0.713
275000	0.071	0.077	0.745	0.718
350000	0.072	0.081	0.756	0.716

Table 2.4 Aggregate budget shares

Table 4
Aggregate Budget Shares

Nondurables

Year	Sample Shares	Fitted Shares	R-Squared	Aggregation Factors: Aggregate Price	Aggregate Expenditure	Aggregate Demographic
1980-81	0.1148	0.1114	0.1356	0.6478	-0.5402	0.0038
1985-86	0.0995	0.1001	0.1596	0.6492	-0.5517	0.0026
1990-91	0.0970	0.0962	0.1795	0.6545	-0.5606	0.0022
1995-96	0.0898	0.0903	0.2164	0.6558	-0.5673	0.0018
1999-2000	0.0842	0.0892	0.1799	0.6648	-0.5774	0.0017

Capital Services

Year	Sample Shares	Fitted Shares	R-Squared	Aggregation Factors: Aggregate Price	Aggregate Expenditure	Aggregate Demographic
1980-81	0.0958	0.1118	0.0734	0.4348	-0.2563	-0.0667
1985-86	0.1137	0.1156	0.1082	0.4419	-0.2612	-0.0651
1990-91	0.1189	0.1186	0.1317	0.4486	-0.2656	-0.0643
1995-1996	0.1222	0.1212	0.1194	0.4539	-0.2687	-0.0640
1999-2000	0.1281	0.1226	0.1101	0.4597	-0.2734	-0.0637

Consumer Services

Year	Sample Shares	Fitted Shares	R-Squared	Aggregation Factors: Aggregate Price	Aggregate Expenditure	Aggregate Demographic
1980-81	0.0567	0.0550	0.0080	0.1054	-0.0282	-0.0223
1985-86	0.0628	0.0662	0.0188	0.1162	-0.0282	-0.0218
1990-91	0.0708	0.0688	0.0379	0.1196	-0.0289	-0.0219
1995-96	0.0734	0.0742	0.0337	0.1245	-0.0291	-0.0212
1999-2000	0.0732	0.0745	0.0388	0.1253	-0.0295	-0.0213

Leisure

Year	Sample Share	Fitted Shares	R-Squared	Aggregation Factors: Aggregate Price	Aggregate Expenditure	Aggregate Demographic
1980-81	0.7327	0.7218	0.1560	-0.1880	0.8247	0.0851
1985-86	0.7239	0.7181	0.1605	-0.2072	0.8411	0.0842
1990-91	0.7133	0.7164	0.1817	-0.2226	0.8551	0.0840
1995-96	0.7146	0.7143	0.1808	-0.2341	0.8651	0.0834
1999-2000	0.7145	0.7138	0.1711	-0.2498	0.8802	0.0833

Table 2.5 Group budget shares

Table 5
Group Budget Shares

Male Head, 2 or more Adults

Year	At least 1 Child			No Children		
	Sample Share	Fitted Share	R-Squared	Sample Share	Fitted Share	R-Squared
1980-81	0.7261	0.7347	0.1191	0.7410	0.7509	0.0351
1985-86	0.7205	0.7219	0.0769	0.7401	0.7453	0.0255
1990-91	0.7184	0.7170	0.0723	0.7388	0.7327	0.0816
1995-96	0.7169	0.7175	0.0761	0.7352	0.7352	0.0667
1999-2000	0.7180	0.7188	0.0667	0.7353	0.7397	0.0435

Table 2.6 Synthetic cohorts

Table 6
Synthetic Cohorts

Cohort	Average Observ.	Range of Observ.	Average Age	Years Covered
1	97	43-148	78-87	1980-1989
2	138	69-189	73-87	1980-1994
3	171	84-258	68-88	1980-2000
4	232	160-302	63-83	1980-2000
5	282	210-353	58-78	1980-2000
6	301	247-375	53-73	1980-2000
7	292	242-408	48-68	1980-2000
8	302	259-362	43-63	1980-2000
9	370	282-474	38-58	1980-2000
10	469	379-608	33-53	1980-2000
11	528	398-742	28-48	1980-2000
12	551	350-769	23-43	1980-2000
13	460	110-774	19-38	1980-2000
14	364	92-713	19-33	1985-2000
15	315	78-603	19-28	1990-2000
16	240	66-429	19-23	1995-2000

Table 2.7 Parameter estimates – intertemporal model

Table 7

Parameter Estimates-- Intertemporal Model

Unweighted Estimates

	OLS		IV		GMM	
Variable	Estimate	SE	Estimate	SE	Estimate	SE
DELTA	0.0297	0.0021	0.0300	0.0022	0.0318	0.00181
SIGMA	0.2683	0.0295	0.2378	0.0510	0.2325	0.0488

Weighted Estimates

	OLS		IV		GMM	
Variable	Estimate	SE	Estimate	SE	Estimate	SE
DELTA	0.0277	0.0021	0.0297	0.0023	0.0328	0.0018
SIGMA	0.3063	0.0306	0.2033	0.0534	0.1618	0.0487

Figure 2.1A Regional wages

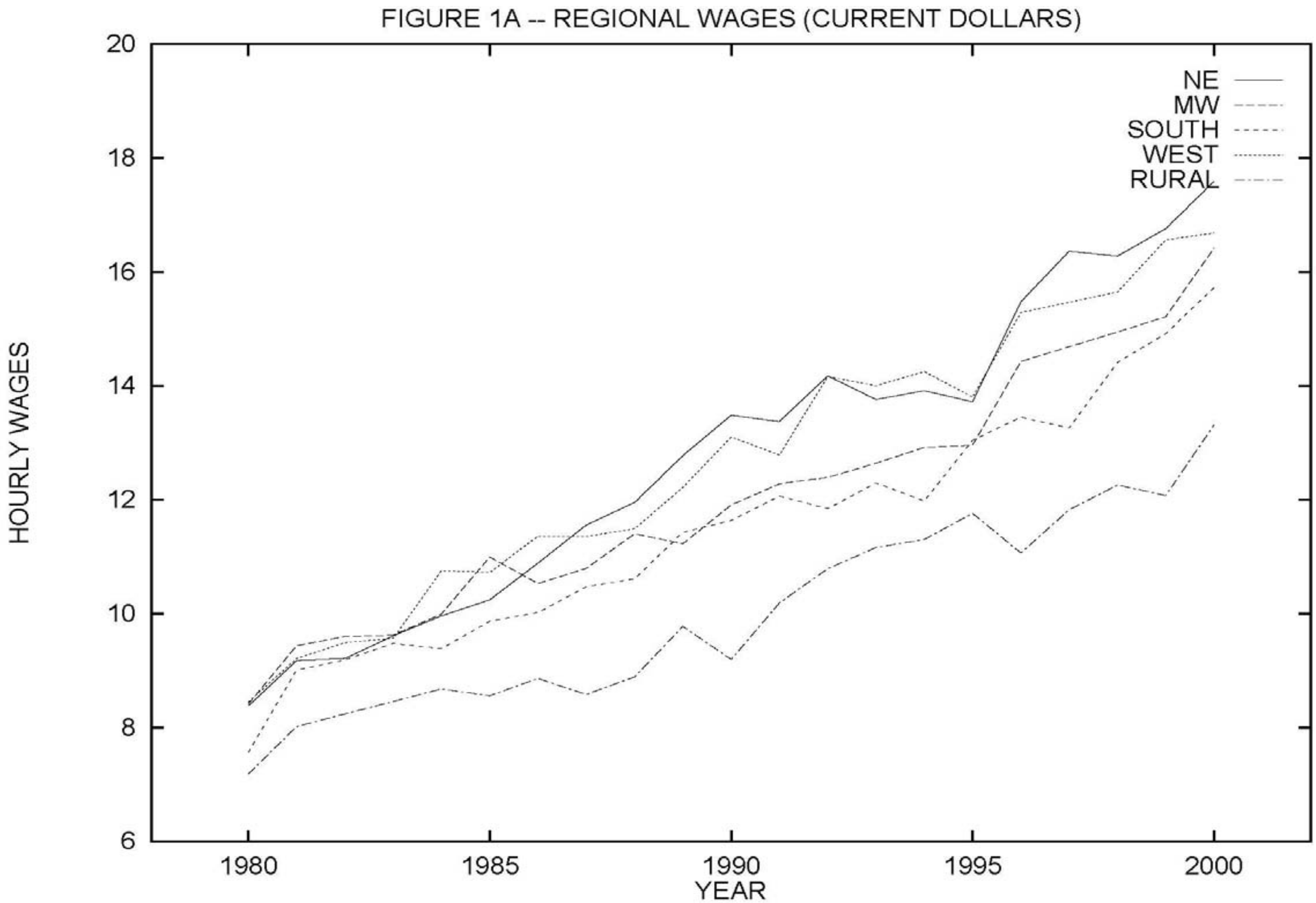


Figure 2.1B Regional real wages

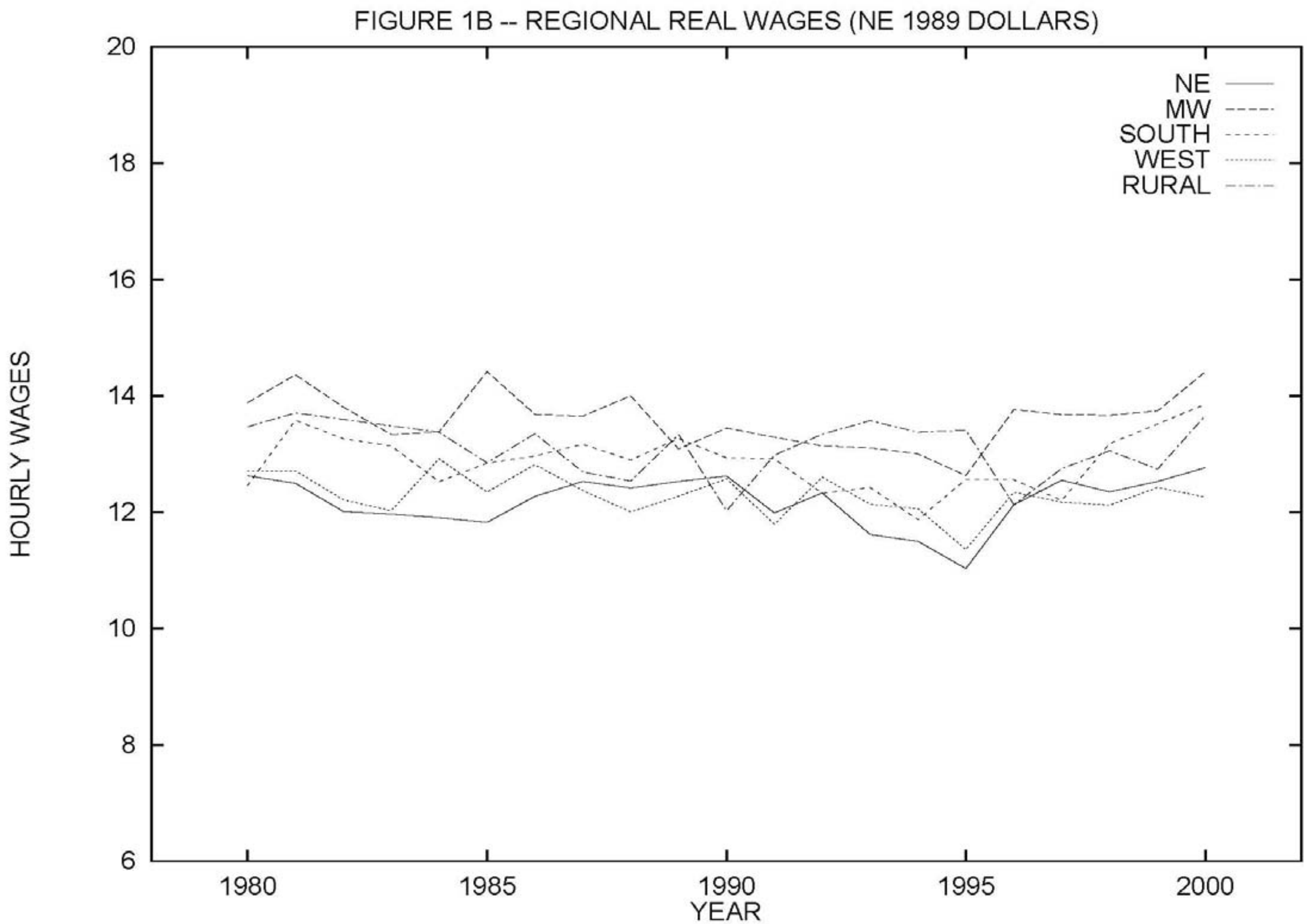


Figure 2.2A Consumption per capita

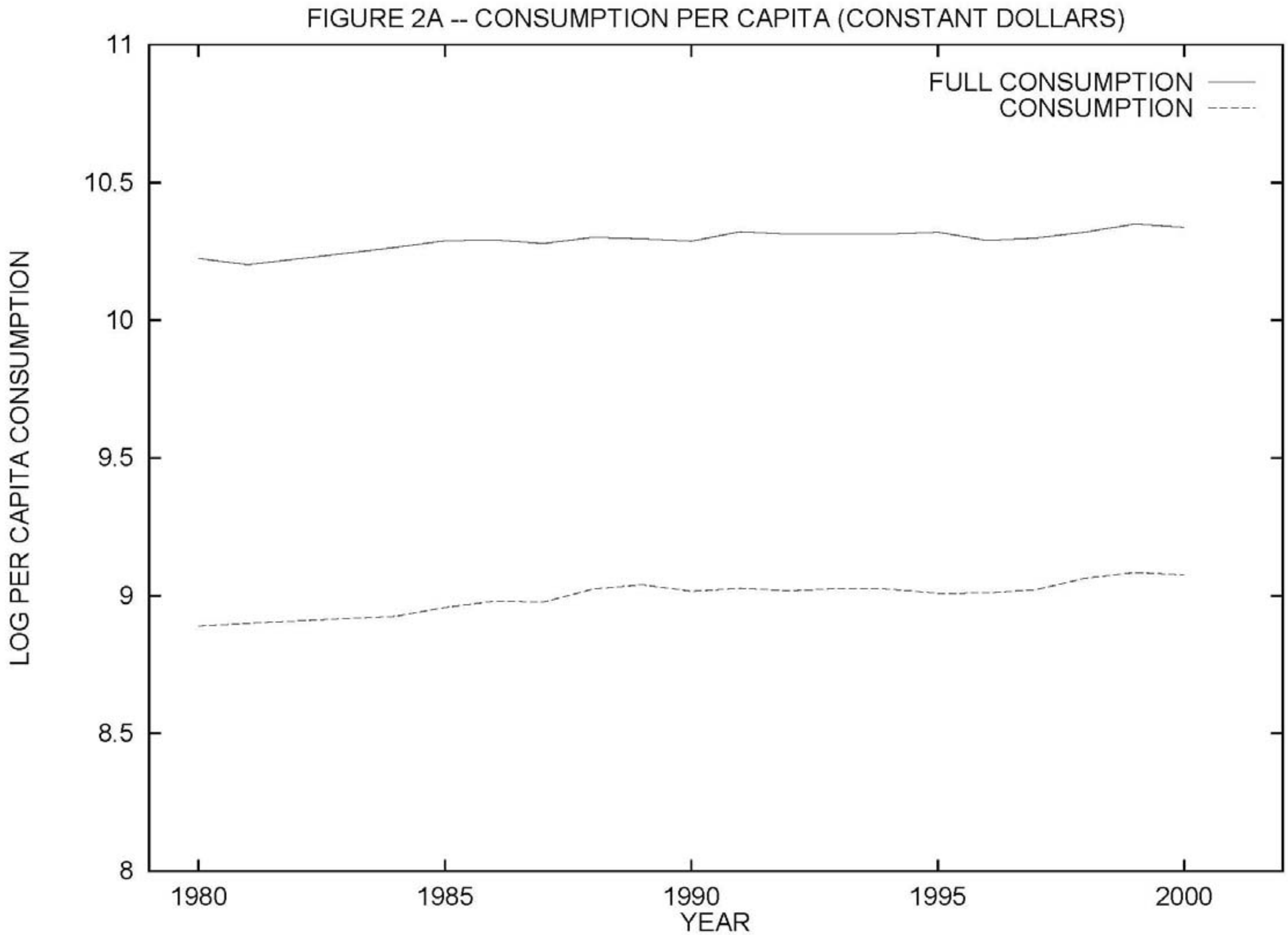


Figure 2.2B Quality-adjusted leisure per adult

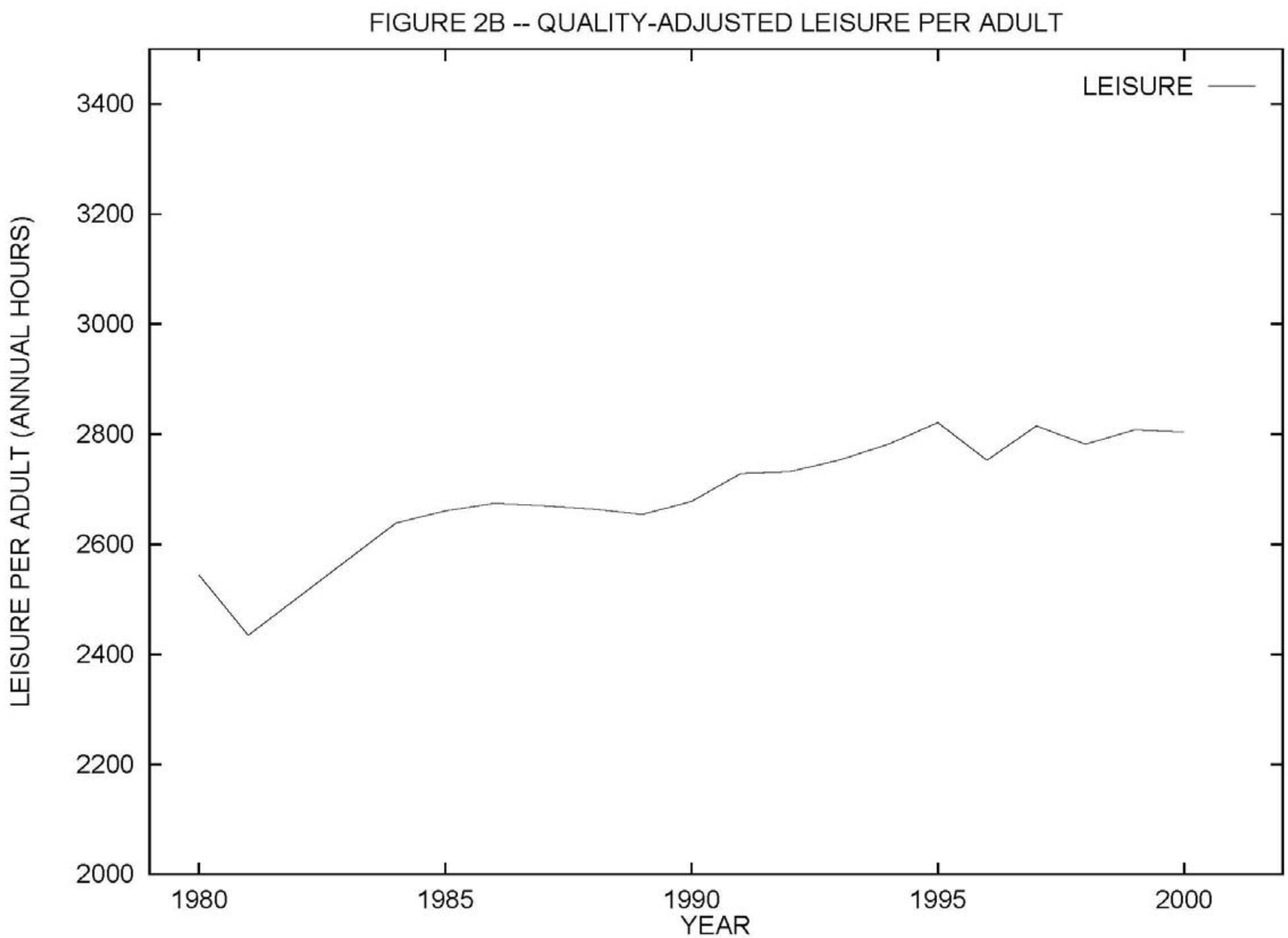


Figure 2.2C Inequality in per capita consumption

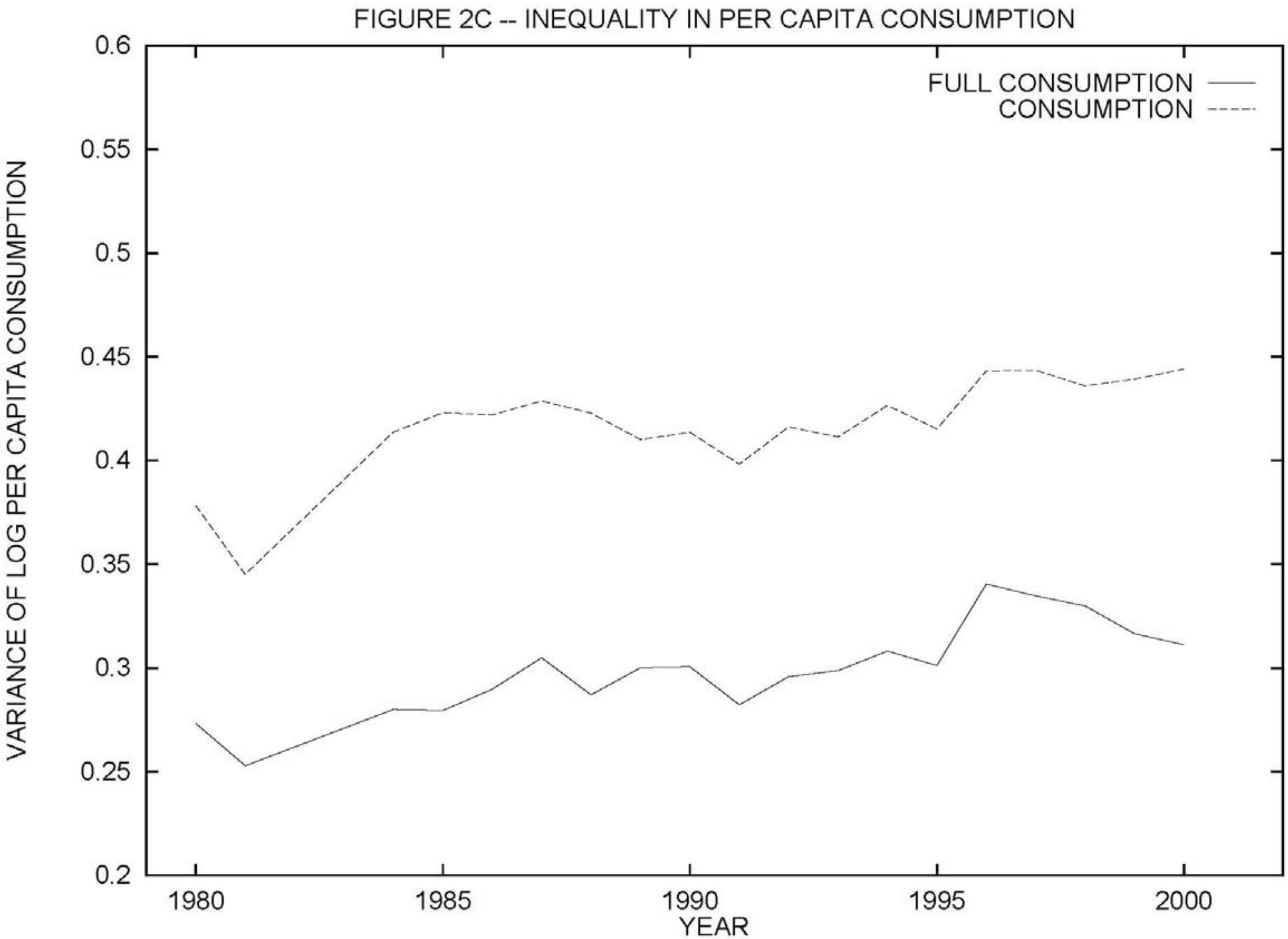


Figure 2.3B Age profile of per capita consumption

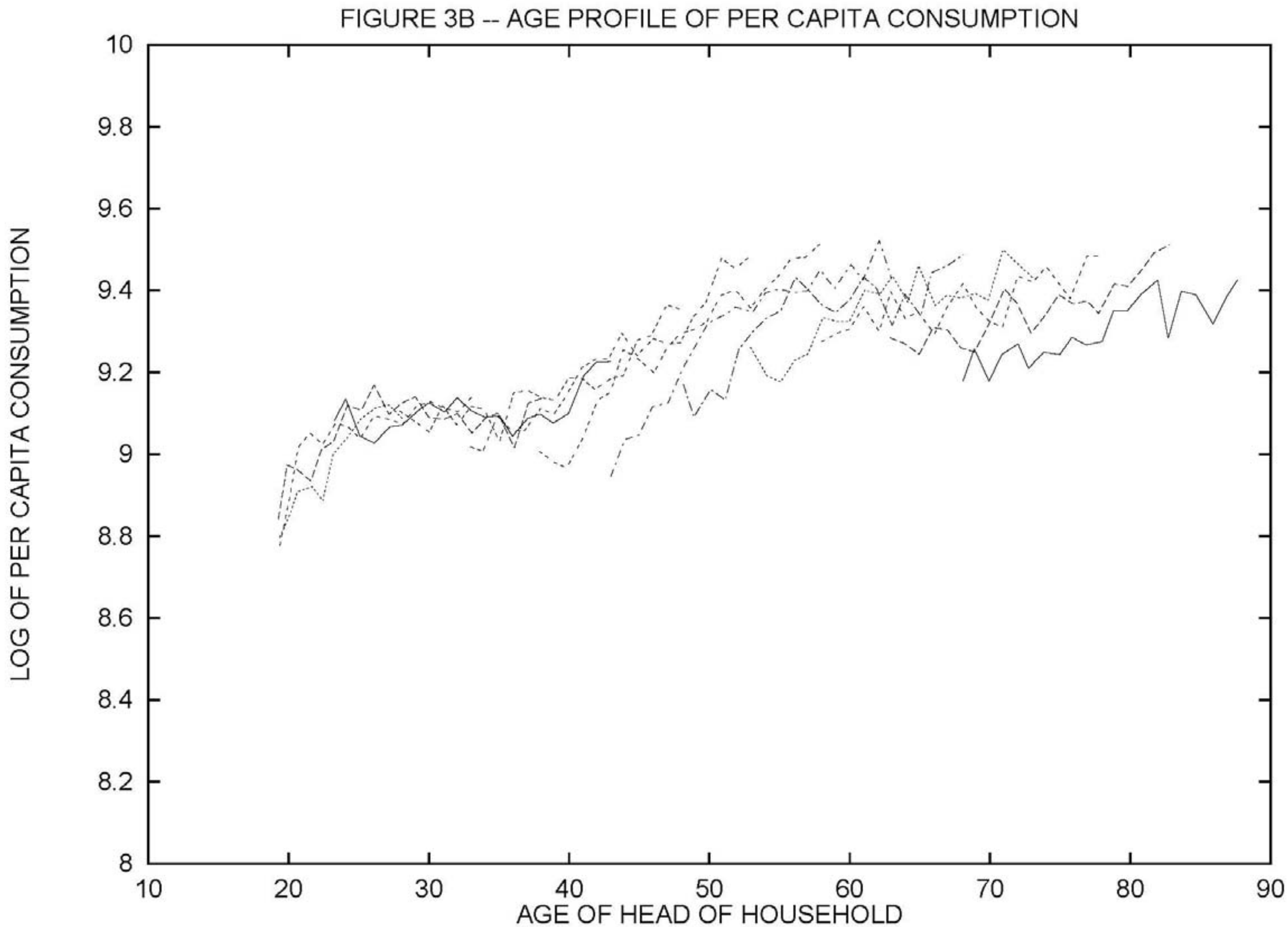


Figure 2.3C Age profile of per capita leisure

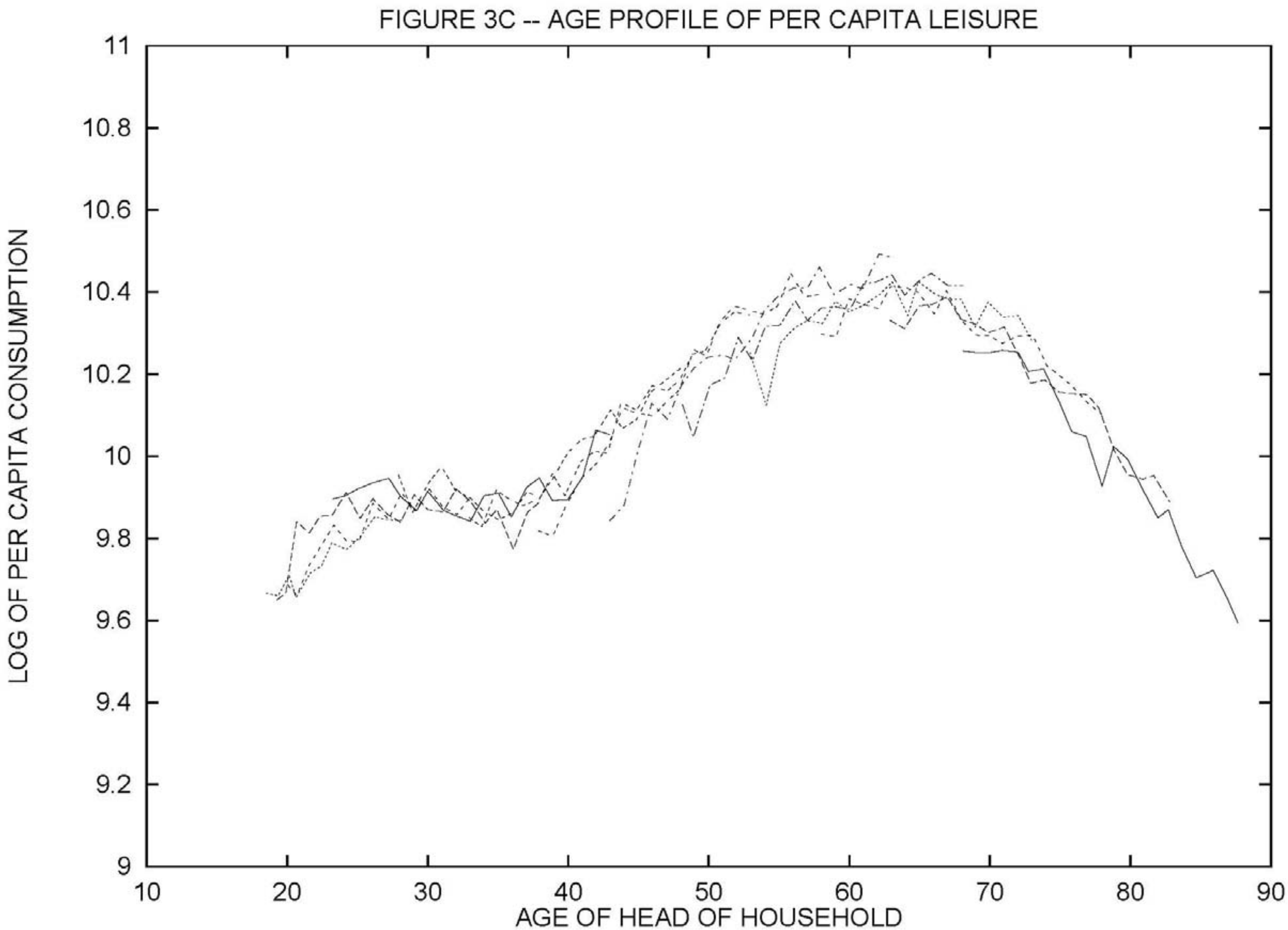


Figure 2.4 Age profile of ln VK

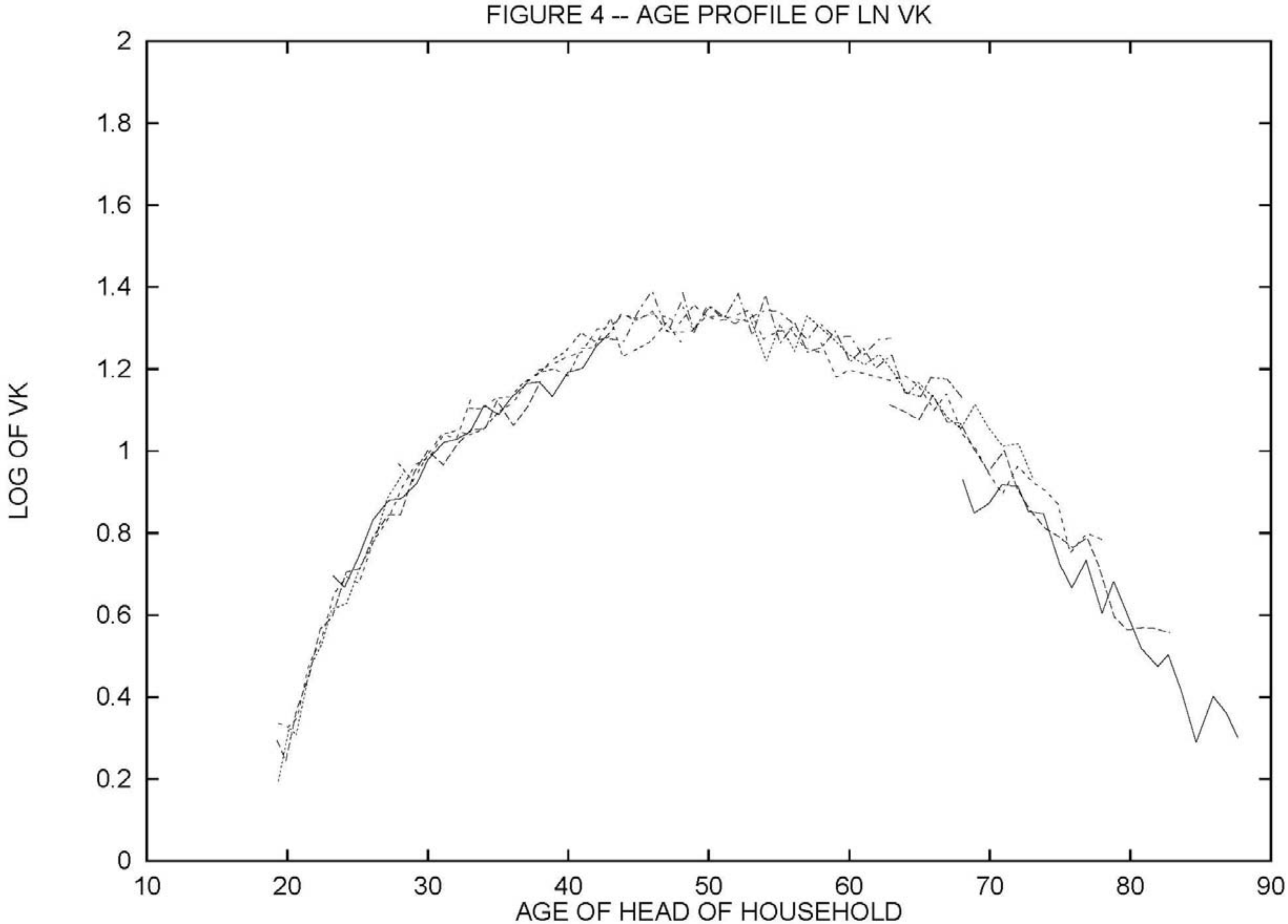


Table 2.8 Aggregate Consumption in the U.S.; top tier

	1960	1970	1980	1990	2000	2005
Value (billion $)						
Nondurables	161.4	287.7	754.1	1351.9	2091.9	2714.8
Capital Services	81.9	154.7	416.1	892.6	1613.6	1972.4
Consumer Services	99.2	222.8	649.9	1711.8	3280.1	4303.1
Leisure	641.3	1386.6	3316.2	7053.4	10452.2	14432.3
Full Consumption	983.8	2051.9	5136.3	11009.7	17437.7	23422.6
% share of Full Consumption						
Nondurables	16.4%	14.0%	14.7%	12.3%	12.0%	11.6%
Capital Services	8.3%	7.5%	8.1%	8.1%	9.3%	8.4%
Consumer Services	10.1%	10.9%	12.7%	15.5%	18.8%	18.4%
Leisure	65.2%	67.6%	64.6%	64.1%	59.9%	61.6%

Table 2.9 Tier structure of consumption function, 2005 (bil $) (NIPA-PCE categories)

Full consumption	23423	Nondurables	2715	Energy	503	gasoline & oil	284		
						Fuel-coal	21	coal	0.3
								fuel-oil	21
						electricity	133		
						gas	65		
				Food	1270	food	720		
						meals	449		
						meals-emp	12		
						tobacco	88		
				Cons. Goods	942	Clothing-shoe	342	shoes	55
								clothing	287
						Hhld articles	181	toilet art.; cleaning	138
								furnishings	43
						drugs	265		
						Misc goods	154	toys	66
								stationery	20
								imports	7
								reading materials	61
		Capital svc	1972						
		Cons. svc	4303	Housing	536	rental housing	334		
						owner maintenace	202		
				HH operation	281	water	64		
						communications	133		
						domestic service	20		
						other household	64		
				Transportation	324	own transportation	263		
						transportation svc	62		
				Medical	1491	medical services	1350		
						health insurance	141		
				Misc svcs	1670	personal svcs	116		
						Business Svcs	646	financial svcs	499
								other bus. svcs	147
						Recreation	458	recreation	358
								foreign travel	100
						educ & welfare	451		
		Leisure	14432						

Table 2.10. Estimated parameters of consumption functions; lower tiers

node	input	alpha	(s.e.)	beta1	(s.e.)	beta2	(s.e.)	beta3	(s.e.)	beta4	(s.e.)	beta5	(s.e.)
2 Nondur-	Energy	0.196	(0.025)	0.083	(0.01)	-0.064	(0.01)	-0.019	(0.01)				
ables	Food	1.095	(0.003)	-0.064	(0.01)	-0.019	(0.01)	0.082	(0.01)				
	Consumer goods	-0.291	(0.025)	-0.019	(0.01)	0.082	(0.01)	-0.063	(0.02)				
3 Energy	gasoline	0.080	(0.007)	0.160	(0.04)	0.015	(0.04)	-0.119	(0.02)	-0.056	(0.05)		
	Fuel-coal	-0.329	(0.008)	0.015	(0.04)	-0.001	(0.06)	-0.002	(0.00)	-0.011	(0.07)		
	electricity	-0.210	(0.086)	-0.119	(0.02)	-0.002	(0.00)	0.138	(0.05)	-0.017	(0.05)		
	gas	1.459	(0.087)	-0.056	(0.05)	-0.011	(0.07)	-0.017	(0.05)	0.085	(0.10)		
4 Food	food	0.199	(0.072)	0.011	(0.05)	0.021	(0.07)	0.000	*	-0.031	(0.09)		
	meals	0.043	(0.093)	0.021	(0.07)	-0.025	(0.09)	0.000	*	0.004	(0.12)		
	meals-employee	0.010	*	0.000	*	0.000	*	0.000	*	0.000	*		
	tobacco	0.748	(0.118)	-0.031	(0.09)	0.004	(0.12)	0.000	*	0.027	(0.15)		
5 Consumer	Clothing-shoes	0.337	(0.055)	0.093	(0.03)	-0.035	(0.07)	-0.023	(0.05)	-0.035	(0.09)		
goods	Household articles	0.224	(0.007)	-0.035	(0.07)	0.077	(0.04)	-0.003	(0.08)	-0.038	(0.11)		
	Drugs	0.099	(0.018)	-0.023	(0.05)	-0.003	(0.08)	0.018	(0.03)	0.008	(0.10)		
	Misc. goods	0.341	(0.059)	-0.035	(0.09)	-0.038	(0.11)	0.008	(0.10)	0.065	(0.17)		
6 Consumer	Housing	-0.014	(0.048)	-0.079	(0.47)	0.054	(0.63)	-0.045	(0.26)	-0.092	(0.19)	0.163	(0.86)
Services	HH operation	0.060	(0.089)	0.054	(0.63)	-0.107	(1.17)	-0.016	(0.53)	-0.103	(0.77)	0.172	(1.63)
	Transportation	0.078	(0.122)	-0.045	(0.26)	-0.016	(0.53)	-0.062	(0.97)	-0.101	(0.15)	0.224	(1.14)
	Medical	-0.052	(1.240)	-0.092	(0.19)	-0.103	(0.77)	-0.101	(0.15)	-0.056	(6.22)	0.353	(6.27)
	Misc. services	0.927	(1.250)	0.163	(0.86)	0.172	(1.63)	0.224	(1.14)	0.353	(6.27)	-0.911	(6.64)
7 Fuel-coal	fuel oil	0.014	*	0.000	*	0.000	*						
	coal	0.986	*	0.000	*	0.000	*						
8 Clothing-	shoes	0.009	(0.034)	-0.0003	(0.01)	0.0003	(0.01)						
shoes	clothing	0.991	(0.034)	0.0003	(0.01)	-0.0003	(0.01)						
9 Household	cleaning supplies	0.737	(0.021)	0.001	(0.00)	-0.001	(0.00)						
articles	furnishings	0.263	(0.021)	-0.001	(0.00)	0.001	(0.00)						

10	Miscellan. goods	toys	0.049	(0.012)	-0.050	(0.04)	0.002	(0.03)	0.013	(0.00)	0.035	(0.05)
		stationery	0.034	(0.011)	0.002	(0.03)	-0.095	(0.04)	0.006	(0.01)	0.087	(0.04)
		imports	-0.028	(0.006)	0.013	(0.00)	0.006	(0.01)	-0.086	(0.03)	0.067	(0.03)
		reading material	0.945	(0.017)	0.035	(0.05)	0.087	(0.04)	0.067	(0.03)	-0.189	(0.07)
11	Housing Services	Housing rental	1.238	(0.073)	-0.210	(0.07)	0.210	(0.07)				
		Owner maintenance	-0.238	(0.073)	0.210	(0.07)	-0.210	(0.07)				
12	Household operation	water	0.179	(0.165)	0.041	(0.09)	0.005	(0.04)	0.021	(0.08)	-0.067	(0.13)
		Communications	0.226	(0.031)	0.005	(0.04)	-0.074	(0.03)	0.079	(0.08)	-0.010	(0.09)
		domestic services	-0.015	(0.189)	0.021	(0.08)	0.079	(0.08)	-0.086	(0.14)	-0.013	(0.18)
		other hh services	0.610	(0.253)	-0.067	(0.13)	-0.010	(0.09)	-0.013	(0.18)	0.091	(0.24)
13	Transport-ation	own transportation	1.045	(0.203)	0.118	(0.02)	-0.118	(0.02)				
		transportation	-0.045	(0.203)	-0.118	(0.02)	0.118	(0.02)				
14	Medical	medical svcs	0.931	*	0.000	*	0.000	*				
		health insurance	0.069	*	0.000	*	0.000	*				
15	Misc. Services	personal svcs	0.022	(0.542)	-0.001	(0.01)	0.005	(0.03)	0.018	(0.05)	-0.021	(0.06)
		business svcs	-0.006	(0.272)	0.005	(0.03)	0.079	(0.14)	-0.053	(0.01)	-0.031	(0.14)
		Recreation	0.078	(0.037)	0.018	(0.05)	-0.053	(0.01)	-0.126	(0.14)	0.161	(0.15)
		education	0.905	(0.608)	-0.021	(0.06)	-0.031	(0.14)	0.161	(0.15)	-0.109	(0.21)
16	Business Services	financial svcs	0.552	(4.649)	-0.224	(0.03)	0.224	(0.03)				
		other bus. svcs	0.448	(4.649)	0.224	(0.03)	-0.224	(0.03)				
17	Recreation	Recreation	1.357	(0.029)	-0.231	(0.31)	0.231	(0.31)				
		Foreign Travel	-0.357	(0.029)	0.231	(0.31)	-0.231	(0.31)				

Note: * denotes parameters that are not estimated.

Table 2.11 Fixed investment by input-output commodities ($bil)

	Commodity	2000	2005
1	Agriculture	0.0	0.0
2	Metal Mining	0.6	1.4
3	Coal Mining	0.0	0.0
4	Petroleum and Gas	34.0	83.8
5	Nonmetallic Mining	0.0	0.0
6	Construction	634.2	823.8
7	Food Products	0.0	0.0
8	Tobacco Products	0.0	0.0
9	Textile Mill Products	13.2	17.7
10	Apparel and Textiles	2.3	2.9
11	Lumber and Wood	11.7	13.1
12	Furniture and Fixtures	62.4	81.5
13	Paper Products	0.0	0.0
14	Printing and Publishing	18.8	24.2
15	Chemical Products	3.0	2.6
16	Petroleum Refining	0.0	0.0
17	Rubber and Plastic	15.6	21.9
18	Leather Products	0.9	1.6
19	Stone, Clay, and Glass	4.9	5.5
20	Primary Metals	0.5	0.7
21	Fabricated Metals	17.9	22.4
22	Industrial Machinery and Equipment	255.1	278.6
23	Electronic and Electric Equipment	147.6	160.7
24	Motor Vehicles	331.2	376.8
25	Other Transportation Equipment	55.8	59.9
26	Instruments	88.6	103.9
27	Miscellaneous Manufacturing	44.2	59.9
28	Transport and Warehouse	24.4	28.1
29	Communications	11.6	9.5
30	Electric Utilities	0.0	0.0
31	Gas Utilities	0.0	0.0
32	Trade	446.2	532.2
33	FIRE	64.7	111.1
34	Services	248.1	260.3
35	Goverment Enterprises	0.0	0.0
	Total	2537.8	3083.8

Table 2.12. Estimated parameters of investment function tiers

node		input	alpha	(s.e.)	beta1	(s.e.)	beta2	(s.e.)	beta3	(s.e.)	beta4	(s.e.)
1	Fixed	Long-lived	0.054	(0.013)	0.128	(0.089)	-0.128	(0.089)				
	investment	Short-lived	0.946	(0.013)	-0.128	(0.089)	0.128	(0.089)				
2	Long-lived	construction	0.131		0.028		-0.028					
		fin, insur, real estat	0.869		-0.028		0.028					
3	Short-lived	Transport. Equip	0.042		-0.308		0.046		0.262			
		Machinery	0.173		0.046		0.103		-0.149			
		Services	0.785		0.262		-0.149		-0.113			
4	Transportatior	motor vehicles	0.498		-0.210		0.210					
	equipment	other transp equip.	0.502		0.210		-0.210					
5	Machinery	industrial mach.	0.416		0.008		-0.054		0.045			
		electrical mach.	0.284		-0.054		0.070		-0.016			
		Other machinery	0.301		0.045		-0.016		-0.029			
6	Services	trade	0.487		0.056		-0.056					
		Other services	0.513		-0.056		0.056					
7	Other	Gadgets	0.269		0.112		-0.074		0.023		-0.060	
	Machinery	Wood	0.383		-0.074		0.069		0.053		-0.047	
		Nonmetal inv.	0.179		0.023		0.053		-0.064		-0.012	
		Other other mach	0.169		-0.060		-0.047		-0.012		0.120	
8	Other	services	-0.011		0.022		-0.022					
	Services	Moving services	1.011		-0.022		0.022					
9	Gadgets	primary metals	-0.031		-0.001		-0.002		0.003			
		fabricated metals	0.029		-0.002		0.137		-0.135			
		instruments	1.002		0.003		-0.135		0.132			
10	Wood	lumber & wood	-0.047		-0.004		0.004					
		furniture & fixtures	1.048		0.004		-0.004					
11	Nonmetal	chemicals	0.028		0.000		-0.001		-0.016		0.018	
	investment	rubber & plastics	0.174		-0.001		-0.162		0.082		0.081	

		nonmetal minerals	0.047	-0.016	0.082	-0.012	-0.054
		other manufacturing	0.751	0.018	0.081	-0.054	-0.045
12	Other other mach	printing & publishi	-0.128	0.084	-0.011	-0.073	
		Textile-apparel	-0.067	-0.011	0.086	-0.075	
		Mining	1.195	-0.073	-0.075	0.149	
13	Moving servic	transportation	0.204	-0.083	0.083		
		communications	0.796	0.083	-0.083		
14	Textile-appare	textile	0.553	-0.777	0.894	-0.117	0.000
		apparel	0.141	0.894	-1.013	0.119	0.000
		leather	0.014	-0.117	0.119	-0.002	0.000
		noncompeting impo	0.292	0.000	0.000	0.000	0.000
15	Mining	metal mining	0.034	0.018	-0.018		
		petroleum mining	0.966	-0.018	0.018		

Note: Coefficients without standard errors are those that are not estimated (alpha set to sample average, beta=0)

Table 2.13. Estimated parameters of export function

	Commodity	alpha	beta	f(i,1996)
1	Agriculture	0.000	-0.061	0.153
2	Metal Mining	0.008	0.000	0.083
3	Coal Mining	0.000	-0.075	0.184
4	Petroleum and Gas	0.000	-0.006	0.034
5	Nonmetallic Mining	0.000	-0.050	0.100
6	Construction	0.167	0.000	-0.165
7	Food Products	0.000	-0.057	0.123
8	Tobacco Products	0.000	0.025	0.155
9	Textile Mill Products	0.000	-0.031	0.092
10	Apparel and Textiles	0.004	-0.053	0.122
11	Lumber and Wood	0.000	-0.116	0.168
12	Furniture and Fixtures	0.001	-0.004	0.049
13	Paper Products	0.037	-0.061	0.103
14	Printing and Publishing	0.000	-0.024	0.066
15	Chemical Products	0.004	-0.120	0.252
16	Petroleum Refining	0.000	0.006	0.052
17	Rubber and Plastic	0.000	-0.005	0.070
18	Leather Products	0.014	-0.081	0.150
19	Stone, Clay, and Glass	0.001	-0.035	0.083
20	Primary Metals	0.087	-0.010	-0.011
21	Fabricated Metals	0.000	-0.037	0.097
22	Industrial Machinery and Equipment	0.000	0.044	0.150
23	Electronic and Electric Equipment	0.000	-0.069	0.237
24	Motor Vehicles	0.000	-0.115	0.223
25	Other Transportation Equipment	0.250	-0.274	0.289
26	Instruments	0.122	-0.168	0.159
27	Miscellaneous Manufacturing	0.000	0.026	0.052
28	Transport and Warehouse	0.021	-0.120	0.236
29	Communications	0.012	0.000	0.015
30	Electric Utilities	0.000	-0.009	0.021
31	Gas Utilities	0.023	0.000	-0.007
32	Trade	0.001	0.000	0.047
33	FIRE	0.022	-0.026	0.054
34	Services	0.014	-0.016	0.021
35	Goverment Enterprises	0.002	0.000	0.000

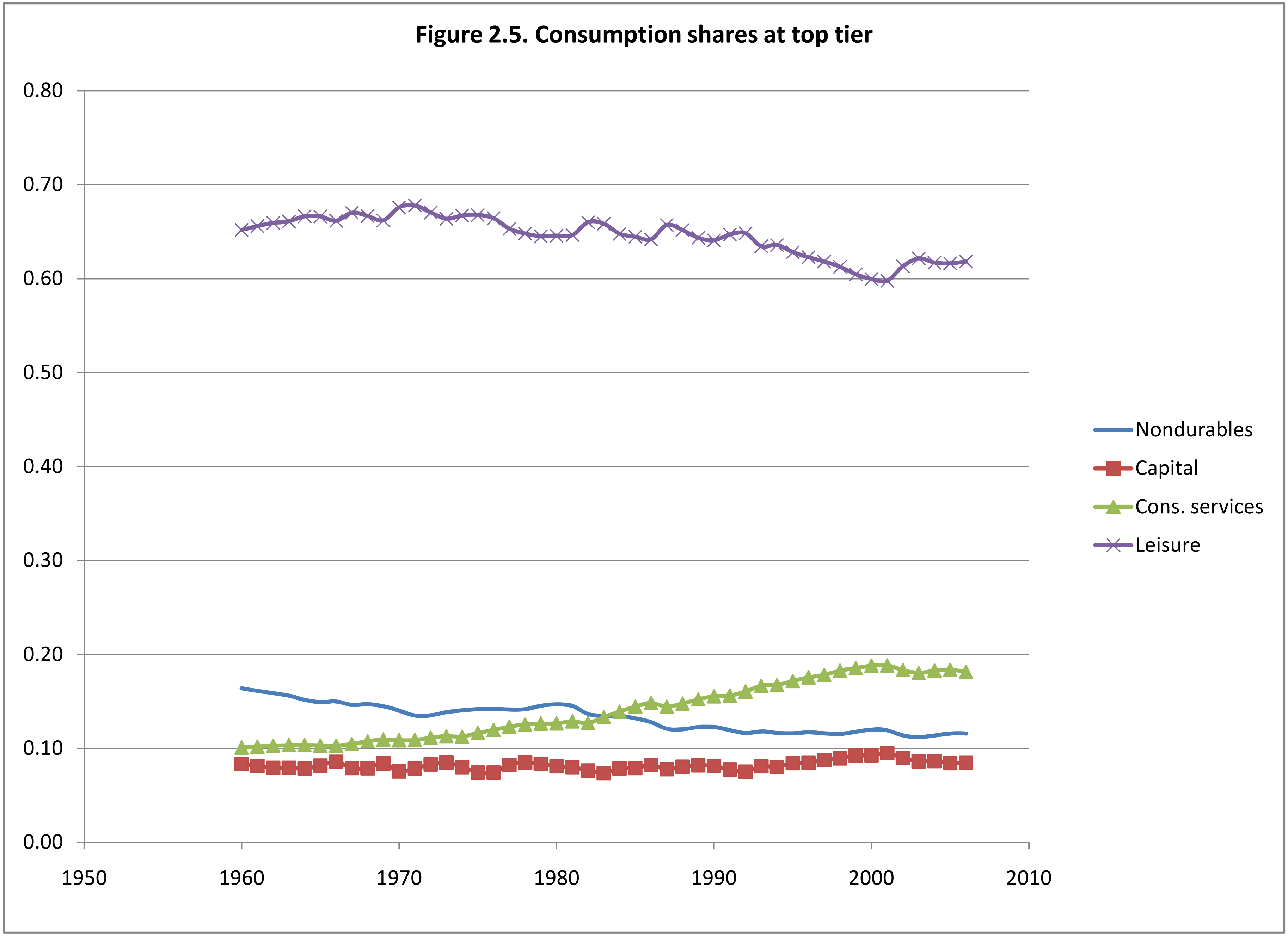


Figure 2.5. Consumption shares at top tier
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1950
1960
1970
1980
1990
2000
2010
Nondurables
Capital
Cons. services
Leisure

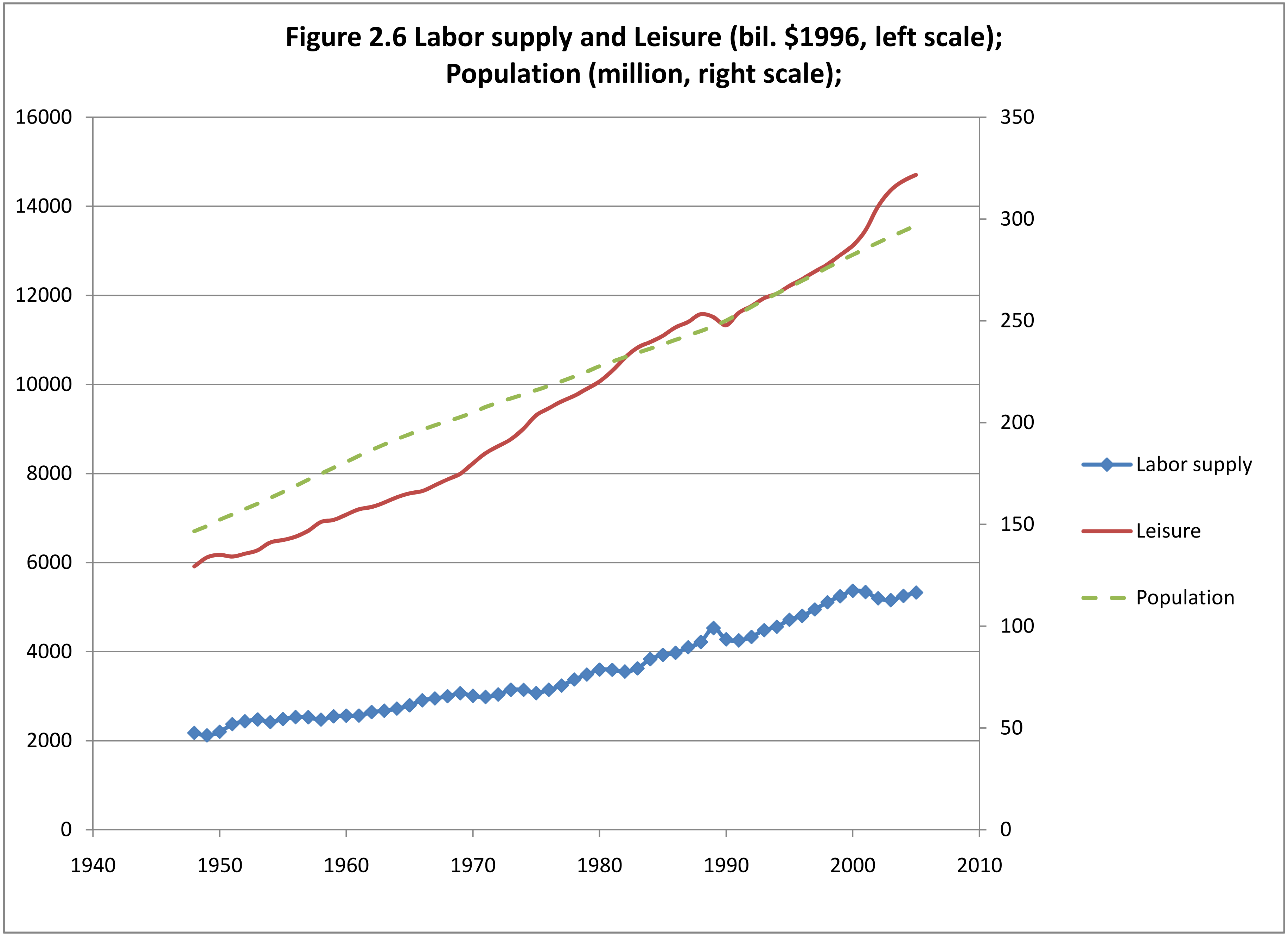


Figure 2.6 Labor supply and Leisure (bil. $1996, left scale);
Population (million, right scale);
16000
14000
12000
10000
8000
6000
4000
2000
0
350
300
250
200
150
100
50
0
1940
1950
1960
1970
1980
1990
2000
2010
Labor supply
Leisure
Population

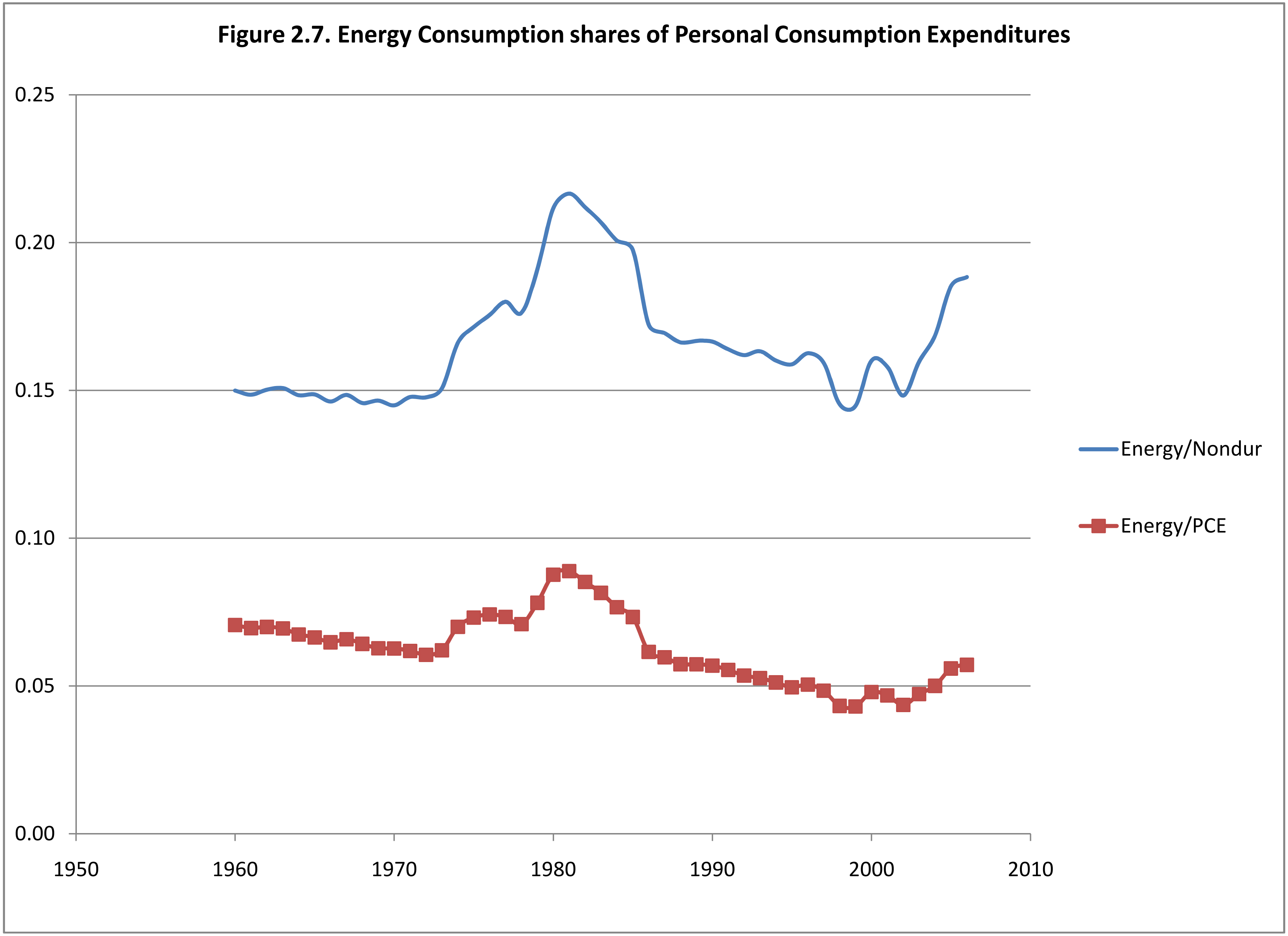


Figure 2.7. Energy Consumption shares of Personal Consumption Expenditures
0.25
0.20
0.15
0.10
0.05
0.00
1950
1960
1970
1980
1990
2000
2010
Energy/Nondur
Energy/PCE

Fig. 2.8 Projection of latent term (ft) in node 3:
Energy=f(gasoline,Fuel,electricity,gas)

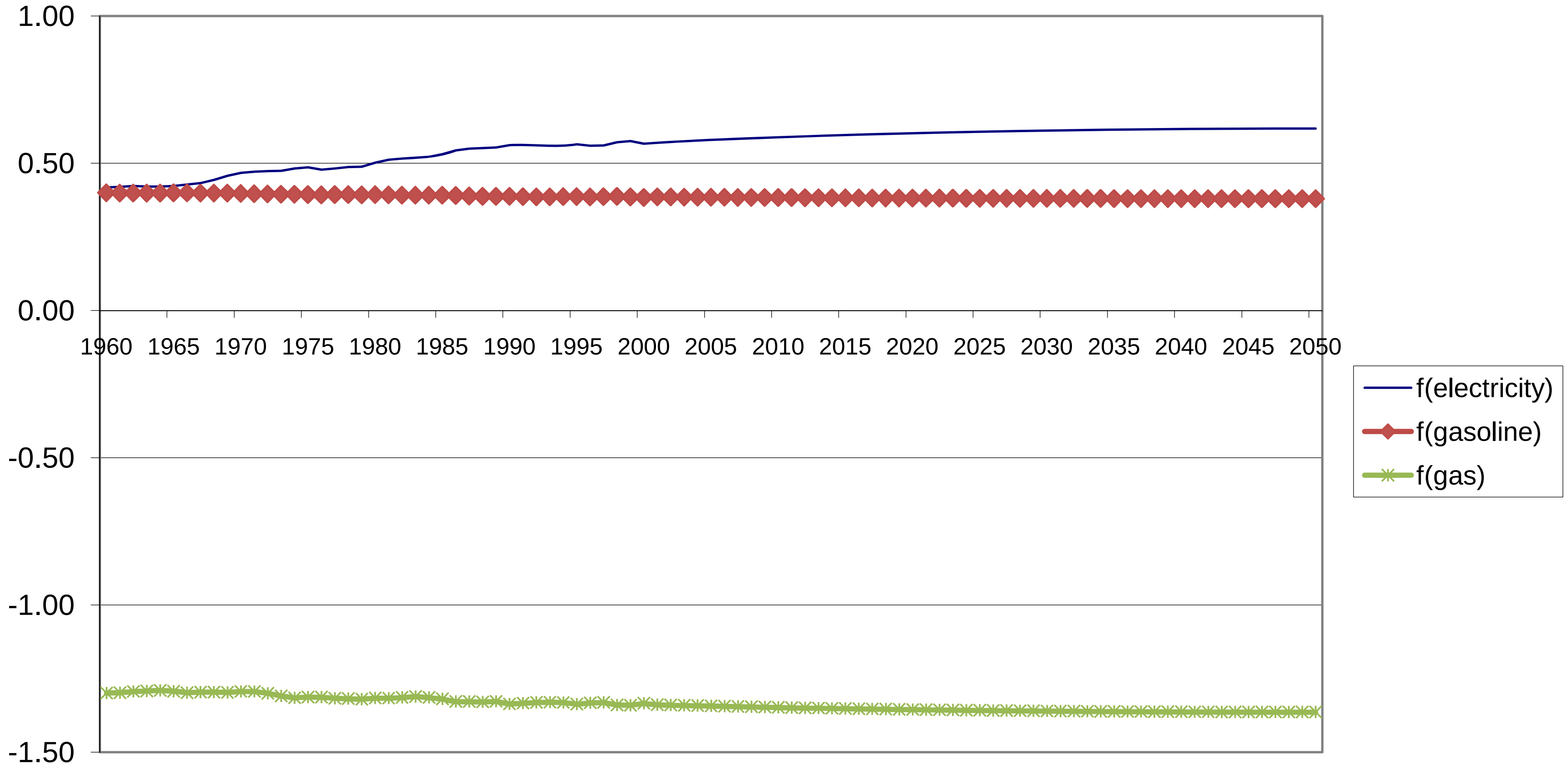
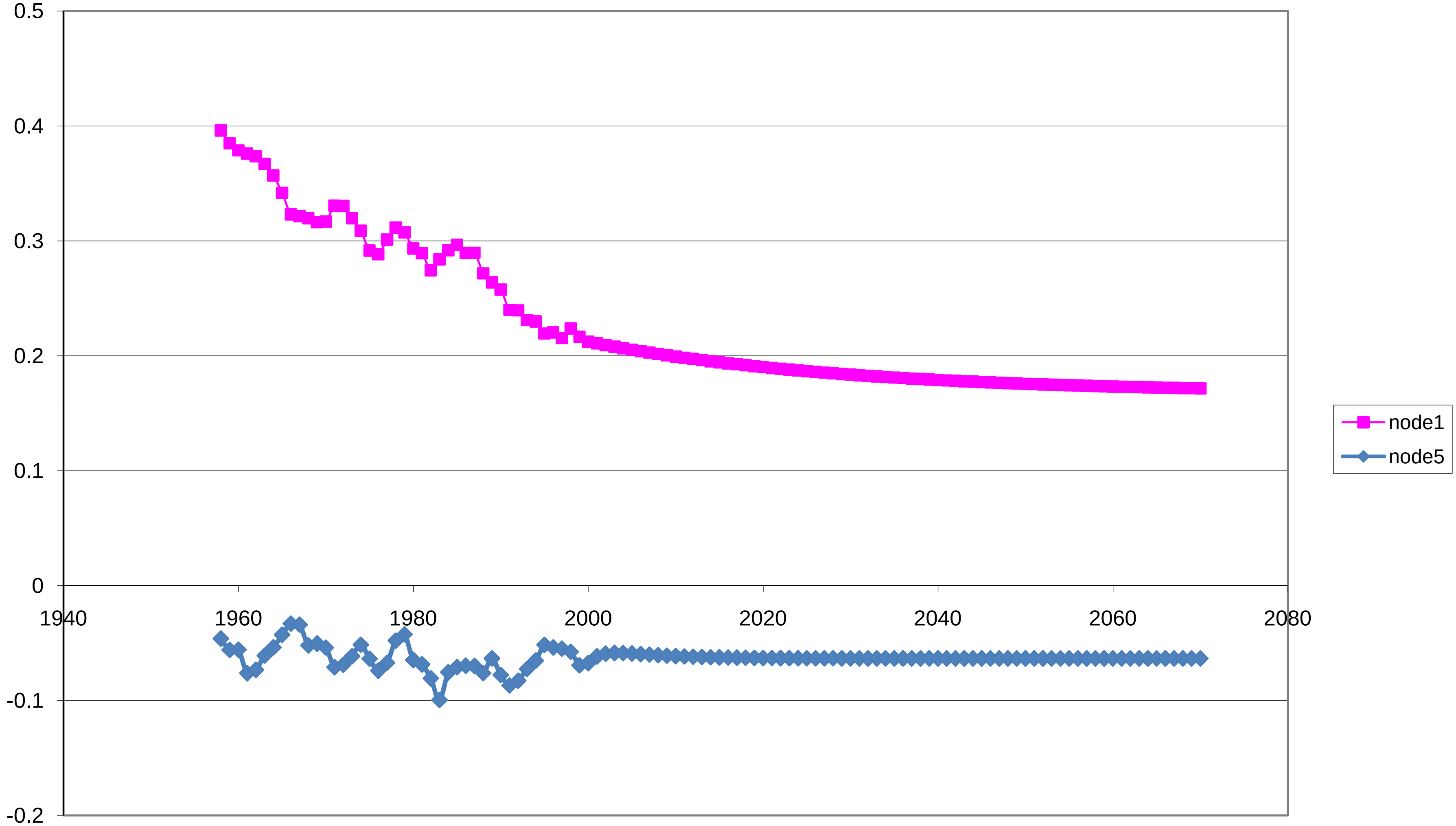


Fig 2.9. Projection of latent term in investment. Node 1: total=f(long, short-lived)
Node 5: machinery=f(industrial mach, elect mach, other mach)



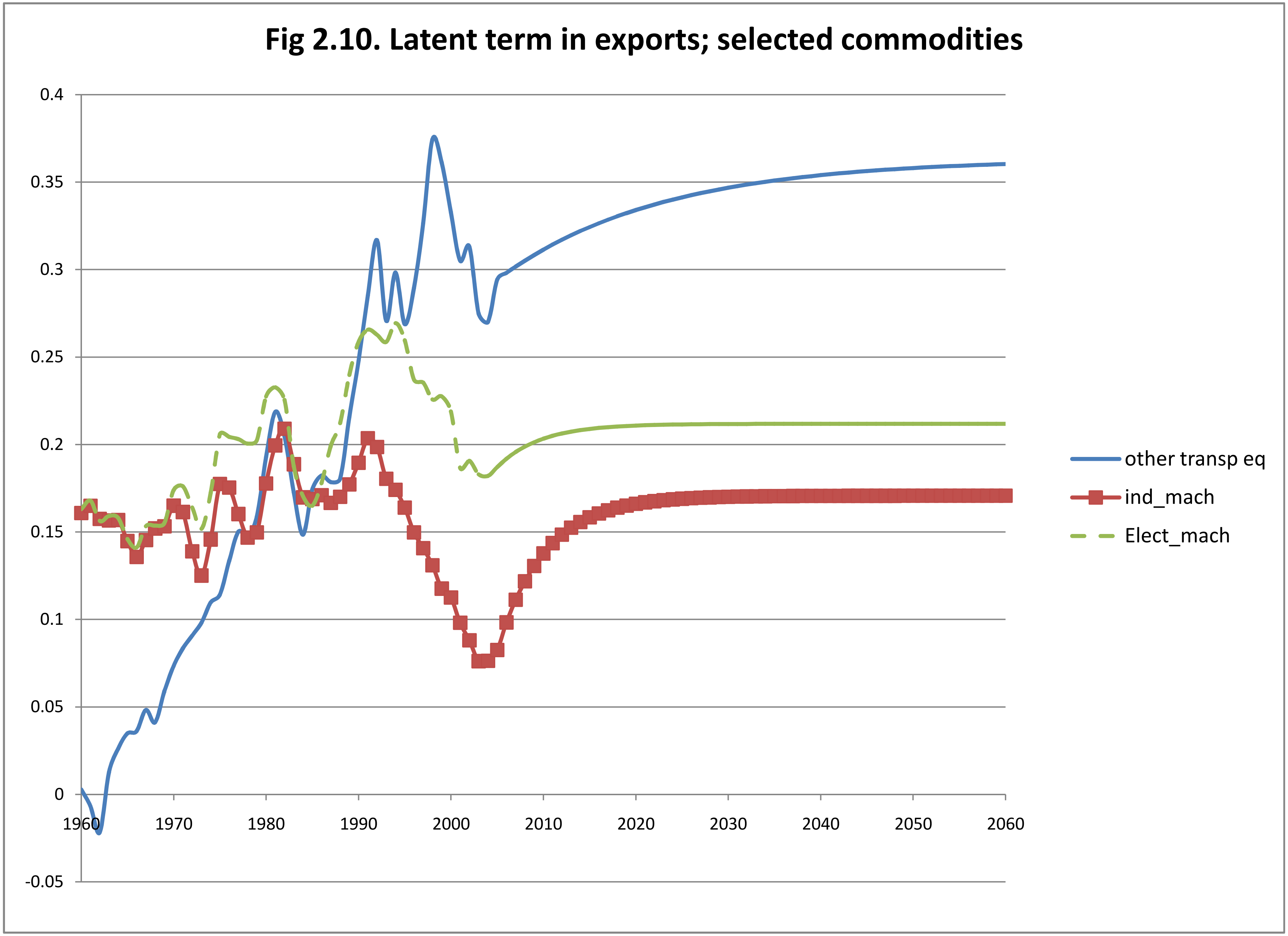


Fig 2.10. Latent term in exports; selected commodities
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
other transp eq
ind_mach
Elect_mach