Econometrica, Vol. 56, No. 2 (March, 1988), 335–360

INTERTEMPORAL PREFERENCES AND LABOR SUPPLY

BY V. JOSEPH HOTZ, FINN E. KYDLAND, AND GUILHERME L. SEDLACEK[1]

Recently, several authors have argued for the use of dynamic preference structures for leisure which incorporate forms of intertemporally nonseparable utility in the analysis of intertemporal labor supply decisions. In this paper, we examine whether such nonseparable utility functions are important in characterizing microdata on life-cycle labor supply. Using longitudinal data on males from the Panel Study of Income Dynamics, we estimate a model of life-cycle labor supply and consumption under uncertainty in which the structure of intertemporal leisure preferences is allowed to be nonseparable in leisure. Our model nests as special cases a number of alternative specifications considered in the literature. We investigate the robustness of our findings to certain forms of population heterogeneity and to some types of model misspecification. Across a number of alternative specifications, we find evidence that the standard assumption of intertemporally separable preferences for leisure is not consistent with data for prime-age males.

KEYWORDS: Labor supply, consumption, life-cycle models, intertemporal substitution.

1. INTRODUCTION

ESTIMATING THE INTERTEMPORAL labor supply response to wage rate changes has received a great deal of attention in the recent literature.[2] These studies emphasize the dynamic context in which labor supply decisions are made and thus the potential for individuals to intertemporally substitute their work effort in response to fluctuations over time in wages and nonlabor income. Almost all of the existing models have assumed an intertemporally separable structure for leisure preferences, and often contemporaneous separability between leisure and consumption.

Recently, several authors have argued for the use of preference structures for leisure which incorporate forms of state dependence in the analysis of intertemporal labor supply decisions. Kydland and Prescott (1982) incorporate an intertemporally nonseparable utility function in their aggregate equilibrium model in which the aggregate labor market is characterized along the lines of Lucas and Rapping (1969). They argue that allowing for intertemporally nonseparable preferences in leisure can generate intertemporal elasticities of substitution of labor supply consistent with observed aggregate employment fluctuations.[3] Johnson and Pencavel (1984) use a form of nonseparable utility in a dynamic

[1]This research was partially supported by the National Science Foundation and by NORC. We benefited from conversations with Joseph Altonji, Ricardo Barros, Gary Becker, Martin Browning, Gary Chamberlain, Angus Deaton, Martin Eichenbaum, Dennis Epple, John Ham, Lars Hansen, James Heckman, John Kennan, Jacob Klerman, Thomas MaCurdy, Alice Nakamura, Robert Topel, and two anonymous referees and by the research assistance of Sumru Altug and Awanti Sethi. Some of this research was carried out while the second author was visiting the Hoover Institution.

[2]For studies using microdata, see papers by Heckman and MaCurdy (1980), MaCurdy (1981, 1983), Altonji (1982, 1986), Ghez and Becker (1975), and Smith (1977).

[3]See also, Eichenbaum, Hansen, and Singleton (1984).

labor supply model to capture the notion that tastes are intertemporally adaptive —i.e., that "standards by which individuals gauge their welfare are molded by their prior experiences" (p. 366). A similar motivation underlies the recent analysis of Browning (1985). Finally, Deaton (1986) suggests that preferences which are intertemporally nonseparable in leisure and contemporaneously non-separable in consumption and leisure provide a potential explanation for the excess sensitivity of the response of aggregate consumption to anticipated changes in income found in the Hall and Mishkin (1982) study of consumption sensitivity to transitory income.

Regardless of the particular motivation and/or interpretation, these papers suggest a form of state dependence in life-cycle labor supply relationships which, if ignored, may bias estimates of intertemporal wage elasticities. Thus, it is natural to ask whether such nonseparable preference structures are important in characterizing data on life-cycle labor supply. In this paper, we estimate a model of life-cycle labor supply and consumption under uncertainty in which the utility function is nonseparable in leisure. One could interpret the nonseparable preference structure we consider as arising from a home production technology in which "consumption capital" or nonmarket experience is produced as a by-product of such production. The specification we use admits the more typical time-separable specification and that of Johnson and Pencavel as special cases. Intertemporally nonseparable utility, in an uncertain environment, implies that optimal leisure decisions will take into account the expected influence of current leisure choice on future utility. Moreover, we show that such specifications yield econometrically tractable decision rules for life-cycle leisure and consumption decisions; the Euler equations generated by such a model can be readily estimated using a recursive application of the generalized method of moments (GMM) estimation strategy recently considered by Hansen (1982) and Hansen and Singleton (1982).

The model in this paper assumes that life-cycle wages are generated by a stochastic process which is exogenously determined. This assumption is consistent with the approach taken in most studies of life-cycle labor supply. Some recent studies have focused on another form of state dependence, namely that current labor supply decisions depend upon one's past labor supply history via a human capital accumulation process which determines life-cycle wages. This latter form of state dependence also implies that optimal leisure choices will take account of the expected future influence of current leisure decisions, in this case due to the effect of labor supply choices on future wage rates. For example, Heckman (1981a) and Nakamura and Nakamura (1985) find evidence of state dependence in female labor-force participation and suggest that it may reflect the influence of a human capital accumulation process. But, as is noted in both of these studies, one cannot reject, with estimates from participation equations, the possibility that such dependence is also due to intertemporally nonseparable preferences. We show that one way to isolate the latter form of dependence is to examine the model's Euler equations for consumption decisions which, in general, are not affected by the nature of the process generating wages. Using the consumption conditions, we provide an indirect test for the appropriateness of the exogenous wage-process assumption.[4]

We also investigate the robustness of empirical results to the presence of certain forms of population heterogeneity. Admitting that individuals differ in their preferences, for example, can lead to inconsistency in estimated structural parameters as such heterogeneity in parameters will generally not yield estimates of the average person's parameters. To examine the importance of this source of misspecification, we allow our parameterization of preferences to depend on a set of individual-specific observed characteristics.

The remainder of the paper is organized as follows. In the next section, we present a life-cycle model of leisure and consumption decisions and characterize the model under an assumption of exogeneous wage rates. In Section 3, we discuss the method for estimating the structural parameters of the model and for testing alternative underlying preference structures and model specifications. Section 4 presents estimates using data on married men from the Panel Study of Income Dynamics. In Section 5, we offer some concluding remarks.

2. THE MODEL SPECIFICATION

In this section, we present a life-cycle model for an individual's intertemporal demand for consumption and leisure (or supply of labor) under the assumption that the utility function is intertemporally nonseparable with respect to leisure. We assume that the individual is uncertain about future realizations of some set of exogenous random variables which influence his leisure and consumption decisions.

Suppose that the typical individual, at each stage of his life cycle, chooses current leisure and consumption to maximize

$$E_t \sum_{\tau=t}^{T} \beta^{\tau-t} U(Z_\tau, C_\tau), \tag{2.1}$$

where U is a twice-differentiable concave function increasing in both of its arguments, Z_τ is a distributed lag of current and past leisure choices to be defined below, C_τ is real consumption, β is a discount factor equal to $1/(1+\rho)$, where ρ is the rate of time preference, and E_t defines the expectations operator conditioned on all the information available to the individual as of time t. We denote the individual's information set as of time t by Ω_t.

Generally, the function Z_t is defined as

$$Z_t = l_t + \sum_{s=1}^{t-t_0} \kappa_s l_{t-s}, \tag{2.2}$$

[4] Focusing on the equations for consumption decisions is not without its disadvantages. In particular such equations do not enable us to identify all of the utility-function parameters needed to calculate labor supply responses to wage changes. Thus our paper is limited to investigating the appropriateness of frequently maintained assumptions concerning preference structures in previous labor supply studies.

where l_t is leisure consumption in period t, t_0 is the year in which the person entered the labor market, and the κ_s's are constant parameters. In the sequel, we shall focus on a more parsimonious specification of Z_t. Following Kydland and Prescott (1982), we assume that Z_t is given by

$$(2.3) \qquad Z_t = l_t + \alpha a_t,$$

and the law of motion for a_t is given by

$$(2.4) \qquad a_t = (1-\eta) a_{t-1} + l_{t-1} = \sum_{s=1}^{t-t_0} (1-\eta)^{s-1} l_{t-s},$$

where $0 < \eta \leqslant 1$. In this specification, the parameter α measures the importance of all past relative to current leisure in the current-period utility function and η is the rate at which the utility flow derived from past leisure choices depreciates with the passage of time.

While consistent with alternative interpretations, equations (2.3) and (2.4) can be viewed as arising from a dynamic household production model of time allocation in which consumption capital is accumulated as a by-product.[5] Suppose that, in their nonmarket activities, households produce some "commodity" (for example, homemaking services), Z_t, via a linear technology using two inputs: current nonmarket time, l_t, and a durable good, a_t, which represents the stock of homemaking skills or experience (household management skills, etc.) acquired over the life cycle. The latter input is produced as a by-product of the time devoted to nonmarket activities in the past but depreciates at the rate η. Then α represents a measure of the relative technical substitution between l_t and a_t in the production of the nonmarket commodity, Z_t. If current nonmarket time and past effort in nonmarket activities are substitutes in the production of homemaking service flows, then $\alpha > 0$; if they are complements, $\alpha < 0$.[6] Given the form of (2.1), a_t and l_t are substitutes in utility if these factors are substitutes in the production of Z_t and complements in utility if $\alpha < 0$. Finally, we note that it is entirely possible that individuals with different characteristics, such as education or number of children, may differ in the efficiency with which they produce Z_t so that α may vary with individual-specific and time-varying household characteristics.[7] In the empirical analysis below, we consider this latter possibility as well as

[5] See Kydland (1984) for a more detailed discussion of the home production interpretation to this model specification.

[6] This formulation is quite similar to that found in the optimal habit formation literature. See, for example, Stigler and Becker (1977), Spinnewyn (1981), Iannaccone (1984), and Becker and Murphy (1985).

[7] For example, one may envision that Z_t is the flow of services from "home life" which is produced by current parental time, l_t, and the quality-adjusted stock of children, $N_t a_t$, where N_t represents the number of children in the household in period t and a_t denotes the stock of accumulated "quality" which is itself generated as a result of previous parental time inputs according to (2.4). Rewriting (2.3) as $Z_t = l_t + \mu N_t a_t$, we have, consistent with the formulation of the model in the text, $\alpha_t = \mu N_t$, where μ measures the relative technical substitution of current parental time and the flow of services from existing children in the production of Z_t.

explicitly test whether the specification of Z_t based on (2.3) and (2.4) is appropriate relative to the more general form in (2.2).

This specification of utility (or home production) allows us to characterize previous preference structures found in the literature as special cases. When $\alpha = 0$, for example, preferences are additively separable in leisure over time. The models of Heckman and MaCurdy (1980), MaCurdy (1981, 1983), and Altonji (1986) have focused on life-cycle models of individual labor supply which assume this latter type of intertemporal separability. If η equals 1, the influence of past leisure on current utility collapses to just the influence of l_{t-1} and we obtain the specification considered by Johnson and Pencavel (1984).

We assume that the individual makes his decision about current-period l_t and C_t subject to a per-period time constraint as well as a budget constraint. In each period t, total time available for nonmarket activity, l_t, and market work, h_t, is assumed to be limited to L, that is, for all t, $L = l_t + h_t$. The per-period budget constraint is $A_{t+1} = (1 + r_t)(A_t + w_t h_t - C_t)$, where A_t is net real assets at the beginning of period t, r_t is the real interest rate,[8] and w_t is the real wage rate, with the consumption good being the numeraire. Given a finite lifetime, we also assume no bequests, so that $A_{T+1} = 0$. For now, we assume that real wages facing the individual are exogeneous, i.e., they do not depend on past labor supply choices. As of the beginning of period t, the realizations of the real wage w_t and the real interest rate r_{t-1} are known to the individual but future realizations are unknown and random.

Based on the above structure, we can characterize the individual's maximization problem as a dynamic programming problem. Defining $\gamma_t = 1 + r_t$, the value function at time t is

$$V^t(A_t, a_t, w_t) = \max_{C_t, h_t} \{ U(Z_t, C_t) + \beta E_t V^{t+1}(\gamma_t(A_t + w_t h_t - C_t), (1-\eta) a_t + l_t, w_{t+1}) \},$$

where V^t is a function of the state variables, A_t and a_t, as well as the current wage rate, w_t. The first-order conditions with respect to C_t and h_t, respectively, are

$$E_t[U_C(t) - \beta \gamma_t V_A^{t+1}] = 0, \quad \text{and} \tag{2.5}$$

$$E_t[-U_Z(t) + \beta \gamma_t w_t V_A^{t+1} - \beta V_a^{t+1}] = 0, \tag{2.6}$$

where $U_y(\tau) \equiv \partial U(Z_\tau, C_\tau)/\partial y$, $y = Z_\tau$, C_τ, and $V_y^\tau \equiv \partial V^\tau(A_\tau, a_\tau, w_\tau)/\partial y$, $y = A_\tau, a_\tau$. The term V_A^{t+1} is simply the marginal utility of wealth as of time $t+1$ and V_a^{t+1} characterizes the impact of changes in h_t on the individual's utility from period $t+1$ on, assuming that he makes optimal leisure and consumption decisions in the future. Conditioned on current information, optimal allocation of

[8] The real interest rate is derived from the equality $1 + r_t = (1 + i_t) p_t / p_{t+1}$, where i_t is the nominal interest rate and p_t is the price level of the numeraire good, C_t, in period t.

financial and time resources over time implies that

$$V_A^t = E_t\gamma_t\beta V_A^{t+1} = E_t\gamma_t\gamma_{t+1}\beta^2 V_A^{t+2} = \dots, \quad \text{and} \tag{2.7}$$

$$V_a^t = \sum_{\tau=t}^{T} [(1-\eta)\beta]^{\tau-t}\alpha E_t U_Z(\tau). \tag{2.8}$$

Exploiting the Euler equations expected to hold in period $t+1$, along with equations (2.7) and (2.8) and the law of motion for a_t, equations (2.5) and (2.6) can be rewritten as

$$E_t\{U_C(t) - \beta\gamma_t U_C(t+1)\} = 0, \quad \text{and} \tag{2.9}$$

$$\begin{aligned} E_t\{&-[U_Z(t) - w_t U_C(t)] \\ &-\beta(\alpha U_Z(t+1) - (1-\eta)[U_Z(t+1) - w_{t+1}U_C(t+1)])\} = 0. \end{aligned} \tag{2.10}$$

Equation (2.9) simply states that C_t should be chosen so that the expected discounted gain of transferring a unit of wealth to period $t+1$ is equal to the marginal utility of consumption in period t. Also note that, unlike previous investigations of optimal consumption, this condition implies that the optimal intertemporal allocation of consumption depends upon both current and past leisure decisions. The fact that lagged labor supply affects the marginal utility of consumption provides an alternative explanation of the empirical finding in Hall and Mishkin (1982) that changes in lagged variables, such as income, have significant effects on intertemporal changes in consumption.[9]

Condition (2.10) is a bit more complicated, but some intuition can be gained by first examining it under the assumption that $\alpha = 0$, i.e., when the utility function is additively time-separable in leisure. In that case, the two terms in square brackets are the familiar expressions for the first-order conditions for labor supply decisions in period t and period $t+1$, respectively. Thus, for this case, equation (2.10) is just a weighted combination of the first-order conditions for the two periods. When α is not equal to zero, equation (2.10) indicates that the future impacts of a choice of h_t, via its effect on $U_Z(t+1)$ and $U_C(t+1)$, will be taken into account in the current-period decision. Note that if $\alpha = 0$, past leisure would have no effect on current or future choices of leisure (or consumption) except through its effect on the individual's available resources; thus, holding constant the marginal utility of consumption, $U_C(t)$, past leisure should not affect current leisure choices. If $\alpha \neq 0$, past leisure does affect current (and future) decisions even when the marginal utility of consumption is held constant.

[9] More precisely, Hall and Mishkin find that intertemporal changes in consumption are correlated with lagged changes in income. They argue that this finding can be explained by the fact that some households are liquidity constrained. In that study, they assume that utility is contemporaneously separable in consumption and leisure and that preferences are intertemporally separable for both goods. The model presented here implies that lagged leisure, and thus lagged hours of work, will be correlated with changes in consumption. Given that income is equal to the product of wages and hours of work, our model provides an alternative explanation for finding the observed correlation between changes in consumption and changes in lagged income.

While these conditions have expectations of zero based on information at time t, actual realizations of future random variables will imply that

$$U_C(t) - \beta\gamma_t U_C(t+1) = u_{1,t+1}, \quad \text{and} \tag{2.11}$$

$$-\left[U_Z(t) - w_t U_C(t)\right] - \beta\left(\alpha U_Z(t+1) - (1-\eta) \cdot \left[U_Z(t+1) - w_{t+1}U_C(t+1)\right]\right) = u_{2,t+1}, \tag{2.12}$$

where $u_{t+1} = (u_{1,t+1}, u_{2,t+1})'$ is a vector of forecast errors associated with the period-t Euler equations. Clearly, the period-t forecast errors derive from the stochastic processes generating variables such as wages and interest rates. But in the estimation strategies described below, we shall attempt to avoid explicit specification of these processes and thus of the exact nature of the mapping between forcing variables and these forecast errors. Nonetheless, we can make some statements about the u_{t+1}'s which will prove crucial in estimation. First of all, given the assumption that the individual chooses leisure and consumption rationally, it follows that

$$E_t(u_{t+1}) = 0, \tag{2.13}$$

for all t. Thus u_{t+1} is orthogonal to everything in the individual's information set at time t, including the information contained in past forecast errors. Secondly, for the particular specification of the above model, these forecast errors for a given individual will be serially uncorrelated. This property holds since $\Omega_{i,t+1}$ contains all of the variables used in conditions (2.9) and (2.10) for period t and all previous periods. In the next section, we shall use these properties for conditions (2.11) and (2.12) to develop a strategy for estimating their unknown parameters.

Heretofore we have assumed that the wages received by the individual, while uncertain, are exogenously given. Theories of human capital investment or learning by doing suggest that wages are not exogenously determined but result from past work decisions made by the individual. The presence of human capital accumulation suggests an alternative reason for finding a dependence between current and past labor supply decisions.[10] In models of human capital accumulation or learning by doing, optimal labor supply decisions will take account of the influence current decisions have on future labor supply choices, in this case via their effects on future wages. (This point is noted in Sedlacek and Shaw (1984), for example.) While this alternative mechanism for generating state dependence in leisure (or hours of work) is potentially distinguishable from that due to intertemporally nonseparable preferences, failure to explicitly account for it in the Euler equations for leisure may result in their misspecification.

One obvious strategy to resolve this potential problem is to estimate Euler equations for leisure in which both mechanisms are explicitly modelled. An alternative approach, adopted here, is to exploit the fact that the Euler equation

[10] See, for example, Weiss (1972), Ghez and Becker (1975), Heckman (1976), Blinder and Weiss (1976), and Ryder, Stafford, and Stephan (1976).

for consumption, (2.9), is not affected by the presence of the human capital accumulation process. It can be shown, given regularity conditions on the data and maintaining the assumption that $U(\ )$ is not contemporaneously separable in Z_t (or l_t) and C_t, that α and $(1-\eta)$, the parameters characterizing the nonseparability of life-cycle leisure preferences, are identifiable from the consumption condition alone. Thus, to test for the importance of intertemporally dependent preferences for leisure, one can obtain estimates using only consumption conditions. Furthermore, as shown below, given estimates (2.9) and (2.10), one can test for the validity of ignoring state dependence arising from human capital investment in the presence of nonseparable utility. This latter test has a distinct computational advantage of avoiding having to estimate the more computationally burdensome model in which both forms of state dependence are explicitly incorporated. Such tests are described in the next section.[11]

3. ECONOMETRIC ISSUES

In this section, we outline a strategy for estimating and testing the parameters characterizing preferences using equations (2.11) and (2.12). We exploit directly the implications of the theory of optimal decision making under uncertainty. Using panel data on individuals over time, we form GMM or nonlinear instrumental variables (NIV) estimators, exploiting, in our choice of instruments, the fact that every variable in an information set Ω_t satisfies the required property of being orthogonal to u_{t+1}. In what follows, we outline a recursive or two-stage procedure for obtaining estimates of preferences using a flexible parameterization of the utility function. We outline methods for testing alternative hypotheses concerning the form of the leisure preference structure and indirect tests for the potential misspecification of the conditions governing optimal leisure choices when assuming that wages are exogenous. Finally, we consider two issues which arise in the analysis of dynamic models with microdata: population heterogeneity and the problem of nonindependent forecast errors.

First, consider estimation of specifications which assume that all households are homogeneous in preferences and that disturbances across individuals are independently distributed. Both of these assumptions are relaxed below. For now, assume: (i) availability of T periods of data for a random sample of N individuals; (ii) that the utility function (2.1) has a known parametric form; and (iii) that wages and all arguments of the utility function are observed without error. In the empirical analysis, we assume that (2.1) has the following form:

$$U(Z_t, C_t) = \delta_1 \ln Z_t + \delta_2 \ln C_t + \delta_3 \ln Z_t \ln C_t + \frac{\delta_4}{2}(\ln Z_t)^2 + \frac{\delta_5}{2}(\ln C_t)^2. \tag{3.1}$$

This specification, the transcendental logarithmic utility function, represents a

[11]As was pointed out by one of the referees, such tests should not be oversold. Distinguishing between mechanisms generating endogenous wages and intertemporally nonseparable utility is not an easy task and will tend to be dependent upon the particular sets of assumptions invoked for the structure of preferences and the wage-generating mechanism.

local second-order approximation to any arbitrary utility function. It does not impose the restrictions of additivity and hometheticity associated with many common utility functions, such as Cobb-Douglas or CES (see Christensen, Jorgenson, and Lau (1975)). The corresponding marginal utility functions are

$$U_Z(Z_t, C_t) = (\delta_1 + \delta_3 \ln C_t + \delta_4 \ln Z_t)/Z_t, \quad \text{and} \tag{3.2}$$

$$U_C(Z_t, C_t) = (\delta_2 + \delta_3 \ln Z_t + \delta_5 \ln C_t)/C_t, \quad \text{for} \quad t = 1, \ldots, T. \tag{3.3}$$

Let $\theta_{01} = (\delta_2, \delta_3, \delta_5, \kappa', \beta)'$ when Z_t is given by (2.2) and where $\kappa = (\kappa_1, \kappa_2, \ldots,)'$ (or $\theta_{01} = (\delta_2, \delta_3, \delta_5, \alpha, \eta, \beta)'$ when Z_t is given by (2.3) and (2.4)), $\theta_{02} = (\delta_1, \delta_4)'$, and x_{it} denote the variables entering the ith individual's Euler equations in *period t* (i.e., (2.11) and (2.12)), including the observed values of h_{t+1}, C_{t+1}, and w_{t+1}. Using the translog utility specification, we represent the ith individual's equations (2.11) and (2.12) as

$$f_1(x_{it}, \theta_{01}) = u_{1i,t+1}, \quad \text{and} \tag{3.4}$$

$$f_2(x_{it}, \theta_{01}, \theta_{02}) = u_{2i,t+1}. \tag{3.5}$$

For now, assume that individuals behave rationally (see condition (2.13)) *and* that information in Ω_{it}, the ith individual's information set at time t, is of no help in forecasting future economy-wide shocks. (We shall discuss the importance of this latter assumption below.) Then $u_{i,t+1}$ is orthogonal to all information in Ω_{it}. That is,

$$E\begin{bmatrix} f_1(x_{it}, \theta_{01}) \cdot z_{it} \\ f_2(x_{it}, \theta_{01}, \theta_{02}) \cdot z_{it} \end{bmatrix} = 0, \tag{3.6}$$

where z_{it} is a p $\times$ 1 vector whose elements are contained in Ω_{it} and E is the unconditional expectations operator.

The orthogonality between the Euler equations and z_{it} in equation (3.6) can be exploited to estimate the elements of $\theta_0 = (\theta_{01}', \theta_{02}')'$. Given panel data covering T years for each individual, the population orthogonality conditions for these years can be written as

$$E\sum_{t=1}^{T}\begin{bmatrix} f_1(x_{it}, \theta_{01}) \cdot z_{it} \\ f_2(x_{it}, \theta_{01}, \theta_{02}) \cdot z_{it} \end{bmatrix} = E\begin{bmatrix} M_1(x_i, z_i, \theta_{01}) \\ M_2(x_i, z_i, \theta_{01}, \theta_{02}) \end{bmatrix} = E[M(x_i, z_i, \theta_0)] = 0, \tag{3.7}$$

where $x_i = (x_{i1}', x_{i2}', \ldots, x_{iT}')'$ and $z_i = (z_{i1}', z_{i2}', \ldots, z_{iT}')'$. To estimate θ_0, we construct sample analogues to (3.7). Given a random sample of N individuals, the following sample orthogonality conditions,

$$O_N(\theta_0) = \begin{bmatrix} O_{N1}(\theta_{01}) \\ O_{N2}(\theta_{01}, \theta_{02}) \end{bmatrix} = \frac{1}{N}\sum_{i=1}^{N}\begin{bmatrix} M_1(x_i, z_i, \theta_{01}) \\ M_2(x_i, z_i, \theta_{01}, \theta_{02}) \end{bmatrix}, \tag{3.8}$$

will approach zero for large values of N.

While one can obtain consistent estimators of all the elements of θ_0 by forming an estimator, θ_N, which minimizes some criterion function using $O_N(\theta_N)$ in (3.8), we focus on estimation of the subvector, θ_{01}, using those conditions associated with the life-cycle consumption decisions, i.e., $O_{N1}(\theta_{01})$. This strategy has several advantages. First, as discussed in the preceding section, leisure conditions of the form of (2.12) may be misspecified if, as is found in Sedlacek and Shaw (1984) for example, the assumption of exogenous wages is inappropriate. Since the consumption conditions hold regardless of the process generating life-cycle wages, we avoid specification bias by using only the consumption conditions to form an estimator of θ_{01}. Second, while potentially sacrificing asymptotic efficiency, the consumption conditions provide sufficient information to estimate alternative intertemporal preference specifications for leisure so long as (2.1) is not separable in Z_t and C_t. Estimating the parameters identified solely from the consumption conditions enables us to formulate a relatively simple misspecification test of the leisure conditions. (We shall describe these tests below.)

We estimate θ_{01} by choosing estimators, θ_{N1}, which minimize the following criterion function:

(3.9) $$O_{N1}(\theta_1)' W_{N1} O_{N1}(\theta_1),$$

where W_{N1} is a symmetric positive definite weighting matrix which may be a function of sample information. As shown by Hansen (1982), alternative choices of W_{N1} yield estimators with alternative asymptotic efficiency. To obtain the "optimal" estimator of θ_{01}, call it $\tilde{\theta}_{N1}$, among those estimators which minimize criterion functions of the form of (3.9), one can use the weighting matrix, $W_{N1} = W^*{}_{N1} = S_{N1}^{-1} = (\Sigma_{i=1}^{N} M_1(x_i, z_i, \hat{\hat{\theta}}_{N1}) M_1(x_i, z_i, \hat{\hat{\theta}}_{N1})')^{-1}$, where $\hat{\hat{\theta}}_{N1}$ is any consistent estimator of θ_{01}.[12] The matrix, W_{N1}^*, is a consistent estimator of $W_{01}^* = S_{01}^{-1} = E[M_1(x_i, z_i, \theta_{01}) M_1(x_i, z_i, \theta_{01})']^{-1}$. The asymptotic covariance matrix for $\tilde{\theta}_{N1}$ is $(D_{01} S_{01}^{-1} D_{01}')^{-1}$, where $D_{01} = E[\partial M_1(x_i, z_i, \theta_{01})/\partial\theta_1]$, and is consistently estimated by $(D_{N1} S_{N1}^{-1} D_{N1}')^{-1}$, where $D_{N1} = \Sigma_{i=1}^{N}(\partial M_1(x_i, z_i, \hat{\theta}_{N1})/\partial\theta_1)$.

Given our assumptions of rationality and the inability of agents to forecast economy-wide shocks, the consistency and asymptotic distribution of $\tilde{\theta}_{N1}$, as well as of θ_{N1}, are established by Ferguson (1958) and Hansen (1982). The above estimators have the advantages of not requiring specification of the underlying distribution of the random variables and of allowing the distribution of the forecast errors to have arbitrary forms of conditional heteroskedasticity.

The GMM estimation strategy also provides a very simple way to test the specification of life-cycle decision rules. It amounts to testing the over-identifying restrictions implied by the underlying model imposed in estimation. As shown in Hansen (1982), under the null hypothesis, N times the value of the criterion function,

(3.10) $$\tau_{N1} = N \cdot O_{N1}(\theta_1)' W_{N1}^* O_{N1}(\theta_1),$$

is asymptotically χ^2 distributed with degrees of freedom equal to the number of over-identifying restrictions.

[12] For example, such an estimator can be formed by minimizing (3.9) using the identity matrix for W_{N1}.

We can also test a number of other hypotheses. To test whether preferences for leisure are intertemporally separable, one can compare the appropriate weighted criterion functions when the κ's are restricted to be zero versus when they are not restricted. As shown in Eichenbaum, Hansen, and Singleton (1982),

$$N \cdot O_{N1}(\tilde{\theta}_{N1}^{r})' W_{N1}^{*} O_{N1}(\tilde{\theta}_{N1}^{r}) - N \cdot O_{N1}(\tilde{\theta}_{N1}^{u})' W_{N1}^{*} O_{N1}(\tilde{\theta}_{N1}^{u}) \tag{3.11}$$

is asymptotically χ^2 distributed with degrees of freedom equal to the number of elements of κ, where $\tilde{\theta}_{N1}^{u}$ is the optimal estimator of the parameterization of θ_{01} when κ is unrestricted, $\tilde{\theta}_{N1}^{r}$ is the optimal estimator of θ_{01} when $\kappa_s = 0$, for all s, and W_{N1}^{*} is evaluated at the unrestricted estimator of θ_{01}. Using the same procedure, we can also test whether the leisure preference specification is characterized by the (α, η) specification, where $\tilde{\theta}_{N1}^{r}$ would be the optimal estimator for the $(\delta_2, \delta_3, \delta_5, \alpha, \eta, \beta)'$.

Finally, given consistent estimates of θ_{01}, we can test whether the first-order condition for leisure is misspecified. The intuition for the test is best seen by considering the following estimation strategy. If the specification in (2.12) is correct, then consistent estimators of θ_0 can be obtained by recursive estimation. For θ_{01}, use the consistent estimates obtained from the consumption conditions. An estimator of θ_{02} can be formed by minimizing the criterion function $O_{N2}(\theta_2; \tilde{\theta}_{N1})' W_{N2}^{*} O_{N2}(\theta_2; \tilde{\theta}_{N1})$, *conditional* on $\tilde{\theta}_{N1}$. Call the resulting estimator $\tilde{\theta}_{N2}$. Then, under the hypothesis that (2.12) is a correct specification of the condition governing leisure choices, the score functions associated with the estimators of θ_{01} in these latter conditions should be equal to zero. If we can reject the hypothesis that they are, we have evidence that the leisure conditions are misspecified. The precise form of this score or Lagrangian Multiplier test is given in the Appendix. We note that interpreting this as a specification test of the leisure condition is valid under the assumption that the consumption condition is correctly specified. The latter requires that the structure of preferences be such that C_t and Z_t are contemporaneously nonseparable and that C_t is intertemporally separable. Given that the form of consumption used in our analysis is not a durable good, we think the latter assumption is tenable. We also note that this specification test is against a general alternative; rejection of the null does not *necessarily* imply a rejection of the exogeneity-of-wages assumption.

It is unreasonable to assume that preferences (or the parameters of preferences) are invariant across people. Individuals from different backgrounds or at different stages of their life cycles may have different preferences for leisure and/or consumption goods. Admitting that individuals have differing preferences generally complicates the estimation of the Euler equations considered above. At the same time, given the nonlinear nature of our estimating equations, heterogeneity in parameters of utility functions across individuals or across time will not generally "average out" so that the parameters actually estimated cannot be interpreted as "representative" or as mean values for the population. Thus, to the extent that preferences are heterogeneous, one would like to deal with their incidental influence in estimation.

In the empirical analysis, we allow for the possibility that preferences differ systematically with respect to observable individual characteristics which may vary over an individual's life cycle.[13] In particular, we specify the parameters δ_1 through δ_5 of the translog utility function in (3.1) to be linear functions of a vector of observable characteristics of the individual, b_i, which may change over time. That is, we assume that

$$\delta_{ji} = \delta_{j0} + \delta_j^{*} b_i \qquad (j = 1, \ldots, 5), \tag{3.12}$$

where δ_j^* is a vector of constants. As mentioned in the previous section, we also wish to consider specifications in which α, the coefficient on lagged leisure in current utility, is allowed to vary with a set of possibly time-varying characteristics d_{it}, i.e.,

$$\alpha_i = \alpha_0 + \alpha^{*\prime} d_{it}, \tag{3.13}$$

where α^* is a vector of constants.

The estimation strategy outlined above is also based on a strong assumption concerning the dependence of forecast errors across individuals at a point in time. The disturbances in our specification arise because of errors individuals make in forecasting future exogenous variables. Estimators formed by using the sample orthogonality conditions in (3.8) yield consistent estimators if, when averaging over individuals at a point in time, they converge to zero as N gets large. Unfortunately, the conditions under which this holds are restrictive (see Chamberlain (1984) and Hayashi (1985)). Suppose that there is an economy-wide stochastic component to the processes generating forcing variables (i.e., wages and prices). This implies that the forecast errors of all individuals in period t are a function of such economy-wide components. While the conditional expectations in (2.9) and (2.10) are zero for each individual, the presence of economy-wide shocks implies that the elements of $M(x_i, z_i, \theta_0)$ in (3.7) need not converge to zero. Then estimators based on minimizing sample orthogonality conditions in (3.9) will generally not yield consistent estimators of θ_0. Intuitively, this is because, in the presence of such common stochastic shocks, the cross-sectional observations will tend to be correlated.

If, as noted above, one assumes that information in Ω_{it} is of no help in forecasting errors of the future economy-wide shocks—i.e., Ω_{it} is orthogonal to future economy-wide components of the individual's forecast errors—then the estimation strategy described above yields consistent estimators. Alternatively, suppose that forecast errors can be decomposed into a period-specific component, reflecting the effect of economy-wide shocks, and an idiosyncratic component. In particular, suppose that $u_{ji,t+1} = v_{0jt} + u_{ji,t+1}^*$, for $j = 1, 2$. Then, in place of the Euler equations in (3.4) and (3.5), suppose one uses

$$f_1^*(x_{it}, \theta_{01}, v_{01t}) = f_1(x_{it}, \theta_{01}) - v_{01t} = u_{1i,t+1}^*, \quad \text{and} \tag{3.14}$$

$$f_2^*(x_{it}, \theta_{01}, \theta_{02}, v_{02t}) = f_2(x_{it}, \theta_{01}, \theta_{02}) - v_{02t} = u_{2i,t+1}^*. \tag{3.15}$$

[13] We do not deal directly with unobserved forms of heterogeneity in this paper

Treating v_{01t} and v_{02t} as separate parameters for each time period, using (3.14) and (3.15) in place of (3.4) and (3.5) to construct sample orthogonality conditions, and implementing the same estimation strategy described above yields consistent estimators which are asymptotically normally distributed. This procedure could be extended to correct for regional, industrial, or occupational common components in the forecast errors. It should be noted that the above specification is arbitrary. Given the nonlinear nature of the Euler equations being estimated, the forcing variables underlying the model will generally not yield forecast errors which take the additively separable form given above.

4. EMPIRICAL RESULTS

In this section, we present parameter estimates for a number of specifications of our model and report tests of alternative intertemporal leisure preference structures, of the robustness of the model to a number of alternative assumptions, and of the specification of the Euler equations for leisure assuming an exogenous wage process. We use longitudinal data on males taken from the Panel Study of Income Dynamics; it contains employment, income, and demographic information on over 5000 heads of households annually starting in 1967. We use twelve years of data from 1967 through 1978. We restrict ourselves to white male heads of households who were between the ages of 23 and 52 as of 1967, were continuously married during the twelve-year interval and who reported hours of work and wages in each of the twelve years. The sample thus excludes nonparticipants. While potentially introducing sample selection bias into our analysis, we note that the nonparticipation rates of U.S. prime-age males are very low; furthermore, we selected this sample for comparison purposes as it closely corresponds to that used by MaCurdy (1981).[14] The sample meeting these criteria consists of 482 individuals. Table I presents descriptive statistics for the variables used in our analysis.

While our theoretical model implies a good deal of structure upon the econometric specification, there are still a number of issues which must be addressed before one can estimate such a model. We describe each in turn and report how we resolved it.

(1) Under its most general form, our specification of intertemporal utility implies that an individual's entire past labor supply history may affect preferences for current leisure. We have only a limited time series of data for each individual. Thus, we can only approximate the distributed lag of past leisure entering the utility function in any particular period of the individual's life cycle. In fact, the more data we use to construct longer lags on the influence of past leisure, the fewer periods we have left for estimating first-order conditions over time. We used the last six years for the latter purpose, leaving six years for the

[14] We also exclude from the sample men who, in any year, report annual hours of work in excess of 4380 (we use 8760 hours as the total time allocation per year). Also, we exclude men for whom either $WAGE_{max}/WAGE_{min} > 3$ or $FOOD_{max}/FOOD_{min} > 10$, where x_{max} and x_{min} are the largest and smallest values of observations on x over the 12-year period.

TABLE I

SAMPLE MEANS OF VARIABLES FOR 1967–1978[a]
(STANDARD DEVIATIONS IN PARENTHESES)

	Older Males, Ages 37–52 in 1967: $N = 281$					Young Males, Aged 23–36 in 1967: $N = 201$					
Year	HOURS	WAGE	FOOD	OTH-INC	#-KIDS	HOURS	WAGE	FOOD	OTH-INC	#-KIDS	INTEREST
1967	2.370	4.37	2.327	2.580	2.13	2.272	3.67	2.014	1.698	2.01	0.51
	(0.534)	(2.31)	(0.911)	(3.007)	(1.62)	(0.502)	(1.43)	(0.796)	(2.470)	(1.41)	
1968	2.358	4.53	1.864	3.056	1.99	2.317	3.90	1.621	1.755	2.11	0.60
	(0.498)	(2.24)	(0.645)	(3.174)	(1.57)	(0.455)	(1.58)	(0.651)	(2.568)	(1.38)	
1969	2.304	4.67	1.853	3.236	1.84	2.338	4.10	1.663	1.770	2.23	0.89
	(0.460)	(2.24)	(0.742)	(3.247)	(1.54)	(0.458)	(1.78)	(0.634)	(2.391)	(1.36)	
1970	2.258	4.72	1.771	3.485	1.64	2.299	4.22	1.630	1.836	2.31	2.19
	(0.485)	(2.16)	(0.707)	(3.411)	(1.49)	(0.472)	(1.96)	(0.612)	(2.519)	(1.36)	
1971	2.252	4.78	1.764	3.744	1.45	2.336	4.28	1.637	2.015	2.38	1.37
	(0.488)	(2.39)	(0.701)	(3.410)	(1.41)	(0.452)	(1.80)	(0.597)	(2.957)	(1.34)	
1972	2.265	5.00	NA	3.837	1.26	2.340	4.55	NA	2.036	2.37	−1.43
	(0.464)	(2.37)		(3.342)	(1.39)	(0.458)	(1.96)		(2.708)	(1.27)	
1973	2.267	5.10	1.882	4.275	1.10	2.328	4.65	1.963	2.312	2.33	−3.99
	(0.461)	(2.60)	(0.760)	(3.825)	(1.32)	(0.481)	(1.95)	(0.684)	(2.924)	(1.25)	
1974	2.234	4.86	1.751	4.392	0.98	2.288	4.62	1.909	2.638	2.30	−1.39
	(0.464)	(2.29)	(0.720)	(4.084)	(1.23)	(0.443)	(1.94)	(0.649)	(3.123)	(1.20)	
1975	2.205	4.86	1.622	4.360	0.86	2.299	4.56	1.876	2.745	2.20	0.50
	(0.493)	(2.47)	(0.686)	(4.555)	(1.18)	(0.493)	(2.03)	(0.708)	(2.826)	(1.14)	
1976	2.186	5.04	1.593	4.589	0.69	2.285	4.69	1.860	3.156	2.08	−0.98
	(0.457)	(2.47)	(0.676)	(4.317)	(1.02)	(0.486)	(2.14)	(0.683)	(3.142)	(1.13)	
1977	2.150	5.07	1.536	4.485	0.62	2.282	4.81	1.910	3.581	1.98	−1.99
	(0.463)	(2.29)	(0.632)	(4.075)	(0.97)	(0.489)	(2.12)	(0.680)	(3.701)	(1.15)	
1978	2.149	5.00	1.562	4.946	0.51	2.316	4.93	1.974	4.123	1.86	−3.56
	(0.506)	(2.46)	(0.617)	(4.559)	(0.88)	(0.501)	(2.31)	(0.778)	(3.917)	(1.15)	
	EDUC	AGE79				EDUC	AGE79				
	1.213	0.5520				1.294	0.4164				
	(0.309)	(0.0428)				(0.278)	(0.0411)				

[a] The variable definitions are as follows—HOURS: Reported annual hours of market work in each year (in thousands of hours); WAGE: Average hourly wage rate (in 1967 $) as of each year; FOOD: Annual household expenditures on food (in thousands of 1967 $); OTH-INC: Total annual income from household members other than the male plus *nonlabor sources (in thousands of 1967 $) as of each year; #-KIDS: Number of children present in the household as of each year*; EDUC: Number of years of schooling attained as of 1967 divided by 10; AGE79: Age of male as of 1979 divided by 100; and INTEREST: Annual rate of interest calculated using annualized 3-month U.S. Treasury bill yields deflated by the Consumer Price Index.

construction of lags on leisure in the first year of that sample. While constrained by these data limitations, we were concerned that this approximation of the distributed lag of past leisure might vary in "quality" by age. These approximations might be poorer for younger workers who are just starting out in work careers since we fail to include the influence of periods prior to entering the labor force in which consumption of nonmarket time would be particularly high. We therefore examine the sensitivity to truncating the lag structure by splitting our sample by age and re-estimating the model for young and old males. The Young sample consists of males who are 23–36 years old in 1967 while the Old sample contains males 37–52 in 1967.

(2) Our theory implies that candidates for instruments include any variables in the individual's information set as of period t. To examine whether results were sensitive to the choice of such instruments, we estimated our model with two alternative sets of instrumental variables. The first, denoted I, includes only the following "strictly exogenous" variables: the male's age in 1979, AGE79, the male's educational attainment in 1979, EDUC, EDUC^2, AGE79^2, and AGE79 $\times$ EDUC; other Family Income, OTH-INC, the number of children present in the household, #-KIDS, the local unemployment rate, UE, the hourly real wage rate, WAGE, WAGE $\times$ EDUC, WAGE $\times$ AGE79, all for years t, $t-1$, and $t-2$; and time dummies for the years 1973–77. The second, denoted I^*, consisted of the variables in I plus the endogenous variables HOURS and FOOD in years $t-1$, $t-2$, and $t-3$.

(3) We used the household's annual real expenditures on food consumption (FOOD) as a measure of consumption.[15] Our choice of this measure was dictated, in part, by the lack of availability of other consumption measures in the PSID. In addition, we felt that food consumption was reasonably assumed to have little durability over time so that our specification of preferences for consumption being time-separable would be reasonable for this good.[16] Note that our inclusion of food consumption as our only measure of consumption goods requires that we assume that all other consumption goods enter the utility function in a separable fashion.

(4) Finally, in order to examine the importance of observed heterogeneity in the specification of preferences, we estimated models with and without a limited set of characteristics as linear shifters of the parameters of the translog utility specification and in the α parameter (see equations (3.12) and (3.13)). The

[15] Hall and Mishkin (1982) and Altonji and Siow (1985) also use food as their measure of consumption.

[16] As noted earlier, we are assuming that FOOD as well as all the variables entering the Euler equations are measured without error. A number of recent studies (see Abowd and Card (1983) and Altonji and Siow (1985), for example) have emphasized the importance of allowing for measurement error in life-cycle models of consumption and labor supply. At the same time, these studies maintain intertemporal and contemporaneous separability in preferences for consumption and labor supply in their analysis. While we relax these latter assumptions, allowance for measurement error in consumption—or the other variables entering the Euler equations—is somewhat difficult to accomplish in our analysis. Future research on life-cycle behavior should address the relative importance of nonseparability versus errors in the measurement of variables in individual-level data.

characteristics used in specifying the translog parameters were EDUC and AGE79 and in specifying α were EDUC, AGE79, and #-KIDS.

We first consider the importance of allowing the lifetime utility function (2.1) to be intertemporally nonseparable in leisure. In results not reported herein but which are available upon request, we estimated the structural parameters of the utility function in which Z_t is a freely parameterized distributed lag of past leisure (see (2.2)) using the two alternative sets of instrumental variables. We obtained these parameter estimates using only the Euler equations for consumption in the years 1973 through 1977 and allowed for observed heterogeneity in preferences (by letting δ_3 and δ_5 be linear functions of EDUC and AGE79) and for common economy-wide shocks (by including time-varying intercepts in the Euler equation).[17] Most of the estimated effects of lagged leisure (the κ's) in the specification of the "production" of Z_t tended to be positive, i.e., past leisure being a substitute for current leisure in the production of Z_t or in current utility. We compared this specification to that in which leisure preferences were restricted to be intertemporally separable (i.e., $\kappa_s = 0$, for all s). The statistics for χ^2 tests for this comparison (see Test 1) and all other model specification tests are found in Table II.[18] For either age group and both sets of instruments, we can reject the latter set of restrictions.[19] Thus the intertemporally separable preference specification, typically invoked in microdata, life-cycle labor supply analysis, is decisively rejected relative to a fairly general nonseparable specification of intertemporal preferences.

Table III contains estimates of the model in which we restrict nonseparability to the (α, η) specification found in Kydland and Prescott. This specification implies a relatively parsimonious parameterization of the influence of past leisure on current utility and greatly simplifies the form of the optimal decision rule for leisure. We cannot reject the (α, η) specification relative to the unrestricted nonseparable one for either age group or instrument set. (See Test 2 in Table II.) In terms of the fit of the (α, η) specification (see the τ_{N1} statistics and their corresponding levels of significance at the bottom of Table III), we cannot reject it for either age group or set of instruments, using the test of the over-identifying restrictions given in (3.10). Thus, we find clear support for this specification. Given these results, we shall focus on the (α, η) specification in the remainder of our analysis.

The estimates of α, which measures the weight of past leisure in current utility, are always positive and significantly different from zero. To facilitate a compari-

[17]Given the form of the marginal utility of consumption in (3.3), it can be readily shown that the contemporaneous preference parameters $(\delta_2, \delta_3, \delta_5)$ cannot all be uniquely identified from the estimation of the sample orthogonality conditions formed from (3.4). Therefore, some normalization must be chosen. In all our empirical analyses, we set $\delta_2 = 1$.

[18]The test statistics in this table compare criterion function values for unrestricted and restricted parameterizations evaluated using the same weighting matrix in both cases (see equation (3.11)). Because of the need to have comparable weighting matrices for each specific test, some of the parameterizations were estimated with several different weighting matrices. (Note that each set of estimates for the same parameterization is consistent.)

[19]We also performed Wald tests for the hypothesis that $\kappa_s = 0$ for all s and we rejected this null hypothesis for each age group and each specification.

TABLE II

TEST RESULTS[a]

Sample: Instrument Set:	Old I	Young I	Old I^*	Young I^*
1. Test of separability of preferences for leisure	77.07 11 0.000	174.27 11 0.000	678.34 11 0.000	589.40 11 0.000
2. Test of the (α, η) specification of preferences	2.88 9 0.969	9.74 9 0.372	2.65 9 0.977	8.44 9 0.490
3. Test of heterogeneity in α parameter	7.43 3 0.059	0.34 3 0.952	13.97 3 0.003	0.31 3 0.958
4. Test of additional orthogonality conditions associated with over-identifying restrictions[b]	10.37 6 0.110	3.83 6 0.708	7.09 6 0.312	1.83 6 0.933
5. Test for presence of common economy-wide shocks (time-varying intercepts)	1.60 5 0.901	6.54 5 0.257	17.38 5 0.004	14.07 5 0.015
6. Test of pooling age groups	13.06 14 0.522		33.33 14 0.003	
7. Test of heterogeneity in contemporaneous preference parameters (δ's)	4.98 4 0.289	4.46 4 0.347	9.40 4 0.052	8.50 4 0.075
8. Specification test of leisure conditions	21.45 9 0.011	48.16 9 0.000	23.66 9 0.005	42.93 9 0.000

[a] The format of the rows in this table is as follows: the top number is the value of the chi-square statistic; the middle number is the associated degrees of freedom; and the third number is the level of significance of the test. Also see footnote 18 for an explanation about the calculations of the tests.

[b] The first two columns give the tests for the Old and Young subsamples from Table III and the last two columns give them for the Old and Young subsamples from Table IV.

son of the relative importance of past leisure in current utility, we present near the bottom of the table the implied weight on current leisure in current utility, $\eta/(\alpha+\eta)$, when the weights on current and past leisure are normalized to add to one. Based on the estimates of α and η, individuals belonging to the Young subsample seem to put relatively more weight on current hours of leisure than individuals in the Old subsample. Our results also indicate that past and current leisure are substitutes in utility. The estimates of η—the rate of depreciation in the influence of past leisure—range in value between 0.35 and 0.43. Finally, we strongly reject the hypothesis, implied by Johnson and Pencavel (1984), that $1-\eta=0$ over all the specifications in Table III and in the remainder of the paper. Thus, not only do last year's hours of leisure directly enter the current utility function but so do hours of leisure in earlier years.

Examining the estimates of the other parameters in Table III, we see that the estimates of the translog preference parameters (the δ's) reported here and elsewhere in the paper are not implausible; they imply, for example, that the mean value of the marginal utility of market goods is positive. Also note that the estimates of the parameters on the interaction of $\ln Z$ and $\ln C$ in the utility

TABLE III

ESTIMATES OF THE EULER EQUATION FOR FOOD CONSUMPTION USING (α, η) TO PARAMETERIZE DISTRIBUTED LAG IN PAST LEISURE

Sample: Instrument Set:	Old I	Young I	Old I^*	Young I^*
$1+\rho$	0.86797	0.84989	0.96510	0.90137
	(0.03875)	(0.05460)	(0.01325)	(0.02420)
α	0.83767	0.57860	1.04544	0.62263
	(0.14864)	(0.16780)	(0.16030)	(0.14061)
$1-\eta$	0.62379	0.64478	0.56855	0.65119
	(0.09223)	(0.10008)	(0.04315)	(0.04900)
δ_{30}	−0.31984	−0.32735	−0.34580	−0.31481
	(0.02571)	(0.03058)	(0.02479)	(0.02483)
δ_{31}^* (EDUC)	−0.00338	−0.00660	−0.01596	−0.00634
	(0.00210)	(0.00619)	(0.00687)	(0.00481)
δ_{32}^* (AGE79)	0.00771	−0.04655	0.06318	−0.06260
	(0.01273)	(0.02901)	(0.04624)	(0.02751)
δ_{50}	0.05225	−0.21711	−0.19611	−0.20800
	(0.09365)	(0.13183)	(0.13905)	(0.08305)
δ_{51}^* (EDUC)	−0.01787	0.02057	−0.06465	0.02024
	(0.01734)	(0.02869)	(0.02967)	(0.02222)
δ_{52}^* (AGE79)	−0.00515	0.36682	0.44915	0.33769
	(0.15875)	(0.24008)	(0.25688)	(0.17165)
$v_{01,1973}$	−0.00099	0.00312	0.00250	0.00309
	(0.00213)	(0.00167)	(0.00073)	(0.00100)
$v_{01,1974}$	−0.00176	0.00314	0.00222	0.00325
	(0.00228)	(0.00200)	(0.00077)	(0.00113)
$v_{01,1975}$	−0.00150	0.00272	0.00213	0.00220
	(0.00237)	(0.00257)	(0.00088)	(0.00166)
$v_{01,1976}$	−0.00116	0.00320	0.00294	0.00299
	(0.00215)	(0.00234)	(0.00067)	(0.00132)
$v_{01,1977}$	−0.00122	0.00195	0.00103	0.00174
	(0.00192)	(0.00205)	(0.00073)	(0.00107)
$\eta/(\alpha+\eta)$	0.310	0.380	0.292	0.359
τ_{N1}	11.225	5.423	21.621	9.375
Degrees of Freedom	14	14	20	20
Level of Significance	0.668	0.979	0.361	0.978

function are significant, which indicates that utility is not contemporaneously separable in LEISURE and FOOD as is assumed in many previous studies, e.g., Hall and Mishkin (1982). Our estimates indicate that these two goods are complementary.

Our estimates of $1+\rho$ imply *negative* rates of time preference, ρ, and are always precise. This finding is counter to our priors that rates of time preference are positive, but it is a result found in other consumption studies based on models with intertemporally separable preference specifications. Finding that $\rho < 0$ may reflect the fact that preferences for consumption systematically grow over ranges of the life cycle. For example, one may expect that the desire for food expenditures increases as family size increases over the life cycle.

As discussed in Section 2, it is possible that α varies as a function of personal characteristics, such as the person's education or existing family size. Table IV presents a specification which allows for this type of heterogeneity. Examining

TABLE IV

ESTIMATES OF THE EULER EQUATION FOR FOOD CONSUMPTION WITH α PARAMETERIZED AS A FUNCTION OF AGE79, EDUC, AND #-KIDS

Sample: Instrument Set:	Old I	Young I	Old I^*	Young I^*
$1+\rho$	0.95048	0.83049	0.98785	0.93118
	(0.03887)	(0.06005)	(0.01193)	(0.02301)
α_0	3.03343	0.27409	4.55883	3.18025
	(0.89704)	(0.95522)	(1.30838)	(2.36610)
α_1^* (EDUC)	−0.36551	−0.03552	−0.52248	0.23880
	(0.21809)	(0.25392)	(0.20866)	(0.50376)
α_2^* (AGE79)	−3.27155	0.71958	−5.21560	−5.40255
	(1.28265)	(2.25456)	(1.92332)	(4.37759)
α_3^* (#-KIDS)	−0.03581	0.00708	−0.03808	−0.05007
	(0.01466)	(0.01001)	(0.01298)	(0.03673)
$1-\eta$	0.57134	0.67121	0.62196	0.64440
	(0.10010)	(0.10998)	(0.05141)	(0.05353)
δ_{30}	−0.11819	−0.35664	−0.04893	−0.20753
	(0.07953)	(0.14084)	(0.07069)	(0.10802)
δ_{31}^* (EDUC)	−0.04154	−0.01381	−0.05922	0.01507
	(0.01897)	(0.03620)	(0.01786)	(0.03644)
δ_{32}^* (AGE79)	−0.32214	0.04519	−0.38899	−0.30673
	(0.12964)	(0.32221)	(0.13889)	(0.21763)
δ_{50}^*	0.01708	−0.20871	0.00907	−0.30279
	(0.15658)	(0.13186)	(0.21229)	(0.15738)
δ_{51}^* (EDUC)	−0.00256	0.03349	−0.04966	−0.09075
	(0.03370)	(0.03260)	(0.05087)	(0.05727)
δ_{52}^* (AGE79)	−0.01261	0.32318	0.01769	0.79168
	(0.29393)	(0.24895)	(0.40547)	(0.33239)
$v_{01,1973}$	0.00201	0.00349	0.00349	0.00420
	(0.00232)	(0.00197)	(0.00119)	(0.00161)
$v_{01,1974}$	0.00247	0.00344	0.00495	0.00526
	(0.00253)	(0.00252)	(0.00143)	(0.00227)
$v_{01,1975}$	0.00232	0.00308	0.00390	0.00438
	(0.00206)	(0.00310)	(0.00124)	(0.00316)
$v_{01,1976}$	0.00224	0.00304	0.00314	0.00613
	(0.00162)	(0.00292)	(0.00082)	(0.00269)
$v_{01,1977}$	0.00232	0.00207	0.00140	0.00314
	(0.00122)	(0.00266)	(0.00082)	(0.00230)
$\bar{\alpha}$[a]	0.754	0.543	1.014	1.131
$\eta/(\eta+\bar{\alpha})$	0.362	0.377	0.272	0.239
τ_{N1}	3.788	5.032	10.844	6.960
Degrees of Freedom	11	11	17	17
Level of Significance	0.976	0.930	0.865	0.984

[a] $\bar{\alpha}$ denotes the value of α evaluated at the means of EDUC, AGE79, and #-KIDS.

the estimates of α^*, current and past leisure generally become less substitutable in utility the greater are EDUC (for the Old subsample) and #-KIDS and the older the male in the Old subsample; moreover, these effects are statistically significant.

These results have important implications for explaining differences in labor supply elasticities with respect to transitory wage variation across individuals with various characteristics. For several reasons we cannot directly calculate estimates of labor supply elasticities.[20] However, we can infer qualitative properties of the responsiveness of current labor supply to *exogenous* transitory changes in wage rates from the sign and magnitude of α. The greater is α, all other things being equal, the more substitutable current leisure is for future leisure; thus, the corresponding elasticity with respect to a change in the price of labor in the *current* period should be greater. The coefficient estimates for α^* imply that males with more years of schooling and with children present will have lower short-run wage elasticities and that older workers' elasticities decline with age. Thus, our results suggest a structural motivation for how wage elasticities might differ across groups of individuals and might evolve over the life cycle of individuals.

The significant effects of observed heterogeneity in α also suggest that estimates of intertemporal substitution elasticities which ignore such heterogeneity may be misleading. To see this point, note that the values of α for the representative individual—i.e., the individual with the mean value for the three observed characteristics—for each age group and for the two instrument sets are all positive (see the estimates of $\bar{\alpha}$), indicating that current and future leisure are substitutes; they also differ substantially from the estimates of α in Table III. These results suggest that observed changes in the empirical distribution of observable traits in the population may be especially important in explaining changes in aggregate labor supply behavior.

Allowing for observed heterogeneity in α also improves the fit of the model, at least for the Old subsample. For both instrument sets, we reject the hypothesis that α does not vary with observed characteristics for this group (see Test 3 in Table II). Furthermore, for the instrument set I, we cannot reject the over-identifying restrictions of the model for either age group at conventional significance levels, indicating that the restrictions implied by optimal dynamic decision making are not inconsistent with the data for the specification in Table IV.

Looking across Tables III and IV, we do find some sensitivity of the estimates of α and $1-\eta$ to the choice of instruments. The normalized weights on current hours of leisure, $\eta/(\eta+\alpha)$ and $\eta/(\eta+\bar{\alpha})$, respectively, fall in the interval from 0.239 to 0.380, but generally take lower values when instrument set I^* (which contains lagged endogenous variables) is used in estimation. However, the general implications of the model—in terms of sign and significance patterns—are very similar across choices of instruments. To isolate the influence of these additional instruments in I^*, we test their use in forming additional over-identifying restrictions relative to those in I by comparing the comparably weighted criterion functions obtained with the two instruments sets. These results are given in Test 4 of Table II. We cannot reject the overidentifying restrictions associated with using lagged endogenous variables at the .05 significance level for either age group, or alternative parameterization of the intertemporal substitution parameter, α.

[20] In particular, calculating such elasticities cannot be done from the consumption conditions alone as such conditions do not identify all of the preference parameters needed to calculate wage responses.

We also investigated the robustness of our findings concerning the nonseparability of intertemporal preferences to: (a) the appropriateness of alternative definitions of variables; (b) the importance of time-period effects; (c) differences across age groups; and (d) heterogeneity of preferences. (Again, the actual estimates are available upon request.) To investigate the sensitivity of our results to alternative definitions of the real interest rates, we re-estimated the specification in Table III using two alternative measures of after-tax real rates in place of the real rate based on 3 month U.S. Treasury bill yields.[21] While the estimates of $1+\rho$ were somewhat sensitive to the interest rate definition, the remaining parameters and the overall fit of the models were not. We also re-estimated the consumption condition deflating the food expenditures by the food component of the CPI instead of using the overall CPI as a deflator. We found virtually no change in the parameter estimates or in the overall fit.

We re-estimated the consumption Euler equations restricting the time-specific intercepts to be zero (i.e., common aggregate time-specific shocks are ignored). The hypothesis that time-specific intercepts are equal to zero was strongly rejected for estimates using I^* but not rejected for those using I (see Test 5 in Table II). Thus, our evidence is somewhat ambiguous concerning the contention that aggregates shocks (which cause the forecast error of different individuals to be correlated) have an important impact on the labor supply behavior of married males. We also examined whether the structural parameters differed substantially across the Young and Old subsamples. Based on a χ^2 test (Test 6 in Table II), we could not reject pooling the two age groups for the (α, η) specification when using the instrument set I while pooling is rejected using the instrument set I^* containing lagged choice variables.

Finally, to examine the importance of allowing for observed heterogeneity in the translog preference parameters in the marginal utility of consumption, we re-estimated the model assuming that $\delta_j^* = 0$ for $j = 3$ and 5. Comparing the latter specification with that in Table III, we could not reject the hypothesis that these parameters are invariant to differences in education or the age cohort of the male for either age group or instrument set at the 5% level, although the test for the Old subsample using instrument set I^* is close to being rejected (see Test 7 in Table II). While we have allowed individual preferences to depend upon observable characteristics in some of the above specifications, we may not have been entirely successful in controlling for other, unobserved, sources of heterogeneity across individuals in estimating the above Euler equations. As Heckman (1979, 1981a, 1981b) has argued, the presence of unobserved heterogeneity in dynamic models may bias one's findings concerning the presence or forms of state dependence. Unfortunately there is no simple "fix" for this problem; any method of control for unobservables is subject to the criticism of being arbitrary. Nonetheless, we think that future work should attempt to examine the sensitivity of the above findings concerning intertemporally nonseparable preferences for leisure to alternative assumptions about unobserved heterogeneity. We note,

[21] We used the Treasury bill yields with estimates of annual average tax rates constructed by Barro and Sahasakul (1983) and by Seater (1985), respectively, to construct these rates.

though, that we were unable to reject the over-identifying restrictions when we added lagged values of FOOD and HOURS (see Test 4 in Table II). If, for example, the preference parameters (δ's) in this equation were subject to variation across individuals not captured by the observed characteristics we have included in b_i, one would not expect such lags to be orthogonal to the variables included in the Euler equation for consumption.

All of the estimates considered to this point have been obtained using only the Euler equation for consumption. We have chosen not to use the equation for leisure choices because of the concern about misspecification discussed above as well as the additional computational burden of using it in estimation. To examine whether the data are consistent with the Euler equation for leisure given in equation (2.12) (which maintains, amongst other assumptions, the exogeneity of the wage process to labor supply decisions), we performed the specification test described in the Appendix. We first obtained parameter estimates (also available upon request) for the leisure condition estimated conditional on parameter estimates from the first-stage consumption-condition results. We then tested whether the score functions in just the leisure conditions for those parameters common to both consumption and leisure decision rules were zero in a statistical sense. The results of this test are reported in Table II under Test 8. For both age groups and both sets of instruments, we decisively reject the appropriateness of the cross-equation restrictions implied by the model when wages are exogenous. It is important to re-emphasize the caveat that this test does not discriminate between the lack of exogeneity of wages versus other sources of misspecification in accounting for the rejection.[22] But these results along with those of others[23] do call into question the appropriateness of this former assumption. Thus, in addition to the potential importance of nonseparabilities in preferences such as the type examined here, these results suggest that an adequate characterization of life-cycle labor supply behavior will require characterizing the dynamic relationship between life-cycle labor supply decisions and wage determination.

5. CONCLUSIONS

This paper has examined the importance of nonseparable preference structures in characterizing life-cycle microdata on labor supply behavior among white male workers in the U.S. Such structures can be motivated, for example, by extending life-cycle labor supply models to include home production in which past leisure or its by-products influence current preferences (and thus current choices) about leisure as well as consumption.

[22] For example, it is possible that this rejection could be due to the failure to account for measurement error in such variables as FOOD, LEISURE, and/or WAGE or due to the presence of unobserved heterogeneity in the specification of $U_C(Z_t, C_t)$ and/or $U_Z(Z_t, C_t)$. More generally, as was pointed out by one of the referees, distinguishing between mechanisms generating endogenous wages and intertemporally nonseparable preference structures is not an easy task and will tend to depend upon the particular sets of assumptions invoked for the structure of preferences and the wage generating mechanism.

[23] Sedlacek and Shaw (1984), in a study of life-cycle labor supply for prime-age males, and Mroz (1987), in analysis of married women, also reject the exogeneity of wages.

The novel aspect of the methodology used in this paper is that structural specification tests are conducted using only the consumption Euler equations. While this approach has the drawback of not identifying enough information to explicitly calculate estimates of long-run and/or short-run labor supply responses to changes in wages, we have taken this approach to minimize the importance of specification errors which may arise in the characterization of conditions governing optimal life-cycle leisure choice. This approach does provide remarkably robust results concerning the intertemporal preference structure for leisure and allows us to test for the potential misspecification in alternative specifications of optimal leisure conditions.

Several conclusions can be drawn from our work. First, when we compare the parameter estimates obtained by fitting the different preference specifications tested, we find strong statistical evidence in favor of models which incorporate nonseparable leisure features. The statistical evidence supports the hypothesis that agents' preferences do directly depend upon past leisure decisions. In particular, we find empirical support for the relatively simple specification of nonseparable preferences proposed by Kydland and Prescott (1982). A noteworthy feature of these results is the remarkable robustness of the parameter estimates of α and η (parameters associated with the intertemporal leisure index) across a number of different specifications.

Second, we find some evidence that observed heterogeneity in model parameters is an important model feature in explaining the microdata. In the models estimated, preference parameters are allowed to be linear functions of observed individual characteristics. Our results point to the existence of important differences in the degree of intertemporal substitution across different groups in the population. Thus, changes in the empirical distribution of observable traits in the population may be especially important in explaining aggregate labor supply responses to short-run wage fluctuation. Finally, our findings of the importance of observed heterogeneity suggest that representative agent models, when applied to the study of microdata, may result in misleading inferences.

Third, our findings of negative rates of time preference in the estimation of Euler equations for consumption suggest, at least when using microdata, that our specification of this relationship is misspecified. Such estimates suggest that we have not properly accounted for the life cycle growth in household consumption associated with changes in household composition (e.g., changes in the numbers and ages of children in the household). Further investigation of the role changing household demographics play in life cycle consumption patterns seems warranted given the unsettling implications of our results for the theoretical link between the rate of growth of consumption and the real interest rate.

Fourth, our results call into question the assumption of exogenous life-cycle wages which is maintained in this and most other recent studies of life-cycle labor supply using longitudinal data. While our testing has not been conclusive on this point, it, along with findings of others, suggests that this assumption needs to be relaxed in future empirical studies.

The evidence presented here suggests that recent attention in the literature concerning nonseparable preferences is not unwarranted. These findings are certainly not without cost. Structural models in which leisure of different periods are allowed to affect current preferences are more cumbersome to estimate and interpret than those derived from intertemporally separable preference specifications. But, our results do suggest potentially rich and interesting motivations for life-cycle variations in behavior and they may improve our ability to explain differences in labor supply behavior across demographic groups as the empirical results presented above seem to indicate.

Program in Quantitative Economic Analysis/NORC, University of Chicago, Chicago, IL 60637, U.S.A.;

Graduate School of Industrial Administration, Carnegie Mellon University, Pittsburgh, PA 15213, U.S.A.

and

IPEA/INPES, Av. Pres. Antonio Carlos, 51-17th andar, Rio de Janeiro, R.J. 20020, Brazil

Manuscript received January, 1986; final revision received April, 1987.

APPENDIX

Testing for Misspecification of the Euler Equation for Leisure Choices

A test of the model specification is whether the θ_1 in M_1 (see condition (3.7)) is the same as the θ_1 in M_2. Denote the first parameter vector as $\theta_1^{(1)}$ and the second parameter vector as $\theta_1^{(2)}$. The null hypothesis is $\theta_1^{(1)} = \theta_1^{(2)}$. Consider the following test. Under the null, the score vector with respect to θ_1^2 evaluated at $\theta_1^{(2)} = \theta_{N1}^{(1)}$ should be not significantly different from zero. If it is not, then we reject the null hypothesis. Let π denote the "augmented" $(K \times 1)$ parameters vector, i.e., $\pi^u = (\theta_{N1}^{(1)\prime}, \theta_2', \theta_{N1}^{(2)\prime})' = (\pi_1^{u\prime}, \pi_2^{u\prime}, \pi_3^{u\prime})'$, where π_1 is $(K_1 \times 1)$, π_2 is $(K_2 \times 1)$, and π_3 is $(K_3 \times 1)$, and let π^r denote the $(J \times 1)$ vector θ, $P_0(\pi) = E\,\partial M(x_i, z_i, \pi)/\partial\pi$, where $P_{0j}(\pi) = E\,\partial M(x_i, z_i, \pi)/\partial\pi_j$, $j = 1,2,3$, and $S_0 = EM(x_i, z_i, \pi)M(x_i, z_i, \pi)'$. Under the null, the following normalized "score" function

$$\text{(A.1)} \qquad \sqrt{N}\lambda_N = RP_N(\pi)S_N(\pi)^{-1}O_N(\pi)\big|_{\pi=\pi_N^r},$$

where $R = [0\ 0\ I_3]$ is asymptotically normally distributed with mean 0 and covariance matrix $P_{N1}S_N^{-1}P_{N1}'$, evaluated at π^r. Under this null hypothesis, the scores associated with π_3 should be close to zero. To test this hypothesis, form the test statistic:

$$\text{(A.2)} \qquad \tau_{N1}^* = O_N(\pi)'S_N(\pi)^{-1}P_{N1}(\pi)'\left(P_{N1}(\pi)S_N(\pi)^{-1}P_{N1}(\pi)'\right)^{-1} \cdot P_{N1}(\pi)S_N(\pi)^{-1}O_N(\pi)\big|_{\pi=\pi^r}$$

which, under the null, is asymptotically distributed χ^2 with degrees of freedom equal to the dimension of π_3.

REFERENCES

Abowd, J., and D. Card (1983): "Intertemporal Substitution in the Presence of Long Term Contracts," Unpublished Manuscript, Princeton University.

Altonji, J. (1982): "The Intertemporal Substitution Model of Labor Market Fluctuations: An Empirical Analysis," *Review of Economic Studies*, 49, 783–824.

——— (1986): "Intertemporal Substitution in Labor Supply: Evidence from Micro Data," *Journal of Political Economy*, 94, S176–S215.

ALTONJI, J., AND A. SIOW (1985): "Testing the Response of Consumption to Income Changes with (Noisy) Panel Data," Unpublished Manuscript, Industrial Relations Section, Princeton University.
BECKER G., AND K. M. MURPHY (1986): "A Theory of Rational Addiction," Paper presented in Workshop in Applications of Economics, University of Chicago.
BARRO, R., AND C. SAHASAKUL (1983): "Measuring the Average Marginal Tax Rate from the Individual Income Tax," *Journal of Business*, 56, 419–452.
BLINDER, A., AND Y. WEISS (1976): "Human Capital and Labor Supply: A Synthesis," *Journal of Political Economy*, 84, 449–472.
BROWNING, M. (1985): "Testing Inter-Temporal Separability in Models of Household Behaviour," Program for Quantitative Studies in Economics and Population, McMaster University.
CHAMBERLAIN, G. (1984): "Panel Data," in *Handbook of Econometrics*, Vol. II., ed. by Z. Griliches and M. Intriligator. Amsterdam: Elsevier Science Publishers BV.
CHRISTENSEN, L., D. JORGENSON, AND L. LAU (1975): "Transcendental Logarithmic Utility Functions," *American Economic Review*, 65, 367–383.
DEATON, A. (1986): "Life-cycle Models of Consumption: Is the Evidence Consistent with the Theory?" Unpublished Manuscript, Princeton University.
EICHENBAUM, M., L. P. HANSEN, AND K. SINGLETON (1982): "Testing Restrictions in Nonlinear Rational Expectations Models," Unpublished Manuscript, Carnegie Mellon University.
——— (1984): "A Time Series Analysis of Representative Agent Models of Consumption and Leisure Decisions Under Nonseparable Utility," Working Paper, Carnegie Mellon University.
FERGUSON, T. (1958): "A Method of Generating Best Asymptotically Normal Estimates with Application to the Estimation of Bacterial Densities," *Annals of Mathematical Statistics*, 29, 1046–1062.
GHEZ, G., AND G. BECKER (1975): *The Allocation of Time and Goods over the Life Cycle*. New York: Columbia University Press.
HALL, R., AND F. MISHKIN (1982): "The Sensitivity of Consumption to Transitory Income: Estimates from Panel Data on Households," *Econometrica*, 50, 461–482.
HANSEN, L. P. (1982): "Large Sample Properties of Generalized Method of Moments Estimators," *Econometrica*, 50, 1029–1054.
HANSEN, L. P., AND K. SINGLETON (1982): "Generalized Instrumental Variables Estimation of Nonlinear Rational Expectations Models," *Econometrica*, 50, 1269–1286.
HAYASHI, F. (1985): "The Permanent Income Hypothesis and Consumption Durability: Analysis Based on Japanese Panel Data," *Quarterly Journal of Economics*, 100, 1083–1113.
HECKMAN, J. (1976): "A Life Cycle Model of Earnings, Learning and Consumption," *Journal of Political Economy*, 84, S11–S44.
——— (1979): "New Evidence on the Dynamics of Female Labor Supply," in *Women in the Labor Market*, ed. by C. B. Lloyd, E. S. Andrews, and G. L. Gilroy. New York: Columbia University Press.
——— (1981a): "Heterogeneity and State Dependence," in *Studies in Labor Markets*, ed. by S. Rosen. Chicago: University of Chicago Press.
——— (1981b): "Statistical Models for Discrete Panel Data," in *The Structural Analysis of Discrete Data*, ed. by C. Manski and D. McFadden. Cambridge: MIT Press.
HECKMAN, J., AND T. MACURDY (1980): "A Life Cycle Model of Female Labour Supply," *Review of Economic Studies*, 47, 47–74.
IANNACCONE, L. (1984): "Consumption Capital and Habit Formation with an Application to Religious Participation," Unpublished Ph.D. Dissertation, University of Chicago.
JOHNSON, T., AND J. PENCAVEL (1984): "Dynamic Hours of Work Functions for Husbands, Wives, and Single Females," *Econometrica*, 52, 363–390.
KYDLAND, F. (1984): "Labor-Force Heterogeneity and the Business Cycle," in *Essays on Macroeconomic Implications of Financial and Labor Markets and Political Processes*, ed. by K. Brunner and A. Meltzer. Carnegie-Rochester Series on Public Policy, 21, 173–208.
KYDLAND, F., AND E. PRESCOTT (1982): "Time to Build and Aggregate Fluctuations," *Econometrica*, 50, 1345–1370.
LUCAS, R., JR., AND L. RAPPING (1969): "Real Wages, Employment, and Inflation," *Journal of Political Economy*, 77, 721–754.
MACURDY, T. (1981): "An Empirical Model of Labor Supply in a Life-Cycle Setting," *Journal of Political Economy*, 89, 1059–1085.
——— (1983): "A Simple Scheme for Estimating an Intertemporal Model of Labor Supply and Consumption in the Presence of Taxes and Uncertainty," *International Economic Review*, 24, 265–289.

Mroz, T. (1987): "The Sensitivity of an Empirical Model of Married Women's Hours of Work to Economic and Statistical Assumptions," *Econometrica*, 55, 765–799.

Nakamura, A., and M. Nakamura (1985): *The Second Paycheck: A Socioeconomic Analysis of Earnings*. New York: Academic Press.

Ryder, H., F. Stafford, and P. Stephan (1976): "Labor, Leisure and Training over the Lifecycle," *International Economic Review*, 17, 651–74.

Seater, J. (1985): "On the Construction of Marginal Federal Personal and Social Security Tax Rates in the U.S.," *Journal of Monetary Economics*, 15, 121–135.

Sedlacek, G., and K. Shaw (1984): "An Empirical Model of Life Cycle Labor Supply and Human Capital Accumulation," Working Paper, Carnegie Mellon University.

Smith, J. (1977): "Family Labor Supply Over the Life Cycle," *Explorations in Economic Research*, 4, 205–276.

Spinnewyn, F. (1981): "Rational Habit Formation," *European Economic Review*, 15, 91–110.

Stigler, G., and G. Becker (1977): "De Gustibus Non Est Disputandum," *American Economic Review*, 67, 76–90.

Weiss, Y. (1972): "On the Optimal Pattern of Labor Supply," *Economic Journal*, 82, 1292–1315.