INTERTEMPORAL SUBSTITUTION IN MACROECONOMICS*

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Modern neoclassical business cycle theories posit that the observed fluctuations in consumption and employment correspond to decisions of an optimizing representative individual. We estimate three first-order conditions that represent three tradeoffs faced by such an optimizing individual. He can trade off present for future consumption, present for future leisure, and present consumption for present leisure. The aggregate U. S. data lend no support to this model. The overidentifying restrictions are rejected, and the estimated utility function is often convex. Even when it is concave, the estimates imply that either consumption or leisure is an inferior good.

I. INTRODUCTION

Modern neoclassical theories of the business cycle are founded upon the assumption that fluctuations in consumption and employment are the consequence of dynamic optimizing behavior by economic agents who face no quantity constraints. In this paper we present and estimate an explicit operational model of an optimizing household. Our examination of postwar aggregate data provides no support for these theories.

As in many recent studies of consumption and asset returns, we posit that observed fluctuations can be modeled as the outcome of optimizing decisions of a representative individual. The individual has a utility function that is additively separable through time and faces an economic environment where future opportunities are uncertain. Our approach avoids the intractable problem of finding a closed-form solution for the representative individual's choices. Instead, we use the restrictions on the data implied by the first-order conditions for an optimum. The estimation of these first-order conditions makes it possible to recover the structural parameters of the underlying utility function.

The three first-order conditions we consider represent three margins on which the representative individual is optimizing. He

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can trade off present and future consumption at a stochastic real interest rate measured in terms of the consumption good. He can trade off present leisure and future leisure at a stochastic real interest rate measured in terms of leisure. And he can trade off present consumption and present leisure at the real wage. Thus, the approach here has the potential to recover parameters describing both consumption and labor supply decisions.

The estimation technique we use is the nonlinear instrumental variables procedure Hansen and Singleton [1982] suggest. It not only produces consistent estimates of the relevant parameters, but also allows us to test overidentifying restrictions implied by the theory. Throughout the study we experiment with different measures of consumption, different lists of instruments, and different frequency data. We also try various functional forms for the underlying utility function. In particular, we allow the utility function to be nonseparable in consumption and leisure. Such experimentation assures that our conclusions are somewhat robust to changes in the various auxiliary assumptions necessary for implementation of the model.

We find that aggregate data are not readily characterized as ex post realizations from a stochastic dynamic optimization. In particular, the orthogonality conditions implied by theory are frequently rejected. More importantly, the parameter estimates are usually highly implausible. The estimated utility function is often not concave, which implies that the representative individual is not at a maximum of utility, but at a saddle-point or at a minimum. In addition, when the utility function is concave, the estimates imply that either consumption or leisure is an inferior good. We conclude that observed economic fluctuations do not easily admit of a neoclassical interpretation.

Section II discusses the previous work on intertemporal substitution. Section III develops the model; while Section IV discusses the data. Section V explains the estimation procedure, and Section VI presents the results. Section VII considers the implications of the model's failure for equilibrium theories of the business cycle, and suggests directions for future research.

II. Motivation

The major difference between modern neoclassical and traditional Keynesian macroeconomic theories is that the former regard observed levels of employment, consumption, and output as realizations from dynamic optimizing decisions by both households and firms, while the latter regard them as reflecting constraints on households and firms. This distinction is clearest in the case of labor supply decisions. In classical macroeconomic models, observed levels of labor supply represent the optimizing choices of households given their perceptions of the macroeconomic environment. In Keynesian macro models, employment is frequently regarded as "demand determined," and fluctuations in employment do not necessarily correspond to any change in desired labor supply.

The goal of the present paper is to examine the extent to which data on consumption and labor supply for the United States over the postwar period are consistent with the hypothesis of continuous dynamic optimization. At the outset it is crucial to understand the limitations of this empirical inquiry or any investigation of this kind. It is impossible to test the general proposition about continuous optimization discussed above. Only particular simple versions of the dynamic optimization problem can be considered. Any rejections of the models estimated can be interpreted as a failure of the underlying theory or of the particular parameterization of it that is tested. Of course, to the extent that a theory fails when simply expressed, its utility as an organization framework for understanding economic events is called into question.

Explanations of business cycles based on continuous dynamic optimization differ in many respects. However, they share the notion that the elasticity of labor supply with respect to changes in the relative return from working currently and in the near future is likely to be high. This would seem to be a necessary implication of any such theory, since cyclical fluctuations in employment are large and the long-run labor supply elasticity observed in cross sections is typically small. A central thrust of this paper is to examine empirically the differential response of labor supply to permanent and transitory shocks to real wages.

Recent research on consumption by Grossman and Shiller [1980], Hansen and Singleton [1982], Hall [1978, 1981], and Mankiw [1981] shows how it is possible to estimate directly the parameters of the intertemporal utility function characterizing the behavior of the representative individual. Hansen and Singleton [1982] and Mankiw [1981] show how to test the overidentifying restrictions that are implied by the hypothesis of continuous optimization of a stable additively separable utility function. The major virtue of the approach pioneered by these authors is that it permits the direct estimation of utility function parameters without requiring explicit solutions of the consumers' dynamic optimization problem. Unfortunately, both Hansen and Singleton and Mankiw report rejections of their estimated models.

This paper uses techniques similar to those developed in connection with consumption to estimate the parameters of an intertemporal utility function characterizing the labor supply behavior of the representative consumer. This permits judgments about the magnitude of the key intertemporal elasticities. In addition, we can directly test the hypothesis of dynamic optimization using the implied overidentifying restrictions on the data. Another motivation for this research is the rejection of the overidentifying restrictions in the models Hansen and Singleton [1982] and Mankiw [1981] estimate. These models all maintain the assumption that the marginal utility of consumption depends only on the level of consumption. It is natural to entertain the hypothesis that the utility function is not separable so that the marginal utility of consumption depends on the level of leisure. The intertemporal utility functions we estimate allow this possibility.

Papers like those of Lucas and Rapping [1969], Altonji [1982], and Hall [1980] attempt to estimate the structural labor supply functions that result from the dynamic optimization of a representative individual. These studies face three difficulties. First, the closed-form solution of this optimization problem is unknown when the environment is stochastic. Second, identification is problematic. Since the labor supply schedule is likely to shift through time, it is inappropriate to regard the real wage as an exogenous variable. The problem is that satisfactory instruments are almost impossible to find. Labor supply shocks are likely to affect most macroeconomic policy variables.

The third difficulty involves the measurement of expectations. The theory holds that labor supply should be a function of the distribution of the entire path of future real wages and interest rates, not just of the first moments of those variables in the succeeding period. Satisfactory proxies for these expectations are almost impossible to develop.

Altonji [1982] also estimated, for a utility function that is separable in consumption and leisure, the first-order condition that equates the real wage and the marginal rate of substitution of consumption for leisure. This is analogous to some of the procedures used in this paper.

In recent papers MaCurdy [1981a,b] examines intertemporal substitution effects at the microeconometric level. It might at first seem that micro data provide a much firmer basis for estimating intertemporal substitution effects than do aggregate data. However, the use of micro data involves serious problems.

At the micro level even when wages and changes in wages are treated as endogenous, variables like schooling and age are used as instruments for the wage. The validity of these variables as instruments is doubtful, since they are likely to be correlated with the individual's taste for working.

III. THEORY

This section describes the model. Its estimation requires a number of auxiliary assumptions about the behavior of consumers. These assumptions pertain to issues such as the information set available to consumers and the functional form of their utility functions. Tests of the model are also tests of these auxiliary assumptions, so they require careful attention. We make a major effort to explore alternative sets of auxiliary assumptions to increase the robustness of our conclusion regarding the economic issues of major interest.

We examine a basic premise of many classical macroeconomic models that observed movements in per capita consumption and leisure correspond to the behavior of a rational individual who derives pleasure from these two goods and whose utility function is stationary and additively separable over time.[1] That is,

$$V_t = E_t \sum_{\tau=t}^{\infty} \rho^{\tau-t} U(C_\tau, L_\tau). \tag{1}$$

Here, V_t is expected utility at t, E_t is the expectations operator conditional on information available at t, ρ is a constant discount factor, C_τ is consumption of goods at τ, L_τ is leisure at τ, and U is a function that is increasing and concave in its two arguments.

1. The models of Prescott and Mehra [1980], Long and Plosser [1983], and King and Plosser [1984], for example, exhibit this feature. Some models such as those of Kydland and Prescott [1982] rely on the absence of additive separability to generate intertemporal substitution effects. We return to this possibility in the final section of the paper.

Given a specification of the budget constraint, and of the conditional distributions of all future wages, prices, and rates of return on all assets, it would in principle be possible to use (1) to find consumers' choices of consumption and leisure at time t. In practice, it is almost impossible to conceive of all this information being available to the econometrician. Even if it were available, analytical solutions of (1) do not exist even for very simply functional forms. Therefore, following earlier work on consumption by Mankiw [1981], Hansen and Singleton [1981], and Hall [1982], we attempt to estimate directly the form of U in (1) without specifying a model capable of predicting the chosen levels of C_t and L_t. We exploit the restrictions on the data imposed by the first-order conditions necessary for the maximization of (1) subject to a budget constraint.

We assume that the representative individual has access to some financial assets which can be both bought and sold. In addition, he has access to spot markets in which labor and consumption are freely traded. As long as the optimum path lies in the interior of the budget set, we can use simple perturbation arguments to establish certain characteristics of this optimal path. At any point along an optimal path, the representative individual cannot make himself better off by forgoing one unit of consumption or leisure at time t and using the proceeds to purchase any other good at any other point in time. In particular, when the representative individual is following his optimal path of consumption and leisure, these three first-order conditions must hold.

$$\text{(S):} \qquad \frac{W_t\, \partial U/\partial C_t}{P_t\, \partial U/\partial L_t} - 1 = 0$$

$$\text{(EC):} \qquad E_t\, \rho\, \frac{\partial U/\partial C_{t+1}}{\partial U/\partial C_t} \frac{P_t(1 + r_t)}{P_{t+1}} - 1 = 0$$

$$\text{(EL):} \qquad \mathrm{E}_t\, \rho\, \frac{\partial U/\partial L_{t+1}}{\partial U/\partial L_t} \frac{W_t(1 + r_t)}{W_{t+1}} - 1 = 0.$$

Here, P_t is the nominal price of a unit of C_t, W_t is the wage the individual receives when he forgoes one unit of L_t, and r_t is the nominal return from holding a security between t and $t + 1$.[2]

The static first-order condition (S) says that the individual cannot make himself better off by forgoing one unit of consump-

2. If more than one security is available, (EC) and (EL) should hold for all securities that can be freely bought and sold.

tion (thereby decreasing his utility by $\partial U/\partial C_t$) and spending the proceeds (P_t) on P_t/W_t units of leisure, each of which he values at $\partial U/\partial L_t$. The reverse transaction is also unable to increase his utility. Note that the model considered here, in which tastes are constant, implies that equation (S) holds exactly. Since we assume at time t that the consumer knows the real wage $(W/P)_t$, he chooses consumption and leisure to equate the real wage and the marginal rate of substitution.

The Euler equation for consumption (EC) states that along an optimal path the representative individual cannot alter his expected utility by giving up one unit of consumption in period t, investing its cost in any available security, and consuming the proceeds in period $t + 1$. The utility cost of giving up a unit of consumption in period t is given by $\partial U/\partial C_t$. The expected utility gain is given by

$$E_t\, \rho \frac{\partial U}{\partial C_{t+1}} \frac{P_t}{P_{t+1}} (1 + r_t).$$

Equating the cost and gain from this perturbation yields the first-order condition (EC). It is important to be clear about the generality of this result. The condition (EC) will hold even if labor supply cannot be freely chosen, and trading is not possible in many assets, as long as some asset exists which is either held in positive amounts or for which borrowing is possible.

Finally, the Euler equation for leisure (EL) asserts that along an optimal path the representative individual cannot improve his welfare by working one hour more at t (thereby losing $\partial U/\partial L_t$ of utility) and using his earnings W_t to purchase a security whose proceeds will be used to buy back $W_t(1 + r_t)/W_{t+1}$ of leisure at $t + 1$ in all states of nature. Such an investment would increase expected utility by $E_t\rho[\partial U/\partial L_{t+1}]W_t(1 + r_t)/W_{t+1}$. Therefore, (EL) ensures that this expression is equal to $\partial U/\partial L_t$.

If the static first-order condition (S) held exactly, one of (EC) and (EL) would be redundant. We can see this by replacing $\partial U/\partial C_t$ and $\partial U/\partial C_{t+1}$ in (EC) using (S). This procedure produces (EL). However, since (S) is unlikely to hold exactly in the data, we use the information in all three of these first-order conditions to estimate the parameters of the utility function (1).

In order to estimate the instantaneous utility function U, it is necessary to specify a functional form. The most general utility function we use is

$$(2) \qquad U(C_t,L_t) = \frac{1}{1-\gamma}\left[\frac{C_t^{1-\alpha}-1}{1-\alpha} + d\,\frac{L_t^{1-\beta}-1}{1-\beta}\right]^{1-\gamma}.$$

This utility function, which is similar to MaCurdy's [1981], has, as special cases, an additively separable utility function in consumption and leisure, ($\gamma = 0$);[3] a CES form for the ordinal utility function characterizing single-period decision making ($\alpha = \beta$);[4] and a logarithmic utility function ($\alpha = 1, \beta = 1, \gamma = 0$). This functional form also provides for the possibility of differential degrees of intertemporal substitution in consumption and leisure. This is easiest to see when $\gamma = 0$, so that $1/\alpha$ represents the elasticity of intertemporal substitution consumption and $1/\beta$ represents the corresponding elasticity for leisure.[5]

Previous work on intertemporal substitution in consumption estimates the condition (EC) maintaining the hypothesis that $\gamma = 0$. Even if this supposition is correct, this is not an efficient estimation procedure, since it neglects the information contained in (S).

Below, we describe how to test statistically the orthogonality restrictions implied by the hypothesis of dynamic optimization. Here, we describe how the parameter estimates can be used to examine the issues of economic interest. This may provide a more satisfactory way of testing the relevance of the model than is provided by statistical tests of overidentifying restrictions. The model is at best an approximation to reality. Therefore, with enough data the point hypotheses corresponding to the overidentifying restrictions will be rejected at any given critical value.

We assess the estimates in two ways: by checking that they obey the restriction on utility functions implied by economic theory, and by examining the implied values of short-run and long-run elasticities. Theory requires that the function U be concave;

3. This restricted utility function ($\gamma = 0$) is the one considered by Altonji [1981] and Blinder [1974] among others.

4. In fact, we consider a slight variation of (2) when we impose $\alpha = \beta$. This variation, which has been used by Auerbach and Kotlikoff [1981] and Lipton and Sachs [1981], is given by $[C_t^{1-\alpha} + dL_t^{1-\alpha}]^{1-\gamma/1-\alpha)}$. This utility function has the advantage that α and γ are readily interpretable. $1/\alpha$ is the elasticity of substitution of consumption for leisure, while $1/\gamma$ is the intertemporal elasticity of substitution of the composite good $[C_t^{1-\alpha} + dL_t^{1-\alpha}]$ $(1/1 - \alpha)$.

5. This elasticity is simply the percentage change in the ratio of consumption (or leisure) at $t + 1$ to consumption (or leisure) at t over the percentage change in the real interest rate $P_t(1 + r_t)/P_{t+1}$ (or $W_t(1 + r_t)/W_{t+1}$). Elasticities like these have been studied by Hall [1981] and Hansen and Singleton [1982].

otherwise, the first-order conditions correspond to a local minimum or saddle-point rather than a local maximum. We check this by verifying that the matrix of second derivatives of U is negative definite at all points in our sample.

In informal discussion of the importance of intertemporal substitution, it is often pointed out that the responses of consumption and leisure to temporary changes in prices and wages must be different from the response to permanent changes in these magnitudes. However, the actual responses are impossible to compute without first solving the stochastic control problem whose objective is (1). Instead, we compute some simple measures of responses of consumption and leisure. We derive all measures under the assumption that individuals face a deterministic environment.

The "short-run" elasticities illustrate the changes in consumption and leisure at t in response to temporary changes in W_t, P_t, and r_t. We derive these elasticities under the assumption that the effects of these changes on consumption and leisure after t can be neglected. These effects are all mediated through the change in total wealth at $t + 1$ that results from the changes in W_t, P_t, and r_t. Insofar as this change in wealth must be very small compared with the wealth of the individual at $t + 1$ if he still has long to live, this approximation is valid. The "short-run" elasticities can be computed by totally differentiating (EC) and (EL):

$$\begin{bmatrix} C_t\dfrac{\partial^2 U}{\partial C_t^2} & L_t\dfrac{\partial^2 U}{\partial C_t\,\partial L_t} \\ C_t\dfrac{\partial^2 U}{\partial C_t\,\partial L_t} & L_t\dfrac{\partial^2 U}{\partial L_t^2} \end{bmatrix} \begin{bmatrix} \dfrac{dC_t}{C_t} \\ \dfrac{dL_t}{L_t} \end{bmatrix} = \begin{bmatrix} \dfrac{\rho P_t(1+r_t)}{P_{t+1}}\dfrac{\partial U}{\partial C_{t+1}} & 0 & \dfrac{\rho P_t(1+r_t)}{P_{t+1}}\dfrac{\partial U}{\partial C_{t+1}} \\ 0 & \dfrac{\rho W_t(1+r_t)}{W_{t+1}}\dfrac{\partial U}{\partial C_{t+1}} & \dfrac{\rho W_t(1+r_t)}{W_{t+1}}\dfrac{\partial U}{\partial C_{t+1}} \end{bmatrix} \begin{bmatrix} \dfrac{dP_t}{P_t} \\ \dfrac{dW_t}{W_t} \\ \dfrac{dr_t}{1+r_t} \end{bmatrix}. \tag{3}$$

One simple measure of the "long-run" or average response of consumption and leisure when the real wage changes permanently is obtained from assuming that the individual has no nonlabor income, that both the real interest rate in terms of leisure and the one in terms of consumption $[P_t(1 + r_t)]/P_{t+1}$ and $[W_t(1 + r_t)]/W_{t+1}$ are equal to $1/\rho$. Then, the individual plans to maintain a constant level of consumption and of leisure. His plan is consistent with a static budget constraint that makes his expenditure on consumption equal to his labor income:

$$C_t - (W_t/P_t)(N - L_t) = 0, \tag{4}$$

where N is his endowment of leisure. Totally differentiating (4) and (S), one obtains the following long-run elasticities:

$$\begin{bmatrix} C_t & \frac{W}{P}L_t \\ \frac{C_t\,\partial^2U/\partial C_t^2}{\partial U/\partial L_t} - \frac{C_t\,\partial^2U/\partial C_t\,\partial L_t}{(\partial U/\partial L_t)^2} & \frac{L_t\partial^2U/\partial C_t\,\partial L_t}{\partial U/\partial L_t} - \frac{L_t\partial U/\partial C_t\,\partial^2U/\partial L_t^2}{(\partial U/\partial L_t)^2} \end{bmatrix} \begin{bmatrix} \frac{dC_t}{C_t} \\ \frac{dL_t}{L_t} \end{bmatrix} \tag{5}$$

$$= \begin{bmatrix} (N - L_t)\frac{W_t}{P_t} \\ \frac{P_t}{W_t} \end{bmatrix} \frac{d(W_t/P_t)}{(W_t/P_t)}.$$

IV. Data

Estimation of the parameters of (2) requires several choices about the data to be used. These choices are of pivotal importance because the estimation results depend on their validity as well as on the basic theoretical notions being examined.

The first-order conditions (S), (EC), and (EL) characterize optimization for a single individual with a given utility function. Their application to aggregate data is more problematic. Rubinstein [1974] presents results showing that if all individuals have identical, separable utility functions, and if all risky assets including human capital are freely traded, the model we consider here can be rigorously justified as applied to aggregate data. To state these conditions is to recognize their falsity. They imply that the consumption of all individuals should be perfectly correlated. Hall and Mishkin [1982] present data indicating that, at least using one measure of consumption, there is only negligible correlation between the consumption of different individuals.[6] It

6. Grossman and Shiller present another aggregation theorem. However, their theorem cannot be used to rigorously justify the estimation of a representative consumer's utility function as is done here. Their results are only local and so do not apply over the discrete intervals that generate the data, unless the utility function has a special form, different from the one assumed here. Furthermore, their theorem assumes interior solutions for each agent, which is unrealistic for leisure.

is standard in studying consumption to model per capita consumption as if it were chosen by a representative consumer. We follow the standard convention of using consumption and labor input per member of the adult population. As Summers [1982] points out, the rationale for this procedure is unclear. If it is appropriate to give individuals under 16 zero weight, presumably because they consume little, might it not also be appropriate to weight individuals of different ages according to their consumption or labor supply in constructing per capita variables? This approach is taken in Summers [1982] where it has a significant impact on the results. It is not pursued here because of the difficulty in finding a population index that is appropriate for both consumption and leisure.

The main problem with measuring consumption is that the available data pertain to consumer expenditure, which, as Mankiw [1982] points out, has a durable component. The pen with which this sentence is written was classified as nondurable consumption nine months ago. We use as our measure of consumption alternatively real expenditures on nondurables and nondurables and services as reported in the National Income and Product Accounts. The NIPA price deflators are used to measure prices.[7]

The measurement of leisure also poses problems. Somewhat arbitrarily we specify that the representative individual has a time endowment of $7 \times 16 = 112$ hours a week. We compute leisure by subtracting per capita total hours worked by the civilian labor force from this time endowment. In principle, it would be possible to estimate econometrically the size of the time endowment. In practice, this parameter is difficult to estimate, so we constrain it a priori. The specification we adopt here based on total hours worked is open to the serious criticism that it does not distinguish between changes in the number of persons working and in average hours per worker. The former poses serious problems for the model, since the first-order conditions (S) and

7. Both measures of consumption with which we experiment in this study can proxy only part of total consumption, since the expenditure and the services from durable goods are completely excluded. Implicitly, each of our alternative specifications impose the assumption that the excluded forms of consumption enter the utility function in additively separable ways. This standard assumption is obviously problematic. Consider freezers and food, or cars and gasoline. An alternative defense of using a subset of consumption as a proxy for aggregate consumption is to rely on Hicks or Leontief aggregation. There is, however, no empirical support for the view that either the relative price of different types of consumption is fixed or that different goods are consumed in fixed proportions.

(EL) need not hold for individuals whose labor supply is at the corner solution of zero hours worked.

The measurement of the price of leisure, the wage, also involves a choice between less than fully satisfactory alternatives. The series we use refers to average total compensation of employees in the nonfarm business sector. We calculate after-tax wages by using a time series of marginal tax rates on labor income, measured as the sum of Federal Income taxes,[8] Social Security taxes, and state income taxes. The problems with this measure of wages include its partial coverage and its failure to include some forms of compensation, such as the accrual of Social Security and private pension benefits. Perhaps more seriously, the extent to which market wages reflect the marginal return from working has been questioned. Hall [1980] argues that certain features of the economy's cyclical behavior can be explained by assuming that wages do not reflect true compensation for working on a period-by-period basis, even though the economy always attains the Walrasian equilibrium level of employment.

The final data decision is the choice of an asset return r. We experiment with estimates of both the before- and after-tax Treasury Bill interest rate. As a crude approximation, we assume a 30 percent tax rate on interest income. Since the results are fairly similar, only the after-tax results are reported. The Treasury Bill rate is appropriate for recent years when savings instruments paying near market rates of return were widely available. Its appropriateness is less clear during the bulk of the sample period when interest rate ceilings constrained the rates obtainable by most individuals. The extent to which installment credit rates match with the Treasury Bill rate is not clear. Summers [1982] finds very similar results in a study of fluctuations in consumption that uses both time deposit and Treasury Bill yields. The time deposit rate is not used here because data are not available over a long enough period.

A final issue is the appropriate period of observation. As is now well-known, the use of discrete time data can lead to biases if the data are generated by a continuous time process. In particular, time averages of a random walk will not have serially uncorrelated increments. There is the additional problem that the link between consumption and consumption expenditure is likely to be better at lower than at higher frequencies. Because of the

8. The data on average Federal marginal tax rates came from Seater [1980].

latter problem we reject the common view that models of this type should be estimated with data for as short a period as possible. In addition, the assumption of additive separability is more realistic for large period lengths. We use two different procedures. The first, which we employ with apology but without excuse, is to use seasonally adjusted quarterly data. There is a risk that the averaging involved in seasonal adjustment disturbs the results. The second procedure involves using only data from the fourth quarter of each year. The interval between observations reduces time aggregation problems. In addition, the gap between observations may reduce the problems that come from the use of expenditure to proxy consumption. Finally, the use of data from only one quarter may reduce seasonality problems.

An Appendix containing the data we used is available from the authors upon request. We use three lists of instruments for every specification we estimate. List A includes a constant, the rates of inflation between $t - 2$ and $t - 1$ and between $t - 5$ and $t - 1$, the nominal rate of return between $t - 1$ and t, and the holding period yield between $t - 5$ and $t - 1$. List B includes a constant and the levels of consumption, the interest rate, leisure, prices, and wages at $t - 1$ and $t - 2$. Instead, List C includes the values of these variables at t and $t - 1$. Therefore, list C allows us to check whether the estimates worsen when current variables are included as instruments.

V. Estimation Method

We estimate the parameters α, β, d, and γ of the function U given by (2). This is done by fitting the implied first-order conditions (S), (EC), and (EL) to U. S. data. Hansen and Singleton [1982] suggest that the theoretically correct method for estimating Euler equations like (EC) and (EL) is a nonlinear instrumental variables procedure. The rationale for this procedure can be stated as follows: the equations (EC) and (EL) state that the expectation at t of a function of variables at t and $(t + 1)$ is zero. Hence they can be written as $E_t h(X_{t+1},\theta) = 0$, where h is a vector function, X_{t+1} includes variables at t and $t + 1$ and θ is a vector of parameters. This implies that the expectation of the product of any variable in the information set at t with the actual values of $h(X_{t+1},\theta)$ must be zero. This suggests as a natural estimator for θ the value of θ that minimizes an appropriately weighted sum of the squares of the product of instruments at t with

$h(X_{t+1},\theta)$. Hansen [1982] derived the weights that produce the smallest asymptotic standard errors for θ even when the h's are heteroskedastic conditional on the instruments. For simplicity, we assume instead that the h's are conditionally homoskedastic. This allows estimation by three-stage least squares.[9]

Hansen [1982] also provides a statistic J, which, under the null hypothesis, is asymptotically distributed as χ^2 with degrees of freedom equal to $(qm - r)$, where q is the number of equations, m the number of instruments, and r is the number of estimated parameters. This provides a very simple test of the overidentifying restrictions. These restrictions simply require that the addition of extra instruments should not increase the value of J very much. This is so because, according to the model, at the true θ, the expectation of the cross product of any new instrument and h is zero.

The main problem with using any variable in the information set at t as an instrument is that this procedure is appropriate only when the sole reason for h to differ from zero is that, at $t + 1$, agents discover new information about prices and incomes. If this were indeed the only source of uncertainty in the economy, then the static condition (S) would hold exactly; there is no reason for the marginal rate of substitution of consumption for leisure to be different from the real wage. However, it is inevitable that any empirical estimate of (S) will not fit perfectly. Any of the natural explanations of this residual seems to invalidate the use as instruments of all the variables known at t. One explanation is that tastes are random and that, for instance, d follows a stochastic process. This is the view taken in Altonji [1982] when he estimates a version of (S). However, if d were stochastic, our methods would not allow us to estimate (EL) and (EC). Other explanations include the presence of errors of measurement of the variables, errors of specification, the presence of nominal contracts, and the absence of full information by the agents at t about variables that occur at t. These last two explanations for the residual in (S) appear to be consistent with assuming that all three first-order conditions hold in expectation with respect to a weaker conditioning set than the one Hansen and Singleton [1981] suggest.

In particular, suppose that workers sign contracts at $t - 1$

9. We also reestimated some of our equations allowing for conditional heteroskedasticity without affecting our results.

for t specifying the nominal wage and the amount they will work. Then, the static first-order condition becomes

$$E_{t-1}\frac{\partial U}{\partial L_t} = E_{t-1}\frac{\partial U}{\partial C_t}\frac{W_t}{P_t}.$$

When the utility function is separable in consumption and leisure, $E_{t-1}(\partial U/\partial L_t)$ becomes known as $t - 1$, and this condition reduces to (S) with an error term uncorrelated with information available at $t - 1$. Likewise, in a model like that of Lucas [1973] the first-order conditions would hold when the conditioning set is the set of economy wide variables known by agents at t. However, the aggregation over agents who signed contracts at different dates or over agents who have different private information might present serious difficulties. In any event, these considerations suggest that an appropriate estimator of α, β, d, and γ can be obtained by estimating the system of equations (S), (EL), and (EC) by nonlinear three-stage least squares where the instruments are variables whose realizations occur before t. In fact, we compare the results of using current and lagged instruments with those of using only lagged instruments.

The estimation of the systems might be thought to present a problem, since the residuals are not independent. Indeed, letting u_t^s, u_{t+1}^{EC}, and u_{t+1}^{EL} denote the residuals of (S), (EC), and (EL) as these equations are written in Section III, we see it is easy to verify that

$$(1 + u_{t+1}^{EC})(1 + u_t^s) = (1 + u_{t+1}^s)(1 + u_{t+1}^{EL}).$$

This does not, however, make one equation redundant from the point of view of estimation because the products of instruments and residuals in one equation are not linear combinations of the products of instruments and residuals of the other equations.[10]

VI. RESULTS

We begin by estimating the three first-order conditions separately, since each of these equations requires a different set of assumptions regarding which markets clear. We then estimate

10. The inclusion of the third equation is analogous to the inclusion as instruments of nonlinear transformations of the instruments. Such an inclusion would also leave the asymptotic properties of our estimators intact.

the entire system of equations. These system estimates require that the individual does not face a quantity constraint in any market. Because the estimated parameters using only fourth quarter data are essentially identical to those using quarterly data, we report only the latter.

The first Euler equation (EC) requires that the expectation of the product of the marginal rate of substitution between consumption in t and consumption in $t + 1$ with the real interest rate equals unity. This condition holds so long as the individual is not constrained either in the goods market or in the capital market. In particular, (EC) does not embody any assumption regarding the determination of the level of employment.

Table I contains the estimates of (EC) imposing additive separability between consumption and leisure ($\gamma = 0$) as is done implicitly in earlier work. The estimates of α are positive, as is necessary for concavity. They vary between 0.09 and 0.51, and center at about 0.3. Other studies estimate this Euler equation in the additively separable case and generally report higher estimates of α. Hansen and Singleton [1982] find α to be about 0.8; Summers [1982] about 3; Mankiw [1981] about 4; and Hall [1981] about 15. *In all cases*, the overidentifying restrictions are clearly rejected, indicating that the orthogonality conditions upon which these estimates are premised do not hold. This is the same rejection Hansen and Singleton [1982] and Mankiw [1981] report. (We do not reject the overidentifying restrictions with only fourth

TABLE I

ESTIMATES OF EULER EQUATION FOR CONSUMPTION (EC) SEPARABLE CASE

	(1)	(2)	(3)	(4)	(5)	(6)
Consumption measure	*ND*	*ND*	*ND*	*ND* + *S*	*ND* + *S*	*ND* + *S*
Instrument list	*A*	*B*	*C*	A	B	C
α	0.234	0.174	0.512	0.330	0.092	0.333
	(0.219)	(0.199)	(0.193)	(0.237)	(0.209)	(0.182)
ρ^{-1}	0.997	0.997	0.996	0.996	0.997	0.996
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Concave?	Yes	Yes	Yes	Yes	Yes	Yes
J	25.48	43.06	35.43	24.8	47.41	44.78
Critical J^* at 1%	11.34	21.66	21.66	11.34	21.66	21.66

Standard errors are in parentheses.

quarter data.) Beyond the variations in the measure of consumption and the instrument list shown in the table, we also experimented with the use of pre-tax returns, with little impact on the results.

Table II contains the estimates of (EC) that allow nonseparability between consumption and leisure. The standard errors of the parameter estimates are extremely high. In particular, we cannot reject the null hypothesis of additive separability between consumption and leisure ($\gamma = 0$). Alternative values of α, β, and γ have very similar implications for the short-run and long-run behavioral elasticities. For example, if d is close to zero, it will be impossible to separately identify α and γ. Furthermore, we continue to reject the overidentifying restrictions. Thus, the rejection of the model Hansen and Singleton [1982] and Mankiw [1981] report cannot be attributed to their maintained hypothesis of separability between consumption and leisure.

The second Euler equation (EL) specifies that the product of the marginal rate of substitution of leisure in t and leisure in $t + 1$ and the real interest rate in terms of leisure has an expectation of 1. This condition is premised upon the absence of quantity constraints both in the capital market and in the labor market.

Table III presents the estimates of (EL) in the additive separable case. The estimates of β often have the wrong sign (negative) and are thus inconsistent with concavity. Note that when the concavity restriction is violated, the estimated parameters imply a utility function whose maximum is given by a corner solution, or which does not exist. In principle, concavity of the utility function should be imposed as it is impossible to observe interior solutions for consumption or leisure if the utility function were truly convex. In practice, imposing this restriction is difficult. Therefore, it is hard to interpret in a very meaningful way the standard errors or the parameters in the case where the concavity restrictions are rejected. Nonetheless, the data indicate no clear relation between the quantity of leisure and the relative price of present versus future leisure. This result casts serious doubt on the premise of most classical macroeconomic models that observed labor supply represents unconstrained choices given perceived opportunities. Note especially that the results are not very sensitive to the choice of instrument list. In particular, the use of lagged instruments to capture the possibility of imperfect information has little effect on the results.

TABLE II

ESTIMATES OF EULER EQUATION FOR CONSUMPTION (EC) NONSEPARABLE CASE

	(1)	(2)	(3)	(4)	(5)	(6)
Consumption measure	*ND*	*ND*	*ND*	*ND* + *S*	*ND* + *S*	*ND* + *S*
Instrument list	A	B	C	A	B	C
α	1.118	0.257	0.375	−0.204	0.147	0.799
	(118.13)	(1.568)	(1.302)	(15.94)	(4.112)	(0.393)
β	−45.827	151.9	150.99	−71.39	134.5	−41.858
	(12,839.8)	(472.3)	(612.97)	(872.6)	(248.95)	(800.2)
γ	−4.730	0.098	0.086	−0.537	0.1780	0.034
	(1299.3)	(1.592)	(1.329)	(21.8)	(3.757)	(0.549)
d	1.383	280.8	280.0	301.2	264.3	284.2
	(332.3)	(3,480.0)	(3,364.8)	(23,595.)	(2,840)	(4,454.)
ρ^{-1}	0.999	0.997	0.997	1.001	0.996	0.993
	(0.048)	(0.001)	(0.001)	(0.015)	(0.002)	(0.002)
Concave?	No	Yes	Yes	No	Yes	No
J		29.23	24.63		33.51	27.50
Critical J^* at 1%		16.81	16.81		16.81	16.81

Standard errors are in parentheses.

TABLE III

ESTIMATES OF EULER EQUATION FOR LEISURE (EL) SEPARABLE CASE

	(1)	(2)	(3)
Instrument list	A	B	C
β	-0.739	-0.996	0.121
	(0.959)	(0.474)	(0.480)
ρ^{-1}	0.994	0.994	0.994
	(0.001)	(0.001)	(0.001)
Concave?	No	No	Yes
J	8.47	15.75	21.7
Critical J^* at 1%	11.35	21.66	21.66

Standard errors are in parentheses.

Table IV presents the estimates of (EL) that allow nonseparability. The standard errors are huge, and thus do not reject separability. The estimated utility function is almost never concave. Hence, the failure reported above for the separable case cannot be attributed to the then maintained hypothesis of separability.

The third condition (S), which equates the marginal rate of substitution between consumption and leisure to the real wage, is the crucial test of labor-market clearing. Unlike either of the other first-order conditions, this static relation does not rely upon the assumed absence of liquidity constraints. It relies only upon the ability of the individual to trade off consumption and leisure within a single period. Since consumers are generally not constrained in the goods market, this equation should hold so long as observed employment lies on the labor supply curve.

Table V presents the estimates obtained from the estimation of (S). In almost every case, the estimate of α is positive, and the estimate of β is negative. We find these signs for different instrument lists, for different measures of consumption, for different frequency data, and for different estimation periods. Although not displayed, these signs also emerge when (S) is estimated in first differences. Altonji [1982] also reports estimates of α and β with these signs.

This result provides powerful evidence against the hypothesis that observed labor supply behavior can be described as resulting from continuous maximization of a stable additively separable intertemporal utility function. The estimated utility function is extremely implausible, as can be illustrated easily. Holding the

TABLE IV

ESTIMATES OF EULER EQUATION FOR LEISURE (EL) NONSEPARABLE CASE

	(1)	(2)	(3)	(4)	(5)	(6)
Consumption measure	*ND*	*ND*	*ND*	*ND* + *S*	*ND* + *S*	*ND* + *S*
Instrument list	A	B	C	A	B	C
α	2.286	−0.227	1.6332	1.696	1.970	2.947
	(5.490)	(39.4)	(35.9)	(2.975)	(2.434)	(64.315)
β	8.753	−1.032	0.1837	13.083	7.23	0.481
	(22.78)	(4.504)	(52.0)	(19.374)	(11.49)	(2344.9)
γ	−18.42	−0.318	−0.466	−21.457	−18.8	−9.678
	(217.3)	(9.155)	(30.4)	(143.31)	(110.1)	(1754.)
d	0.528	1.132	0.510	1.355	0.478	0.021
	(7.763)	(344.3)	(118.7)	(13.5)	(3.305)	(121.9)
ρ^{-1}	0.995	0.995	0.994	1.0002	0.996	0.994
	(0.001)	(0.0001)	(0.0009)	(0.008)	(0.002)	(0.002)
Concave?	No	No	No	No	No	Barely*
J		8.26	21.63		5.76	25.47
Critical J^* at 1%		16.81	16.81		16.81	16.81

Standard errors are in parentheses.
*The determinant of the matrix of second partials of U is negative, but very close to zero, making inversion of the matrix, and thus computation of elasticities, impossible.

TABLE V

ESTIMATES OF STATIC CONDITION (S)

	(1)	(2)	(3)	(4)	(5)	(6)
Consumption measure	*ND*	*ND*	*ND*	*ND* + *S*	*ND* + *S*	*ND* + *S*
Instrument list	A	B	C	A	B	C
α	1.873	2.377	4.636	3.694	3.639	2.789
	(0.118)	(0.053)	(0.040)	(0.035)	(0.032)	(0.032)
β	0.018	−1.107	−8.042	−5.426	−16.231	−0.212
	(1.417)	(1.097)	(5.306)	(10.038)	(9.324)	(4.235)
J	63.98	118.05	118.97	87.91	118.25	121.86
Critical J^* at 1%	9.21	20.09	20.09	9.21	20.09	20.09

Standard errors are in parentheses.

real wage constant, consider an increase in nonlabor income. If α and β have opposite signs, then either consumption or leisure must fall. That is, since consumption and leisure move in opposite directions for any given real wage, one must be inferior if the movements represent voluntary maximizing behavior. These results probably emerge because over the business cycle consumption and leisure move in opposite directions. At the same time, we simply do not observe at the aggregate level the procyclical movements in the real wage that would rationalize this behavior.

We next estimated the three first-order conditions jointly as a system. These estimates also generally rejected the overidentifying restrictions. In the separable case the estimates for β continued to be negative.

Table VI presents the system estimates for the nonseparable case. The estimated utility function is concave for only half of the estimates. In most of the concave cases, α and β have opposite signs, implying that either consumption or leisure is an inferior good.

We next experimented imposing the constraint $\alpha = \beta$. When γ was allowed to vary, the estimates were usually not concave. Only when we also imposed separability ($\gamma = 0$), did we obtain consistently concave parameters. In this latter case we obtained for all three instrument lists estimates of α near 1.5 for nondurables and near 1.0 for nondurables and services.

Various elasticities are presented in Table VII for those nonseparable estimates that imply a concave utility function.[11] Since the estimates of the utility function parameters vary greatly, the estimated elasticities also vary greatly. The long-run elasticity of consumption with respect to the wage is approximately 0.6, and the long-run elasticity of leisure with respect to the wage is 0.26, implying a backward-bending long-run labor supply curve.

Probably the most important elasticity for evaluating the intertemporal substitution hypothesis is the short-run elasticity of leisure with respect to the current wage. This elasticity varies from -0.0027 to -0.99 across estimates. This implies a short-run labor supply elasticity between 0.01 and 17, since leisure is

11. These elasticities are computed using data corresponding to the first quarter of 1980. A problem arises from the fact that all three equations have a residual in this period. This residual is ignored in our calculations that use the actual values for C, L, P, W, and r on both sides of (3) and (5). Alternatively, we could have changed some of these variables to make (S), (EC), and (EL) hold exactly and then computed the elasticities.

TABLE VI

SYSTEM ESTIMATES: NONSEPARABLE CASE

	(1)	(2)	(3)	(4)	(5)	(6)
Consumption measure	*ND*	*ND*	*ND*	*ND* + *S*	*ND* + *S*	*ND* + *S*
Instrument list	A	B	C	A	B	C
α	1.407	1.680	1.713	0.789	0.889	0.928
	(0.030)	(0.033)	(0.035)	(0.017)	(0.014)	(0.018)
β	−4.937	−0.340	0.158	−3.637	−1.718	−0.688
	(0.549)	(0.414)	(0.493)	(0.464)	(0.281)	(0.324)
γ	−6.452	0.050	0.321	−2.720	−2.716	0.080
	(1.791)	(0.035)	(1.178)	(0.967)	(0.602)	(0.176)
d	0.843	146.406	16.540	8.297	−0.640	114.612
	(0.448)	(71.198)	(68.970)	(4.112)	(0.776)	(310.028)
ρ^{-1}	0.997	0.994	0.993	0.999	0.997	0.993
	(0.001)	(0.0005)	(0.001)	(0.001)	(0.001)	(0.0005)
Concave?	No	Yes	Yes	No	No	Yes
J	21.308	41.91	47.23	31.45	99.07	128.24
Critical J^* at 1%	21.67	46.96	46.96	21.67	46.96	46.96

Standard errors are in parentheses.

TABLE VII

ELASTICITIES IMPLIED BY THE ESTIMATES

Table and column of estimates	II.2	II.3	II.5	VI.2	VI.3	VI.6
			Short-run elasticities			
C with respect to P	−3.1	−2.4	−3.4	−0.61	−0.60	−1.1
C with respect to W	0.0055	0.0047	0.0061	−0.64	0.55	1.8
C with respect to $1 + r$	−3.1	−2.3	−3.4	−0.045	−0.045	−0.72
L with respect to P	0.0015	0.00086	0.0038	0.0005	−0.18	0.21
L with respect to W	−0.0027	−0.0028	−0.0035	−0.36	−0.25	−0.99
L with respect to $1 + r$	−0.0013	−0.0020	−0.00030	−0.36	−0.22	−0.99
			Long-run elasticities			
C with respect to W/P					0.54	0.61
L with respect to W/P					0.26	0.26

roughly four times labor supply. Note that the elasticity of leisure with respect to changes in the interest rate is in all cases but one essentially identical to the elasticity with respect to the wage. The short-run elasticity of consumption with respect to changes in price varies from -0.6 to -3.4. It is not surprising, given the poor performance of the model that these short-run elasticities are not well pinned down.

VII. CONCLUSIONS

The empirical results reported in this paper are consistently disappointing. The overidentifying restrictions implied by the model of dynamic optimization in the absence of quantity constraints are rejected by virtually all of the estimates using quarterly data. The estimated utility function parameters always imply implausible behavior. We can conclude that the data strongly reject specifications of the type used in this paper. In this final section we examine a number of alternative explanations for the results obtained.

A first possibility is that our poor results are a consequence of problems of measurement and estimation. As emphasized in the initial discussion of the data, our measures of consumption and leisure are all open to question, as is our proxy for real returns. Probably more serious is the use of seasonally adjusted data. Seasonal fluctuations, which account for most of the variance in leisure, should be explained by dynamic optimization rather than averaged out as in our data. Utility presumably depends on actual consumption not on consumption as adjusted by $X - 11$. Time aggregation issues are possibly serious as well.

A second, more likely, possibility is that the auxiliary assumptions we maintain to make the problem tractable are false. Aggregation in models of this type is very problematic. It is also possible that our assumption of additive separability across time is the root of the problem. Over some intervals, this assumption is unwarranted. People who have worked hard want to rest. Mealtimes are not staggered through the day by accident. How serious these types of effects are at the macro level remains an open question. Clark and Summers [1979] examine several types of evidence bearing on the effects of previous employment experience on subsequent experience, and conclude that habit formation and persistence effects predominate over intertemporal substitution effects. This suggests that while nonseparability may help to explain the failure of our results, the sign of the key cross derivatives may well be the opposite of that usually assumed in intertemporal substitution theories.

A third general class of explanation for the results we obtained involves changing tastes. Just as the identification of traditional demand curves depends on the predominance of technological shocks relative to taste shocks, identification in models of the type estimated here depends on the maintained hypothesis of constant tastes. This is clearly a fiction. In every arena where taste shocks are easy to disentangle, fashion being an obvious example, they are pervasive. Even if the tastes of individuals were stable over time, the tastes of individuals of different ages differ, and the age distribution represented by the representative consumer has changed through time. An important topic for future research is the estimation of models that allow for changing tastes, either through random shocks, or endogenously on the basis of experience. The latter possibility relates closely to the problem of nonseparability in the utility function.

A final possible reason for the failure of the model is that individuals are constrained in the labor or capital market. The apparently large effects of sharp nominal contractions that have been observed in repeated historic episodes support the view that wages are rigid. Analyses of the macro character of unemployment, such as Clark and Summers [1979] and Akerlof and Main [1981], find that it is extremely concentrated among relatively few individuals whose employment is strongly pro-cyclical. This suggests a role for disequilibrium in certain labor market segments in explaining cyclical fluctuations.

In sum, the results of this investigation are discouraging. We find little evidence in favor of any of the models estimated here. In particular, we conclude that taking account of leisure does not rationalize the failure of previous models of consumption based on intertemporal decision making.

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