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**TESTING THE RESPONSE OF CONSUMPTION TO INCOME CHANGES
WITH (NOISY) PANEL DATA**

by

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ABSTRACT

This paper tests the rational expectations lifecycle model of consumption against (i) a simple Keynesian model and (ii) the rational expectations lifecycle model with imperfect capital markets. The tests are based upon the relative responsiveness of consumption to income changes which can be predicted from past information and income changes which cannot be predicted. Problems caused by measurement error in the income changes are circumvented by using the innovations from a vector autoregression of the measures of the determinants of income to form a noisy instrument for the unanticipated change in income, and using the lagged values of the measures of the income determinants to form an instrument for the anticipated income change. We show that the Keynesian model implies that the regression coefficients relating the change in consumption to the instruments for the anticipated and unanticipated components of the income change should be equal. The lifecycle model (with perfect capital markets) implies that only the instrument for the unanticipated component should affect consumption. The empirical results support the lifecycle model. In addition, we incorporate capital market imperfections into our empirical formulation of the lifecycle model by assuming that the marginal interest rate at a point in time is a differentiable, concave function of net assets. This leads to a test for capital market imperfections based upon whether consumption responds differently to positive and negative predictable changes in income. Our results are inconclusive.

1. Introduction

Starting with Hall and Mishkin's (1982) paper, researchers have begun using micro panel data sets to study rational expectations models of the response of consumption to income changes (e.g. Bernanke (1984), Hayashi (1984)).^{1,2} These studies assume that income is measured without error, usually to identify the consumption response to transitory income. This is a very strong assumption (as Hall and Mishkin point out), since many variables in micro data sets are widely believed to contain substantial measurement error, and the ratio of signal to noise in first differences of the data may be very poor.³ Indeed, Abowd and Card(1983) estimate that 75 to 90 percent of the variance of changes in the log of labor income in the Panel Study of Income Dynamics (Hall and Mishkin's data set) may be measurement error. For the same data Altonji (1984) finds strong evidence that the change in the log of labor earnings divided by annual hours worked contains a large amount of measurement error. Duncan and Hill (1984) have provided some more direct evidence on the importance of measurement error by comparing the responses of employees of a single large firm with the records of the employer. They find that measurement error accounts for 16.8 percent of the variance in the earnings level.⁴ Under reasonable assumptions, this would translate into a much larger percentage of the variance in the first difference of earnings.⁵ Measurement error in nonlabor income is likely to be an even more serious problem. In summary, the measurement error problem is likely to be important empirically.

Fortunately, large scale micro data sets such as the Panel Study of Income Dynamics contain a variety of measures of determinants of income, (such as wage rates, layoffs, quits, promotions, hours unemployed, and hours lost due to illness) that are based upon questions which are independent of the ones used to construct family income.⁶ If one is willing to assume that the measurement errors in the income determinants are independent of measurement errors in

reported income and consumption,⁷ then these variables provide some leverage with which to estimate structural models of the income process and consumption which account for measurement error, and, less ambitiously, to implement tests of the lifecycle model which are free of bias from measurement error.⁸ Use of indicators of the factors which drive income also makes it possible to relax the assumption made in many studies of the permanent income hypothesis that the income process is exogenous with respect to consumption preferences, and to integrate work on consumption of goods with research on lifecycle labor supply.⁹

For a rough quantitative assessment of the above issues, we regressed the first difference of the log of food consumption on the first difference of the log of family income for a sample from the Panel of Income Dynamics (described in Section 4). The coefficient estimate for the first difference of the log of family income was .076 with an estimated standard error of .013. If income is measured with error, then this estimated coefficient is biased downward. We reestimated the equation using a variety of income determinants as instrumental variables for the income variable. (The first stage regression is in Column 7, Table 1). The new point estimate is three times larger than the ordinary least squares estimate. (.229 with a standard error of .047.) This simple comparison suggests that (i) the measurement error problem for panel studies of consumption behavior is quantitatively important, and (ii) there are other variables in the data set that provide leverage to implement tests of consumption models which are free of bias from measurement error.

This paper tests the rational expectations (RE) lifecycle model of consumption against (i) a simple Keynesian model and (ii) the RE lifecycle model with imperfect capital markets. The tests are based upon the relative responsiveness of consumption to income changes which can be predicted from past information and income changes which cannot be predicted. If the substitution effects of wages and interest rates are unimportant, as is assumed in much of

the literature, then the RE-lifecycle model implies that changes in consumption are uncorrelated with past information about the change in income. Both the simple Keynesian consumption function and more sophisticated models with liquidity constraints imply otherwise.

The first set of tests simply checks whether the change in consumption is correlated with the past values of various variables which might be related to income and wealth, such as past wage changes, unemployment, and layoffs. This approach has been used in a number of time series studies, beginning with papers by Hall(1978) and Sargent (1978). Micro data tests have been conducted as well (Hall and Mishkin (1982), Hayashi(1984), Altonji (1984), Runkle (1983) and Zeldes (1984)), but these have worked with only a few variables.

The second set of tests, which also parallels work in the aggregate time series literature and is the main contribution of the paper, studies the relationship between the change in consumption and (partial) measures of anticipated and unanticipated changes in income. Problems caused by measurement error in the income changes may be circumvented by using the innovations from a vector autoregression of the measures of the determinants of income to form a noisy instrument for the unanticipated change in income and using the lagged values of the measures of the income determinants to form an instrument for the anticipated income change. Because of measurement errors, the VAR representation of the measures of income and its determinants is biased as a description of the VAR process for the true values of income and its determinants. In particular, it cannot be used to estimate the response of consumption to unanticipated transitory and permanent shocks to income. However, we show that the Keynesian model implies that the coefficients of a regression of the change in consumption on the instruments for the anticipated and unanticipated components of the income change should be equal, while a simplified RE-lifecycle model (which imposes the assumptions of perfect capital

markets and separability of preferences between consumption and leisure within the period and between periods) implies that only the instrument for the unanticipated component matters. These restrictions form the basis of our test of the models. They hold even though the instrument for the unanticipated change in income formed using the estimated VAR model is contaminated by past innovations in the true income determinants as well as measurement errors. The empirical results strongly support the lifecycle model.

Finally, we incorporate capital market imperfections into our empirical formulation of the RE-lifecycle model by assuming that the marginal interest rate at a point in time is a differentiable function of the net assets. This approach to modeling "liquidity constraints" leads to a simple modification of the conventional Euler equation for consumption and is analytically more tractable than approaches based upon discontinuous borrowing constraints. Our modified model, in common with models by Dolde (1978), Flemming (1973), Mariger (1983), and Zeldes (1984) using discontinuous constraints, implies that the response of consumption to positive and negative changes in income is asymmetric. We present a preliminary investigation of whether consumption responds differently to positive and negative predictable changes in consumption.

The paper is organized as follows. Section 2 presents the multivariate model for the change in income which is used to studying consumption behavior. Section 3 presents the RE-lifecycle and Keynesian model and discusses the restrictions which they impose on the relationship between the change in consumption and noisy measures of the unanticipated and anticipated components of the income change. Section 4 discusses econometric issues and data and Section 5 presents the results. Section 6 examines capital market imperfections constraints.

2: A Multivariate Model of the Change in Income

In this section we begin by presenting a model relating the change in the log of a noisy measure of family income to current and past values of a variety of explanatory variables, all of which may also be measured with error. It is easy to decompose the change in income into a (1) component which is predictable given information which is available to the consumer and (2) a component which is in part unanticipated by the consumer, and (3) a composite error term. One may then estimate the effects of the first two components on the change in consumption. We then present the RE-lifecycle model and a simple Keynesian model of the change in consumption. We show that they imply testable restrictions on the coefficients of the least squares regression of the consumption change on the two income components.

Let y_t denote real family income in period t . We assume that

$$(2.1) \quad \Delta \ln y_t = h_1 \Delta X_t^* + h_2 \Delta X_{t-1}^* + v_t$$

$$(2.2) \quad \Delta \ln y_t^* = h_1 \Delta X_t^* + h_2 \Delta X_{t-1}^* + v_t + \Delta \epsilon_{yt}$$

$$(2.3) \quad \Delta X_t^* = \Delta X_t + \Delta \epsilon_{xt}$$

In the above equations $\Delta \ln y_t$ is $\ln y_t - \ln y_{t-1}$. $\Delta \ln y_t^*$ is the sum of $\Delta \ln y_t$ and a measurement error $\Delta \epsilon_{yt}$. v_t is an error component. ΔX_t is a vector of exogenous determinants of income which are known to consumers at t , including determinants of wage rates, labor supply determinants, and constraints on hours. ΔX_t^* is a set of measures of ΔX_t and $\Delta \epsilon_{xt}$ is a vector of measurement errors in ΔX_t^* . Equation (2.1) and (2.2) are least squares linear prediction equations. The error component v_t is orthogonal to ΔX_t^* by definition of h_1 and h_2 .

Let the linear least squares prediction equation for ΔX_t^* be:

$$(2.4) \quad \Delta X_t^* = \theta(L) \Delta X_{t-1}^* + u_{xt} \quad .$$

where $\theta(L)$ is a matrix polynomial in the lag operator, L . Note that the composite error u_{xt} is serially uncorrelated but is a function of current and

past innovations in ΔX_t and current and past measurement errors.¹⁰ It is not possible to extract a clean measure of the innovation in ΔX_t from the ARMA representation of ΔX_t^* if ΔX_t^* is measured with error. Although u_{xt} is contaminated by measurement error and past innovations in ΔX_t , we will refer to it as a component of the unanticipated change in income for lack of a better name. Equations (2.2) and (2.4) imply that the regression equation relating Δny_t^* and ΔX_{t-1}^* is

$$(2.5) \quad \Delta ny_t^* = [h_2 + h_1 \theta(L)] \Delta X_{t-1}^* + h_1 u_{xt} + v_t + \Delta \varepsilon_{yt}$$

3: Implications of the Lifecycle and Keynesian Models of Consumption

Below we will examine the relationship between the change in consumption and the two components of the change in income using equation (3.0)

$$(3.0) \quad \Delta \ln C_t^* = \phi_1 h_1 u_{xt} + \phi_2 [h_2 + h_1 \theta(L)] \Delta X_{t-1}^* + \text{error}$$

which decomposes the consumption change $\Delta \ln C_t^*$ into its least squares linear projection on $h_1 u_{xt}$ and $[h_2 + h_1 \theta(L)] \Delta X_{t-1}^*$ and an orthogonal error. The equation provides a useful framework for testing because the RE-lifecycle model (with interperiod and intraperiod substitution effects and credit constraints ruled out) implies that $\phi_2 = 0$. Hueristically, ϕ_2 should be zero because $[h_2 + h_1 \theta(L)] \Delta X_{t-1}^*$ contains only old information and therefore should not affect current consumption given past consumption. Although $h_1 u_{xt}$ contain old information and measurement error, it also contains some new information which induces a nonzero coefficient on ϕ_1 . The Keynesian consumption model implies that $\phi_1 = \phi_2$. This because the coefficient relating $\Delta \ln C_t^*$ to Δny_t is the marginal propensity to consume. The regression coefficients relating Δny_t^* to $[h_2 + h_1 \theta(L)] \Delta X_{t-1}^*$ and $h_1 u_{xt}$ are both unity (see equation (2.5)). Both of these variables are orthogonal to each other and neither is related to the measurement error and taste shifters which affect $\Delta \ln C_t^*$. Therefore these two variables should have the same effects on $\Delta \ln C_t^*$ if the Keynesian model is

correct. We now systematically review the two alternative consumption models and establish their implications for (3.0).

3.1 The Lifecycle Model with Rational Expectations

The lifecycle model of consumer behavior under uncertainty is as follows. (See MaCurdy (1983) and Browning et al (1984) for more detailed discussions and references to the literature.) At age t consumers choose consumption C_t , and labor supply N_t to maximize the expected value of utility over their remaining lifetime. We assume throughout the paper that preferences are additively separable over time, which means that past and future consumption and hours decisions enter today's decision only through the budget constraint. The consumer objective function $\underline{U}_t$ is

$$(3.1) \quad \underline{U}_t = \sum_{i=0}^{T-t} \frac{U_{t+i}(C_{t+i}, N_{t+i})}{(1 + \delta)^{i-t}}$$

where U_{t+i} is the worker's within period utility function, δ is a discount factor, and T is the end of the planning horizon. For notational convenience, subscripts for individuals are left implicit. In maximizing (3.1) the consumer must satisfy the constraints

$$(3.2) \quad \underline{A}_{t+i+1} = (1 + r_{t+i}) R(A_{t+i}) \quad , \quad 0 \leq i \leq T-t$$

$$(3.3) \quad A_T \geq 0 \quad ,$$

where

$$A_{t+i} \equiv \underline{A}_{t+i} + w_{t+i}N_{t+i} - P_{t+i}C_{t+i};$$

w_t represents the worker's nominal wage at time t ; P_t is the price level at t . $\underline{A}_t$ is nominal wealth at the beginning of period t ; A_t is nominal wealth at the end of period t ; r_t is a base lending rate in period t such as the Treasury bill rate; and the return function $(1 + r_t)R(A_t)$ relates net wealth at the end of period t (A_t) to wealth at the beginning of period $t + 1$ ($\underline{A}_{t+1}$) given the base lending rate r_t . Equation (3.2) allows for the possibility

that the rate of return on net wealth (net wealth is negative for net borrowers) may be a function of the level of net wealth. If credit markets are perfect, then $R(A_t) = A_t$ and $R'(A_t)=1$.

Assuming an interior solution, the first order conditions with respect to C_t and N_t are

$$(3.4) \quad \partial U_t / \partial N_t = \partial U_t / \partial N_t (1+\delta)^{-t} + w_t \lambda_t = 0$$

$$(3.5) \quad \partial U_t / \partial C_t = \partial U_t / \partial C_t (1+\delta)^{-t} - P_t \lambda_t = 0$$

where λ_t is the expected value of the marginal utility of period t income and is influenced by the effect of current net wealth on current and future rates of return on net wealth. The optimal values of N_t and C_t must also satisfy the intertemporal first order condition

$$(3.6) \quad \lambda_t = E_t[\lambda_{t+1}[1 + r_t] R'(A_t)] , \quad \text{if} \quad 0 \leq t \leq T-1$$

where E_t is the expectations operator conditional on information available to the consumer in period t . Equation (3.6) states that the expected gain from an extra unit of wealth in period $t+1$ must be equal to its cost in terms of utility in period t .

The first order condition (3.6) for λ_t implies (after backdating one period) that

$$(3.7) \quad \lambda_t[1 + r_{t-1}]R'(A_{t-1}) = \lambda_{t-1} + \varepsilon_{\lambda t} \quad (1 \leq t \leq T)$$

where $\varepsilon_{\lambda t}$ is the forecast error

$$[\lambda_t[1 + r_{t-1}]R'(A_{t-1})] - E_t(\lambda_t[1 + r_{t-1}]R'(A_{t-1})).$$

Under rational expectations, $\varepsilon_{\lambda t}$ is orthogonal to the information available at $t-1$.

To proceed further, it is necessary to substitute a specific form for the marginal utility of consumption $\partial U_t / \partial C_t$. We assume that

$$(3.8) \quad \partial U_t / \partial C_t = \exp^{\varepsilon_{ct} C_t^{1/B_c}}.$$

This equation holds if within period preferences take the form

$$(3.9) \quad U_t(C_t, N_t) = [(B_c/B_c + 1) \exp^{\epsilon_{ct} C_t (1 + 1/B_c)} - \exp^{\epsilon_{nt} N_t (B_n/(1+B_n))}]^\gamma$$

where B_c and B_n are taste parameters (assumed constant across the sample) that satisfy the restrictions $B_c < 0$, $B_n > 0$, the terms ϵ_{ct} and ϵ_{nt} are taste shifters which vary over time for a given individual as well as across individuals, and the parameter γ is assumed to equal 1. The assumption that γ is set equal to 1 constrains preferences to be separable between consumption and leisure within the period.¹¹

The intertemporal optimality condition may be expressed in terms of the marginal utility of consumption by combining (3.5) and (3.7), yielding

$$(3.10) \quad [1+\delta]^{-t} [1/P_t] [1 + r_t] R'(A_{t-1}) \partial U_t / \partial C_t = [1+\delta]^{-t-1} [1/P_{t-1}] \partial U_{t-1} / \partial C_{t-1} + \epsilon_{\lambda t}$$

Substituting for $\partial U_t / \partial C_t$ from (3.8) into (3.10), taking logs of both sides of the equation, using a first order Taylor approximation of $\ln(\lambda_{t-1} + \epsilon_{\lambda t})$ around $\epsilon_{\lambda t}=0$ for each consumer, and using the fact that

$\ln(1 + r_{t-1}) \approx r_{t-1}$ leads to the approximation

$$(3.11) \quad \ln \lambda_t \approx \ln \lambda_{t-1} - r_{t-1} - \ln R'(A_{t-1}) + r_t$$

$$(3.12) \quad \Delta \ln C_t \approx \text{const} + B_c \Delta \ln P_t + B_c r_t - B_c [r_{t-1} + \ln R'(A_{t-1})] - B_c \Delta \epsilon_{ct}$$

$$(3.13) \quad \Delta \ln N_t + \Delta \ln w_t \approx \text{const} + [1 + B_n] \Delta \ln w_t - B_n [r_{t-1} + \ln R'(A_{t-1})] + B_n r_t + B_n \Delta \epsilon_{nt},$$

where r_t equals $\epsilon_{\lambda t} / \lambda_{t-1}$. The first difference equation for earnings implied by the difference equation for labor supply is presented as (3.13) in order to highlight the fact that income from labor is endogenous in the model.

The change in the marginal utility of income r_t summarizes the effects on consumer decisions via the budget constraint of changes in lifetime resources and preferences. For most preference structures an analytical solution for λ_t does not exist, and there is little hope of obtaining an analytical solution for the relationship between r_t and innovations in the exogenous factors entering the lifetime budget constraint. To proceed empirically, we specify r_t as a linear function of unanticipated changes in exogenous (with respect to

preferences) factors affecting income (such as wage rates) and preferences. In addition, since one may easily show in the perfect foresight case that λ_t is a decreasing function of w_{t+i} and $-\epsilon_{Nt+i}$, $i=0\dots T-t$, we assume in some of the discussion below that permanent shocks to these variables have larger effects on r_t than transitory ones. Since both of these variables are exogenous influences on income, in some of the discussion we also assume that relative size of the effects on r_t of unanticipated changes in the various exogenous factors driving w_{t+i} and ϵ_{Nt+i} are related to the size of effects of the unanticipated changes on the expected value of current and future earnings.

Specifically, we orthogonally decompose the revision r_t in the marginal utility of income into its least squares linear prediction given the scalar variable $h_1 u_{xt}$ and the error component ξ_t

$$(3.14) \quad r_t = b(h_1 u_{xt}) + \xi_t ,$$

where h_1 is the coefficient vector relating u_{xt} to $\Delta \ln y_t^*$ in (2.5) and the coefficient b depends on the size and degree of permanence in the effects of the components of ΔX_t^* on income.

To sharpen the contrast between the RE-lifecycle model and the Keynesian model we assume in our initial set of tests that credit markets are perfect. ($R'(A_t)=1$). Since the effects of changes in the price level and the base interest rate will be removed through the use of dummy variables for each year in the empirical analysis, we suppress these variables in the presentation.

Finally, we replace $\Delta \ln C_t$ with the consumption measure $\Delta \ln C_t^*$, which is equal to the true change in consumption plus measurement error, and use (3.14) to eliminate r_t from (3.12). With these modifications equation (3.12) becomes

$$(3.15) \quad \Delta \ln C_t^* = \text{const.} + B_c b h_1 u_{xt} + e_{ct} + B_c \xi_t$$

where e_{ct} is a (serially correlated) composite disturbance combining measurement error and variation in preferences.

A comparison of (3.15) with (3.0) establishes that the RE-lifecycle model implies that $\phi_2=0$, as was claimed above, and that the parameter ϕ_1 is equal to $B_c b$. Essentially, the restriction on ϕ_2 states that change in income arising from past ΔX^*_{t-1} or from the expected value of ΔX^*_t given ΔX^*_{t-1} have no effect on consumption. However, to establish that the coefficients ϕ_1 and ϕ_2 of the linear projection equation (3.0) are indeed $B_c b$ and 0 it is necessary to show that $h_1 u_{xt}$ and ΔX^*_{t-1} are uncorrelated with the error components in (3.15). $h_1 u_{xt}$ is uncorrelated with ξ_t by definition of ξ_t in (3.14). Both u_{xt} and ΔX^*_{t-1} are uncorrelated with e_{ct} by assumption about the properties of measurement errors and preferences for consumption. Since ΔX_{t-1} is known at $t-1$, ΔX^*_{t-1} is uncorrelated with the forecast error r_t , which implies (given 3.14) that it is uncorrelated with $b(h_1 u_{xt}) + \xi_t$. Since ΔX^*_{t-1} is also uncorrelated with $b(h_1 u_{xt})$ (by definition of u_{xt}) it must be uncorrelated with ξ_t as well.

It is important to keep in mind in examining the results below that the restriction $\phi_2=0$ is based upon the assumption of separability of preferences. King(1983) and many others have noted that nonseparability of preferences between consumption and leisure within a given time period and/or intertemporal nonseparability of preferences will lead to a nonzero correlation between the change in consumption and lagged determinants of the income change.¹² For example, past wages levels or unemployment may be related to past hours or consumption decisions, which in turn will affect the marginal utility of current consumption if preferences are not separable between periods. Alternatively a predictable change in the wage (and income) may be related to the consumption change due to intra-period substitution between consumption and leisure.^{13,14}

3.2: The Keynesian Model of Consumption

The essence of the Keynesian model of consumption is the hypothesis that

consumption varies with current income. In first differences of the logs of consumption and income the model may be represented as

$$(3.16) \quad \Delta \ln C_t^* = \text{const.} + \alpha \Delta \ln y_t^* - \alpha \Delta \epsilon_{yt} + e_{ct}$$

where e_{ct} is again used represent the sum of the effect of variation in preferences and the measurement error in the consumption data. Substituting for $\Delta \ln y_t^*$ from (2.5) leads to

$$(3.17) \quad \Delta \ln C_t^* = \text{const.} + \phi_1 u_{xt} + \alpha [h_1 \theta(L) + h_2] \Delta X_{t-1}^* + \alpha v_t + e_{ct}$$

Comparison of (3.17) with (3.0) indicates that the Keynesian model implies that $\phi_1 = \phi_2$, as claimed. That is, the component of $\Delta \ln y_t^*$ due to ΔX_{t-1}^* and the component arising from u_{xt} have the same affect on $\Delta \ln C_t^*$. $h_1 u_{xt}$ and ΔX_{t-1}^* are both orthogonal to v_t and e_{ct} given the definition of v_t in (2.1), the assumption that the measurement error components are independent of the true variables and each other, and the assumption that ΔX_t is unrelated to shifts in consumption preferences. Consequently, coefficients ϕ_1 and ϕ_2 of linear projection equation (3.0) are equal to α if the Keynesian model is correct.

Why are the income determinants ΔX_t^* essential to the above analysis? It is easy to show that the restrictions on ϕ_1 and ϕ_2 implied by the RE-lifecycle model and the Keynesian model do not hold if measurement errors in ΔX_t^* or its lags are correlated with measurement error in $\Delta \ln y_t^*$. Such a correlation would exist if $\ln y_t^*$ contained a serially uncorrelated measurement error and one were to use $\Delta \ln y_{t-1}^*$ as the sole element of ΔX_{t-1}^* in estimating the model. We show below that ignoring measurement error leads one to accept the Keynesian model while rejecting the RE-lifecycle model.

In addition to the above test, we extend earlier analyses of the effect of past income on the consumption change by analyzing the relationship between ΔC_t^* and ΔX_{t-1}^* , with ΔX_t^* left out of the model. The Keynesian model

obviously implies that the relationship is

$$(3.18) \quad \Delta \ln C_t^* = \alpha[h_2 + h_1 \theta(L)] \Delta X_{t-1}^* + e_{ct} + \alpha h_1 u_{xt} + \alpha v_t$$

where $h_1 u_{xt}$ is treated as part of the error term. The RE-lifecycle model implies that the coefficient on ΔX_{t-1}^* and its lags are all 0.

4: Econometric Methodology and Data

Estimation of (3.0) is complicated by the fact that $h_1 u_{xt}$ and $[h_2 + h_1 \theta(L)] X_{t-1}^*$ are unobserved. However, one may form instruments for these variables from regressions of $\Delta \ln y_t^*$ on ΔX_t^* and its lags. In practice it is convenient to use the fact that

$$(4.1) \quad h_1 u_{xt} = [h_1 \Delta X_t^* + h_2 \Delta X_{t-1}^*] - (h_1 \theta(L) + h_2) \Delta X_{t-1}^*$$

to rewrite (3.0) in the form

$$(4.2) \quad \Delta \ln C_t^* = \text{const.} + \phi_1 [h_1 \Delta X_t^* + h_2 \Delta X_{t-1}^*] + [\phi_2 - \phi_1] [h_2 + h_1 \theta(L)] \Delta X_{t-1}^* + \text{error.}$$

We then rewrite (4.2) by replacing $[h_2 + h_1 \theta(L)] \Delta X_{t-1}^*$ with the estimate $\hat{[h_2 + h_1 \theta(L)] \Delta X_{t-1}^*}$ obtained from least squares estimation of (2.5) and by using equation (2.2) to replace the unobservable $[h_1 \Delta X_t^* + h_2 \Delta X_{t-1}^*]$ with $\Delta \ln y_t^*$ and an error component. These changes lead to

$$(4.3) \quad \Delta \ln C_t^* = \text{const.} + \phi_1 \Delta \ln y_t^* + [\phi_2 - \phi_1] [h_2 + \hat{h_1 \theta(L)}] \Delta X_{t-1}^* - \\ [\phi_2 - \phi_1] [\hat{h_2 + h_1 \theta(L)}] \Delta X_{t-1}^* + \text{error,}$$

where $[\phi_2 - \phi_1] [\hat{h_2 + h_1 \theta(L)}] \Delta X_{t-1}^* - [\phi_2 - \phi_1] [h_2 + \hat{h_1 \theta(L)}] \Delta X_{t-1}^*$ is treated as part of the error term for equation (4.3).

Equation (4.3) may be estimated by two stage least squares using ΔX_t^* and ΔX_{t-1}^* as instrumental variables for $\Delta \ln y_t^*$.

The composite error term in (4.3) is probably serially correlated over the time for the same individual and heteroscedastic. For this reason, we have used a variant of the formulae in Chamberlain (1982, pg. 56) and White (1984, pg. 143) to compute standard errors which account for non-parametric forms of heteroscedasticity and correlations over time for a given family at

one and two lags.¹⁵

Another complication in the error term in (4.3) arise from the fact that we use a two step procedure in estimating equation (4.2). If the Keynesian hypothesis correct, then then the reported standard errors are consistent (see Pagan (1984)). If the RE-lifecycle model is correct, the reported standard errors may be inconsistent. The simple corrections suggested by Murphy and Topel (1985) and Pagan (1984) cannot be applied in our case because our errors in both equations do not have simple parametric structures. However, the reported standard errors do account for any additional heteroscedacity which might be induced by the two step procedure.

For computational convenience we have followed the lead of Hall and Mishkin (1982) and Hayashi (1984) and have removed the effects of economy wide disturbances and a variety of demographic characteristics from the variables used in the analysis by first regressing the change in the log of consumption, the change in the log of income, and the income determinants against a set of year dummies, age, age², age³, education, the change in a dummy variable for marital status, current and lagged values of dummy variables for 8 Census regions, residence in an SMSA, and residence in a city with more than 500,000 people, as well as variables for the level and squared value of the change of family size, the change in the number of children in the family unit, and the change in the number of children under age 6. The residuals from these regressions form the basis for the analysis below. Given the large samples which were used to form the residuals, the fact that the estimation was performed in two stages is of little consequence.

The data are from the 1968-1981 Panel Study of Income Dynamics individuals tape (See Survey Research Center (1982)). The sample is a subset of observations on individuals who were male heads of household in 1981. Although the survey starts in 1968, many individuals entered the survey in

later years. However, individuals who were not heads of household in 1979, 1980, and 1981 and/or who retired prior to 1973 are excluded from the analysis. Note that we do make use of observations on families who were originally part of the nonrandom poverty subsample of the original PSID sample. Also, in contrast to MaCurdy (1981), Altonji (1984) and a number of other studies but in keeping with Hall and Mishkin, we do not exclude observations on heads of household who change marital status or change wives during the sample period.¹⁶

For a given year, the sample contains individuals who were between the ages 18-60 inclusive, who were employed, temporarily laid off or unemployed at the time of the survey. Additional observations are lost due to missing data on current or lagged variables in the income or consumption equations.

A few of the variables require discussion. $\ln C_t^*$ is the log of the sum of the family's food expenditures at home and outside of the home, deflated by the food component of the consumer price index. This is the consumption measure used in Hall and Mishkin (1982), Altonji (1984), and other recent studies of lifecycle models based upon the PSID. The use of food consumption in isolation from other goods may be justified in terms of the lifecycle model presented earlier if the period utility function depends on the sum of food consumption raised to an exponent and a separate argument for the consumption of other goods. The use of dummy variables for each year control for the effects of shifts in the relative price of food. The fact that food is a nondurable good is an advantage, since the theory we presented does not apply to expenditures on durable goods without further modifications (Hayashi (1984) discusses the durables case). It should also be noted that the fact that the relationship between food expenditures and income is known to be relatively flat is not a valid objection to the use of food in the analysis, since α , B_c and ϕ_1 are free parameters. But it obviously would be desirable to extend

the analysis to additional categories of consumption in future work, if the data can be found.

One of the components of ΔX_t^* is the change in the log of the real straight time wage at the time of the survey. For hourly workers this variable is the response to a direct question about the hourly wage rate and is available from 1970-1981. For salary workers the variable is only available from 1976 on and is imputed from the response to a question about salary per year, per month, per week, etc. For years prior to 1978 hourly wage responses above \$9.98 per hour were coded as \$9.98 on the data tape. Observations affected by this bound were excluded from the sample.

Unfortunately, the consumption measure and the hourly wage measure refer to the time of the survey (typically in March) while family income and a number of key elements of ΔX_t^* , including hours of unemployed and hours of lost due to illness, refer to the calendar year which precedes the survey date.¹⁷ This poses a problem, since the inconsistency of the timing will tend to weaken the relationship between $\Delta \ln y_t^*$ and the wage change variable relative to the true relationship, and as a result bias upward the association between changes $\Delta \ln y_t^*$ which result from changes in the wage relative to the true association. It also complicates the interpretation of changes in the consumption parameters which occur when hours of unemployment and/or hours lost due to illness are dropped from the first stage equation for $\Delta \ln y_t^*$ in (4.3). This problem, and possible remedies, are considered further below.

To limit the influence of outliers, observations were excluded if real food expenditures rose by more than 400 percent or fell by 75 percent from the preceding year, or if the real wage or real family income rose by more than 500% or fell by more than 80%. Very few observations are lost as a result, but the standard deviations of $\Delta \ln C_t^*$ and $\Delta \ln y_t^*$ are reduced substantially.

Finally, note that family income has not been adjusted for taxes. Provided that the changes in income resulting from the explanatory variables used in the model are not associated with large changes from year to year in the marginal tax rate faced by the particular family, then taxes are unlikely to have an important influence on the analysis of the response to changes in income. Permanent differences across families in taxes associated with differences in income and wealth may produce variation in the after tax interest rate faced by the family. The lifecycle model implies that this variation will affect rates of growth of consumption. (See equation (3.12)) and interpret the interest rate terms as net of taxes.) Shapiro (1983) and Zeldes (1984) have investigated this issue using the PSID, while Runkle has done so using the data from the negative income tax experiments.

5: Results

Table 1 reports a series of estimates of (3.18) and consists of regressions of the change in the log of real food consumption (the principle consumption measure in the PSID data set) on a series of variables dated $t-1$ or earlier which are determinants of income. These variables include the real wage change; past quits and layoffs, the log of 2,000 plus hours unemployed, the log of 2,000 plus hours lost due to illness, past promotions, and interactions of the wage change with quit, layoff and promotion dummy variables. As mentioned earlier, all of the income determinants are assumed to be exogenous with respect to the consumption disturbance e_{ct} , although they may be correlated with the labor supply taste disturbance ϵ_{nt} .¹⁸ The first lag of the change in family income is used when bias due to correlation of measurement errors in adjacent lags of $\Delta \ln y_t^*$ is not an issue.

For our main sample, we do not find that the lagged income determinants have a significant effect on consumption. For example, the marginal significance level of the first 2 lags of the change in family income is only

.342 (see column 2), and the broad array of variables in column 3 are not jointly significant either, although they are highly significant predictors of the income change (see column 5.) All of the variables are also statistically insignificant in the consumption equation when considered individually (note the standard errors).

The failure to find a significant role for the past income change is surprising in view of Hall and Mishkin's (1982, pg. 478) results. The difference in findings may in part be due to our removal of outliers or use of logs. However, when we drop the sample selection requirement that valid data be available on all of the various income determinants used in the analysis, the sample size more than doubles, and in the larger sample (20,762 observations, which compares to 9,913 for the other equations in the table and 6,926 for Hall and Mishkin) the relationship between the lagged income changes and consumption is statistically significant (see column 1). The main difference in the samples arises from the fact that data on the lagged value of the change in the wage rate is unavailable for salaried workers in the early years, who tend to have high income levels, and for persons who were unemployed and not on temporary layoff at the time of the survey, who tend to have low income levels. Consequently, the full sample may contain a higher percentage of observations on both high income and low income families. It is noteworthy that Zeldes (1984) finds a significant relationship between the consumption change and the value of y_t (as opposed to the first difference) for a subsample of low *wealth* families but not for the high *wealth* families.

In summary, there is only weak evidence against the RE-lifecycle model from the analysis of the relationship between the change in consumption and past determinants of the income change. However, there is reason to question the power of tests of the RE-lifecycle model in Table 1. Many of the point estimates are subject to large standard errors. The problem arises in part

from the fact that the change in food consumption has a large unexplained variance, reflecting measurement error and changes in preferences.

Consequently, we turn to the more powerful tests based upon equation (3.0).

Table 2 reports tests based upon equation (4.3) of the relative role of predictable and unpredictable changes in income in the consumption function. Column 7 indicates that the coefficient on the income change is only .0907 when only lagged ΔX^* variables are used as instruments and is not significantly different from 0. It is basically consistent with the results of Table 1. In column 1 the change in income is added as an additional variable with both ΔX_t^* and past ΔX^* variables used as instruments. Note first that the point estimate of $\phi_1 - \phi_2 = 0$ is $-.211$, and that the hypothesis that it is 0 is rejected, which runs counter to the Keynesian consumption function. Perhaps more importantly, the coefficients on the two income terms, which are estimates of $\phi_1 = B_c b$ and $-\phi_1 = -B_c b$, with $\phi_2 = 0$ under the permanent income hypothesis, are in fact opposite in sign and similar in absolute value. The marginal significance level of the t-statistic for a test of equality is .64.¹⁹

To assess the importance of measurement error, we have also produced estimates treating $\Delta \ln y_t^*$ as exogenous in (4.3), which amounts to including it in ΔX_t^* . (column 5) In this case, the estimates of ϕ_1 and $\phi_1 - \phi_2$ are .076 and .0149 with standard errors of .0162 and .095. The Keynesian hypothesis cannot be rejected. In column 6, $\Delta \ln y_{t-1}^*$ is also included as an instrument for $\Delta \ln y_t^*$. The inclusion is valid if measurement error is not important. The estimate of $\phi_1 - \phi_2$ is $-.0479$ with a standard error of .0961. Again the Keynesian hypothesis cannot be rejected. Thus when measurement error is ignored, the point estimates closely correspond to the Keynesian model and we are unable to reject it statistically. One may in fact show that if the RE-lifecycle model is correct, then ignoring measurement error in income will

bias the estimator of $\phi_1 - \phi_2$ in favor of the Keynesian model (toward 0). However, this is not necessarily true for the procedures used by Hall and Mishkin. (See below.)

Column (2) is identical to column (1) except that the current value of hours unemployed is excluded from the ΔX_t^* vector. This has no effect on the implied estimate of ϕ_2 , since all of the implied estimates of ϕ_2 in columns 1-4 are numerically identical to the estimate .091 obtained when ϕ_1 is constrained to 0 in column 7.²⁰ However, the estimated effect of the unanticipated change in income rises to .351 from .302. When both the current value of hours unemployed and hours lost due to illness are eliminated from the variables in ΔX_t^* , the estimate of ϕ_1 rises to .397 (Table 2, Col 4.). The increase is consistent with the hypothesis that unanticipated transitory income changes have a smaller influence on consumption than unanticipated permanent income changes, since inspection of the income change equation in column 7 of Table 1 reveals that the large effect on income of a one time shock to hours lost due to illness and/or hours lost due to unemployment on income is transitory²¹. Consequently, elimination of both current unemployment and current illness from the ΔX_t^* vector raises the relative importance of permanent factors in the income process (such as wage changes, which appear to persist). In terms of the lifecycle model, the parameter b linking r_t to $h_1 u_{xt}$ rises, and so ϕ_1 ($\phi_1 = B_c b$) also rises.

However, two alternative explanations for the rise in ϕ_1 require discussion. First, if the assumption of intraperiod separability of preferences between food consumption and labor supply is false, then, anticipated and unanticipated changes in wages, unemployment and hours of illness have direct effects on the change in consumption which go beyond their effects on consumption through r_t .²² The coefficient on the change in income will reflect a weighted average of these effects as well as the value of

B_cb. We cannot rule out the possibility that the rise in the estimate of ϕ_1 when the unemployment and illness variables occurs because the direct effect of these variables on consumption (with η_t held fixed) is smaller than that of the wage change, although the failure to detect a significant relationship between lagged values of all three variables and the change in consumption is weak evidence against nonseparability as an explanation for the rise in ϕ_1 .

The second explanation involves the fact that the timing of the unemployment, hours lost due to illness, and family income questions refer to the previous calendar year, while the food consumption and wage rate refer to the survey date (typically March). As a check on this, we repeated the analysis using two year changes rather than one year changes of all variables. This increases the overlap in the time intervals of the two sets of variables as a percentage of the overall time interval and so hopefully reduces the importance of the inconsistency of the timing on the covariances among the variables. The results (Table 3) are very similar to those in Table 2, and so the evidence does not support the view that the inconsistency in the timing of the variables is responsible for our findings.

In summary the results strongly support the RE-lifecycle model. However, it should be noted that the point estimate of ϕ_2 is usually about 1/5 of the point estimate of ϕ_1 , and so the point estimates may be consistent with the possibility that a small fraction of families obey the Keynesian model even though we cannot formally reject the RE-lifecycle model. Since ΔX_t^* contains indicators of both permanent and transitory components of the income change, α for families which obey the Keynesian model is likely to be greater than or equal to B_cb for families which obey the RE-lifecycle model. In this case one may show that $\hat{\phi}_2 / \hat{\phi}_1$ provides an upper bound estimate of the fraction of "Keynesian" families. Consequently, our point estimates may be consistent with the findings of Hall and Mishkin and Hayashi as well as those of Bernanke

(Bernanke finds little evidence of constraints.) One might have expected a transitory measurement error component in income to bias the Hall and Mishkin procedure against the Keynesian model. Presumably, the transitory measurement error component would result in a larger downward bias in the estimated the response of consumption to the transitory component of income than in the estimate of the response of consumption to the permanent income component. In fact, the actual bias depends upon the serial correlation properties of the measurement error, the form of the true income process, (the permanent-transitory scheme used by Hall and Mishkin might be misspecified), and the consequences of the inconsistency in the timing of the consumption and income data discussed above and in Hall and Mishkin. It is reassuring, and perhaps surprising in light of the disparate results of the simple least squares and instrumental variables estimates of the relationship between consumption and income reported in the introduction and the evidence of considerable measurement error in income, that our use of a test procedure which is robust with respect to measurement error leads to findings which are broadly consistent with the earlier studies.^{22a}

6: Testing the RE-Lifecycle Model for Liquidity Constraints

In the discussion of the RE-lifecycle model leading up to equation (3.17), the marginal return on net wealth, $R'(A_{t-1})$, was constrained to equal 1 to sharpen the contrast between the RE-lifecycle model and the Keynesian model. However, if the marginal return depends upon wealth, then anticipated changes in current income affect the change in consumption even if consumers are lifecycle planners with rational expectations. Theoretical work by Dolde (1978) and Mariger (1983) suggests that the response depends upon the direction of the income change, in that anticipated increases in income will lead to a positive change in consumption while anticipated decreases do not have an effect. The asymmetry may be less dramatic if R' decreases smoothly

with A_{t-1} , with $R''(A_{t-1}) < 0$, than if credit constraints are discontinuous , with $(R'(A_{t-1}) = \infty$ when A_{t-1} is below the minimum net wealth position and $R'(A_{t-1}) = 1$ otherwise. However, Dolde and Mariger's basic point appears to carry over to the version of the lifecycle model presented in section 3, in that $\Delta \ln C_t^*$ will tend to be larger for consumers who anticipate positive changes in income than for consumers who anticipate decreases.

Consider the following heuristic argument. $\Delta \ln C_t^*$ must satisfy

$$(6.1) \Delta \ln C_t^* = \text{const} + B_c r_t - B_c \ln(R'(A_{t-1})) + e_{ct}$$

which is similar to (3.15) but permits $R'(A_{t-1})$ to differ from 1. Consider two consumers who have the same value of A_{t-1} and are alike in all respects except for the expected income in period t . Consumer 1 learns prior to choice of C_{t-1} and N_{t-1} that income is likely to rise for exogenous reasons. The increase raises lifetime resources and thus lowers λ_{t-1} , the marginal utility of wealth. (r_{t-1} is negative.) Consequently, consumption in $t-1$ rises above the level which would have been chosen in the absence of the increase in income. However, the increase in C_{t-1} lowers A_{t-1} , which increases $R'(A_{t-1})$. (Recall that A_{t-1} is equal to $\underline{A}_{t-1} + w_{t-1}N_{t-1} - P_{t-1}C_{t-1}$.) Since the coefficient $-B_c$ on $\ln R'(A_{t-1})$ is positive and the anticipated income change does not affect r_t or the other terms in (6.1), $\Delta \ln C_t^*$ will be larger than if $R'(A_{t-1})$ is fixed at 1, which would be the case if capital markets are perfect. Now consider consumer 2, who learns prior to choice of C_{t-1} that income is likely to fall between periods $t-1$ and t . This will lead to a decrease in C_{t-1} . The lower value for C_{t-1} leads to an increase in A_{t-1} and a fall in $R'(A_{t-1})$. Consequently, the value for $\Delta \ln C_t^*$ will be smaller than it would have been in the absence of the capital market imperfections, and smaller than $\Delta \ln C_t^*$ for consumer 1. The consumption response to the increase in income will be larger in absolute value than the response to the decrease if the

derivative of the marginal rate of return $R'(A_{t-1})$ with respect to A_{t-1} decreases with A_{t-1} . This would be the case if $R'''(A_{t-1})$ is sufficiently negative in the neighborhood of the value of A_{t-1} typically found in the sample.

We have performed a preliminary investigation of the possibility that that the response of consumption to the predicted value of Δny_t^* based on ΔX_{t-1}^* is asymmetric, as is implied by the lifecycle model with imperfect credit markets. Specifically, measures of positive and negative anticipated changes in income upon past information were constructed from the regression of Δny_t^* against lagged values of the income determinants (Table 2, column 2) and permitted to have separate coefficients in the consumption equation. The relative size of the coefficients will depend upon the shape of marginal return function $R'(A_{t-1})$ and the fraction of the sample whose net wealth is sufficiently low for R' to vary in response to changes in income prospects. The consumption equation is reported in Table 4. The coefficient on the positive change is .126 while the coefficient on the negative change is -.0346. The variables are not significantly different from 0 or from each other, although they are subject to substantial standard errors.

With somewhat less theoretical justification, we have also looked for asymmetries in the consumption response to positive and negative changes in income predicted from both current and lagged income determinants. In fact, the response to positive changes is slightly larger than the response to negative changes, but the difference in point estimates is not significant (See Table 4, column 1). It should be noted that Runkle (1983) and Zeldes (1984) check whether the level of net wealth and the level of income at the beginning at the period are negatively related to the change in consumption, as is implied by the liquidity constraint hypothesis, and have obtained mixed results.

7. Conclusions

In this paper we have implemented tests of alternative consumption models which are valid in the presence of measurement error in the income variable. We find only weak evidence against the hypothesis, implied by the RE-lifecycle model, that consumption does not respond to changes in income that are predictable from past information. We can reject the Keynesian hypothesis that consumption responds to anticipated and unanticipated changes in income in the same way, although the results are very favorable to the Keynesian model when measurement error is ignored. Finally, preliminary tests of the pure RE-lifecycle model against an RE-lifecycle model with liquidity constraints do not show much evidence against the perfect capital markets assumption, although a much more thorough investigation of this issue is required before any conclusions should be drawn.

Footnotes

¹ Other recent Panel data studies include Zeldes(1984), Runkle(1983), and Shapiro (1984). These do not attempt to measure the response of consumption to the change in income and so are less sensitive to measurement error in the income variable. MaCurdy (1983) and Altonji (1984) use panel data to examine consumption behavior within a rational expectations-life cycle framework as part of studies of intertemporal labor supply.

² There are panel studies on the permanent income hypothesis without rational expectations (e.g. Bhalla (1979), Holbrook and Stafford (1971). Mention should also be made of recent time series studies of the rational expectations permanent income hypothesis, including the key papers by Hall (1978), Sargent (1978), which developed the theory used in several of the panel studies, as well as subsequent work by Hayashi (1981), Flavin (1981,1984), and Mankiw (1981)). See Mayer (1972), Deaton and Muellbauer (1980), and King (1983) for literature surveys and additional references.

³ See Griliches (1984) and Griliches and Hausman(1984) for recent discussions of measurement issues.

⁴ Calculated from the ratio of measurement error to the true variance of the level of income reported in Table 4 of Duncan and Hill. Mellow and Sider (1983) also find substantial discrepancies between employer records and earnings reported by workers in a matched sample from the Employment Opportunity Pilot Project survey and in a matched sample from the 1977 Current Population Survey.

⁵ If measurement error is serially uncorrelated, then the variance of the measurement error in the first difference is double the variance in the level. Furthermore, since a substantial fraction of the variation in income and other variables is across persons rather than from one period to the next for the same person, differencing removes much of the true variance in the data. Duncan and Hill present some evidence that measurement errors are positively correlated for income. However it is based upon a comparison of the income response in year t with the person's recollection of income in year $t-1$ rather than the responses in year t and year $t-1$. There is reason to believe that people impose consistency on such retrospective responses.

⁶ Attention to reporting error problems in work on the consumption function is not new. For example, the interesting study by Bhalla(1979) makes use of an Indian panel data containing independent measures of consumption, savings, and income to study consumption behavior. However, Bhalla's analysis differs in many ways from the work presented here. Hayashi(1984) provides a careful discussion of the problem of measurement error biases which would arise in his estimates of a model relating the change in consumption expenditures to lagged changes in consumption expenditures changes, a survey measure of the unexpected change in income, and the actual change in income. For lack of better alternatives in his data set, Hayashi uses the income measures without instruments.

⁷ As is made clear below, identification requires that the indicators of income be uncorrelated not only with the measurement error in consumption but also with transitory disturbances in consumption that arise from changes in preferences or 'needs'. This assumption is questionable for some variables, but is weaker than Hall and Mishkin's, Bernanke's, and Hayashi's (1984) assumption that all components of the income change are uncorrelated with change in consumption preferences.

⁸ The study by Holbrook and Stafford (1971) analyzed the link between the level of consumption and various components of family income using one year of consumption data and 3 years of income data for a cross section of families. Although Holbrook and Stafford do not work within a rational expectations framework, their results suggest that consumption is less responsive to the elements of family income which are most transitory. An early study by Mincer(1960) uses wage changes as an indicator of permanent income changes and hours changes as an indicator of transitory income changes.

⁹ Killingsworth(1983) and Pencavel (1984) provide recent surveys of this literature.

¹⁰ It is not essential to what follows that u_{xt} be serially uncorrelated or that the lag length of the process for ΔX_t^* be specified properly. One may simply regard (2.4) as defining the decomposition of ΔX_t^* into its least squares linear projection on its own lagged values and the error component u_{xt} . The analysis goes through with this reinterpretation.

¹¹ MaCurdy (1983) and Mankiw et al have used (3.9) with γ as a free parameter. Most studies in the literature on the permanent income hypothesis suppress the labor supply or leisure argument, in which case the function is the constant relative risk aversion specification.

¹² Kydland and Prescott(1983), Hotz et al(1982), and Eichenbaum et al (1984) all emphasize intertemporal nonseparability. Barro and King (1984) provide a useful discussion of the use of the assumption of intertemporal separability in macroeconomics and the restrictions it imposes on behavior.

¹³ Indeed, Altonji (1984) works with the RE-lifecycle model as a maintained hypothesis and examines the relationship between the change in consumption and anticipated changes in the wage in an effort to determine whether intra-period separability holds. His results are inconclusive.

¹⁴ As Chamberlain (1982) pointed out and Hayashi observed in a similar context, the rational expectations hypothesis does not imply that the forecast error r_t is uncorrelated with past information when the distribution is taken across households rather than over time for a given household. If the effect of an aggregate disturbance on the marginal utility of income is systematically related to elements of ΔX_{t-1}^* then ΔX_{t-1}^* may be correlated with r_t in a short panel. However, we doubt if this is a serious problem here, since most of the variation in the change in the wage, hours of unemployment, quits, layoffs, and other key elements of ΔX_{t-1}^* occurs over time for a given household rather than cross-sectional, and we have removed the main effects of aggregate shocks through the use of time dummies.

¹⁵ Unfortunately, one cannot solve the problem of serial correlation by simply performing a GLS transformation of the model. The transformation introduces v_{t-1} and u_{xt-1} into the consumption equation. These variables are likely to be correlated with X_{t-1}^* . A similar problem frequently arises in aggregate time analysis of rational expectations models. One could apply the procedures of Hansen (1980) and Cumby et al (1983) to the present setting, although we question whether the efficiency gains are worth the effort given that the serial correlation is 0 across individuals and very small after one lag for the observations on the same individual.

¹⁶ Within the context of the model, this means that we identify the household with the male head. Changes in family composition, including marital status, alter the current and expected future values of the taste components ε_{nt} and ε_{ct} of the utility function (3.1). That is, changes in family structure alter the utility which the head of household assigns to a given level of labor supply and family food consumption and labor supply. Changes in family structure may also alter expected future income from sources other than earnings of the male household head (eg, wife's earnings). Both the income shifts and the preference shifts associated with changes in family structure are responsible for shifts in λ_t and so contribute to the variance in r_t . There are obvious shortcomings with this treatment of the family unit.

¹⁷ The layoff, quit and promotion variables also refer to the 12 month period prior to the survey date rather than to the previous calendar year. The layoff variable includes only permanent layoffs.

¹⁸ Ham (1983) examines the issue of whether variation in unemployment reflects constraints on hours or variation in labor supply preferences using an intertemporal labor supply model and provides references to earlier work.

¹⁹ We experimented with inclusion of the change in hours worked in ΔX_t^* , although use of this variable might lead to biased results if a strong correlation exists between changes in preferences for consumption and labor supply. The results were fully consistent with those in the table.

²⁰ This is because the difference between $[h_1 \Delta X_t^* + h_2 \Delta X_{t-1}^*]$ and $[h_1 \theta(L) + h_2] \Delta X_{t-1}^*$, which is an estimate of u_{xt} and identifies ϕ_1 , is orthogonal to $[h_1 \theta(L) + h_2] \Delta X_{t-1}^*$. Consequently, if the variables in ΔX_{t-1}^* are not changed, the estimate of ϕ_2 remains the same.

²¹ Ignoring the minor complication posed by the small coefficient on the second lag of real family income in the income change equation, the long run effect of unemployment on income may be estimated from the results in Table 2, Col 2 as the sum of the coefficients on income of the current value, first lag and second lag of unemployment. The sum is near 0 even though the individual coefficients are large. This is also true for the illness variable.

²² The literature on unemployment as a constraint on labor supply (see Ashenfelter (1980), and Deaton and Muellbauer (1980) and Browning et al (1984) suggests that the form of the consumption and marginal utility of income equations are affected by constraints on labor supply.

^{22a} Using the indicators of income determinants, it is possible to modify the econometric framework used by Hall and Mishkin to allow for measurement error in income and a more general income process. We are in the early stages of a study along these lines.

²³ Runkle finds that the net wealth variable is positive and significant for families with low wealth. However, the positive sign is inconsistent with liquidity constraint hypothesis, since presumably the marginal interest rate is negative function of wealth, in which case the change in consumption would be a negative function of net wealth. One possible explanation for the positive sign is measurement error, since the consumption measure used by Runkle is constructed from the data on net wealth (among other variables). A measurement error in the estimate of net wealth as of t will be positively related to the estimate of consumption in period $t + 1$.

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Table 2
Estimates of the Consumption Model (Equation 3.0)

	Second Stage Equations for Consumption Change Dependent variable: $\Delta \log(\text{consumption})_t$ (standard errors in parenthesis)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	$-.360 \times 10^{-3}$ (.167x10 ⁻²)	$-.360 \times 10^{-3}$ (.170x10 ⁻²)	$-.360 \times 10^{-3}$ (.169x10 ⁻²)	$-.360 \times 10^{-3}$ (.171x10 ⁻²)	$-.360 \times 10^{-3}$ (.168x10 ⁻²)	$-.360 \times 10^{-3}$ (.170x10 ⁻²)	$-.360 \times 10^{-3}$ (.172x10 ⁻²)
$\Delta \log(\text{family income})_t^a (\phi_1)$	.302 ¹ (.670x10 ⁻¹)	.351 ² (.791x10 ⁻¹)	.332 ³ (.709x10 ⁻¹)	.397 ⁴ (.836x10 ⁻¹)	.138 ⁵ (.387x10 ⁻¹)	6.758x10 ⁻¹ (.164x10 ⁻¹)	
$\Delta \log(\text{family income})_t^b (\phi_2 - \phi_1)$	-.211 (.101)	-.260 (.115)	-.241 (.103)	-.307 (.119)	$-.479 \times 10^{-1}$ (.961x10 ⁻¹)	$.149 \times 10^{-1}$ (.941x10 ⁻¹)	$.907 \times 10^{-1}$ (.908x10 ⁻¹)
R ²	.0029	.0025	.0031	.0028	.0019	.0036	.0001
number of observations	9913	9913	9913	9913	9913	9913	9913
M.S.E.	.1115	.1131	.1124	.1148	.1084	.1081	.1085

^a Treated as endogenous. The 1st stage regression comes from equation (7), Table 1 or its variant.

^b $\Delta \log(\text{real family income})_t$ is the predicted value of income from variables dated t-1 or earlier [equation 5, Table 1].

1 instrument variables for $\Delta \log(\text{real family income})_t$ include all variables in equation (7), Table 1.

2 instrument variables for $\Delta \log(\text{real family income})_t$ include all variables in equation (7), Table 1

except $\log(\text{hours unemployed}+2000)_t$

3 instrument variables for $\Delta \log(\text{real family income})_t$ include all variables in equation (7), Table 1

except $\log(\text{hours ill}+2000)_t$

4 instrument variables for $\Delta \log(\text{real family income})_t$ include all variables in equation (7), Table 1

except $\log(\text{hours unemployed}+2000)_t$ and $\log(\text{hours ill}+2000)_t$.

5 $\Delta \log(\text{family income})_t$ treated as exogenous.

6 instrumental variables for $\Delta \log(\text{family income})_t$ include all variables in equation (7), Table 1 and

$\Delta \log(\text{family income})_{t-1}$

Table 3.
Effects of Anticipated and Unanticipated Changes in Income on Consumption

First Stage Equations for Income Change Dependent Var: $\Delta_2 \log(\text{family income})_t^a$ (standard errors in parenthesis)			Second Stage Equations for Consumption Change Dependent Var.: $\Delta_2 \log(\text{food consumption})_t$ (Standard errors in parenthesis)				
	(1)	(2)	(3)	(4)	(5)	(6)	
Constant	.115x10 ⁻¹ (.469x10 ⁻²)	.206x10 ⁻¹ (.465x10 ⁻²)	Constant .225x10 ⁻² (.363x10 ⁻²)	.255x10 ⁻² (.364x10 ⁻²)	.255x10 ⁻² (.367x10 ⁻²)	.255x10 ⁻² (.368x10 ⁻²)	
$\Delta_2 \log(\text{wage})_{t-2}$	.362x10 ⁻¹ (.301x10 ⁻¹)	-.261x10 ⁻¹ (.320x10 ⁻¹)	$b \Delta_2 \log(\text{family income})_t \cdot \phi_1$.346 ^d (.765x10 ⁻¹)	.360 ^e (.793x10 ⁻¹)	.397 ^f (.837x10 ⁻¹)	.419 ^g (.868x10 ⁻¹)	
$\Delta_2 \log(\text{wage})_{t-2}$ $\Delta_2 \text{quit}_{t-2}$	.456x10 ⁻¹ (.704x10 ⁻¹)	.197x10 ⁻¹ (.752x10 ⁻¹)	$c \Delta_2 \log(\text{family income})_t \cdot \phi_2 - \phi_1$ -.272 (.141)	-.286 (.142)	-.324 (.152)	-.346 (.155)	
$\Delta_2 \log(\text{wage})_{t-2}$ $\Delta_2 \text{layoff}_{t-2}$	.936x10 ⁻¹ (.117)	.726x10 ⁻¹ (.124)	R ²	.0051	.0050	.0047	.0047
$\Delta_2 \log(\text{wage})_{t-2}$ $\Delta_2 \text{promotion}_{t-2}$	-.460x10 ⁻¹ (.758x10 ⁻¹)	-.626x10 ⁻¹ (.772x10 ⁻¹)	no. of observations	6028	6028	6028	6028
quit_{t-2}	.431x10 ⁻¹ (.228x10 ⁻¹)	.450x10 ⁻¹ (.234x10 ⁻¹)	M.S.E.	.1296	.1303	.1323	.1336
layoff_{t-2}	.417x10 ⁻¹ (.382x10 ⁻¹)	.463x10 ⁻¹ (.388x10 ⁻¹)					
promotion_{t-2}	.454x10 ⁻² (.218x10 ⁻¹)	.150x10 ⁻¹ (.226x10 ⁻¹)					
$\log(\text{hours ill} + 2000)_{t-2}$	.125 (.584x10 ⁻¹)	.533x10 ⁻¹ (.566x10 ⁻¹)					
$\log(\text{hours unemployed} + 2000)_{t-2}$	.662 (.104)	.509 (.992x10 ⁻¹)					
$\Delta_2 \log(\text{wage})_t$	.279 (.357x10 ⁻¹)						
$\Delta_2 \log(\text{wage})_t$ $\Delta_2 \text{quit}_t$	.134 (.674x10 ⁻¹)						
$\Delta_2 \log(\text{wage})_t$ $\Delta_2 \text{layoff}_t$	-.486x10 ⁻¹ (.884x10 ⁻¹)						
$\Delta_2 \log(\text{wage})_t$ $\Delta_2 \text{promotion}_t$	.855x10 ⁻¹ (.105)						
quit_t	-.442x10 ⁻¹ (.219x10 ⁻¹)						
layoff_t	.206x10 ⁻¹ (.393x10 ⁻¹)						
promotion_t	-.170x10 ⁻¹ (.234x10 ⁻¹)						
$\log(\text{hours ill} + 2000)_t$	-.227 (.574x10 ⁻¹)						
$\log(\text{hours unemployed} + 2000)_t$	-.651 (.108)						
R ²	.0756	.0185					
no. of observations	6028	6028					
M.S.E.	.0884	.0937					

^a $\Delta_2 X_t \equiv X_t - X_{t-2}$, $\Delta_2 X_{t-2} \equiv X_{t-2} - X_{t-4}$

^b Treated as endogenous. The first stage regression comes from equation (1) or its variant.

^c $\Delta_2 \log(\text{family income})_t$ is the predicted value of income from variables dated t-2 or earlier (equation 2).

^d Instrumental variables for $\Delta_2 \log(\text{family income})_t$ include all variables in equation (1).

^e Instrumental variables for $\Delta_2 \log(\text{family income})_t$ include all variables in equation (1) except $\log(\text{hours ill} + 2000)_t$.

^f Instrumental variables for $\Delta_2 \log(\text{family income})_t$ include all variables in equation (1) except $\log(\text{hours unemployed} + 2000)_t$.

^g Instrumental variables for $\Delta_2 \log(\text{family income})_t$ include all variables in equation (1) except $\log(\text{hours ill} + 2000)_t$ and $\log(\text{hours unemployed} + 2000)_t$.

TABLE 4

Consumption Responses to Positive and Negative
Income Changes

Constant	$-.209 \times 10^{-2}$ (-.492)	$-.237 \times 10^{-2}$ (-.577)
Positive Predicted ^a Income _t	.251 (3.39)	
Negative Predicted ^a Income _t	.204 (2.59)	
Positive Predicted ^b Income _t		.126 (1.22)
Negative Predicted ^b Income _t		$-.346 \times 10^{-1}$ (-.197)
R ²	.0024	.0002
no. of obs.	9913	9913
S.S.E.	1075.1	1077.5

^aPredicted Income from equation 7 in Table 1 (current and lagged variables).

^bPredicted Income from equation 5 in Table 1 (lagged variables only).