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

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This paper tests the rational expectations lifecycle model of consumption against (i) a 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 that can be predicted from past information and income changes that cannot be predicted. The tests allow for measurement error in income. The results reject the Keynesian model and generally support the lifecycle model. But the results are not sufficiently precise to rule out the possibility that some households are liquidity constrained. Measurement error has a strong influence on the relationship between consumption and income.

I. INTRODUCTION

Hall and Mishkin [1982], Bernanke [1984], and Hayashi [1985] have recently used micro panel data sets to study rational expectations models of the response of consumption to income changes.[1] A critical assumption that these studies have in common is that income is measured without error. This assumption is used to identify the consumption response to transitory income. The

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1. Other recent Panel data studies include Zeldes [1985], 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 [1986] use panel data to examine consumption behavior within a rational expectations-lifecycle framework as part of studies of intertemporal labor supply. See also the recent studies by Dynarski and Sheffrin [1985 a,b]. There are additional 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] and Sargent [1978], which developed the theory used in several of the panel studies, as well as subsequent work by Hayashi [1982], Flavin [1981, 1985], and Mankiw [1981]. See Mayer [1972], Deaton and Muellbauer [1980], and King [1985] for literature surveys and additional references.

assumption of no measurement error in income is very strong (as Hall and Mishkin point out), because many variables in micro data sets contain substantial measurement error, and the ratio of signal to noise in first differences of the data may be very poor.[2] Using the Panel Study of Income Dynamics (Hall and Mishkin's data set), Altonji [1986] 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 gathered direct evidence on the importance of measurement error. They compare 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*.[3] Under reasonable assumptions, this translates into a much larger percentage of the variance in the first difference of earnings.[4] Measurement error in nonlabor income is likely to be an even more serious problem.

Fortunately, micro data sets, such as the Panel Study of Income Dynamics, contain many measures of determinants of income, such as wage rates, layoffs, quits, promotions, hours unemployed, and hours lost due to illness. For those variables that are based on questions that are independent of the ones used to construct family income, one may assume that the measurement errors in the income determinants are independent of measurement errors in reported income and consumption. These determinants provide the leverage necessary to implement tests of consumption models that are free of bias from measurement error. They can also

2. See Griliches [1984] and Griliches and Hausman [1984] for recent discussions of measurement issues.

3. Calculated from the ratio of measurement error to the true variance of the level of income reported in Table 4 of Duncan and Hill. The results of Abowd and Card's [1986] analysis of the covariance structure of earnings and hours are also consistent with a large role for measurement error in changes in the log of labor income in the Panel Study of Income Dynamics, although Abowd and Card point out that their findings have alternative interpretations. Measurement error is not only a problem in the PSID. 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.

4. 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.

be used to relax the assumption made in many studies of the permanent income hypothesis that the income process is exogenous with respect to consumption preferences,[5] and to integrate work on consumption of goods with research on lifecycle labor supply.[6]

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. The coefficient estimate for the first difference of the log of family income was 0.076 with an estimated standard error of 0.013. If income is measured with error, then this estimated coefficient is biased downward. We re-estimated the relationship between the change in consumption and the change in income using the income determinants as instrumental variables for the income variable. (The first stage regression is in column 7, Table I.) The new point estimate is *three* times larger than the ordinary least squares estimate (0.229 with a standard error of 0.047). This simple comparison suggests that the measurement error problem for panel studies of the link between consumption and income is quantitatively important. Moreover, the small standard error of the instrumental variables estimate suggests that the other variables in the data set are important enough in the income process to implement tests of consumption models that are free of bias from measurement error.

The above result also calls into question the findings of previous studies that have not taken measurement error into account.[7] Hall and Mishkin, Bernanke, and Hayashi all find that the vast majority of households obey the lifecycle model. We wish to examine whether this important result is an artifact of measurement error in the income data. We also wish to know whether

5. 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 [1985] assumption that *all* components of the income change are uncorrelated with change in consumption preferences.

6. Killingsworth [1983] and Pencavel [1984] provide recent surveys of this literature.

7. 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 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 [1985] provides a careful discussion of the problem of measurement error biases that would arise in his estimates of a model relating the change in consumption expenditures to lagged changes in consumption expenditures, 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.

TABLE I
THE EFFECTS OF LAGGED VARIABLES ON THE CHANGE IN CONSUMPTION AND INCOME
(STANDARD ERRORS IN PARENTHESES)

Dependent variable	(1) Δlog (food consumption)$_t$	(2) Δlog (food consumption)$_t$	(3) Δlog (food consumption)$_t$	(4) Δlog (food consumption)$_t$	(5) Δlog (family income)$_t$	(6) Δlog (family income)$_t$	(7) Δlog (family income)$_t$
Constant	−0.000158	0.0000494	−0.00196	0.00180	0.0104	0.00455	0.00477
	(0.00115)	(0.00168)	(0.00201)	(0.00200)	(0.00208)	(0.00167)	(0.00197)
Δlog (family income)$_{t-1}$	−0.0292	−0.0187	−0.0186				
	(0.00956)	(0.0154)	(0.0161)				
Δlog (wage)$_{t-1}$			0.0265	0.0223	−0.00264		0.0719
			(0.0274)	(0.0270)	(0.0222)		(0.0201)
layoff$_{t-1}$			0.00924	0.00979	0.0313		0.0286
			(0.0205)	(0.0204)	(0.0197)		(0.0196)
quit$_{t-1}$			0.00757	0.00803	0.00689		0.00830
			(0.0175)	(0.0175)	(0.0135)		(0.0137)
log (hours unemployed +2,000)$_{t-1}$			0.0689	0.0794	0.346		0.543
			(0.0558)	(0.0550)	(0.0596)		(0.0655)
promotion$_{t-1}$			0.0323	0.0322	−0.00690		−0.0185
			(0.0207)	(0.0207)	(0.0145)		(0.0143)
Δlog (wage)$_{t-1}$*quit$_{t-1}$			0.0166	0.0185	0.331		0.228
			(0.0561)	(0.0561)	(0.0515)		(0.0481)
Δlog (wage)$_{t-1}$*layoff$_{t-1}$			−0.0955	−0.0956	0.0725		0.0730
			(0.0720)	(0.0718)	(0.0833)		(0.0751)
log (hours ill +2,000)$_{t-1}$			−0.000287	0.00337	0.0917		0.154
			(0.0469)	(0.0470)	(0.0355)		(0.0396)
Δlog (wage)$_{t-1}$*promotion$_{t-1}$			−0.158	−0.158	0.106		0.118
			(0.0877)	(0.0879)	(0.0944)		(0.0928)

TABLE I
(Continued)

Dependent variable	(1) Δlog (food consumption)$_t$	(2) Δlog (food consumption)$_t$	(3) Δlog (food consumption)$_t$	(4) Δlog (food consumption)$_t$	(5) Δlog (family income)$_t$	(6) Δlog (family income)$_t$	(7) Δlog (family income)$_t$
Δlog (family income)$_{t-2}$	0.0195	0.00500	0.00585	0.0105	−0.0557	−0.0605	−0.0522
	(0.00904)	(0.0140)	(0.0141)	(0.0144)	(0.0113)	(0.0116)	(0.0111)
layoff$_{t-2}$			0.0225	0.0216	−0.0146		−0.0112
			(0.0179)	(0.0179)	(0.0174)		(0.0166)
quit$_{t-2}$			−0.00172	−0.00107	−0.00941		−0.00491
			(0.0139)	(0.0139)	(0.0123)		(0.0119)
log (hours unemployed +2,000)$_{t-2}$			−0.0144	−0.0231	0.0293		0.0736
			(0.0542)	(0.0534)	(0.0494)		(0.0479)
promotion$_{t-2}$			−0.0214	−0.0215	−0.000187		−0.000184
			(0.0198)	(0.0198)	(0.0132)		(0.0131)
log (hours ill+2,000)$_{t-2}$			−0.00912	−0.0110	0.0185		0.0507
			(0.0507)	(0.0506)	(0.0392)		(0.0370)
Δlog (wage)$_t$							0.241
							(0.0256)
layoff$_t$							−0.0206
							(0.0228)
quit$_t$							−0.0100
							(0.0142)
log (hours unemployed +2,000)$_t$							−0.562
							(0.0619)
promotion$_t$							−0.00895
							(0.0148)

TABLE I
(Continued)

Dependent variable	(1) Δlog (food consumption)$_t$	(2) Δlog (food consumption)$_t$	(3) Δlog (food consumption)$_t$	(4) Δlog (food consumption)$_t$	(5) Δlog (family income)$_t$	(6) Δlog (family income)$_t$	(7) Δlog (family income)$_t$
Δlog (wage)$_t$*quit$_t$							−0.0993
							(0.0494)
Δlog (wage)$_t$*layoff$_t$							−0.0502
							(0.0667)
log (hours ill + 2,000)$_t$							−0.194
							(0.0360)
Δlog (wage)$_t$*promotion$_t$							0.149
							(0.0972)
R^2	0.0140	0.0003	0.0016	0.0014	0.0264	0.0046	0.0766
number of observations	20,762	9,913	9,913	9,913	9,913	9,913	9,913
M.S.E.	0.1170	0.1085	0.1085	0.1085	0.0650	0.0663	0.0617

differences in the detailed findings of these studies might be due to differences in their sensitivity to measurement error.

This paper uses measures of income determinants to test the rational expectations (RE) lifecycle model of consumption against (i) a simple Keynesian model and (ii) the RE-lifecycle model with imperfect capital markets. Two major advantages of our test are (1) it is valid in the presence of measurement error in income, consumption, and in the income determinants, and (2) the test allows for more general income processes than have been considered to date in the literature,[8] and does not assume that all components of the income process, such as work hours, are exogenous with respect to consumption.

The first set of tests simply checks whether the change in consumption is correlated with the past values of various variables that 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, 1985; Altonji, 1986; Runkle, 1983; Zeldes, 1985], but these have worked with only a few variables.

The second set of tests, which also parallels work in the aggregate time series literature, is the main contribution of this paper. We study the relationship between the change in consumption and (partial) measures of anticipated and unanticipated changes in income. To circumvent the problem caused by measurement error in the income changes, we construct instruments for the unanticipated changes and the anticipated income change. 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 simple RE-lifecycle model implies that only the instrument for the unanticipated component matters. These restrictions hold even though the instrument for the unanticipated change in income is contaminated by past innovations in the true

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 three 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 that 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.

income determinants as well as by measurement errors in the income determinants.

The empirical results are generally supportive of the lifecycle model, and reject the Keynesian model. Moreover, they show that the Keynesian model cannot be rejected if measurement error in the income process is ignored by the econometrician. We also show that measurement error is likely to bias the Hall and Mishkin study against the lifecycle model, while biasing Bernanke's results in favor of the lifecycle model. Thus, it is possible that the contradiction between Hall and Mishkin's finding that perhaps 20 percent of their sample are constrained and Bernanke's confirmation of the lifecycle model is due to measurement error.

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 [1985], and Zeldes [1985] using discontinuous constraints, implies that the responses of consumption to positive and negative changes in income are asymmetric. We present a preliminary study of whether consumption responds differently to positive and negative predictable changes in income.

The paper is organized as follows. Section II presents the RE-lifecycle and Keynesian model and discusses the restriction that they impose on the relationship between the change in consumption and instruments for unanticipated and anticipated components of the income change. Section III discusses econometric issues and data, and Section IV presents the results. Section V examines capital market imperfections.

II. Implications of the RE-Lifecycle and Keynesian Models of Consumption

The RE-lifecycle model posits that the change in consumption is proportional to the revision in the marginal utility of income. Under RE, past determinants of income do not affect the revision and therefore do not also affect the change in consumption. As developed in the Appendix, a version of the RE-lifecycle model used in several previous studies implies that

$$(1) \qquad \Delta \ln C_t^* = B_c \eta_t + e_{ct}.$$

Equation (1) states that the change in the log of measured consumption, $\Delta \ln C_t^*$, is equal to the coefficient ($B_c < 0$) times the revision in the log of the marginal utility of income, η_t, plus an error term e_{ct}. The error term e_{ct} is used to represent the sum of the effect of variation in preferences and the measurement error in the consumption data. η_t is uncorrelated with past determinants of income. Equation (1) is based on the assumption that credit markets are perfect and taxes are proportional, so that all individuals face a common after-tax interest rate in year t, which we have suppressed for notational convenience. In most of the empirical work we control for the interest rate by using a dummy variable for each year, although we also experiment with introduction of a control for variation in the after-tax rate that arises from the tax system.

The Keynesian model of consumption argues that consumption varies with current income. In first differences of the logs of consumption and income, the model may be represented as

$$(2) \qquad \Delta \ln C_t^* = \alpha \Delta \ln y_t + e_{ct},$$

where e_{ct} is used as in (1).

Our test of the two models is based upon an equation that relates the change in consumption to a component of $\Delta \ln y_t$ that is anticipated by the consumer and a component that is at least partially unanticipated. To derive this equation from the consumption equations (1) and (2), we first decompose the change in measured income into (1) a component that is predictable given information which is available to the consumer, (2) a component that is in part unanticipated by the consumer, and (3) a composite error term.

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

$$(3) \qquad \Delta \ln y_t = h_1 \Delta X_t^* + h_2 \Delta X_{t-1}^* + v_t$$

$$(4) \qquad \Delta \ln y_t^* = \Delta \ln y_t + \Delta \epsilon_{yt}$$

$$(5) \qquad \Delta X_t^* = \Delta X_t + \Delta \epsilon_{xt}.$$

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 that 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

(3) and (4) are least squares linear prediction equations. The error component v_t is orthogonal to ΔX_t^* by definition of h_1 and h_2. We make the assumption that ΔX_t^* is uncorrelated with the measurement error and shifts in consumption preferences driving the consumption error component e_{ct}. We also assume that ΔX_t^* is uncorrelated with the income measurement error $\Delta\epsilon_{yt}$. The justification for these assumptions given our data and choice of ΔX_t^* is discussed in Section III.1 and IV.1 below.

Let the decomposition of ΔX_t^* into its linear least squares projection on its first few lagged values and the error component u_{xt} be

$$\Delta X_t^* = \theta(L)\Delta X_{t-1}^* + u_{xt}, \tag{6}$$

where $\theta(L)$ is a matrix polynomial in the lag operator L, and u_{xt} is uncorrelated with $\theta(L)\Delta X_{t-1}^*$ by construction. Equation (6) need not contain a sufficient number of lags to be the autoregressive representation of ΔX_t^*. The composite error u_{xt} may be serially correlated and in general is a function of current and past innovations in ΔX_t and current and past measurement errors.[9] Although u_{xt} is contaminated by measurement error and past innovations in ΔX_t, we shall refer to it as a component of the unanticipated change in income for lack of a better name. Equations (3), (4), and (6) imply that the regression equation relating $\Delta \ln y_t^*$ and ΔX_{t-1}^* is

$$\Delta \ln y_t^* = [h_2 + h_1\theta(L)]\Delta X_{t-1}^* + h_1 u_{xt} + v_t + \Delta\epsilon_{yt}. \tag{7}$$

The relationship between the change in consumption and income for the RE-lifecycle model may now be derived. First, we project the revision in the marginal utility of income, η_t, onto the scalar variable $h_1 u_{xt}$:

$$\eta_t = b(h_1 u_{xt}) + \xi_t. \tag{8}$$

The coefficient b is less than 0. The absolute value of b increases with the size and degree of permanence in the effects of the components of ΔX_t^* on income.

We shall now examine the relationship between the change in consumption and income using

$$\Delta \ln C_t^* = \phi_1 h_1 u_{xt} + \phi_2[h_2 + h_1\theta(L)]\Delta X_{t-1}^* + \underline{e}_{ct}. \tag{9}$$

Equation (9) decomposes the consumption change $\Delta \ln C_t^*$ into its

9. If ΔX_t^* is measured with error, it is not possible to extract a clean measure of the innovation in ΔX_t even if (6) is the AR representation of ΔX_t^*. In this case u_{xt} would be serially uncorrelated but would still depend on current and past innovations in ΔX_t and current and past measurement errors.

least squares linear projection on $h_1 u_{xt}$ and $[h_2 + h_1\theta(L)\Delta X^*_{t-1}]$ and an orthogonal error, e_{ct}.

The RE-lifecycle model implies that $\phi_1 = B_c b$ and $\phi_2 = 0$. To see this, substitute (8) into (1) and compare the result with (9). Intuitively, ϕ_2 should be zero because $[h_2 + h_1\theta(L)]\Delta X^*_{t-1}$ contains only old information and therefore does not affect the revision in the marginal utility of income.[10] Although $h_1 u_{xt}$ contains old information and measurement error, it also contains new information that induces the nonzero value $B_c b$ for the coefficient ϕ_1. A formal demonstration that the above restrictions do in fact hold for the linear projection equation (9) is in the Appendix.

On the other hand, the Keynesian consumption model implies that $\phi_1 = \phi_2$ in equation (9). Substituting for $\Delta \ln y^*_t$ from (7) and (2) leads to

$$(10) \quad \Delta \ln C^*_t = \alpha h_1 u_{xt} + \alpha[h_1\theta(L) + h_2]\Delta X^*_{t-1} + \alpha v_t + e_{ct}.$$

Comparison of (10) with (9) indicates that the Keynesian model implies that $\phi_1 = \phi_2$, as claimed.[11]

We also perform a secondary test of the RE-lifecycle hypothesis based upon the fact that the parameter b relating η_t to $h_1 u_{xt}$ is a positive function of the extent to which innovations in ΔX^*_t have large permanent effects on lifetime income. We do this by comparing estimates of ϕ_1 when transitory factors (unemployment and hours lost due to illness) are excluded from ΔX^*_t with the results when they are included.

It is important to keep in mind in examining the empirical results below that the restriction $\phi_2 = 0$ is based upon the assumption of separability of preferences. King [1985] and many others

10. As Chamberlain [1982] pointed out and Hayashi observed in a similar context, the rational expectations hypothesis does not imply that the forecast error η_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 η_t in a short panel. However, we doubt if this problem is important empirically, since most of the variation over time in the *change* in the wage, hours of unemployment, quits, layoffs, and other key elements of ΔX^*_{t-1} arises from factors that are largely specific to a given household (rather than as the result of family-specific responses to a common shock). In this case, we should obtain similar results using a long panel on a few families as we obtain using a relatively short panel on a large cross section of families. Furthermore, we have removed the main effects of aggregate shocks through the use of time dummies.

11. The component of $\Delta \ln y^*_t$ due to ΔX^*_{t-1} and the component arising from u_{xt} have the same effect 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 (3), 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 (9) are equal to α if the Keynesian model is correct.

have noted that nonseparability of preferences between consumption and leisure within a given time period or intertemporal nonseparability of preferences will lead to a nonzero correlation between the change in consumption and lagged determinants of the income change.[12]

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

$$(11) \quad \Delta \ln C_t^* = \alpha[h_2 + h_1\theta(L)]\Delta X_{t-1}^* + e_{ct} + \alpha h_1 u_{xt} + \alpha v_t,$$

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.

The above tests were developed to overcome measurement error in income. As we shall see in the next section, ignoring measurement error in the testing procedure when it is present in the data will lead to incorrect inferences.

III. Econometric Methodology and Data

Estimation of (9) 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

$$(12) \quad h_1 u_{xt} = [h_1 \Delta X_t^* + h_2 \Delta X_{t-1}^*] - (h_1\theta(L) + h_2)\Delta X_{t-1}^*$$

to rewrite (9) in the form,

$$(13) \quad \Delta \ln C_t^* = \phi_1[h_1 \Delta X_t^* + h_2 \Delta X_{t-1}^*] + [\phi_2 - \phi_1][h_2 + h_1\theta(L)]\Delta X_{t-1}^* + \underline{e}_{ct}.$$

We then rewrite (13) by replacing $[h_2 + h_1\theta(L)]\Delta X_{t-1}^*$ with the estimate $[h_2 + h_1\hat{\theta}(L)]\Delta X_{t-1}^*$ obtained from least squares estima-

12. Kydland and Prescott [1982], Hotz et al. [1985], 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.

For example, past wage 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 intraperiod substitution between consumption and leisure. Indeed, Altonji [1986] 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 intraperiod separability holds. His results are inconclusive.

tion of (7) and by using equation (3) 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

$$(14)\quad \Delta \ln C_t^* = \phi_1 \Delta \ln y_t^* + (\phi_2 - \phi_1)[h_2 + \hat{h}_1\theta(L)]\Delta X_{t-1}^* + \omega_{ct},$$

where the composite error term ω_{ct} is equal to

$$(15)\quad \omega_{ct} = [\phi_2 - \phi_1]\{[h_2 + h_1\theta(L)] - [h_2 + h_1\hat{\theta}(L)]\}\Delta X_{t-1}^* - \phi_1[v_t + \Delta\epsilon_{yt}] + \underline{e}_{ct}.$$

Equation (14) may be estimated by two-stage least squares using ΔX_t^* and ΔX_{t-1}^* as instrumental variables for $\Delta \ln y_t^*$. We discuss computation of standard errors in a footnote.[13]

We can now show the consequence of ignoring measurement error in income in the testing procedure. If measurement error is absent, then $\Delta \ln y_{t-1}^*$ is a valid instrument for $\Delta \ln y_t^*$ in equation (14), assuming that Δy_{t-1} is uncorrelated with the change in consumption preferences. (This is stronger than our assumption that the income determinants ΔX_{t-1}^* are uncorrelated with the change in consumption preferences). However, if $\ln y_t^*$ contained a serially uncorrelated measurement error, as in equation (4), $\Delta \ln y_{t-1}^*$ will be correlated with $\Delta\epsilon_{yt}$, the measurement error in $\Delta \ln y_t^*$. In fact, the empirical results below show that we shall wrongly reject the RE-lifecycle model if the measurement error problem is ignored.

For computational convenience we have followed the lead of Hall and Mishkin [1982] and Hayashi [1985] 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, age^2, age^3, education, the change in a dummy variable for marital status, the level and squared value of the change of

13. The composite error term in (14) is probably serially correlated over time for the same individual and is heteroskedastic. For this reason, we have used a variant of the formulae in Chamberlain [1982, p. 56] and White [1984, p. 143] to compute standard errors that account for nonparametric forms of heteroskedasticity and correlations over time for a given family at one and two lags. Another complication in the error term in (14) arises from the fact that we use a two-step procedure involving the use of the estimate $[h_2 + \hat{h}_1\theta\ (L)]\Delta X_{t-1}^*$ in estimating equation (14). If the Keynesian hypothesis is correct, 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 heteroskedasticity that might be induced by the two-step procedure.

family size, the change in the number of children in the family unit, the change in the number of children under age six, and current and lagged values of dummy variables for eight Census regions, residence in an SMSA, and residence in a city with more than 500,000 people. The residuals from these regressions form the basis for the analysis below. Given the large samples that were used to form the residuals, the fact that the estimation was performed in two stages is of little consequence.

3.1. Power of the Tests

Because the distribution of the estimators is known under both the Keynesian model and RE-lifecycle model (subject to the caveat in footnote 13), one may say more than is usually possible about the power of the tests to reject the RE-lifecycle model when the Keynesian model is correct, and vice versa. A brief discussion of this issue may be useful in evaluating the findings below and in thinking about the suitability of other data sets for the test we use.

The test of the RE-lifecycle model using (14) is a test of $\phi_2 = 0$. Under the alternative hypothesis of the Keynesian model, ϕ_2 is the elasticity of food consumption expenditures with respect to income, α. The power of the test depends on the standard error of $\hat{\phi}_2$ relative to α, and in a footnote we discuss the factors that determine this standard error.[14] Our estimated standard errors for $\hat{\phi}_2$ are about 0.09. This suggests substantial power against the RE-lifecycle model when the Keynesian model is correct, given that the instrumental variables estimates reported in the introduction imply that α is 0.229 when interpreted using the Keynesian model. However, we doubt whether our test is very powerful, given the quality of the PSID data, against the pure RE-lifecycle model under the alternative hypothesis of a modest departure from this model.

The power of the test of the Keynesian model under the null hypothesis of the RE-lifecycle model is determined by the standard

14. The standard error of $\hat{\phi}_2$ depends upon the variance of $[h_2 + h_1\theta(L)]\Delta X^*_{t-1}$ relative to the variance of the error term in (14). The test would have no power if ΔX^*_{t-1} has no effect on income ($h_2 = 0$) *and* either ΔX^*_t does not affect income ($h_1 = 0$) or ΔX^*_{t-1} does not help predict ΔX^*_t ($\theta(L) = 0$). The parameters h_1 and h_2 depend upon the extent to which the ΔX_t vector and its lag are good predictors of income and the amount of measurement error in ΔX^*_t. Below we find that current and past X variables are highly significant predictors of the change in measured income. The R^2 of the lagged X variables is only 0.0264 (see Table I, column 5), but R^2's of this order of magnitude are not uncommon in analyses based on first differences of micro data. Many of the elements of ΔX^*_t are strongly autocorrelated, so $\theta(L)$ is far from 0. However, the variance of the error term of (14) is very large, with almost none of the variance of $\Delta \ln C^*_t$ explained. This may reflect both preference shifts and measurement error. A data set with more accurate or more extensive consumption measures would result in smaller standard errors for $\hat{\phi}_2$ than we obtain and permit more powerful tests.

error of the estimate of $(\phi_2 - \phi_1)$ relative to its value of $-B_c b$ if the RE-lifecycle model is correct.

We can make some brief remarks about the power of our tests against the RE-lifecycle model under the null hypothesis that consumption behaves according to a Modigliani-type consumption function and responds to a distributed lag of income and to assets (see Modigliani [1971]).[15] If the Modigliani type model is correct and the RE hypothesis is false, then one would expect the lagged determinants of income in the estimates of (11) to play a significant role. One would also expect the coefficient ϕ_2 on $[h_2 + h_1\theta(L)]\Delta X^*_{t-1}$ to be significant in tests based on (9) and (14), since the income equations imply that variables such as the lagged wage change and lagged unemployment have a strong relationship with the lagged income change.

3.2. Data

The data are from the 1968–1981 Panel Study of Income Dynamics Individuals tape. For a given year, the sample contains individuals who were between the ages of 18 to 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.[16]

A few of the variables require discussion. ln C^*_t is the log of the

15. Note that the RE-lifecycle model also implies a distributed lag in the regression relationship between the change in consumption and the change in income, even though consumption responds only to the innovation in income. The coefficients on the lagged income changes will be zero only if one enters the anticipated and the unanticipated component of the income change into the equation as separate variables. Also, the RE-lifecycle model is perfectly consistent with a distributed lag in levels (as opposed to first difference). But under the rational expectations hypothesis the form of the lag should depend on the nature of the income process.

16. 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 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 [1986], 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. Within the context of the model in the Appendix, 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 (A.1). That is, changes in family structure alter the utility that the head of household assigns to a given level of labor supply and family food consumption. Changes in family structure may also alter expected future income from sources other than earnings of the male household head (e.g., 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 η_t. There are obvious shortcomings with this treatment of the family unit.

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 [1986], and other recent studies of lifecycle models based upon the PSID. There appears to be considerable measurement error in the variable. This is accounted for in our model by the error component e_{ct} and does not affect the validity of our tests provided that it is independent of instruments for the income change. The use of food consumption in isolation from other goods may be justified in terms of the lifecycle model presented in the Appendix if the utility function for each period is separable between food consumption and other goods. The use of dummy variables for each year controls 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 [1985] and Bernanke [1984] discuss 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 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. Given our assumptions about measurement error, it is important to note that for both hourly workers and salary workers this wage variable is based upon survey questions that are independent of those used to construct $\Delta \ln y_t^*$.[17]

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 lost due to illness, refer to the calendar year that precedes the survey date.[18] 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

17. 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 available only 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.

18. 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 excludes temporary layoffs.

to the true relationship. One may show that this downward bias in the relationship between the wage change and $\Delta \ln y_t^*$ is likely to result in an upward bias in the consumption response to changes in $\Delta \ln y_t^*$ that result from changes in the wage. This will complicate the interpretation of changes in the consumption parameters that occur when hours of unemployment and hours lost due to illness are dropped from the first-stage equation for $\Delta \ln y_t^*$ in (14). 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 percent or fell by more than 80 percent. 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.

The results in the tables are based upon family income rather than after-tax income. 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. However, we also report results based on after-tax income and the inclusion of the after-tax interest rate in Section 4.2.

IV. Results

In this section we report tests based on the relationship between consumption and past income determinants as described in (11). We then turn to tests based upon (14).

4.1. The Response of Consumption to Past Income Determinants

Table I reports a series of estimates of (11) and consists of regressions of the change in the log of real food consumption (the principal consumption measure in the PSID data set) on a series of variables dated $t - 1$ or earlier that 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. 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.

Before turning to the results, we discuss our assumption, mentioned earlier, that all of the income determinants are assumed to be exogenous with respect to changes in consumption tastes (part of the disturbance e_{ct}). They may be correlated with preference shifts affecting labor supply (i.e., with the term $\Delta\epsilon_{nt}$, which appears in Appendix equation (A.13)). The assumption of exogeneity with respect to consumption preferences is justified for the wage change if most of the large intertemporal variation in wages for a given individual is due to (1) variations in the marginal product of labor within a given job; (2) variation across jobs, which is due to relative demand shifts or noncompetitive features of the wage structure (union effects, for example); (3) differences across firms in the optimal wage level implied by the turnover costs and supervision costs of the firm, or (4) job match specific variation in the productivity associated with complementarities between job requirements and other worker characteristics.[19] The exogeneity assumption is also justified for quits if they usually are a response to differences in wages across jobs arising for any of the above reasons. Our use of layoffs seems justifiable. But it should be noted that wage changes, quits, and perhaps even promotions might be correlated with changes in consumption preferences if increases in consumption needs which raise the marginal utility of income induce workers to seek less desirable working conditions in exchange for higher wages.

Ham [1986] examines the issue of whether variation in unemployment reflects constraints on hours, intertemporal variation in wages, or variation in labor supply preferences using an intertemporal labor supply model, and he provides references to earlier studies. Our maintained assumption that unemployment is unrelated to the shifts in consumption preferences is clearly valid under the first interpretation of unemployment, which Ham's results favor. It may be valid under both the second and third interpretations as well if consumption tastes and labor supply tastes are unrelated.

We are assuming that hours lost due to illness primarily reflects variation in market productivity and in the disutility of working. On the other hand, this variable might be correlated with consumption preferences if illness affects tastes for going to restaurants or entertaining at home, although the relatively modest change in estimates that occurs when this variable is dropped (compare columns (1) and (3) in Table II) suggests that this is not a key problem.

19. See Mortensen [1986] and Katz [1986] for references to the labor economics literature.

TABLE II

ESTIMATES OF THE CONSUMPTION MODEL (EQUATION (14))

	Second-stage equations for consumption change dependent variable: Δlog (consumption)$_t$ (standard errors in parentheses)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Constant	−0.00036	−0.00036	−0.00036	−0.00036	−0.00036	−0.00036	−0.00036
	(0.00167)	(0.00170)	(0.00169)	(0.00171)	(0.00168)	(0.00170)	(0.00172)
Δlog (family income)$_t$[a] (ϕ_1)	0.302[c]	0.351[d]	0.332[e]	0.397[f]	0.138[g]	0.0758[h]	
	(0.0670)	(0.0791)	(0.0709)	(0.0836)	(0.0387)	(0.0164)	
Δlog (family income)$_t$[b] ($\phi_2 - \phi_1$)	−0.211	−0.260	−0.241	−0.307	−0.0479	0.0149	0.0907
	(0.101)	(0.115)	(0.103)	(0.119)	(0.0961)	(0.0941)	(0.0908)
R^2	0.0029	0.0025	0.0031	0.0028	0.0019	0.0036	0.0001
Number of observations	9,913	9,913	9,913	9,913	9,913	9,913	9,913
M.S.E.	0.1115	0.1131	0.1124	0.1148	0.1084	0.1081	0.1085

a. Treated as endogenous. The first stage regression for each column is discussed in the footnote for each coefficient in the row.
b. Δlog (family income)$_t$ is the predicted value of income from variables dated $t-1$ or earlier (column 5, Table I).
c. Instrumental variables for Δlog (family income)$_t$ include all variables in column (7), Table I.
d. Instrumental variables for Δlog (family income)$_t$ include all variables in column (7), Table I except log (hours unemployed + 2,000)$_t$.
e. Instrumental variables for Δlog (family income)$_t$ include all variables in column (7), Table I except log (hours ill + 2,000)$_t$.
f. Instrumental variables for Δlog (family income)$_t$ include all variables in column (7), Table I except log (hours unemployed + 2,000)$_t$ and log (hours ill + 2,000)$_t$.
g. Δlog (family income)$_t$ treated as exogenous.
h. Instrumental variables for Δlog (family income)$_t$ include all variables in column (7), Table I and Δlog (family income)$_{t-1}$.

We now turn to the results in Table I. We do not find that the lagged income determinants have a significant effect on consumption. For example, the marginal significance level of the first two lags of the change in family income is only 0.342 (see column 2), and the broad array of variables in column 3 is 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 of the past income change is surprising in view of Hall and Mishkin's [1982, p. 478] results. The difference in findings may be due in part 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 with 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). Although we have considered a number of possibilities, we do not have a good explanation for why the result is sensitive to the choice of sample. In any event, even in the larger sample the relationship between the past income change and consumption is weak. It is noteworthy that Zeldes [1985] finds a significant relationship between the consumption change and the value of y_{t-1}^* (as opposed to the lagged first difference in income) for a subsample of low-income families but not for the high-income 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 I. 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 (9), which we implement in the form of (14).

4.2. *Effects of Anticipated and Partially Unanticipated Components of Income on Consumption*

Table II reports tests based upon equation (14) 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 0.0907 when only lagged ΔX_t^* variables are used as instruments and is not significantly different from 0. It is basically consistent with the results of Table I. In column 1 the change in income is added as an additional variable with both ΔX_t^* and past ΔX_t^* variables used as instruments. Note first that the point estimate of $\phi_2 - \phi_1$ is -0.211. 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 0.64.[20]

We now explore the sensitivity of the results to exclusion of transitory determinants of income from ΔX_t^*. Column 2 of Table II is identical to column 1 except that the current value of hours unemployed is excluded from the ΔX_t^* vector. The estimated effect of the unanticipated change in income rises to 0.351 from 0.302. When both the current value of hours employed and hours lost due to illness are eliminated from the variables in ΔX_t^*, the estimate of ϕ_1 rises to 0.397 (Table II, column 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 I reveals that the large effect on income of a one-time shock to hours lost due to illness or hours lost due to unemployment is transitory.[21] 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 η_t to $h_1 u_{xt}$ rises in absolute value, and so $\phi_1 (\phi_1 = B_c b)$ also rises.

However, two alternative explanations for the rise in ϕ_1 require discussion. First, if the assumption of intraperiod separability of

20. 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.

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 II, column 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.

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 that go beyond their effects on consumption through η_t.[22] The coefficient on the change in income will reflect a weighted average of these effects as well as the value of $B_c b$. We cannot rule out the possibility that the increase in the estimate of ϕ_1 following removal of the unemployment and illness variables from ΔX_t^* occurs because the direct effect of these variables on consumption (with η_t held fixed) is smaller than that of the wage change. However, the failure to detect a significant relationship between the consumption change and the lagged values of the wage, unemployment, and illness variables provides some limited evidence against nonseparability as an explanation for the rise in ϕ_1. (See Table I.)

The second explanation for the rise in ϕ_1 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. The increased overlap should reduce the effect that inconsistency of timing has on the covariances among the variables. The results are reported in Table III, where the symbol $\Delta_2 Z_t$ refers to $Z_t - Z_{t-2}$ for any variable Z_t. The results are very similar to those in Table II, and so the evidence does not support the view that the inconsistency in the timing of the variables is responsible for our findings.

4.3. Experiments with After-Tax Income and the After-Tax Interest Rate

For a subsample of 3,987 observations we were able to match in data on after-income and the after-tax real rate of interest constructed by Zeldes [1985].[23] When we re-estimate (14) for the subsample and use total income, the estimates of ϕ_1 and $\phi_2 - \phi_1$ are 0.334 and -0.341 with standard errors of (0.134) and (0.179). When we use after-tax income, the estimates of ϕ_1 and $\phi_2 - \phi_1$ are 0.489

22. See page 304 and footnote 12 above. The literature on unemployment as a constraint on labor supply (see Ashenfelter [1981], Deaton and Muellbauer [1981], and Browning et al. [1985]) suggests that the form of the consumption and marginal utility of income equations are affected by constraints on labor supply.

23. We owe a special debt to Stephen Zeldes for making his data available to us.

TABLE III

EFFECTS OF ANTICIPATED AND UNANTICIPATED CHANGES IN INCOME ON CONSUMPTION: TWO-YEAR DIFFERENCES

First-stage equations for income change dependent var: Δ_2 log (family income)$_t$ (standard errors in parentheses)			Second-stage equations for consumption change dependent var.: Δ_2 log (food consumption)$_t$[a] (standard errors in parentheses)				
	(1)	(2)		(3)	(4)	(5)	(6)
Constant	0.0115	0.0206	Constant	0.00225	0.00255	0.00255	0.00255
	(0.00469)	(0.00465)		(0.00363)	(0.00364)	(0.00367)	(0.00368)
Δ_2 log (wage)$_{t-2}$	0.0362	−0.0261	Δ_2 log (family	0.346[d]	0.360[e]	0.397[f]	0.419[g]
	(0.0301)	(0.0320)	income)$_t$.[b] ϕ_1	(0.0765)	(0.0793)	(0.0837)	(0.0868)
Δ_2 log (wage)$_{t-2}$	0.0456	0.0197	Δ_2 log (family	−0.272	−0.286	−0.324	−0.346
*quit$_{t-2}$	(0.0704)	(0.0752)	income)$_t$.[c] $\phi_2 - \phi_1$	(0.141)	(0.142)	(0.152)	(0.155)
Δ_2 log (wage)$_{t-2}$	0.0936	0.0726	R^2	0.00.51	0.0050	0.0047	0.0047
*layoff$_{t-2}$	(0.117)	(0.124)					
Δ_2 log (wage)$_{t-2}$	−0.0460	−0.0626	no. of	6,028	6,028	6,028	6,028
*promotion$_{t-2}$	(0.0758)	(0.0772)	observations				
quit$_{t-2}$	0.0431	0.0450	M.S.E.	0.1296	0.1303	0.1323	0.1336
	(0.0228)	−0.0234)					
layoff$_{t-2}$	0.0417	0.0463					
	(0.0382)	(0.0388)					
promotion$_{t-2}$	0.00454	0.0150					
	(0.0218)	(0.0226)					
log (hours ill + 2,000)$_{t-2}$	0.125	0.0533					
	(0.0584)	(0.0566)					
log (hours unempl. + 2,000)$_{t-2}$	0.662	0.509					
	(0.104)	(0.0992)					
Δ_2 log (wage)$_t$	0.279						
	(0.0357)						

TABLE III
(Continued)

	First-stage equations for income change dependent var: Δ_2 log (family income)$_t$ (standard errors in parentheses)		Second-stage equations for consumption change dependent var.: Δ_2 log (food consumption)$_t^a$ (standard errors in parentheses)			
	(1)	(2)	(3)	(4)	(5)	(6)
Δ_2 log (wage)$_t$	0.134					
*quit$_t$	(0.0674)					
Δ_2 log (wage)$_t$	−0.0486					
*layoff$_t$	(0.0884)					
Δ_2 log (wage)$_t$	0.0855					
*promotion$_t$	(0.105)					
quit$_t$	−0.0442					
	(0.0219)					
layoff$_t$	0.0206					
	(0.0393)					
promotion$_t$	−0.0170					
	(0.0234)					
log (hours ill + 2,000)$_t$	−0.227					
	(0.0574)					
log (hours unemployed + 2,000)$_t$	−0.651					
	(0.108)					
R^2	0.0756	0.0185				
no. of observations	6,028	6,028				
M.S.E.	0.0884	0.0937				

a. $\Delta_2 Z_t \equiv Z_t - Z_{t-2}$, $\Delta_2 Z_{t-2} \equiv Z_{t-2} - Z_{t-4}$, for any variable Z.
b. Treated as endogenous. The instrumental variables are described in the footnote to each column.
c. Δ_2 log (family income)$_t$ is the predicted value of income from variables dated $t-2$ or earlier (column 2).
d. Instrumental variables for Δ_2 log (family income)$_t$ include all variables in column (1).
e. Instrumental variables for Δ_2 log (family income)$_t$ include all variables in column (1) except log (hours ill + 2,000)$_t$.
f. Instrumental variables for Δ_2 log (family income)$_t$ include all variables in column (1) except log (hours unemployed + 2,000)$_t$.
g. Instrumental variables for Δ_2 log (family income)$_t$ include all variables in column (1) except log (hours ill + 2,000)$_t$ and log (hours unemployed + 2,000)$_t$.

and -0.514 with standard errors of (0.184) and (0.236). Thus, the tax adjustment results in a rescaling of coefficients but makes no substantive difference. The point estimates for the subsample are remarkably consistent with the RE-lifecycle hypothesis. Addition of the after-tax real rate of interest to (14) has almost no effect on these point estimates.[24]

4.4. The Effects of Measurement Error

To assess the importance of measurement error, we have also produced estimates treating $\Delta \ln y_t^*$ as exogenous in (14), which amounts to including it in ΔX_t^* (column 5). In this case, the estimates of ϕ_1 and $\phi_2 - \phi_1$ are 0.138 and 0.0479 with standard errors of 0.0387 and 0.0961. 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 and the lagged income change is uncorrelated with the change in consumption preferences. The estimate of $\phi_2 - \phi_1$ is 0.0149 with a standard error of 0.0941. 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 analytically that if the RE-lifecycle model is correct, then ignoring measurement error in income will bias the estimator of $\phi_2 - \phi_1$ in favor of the Keynesian model (toward 0).

In the light of these findings, it is interesting to speculate on what the consequences of measurement error are for Hall and Mishkin's and Bernanke's procedures. Bernanke finds little evidence against the lifecyle model, while Hall and Mishkin obtain an estimate of the discount rate that is too high (from the perspective of the lifecycle model) using one of their specifications and estimate that about 20 percent of the families in their sample are Keynesian consumers using another.

We have used nonlinear least squares to fit the parameters of Hall and Mishkin's lifecycle model (equation (34) of their paper) to

24. 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, although we have suppressed this term in the discussion in Section II. Shapiro [1983] and Zeldes [1985] have investigated this issue using the PSID, while Runkle [1983] has done so using the data from the negative income tax experiments. When adding the after-tax real interest rate, we use the second lag of this variable as an additional instrumental variable for the income change. We treat the after-tax real interest rate as endogenous, using its second lag and the lagged income determinants as instrumental variables. The estimated coefficient for the interest rate is -0.67, which has the wrong sign. However, its standard error is 1.03.

the sample moments reported in their Table II after incorporating a serially uncorrelated measurement error to the level of income into their model. We computed estimates under various assumptions about the variance of the measurement error term. Since Hall and Mishkin did not report values for all of the sample moments that play a role in their model, our analysis is only suggestive. Nevertheless, the results of our sensitivity analysis indicate that if one ignores measurement error and it is in fact substantial, Hall and Mishkin's procedure is biased *in favor* of the Keynesian model. On first glance, this result seems surprising, since one might expect measurement error to result in a larger downward bias in the estimated response of consumption to the transitory component of income than in the estimate of the response of consumption to the permanent component. But this bias in favor of the lifecycle model is more than offset by the fact that ignoring measurement error biases the coefficients on Hall and Mishkin's unrestricted MA(2) process for transitory income to make this income component appear to be more transitory than it actually is. The net result is to overstate the discount rate at which consumers discount future income.

Bernanke does not report the sample moments used to estimate his model. However, the fact that he imposes the assumption that transitory income is white noise in levels (in contrast to Hall and Mishkin's unrestricted MA(2) process) makes it possible to sign the bias analytically in some special cases. Specifically, we simplified the problem by assuming that consumption is nondurable. For this case we found that ignoring measurement error would bias Bernanke's results against the Keynesian model. Thus, our limited analysis suggests that the discrepancy between Hall and Mishkin's and Bernanke's studies is due in part to differences in their sensitivity to measurement error in income.[25] (We were unable to draw conclusions for Hayashi's study.)

To sum up, our results support the RE-lifecycle model and reject the Keynesian model. Our empirical analysis confirms that measurement error in income is an important feature of the PSID data. Nevertheless, our most important conclusion is that taking account of measurement error does not overturn Hall and Mish-

25. 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 pursuing this line of research in Altonji et al. [1986]. It requires much stronger assumptions about the form of the income process and the serial correlation properties of measurement error than do the tests used in the present paper.

kin's, Bernanke's, and Hayashi's qualitative finding that the vast majority of households obey the lifecycle model. Indeed, we doubt whether our tests are sufficiently powerful in the PSID data to detect small departures from the RE-lifecycle model. We have provided some evidence that the quantitative difference in the results of Hall and Mishkin [1982] and Bernanke [1984] may be due to differences in the way in which measurement error affects these studies.

V. Testing the RE-Lifecycle Model for Imperfect Credit Markets

The RE-lifecycle model represented by equation (1) assumed that consumers face perfect capital markets, and that their marginal return on net wealth was independent of their level of assets. 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 [1985] 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 the marginal return to wealth decreases smoothly with the level of assets than if credit constraints are discontinuous (credit rationing). However, Dolde and Mariger's basic point carries over to the version of the lifecycle model presented in the Appendix 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.

To see this, consider the following argument. Let $(1 + r_{t-1}) R(A_{t-1})$ denote the return function relating nominal wealth following consumption and labor supply in period $t-1$, A_{t-1}, to nominal wealth prior to consumption and labor supply in period t, $\overline{A}_t$. r_{t-1} is a base lending rate in period $t-1$ such as the Treasury bill rate. The function $R(A_{t-1})$ permits the rate of return on net wealth to depend on the level of net wealth. (Net wealth is negative for net borrowers.) If credit markets are perfect, then $R(A_{t-1}) = A_{t-1}$, and $R'(A_{t-1}) = 1$. The RE-lifecycle model in the Appendix implies that

$$(16) \qquad \Delta \ln C_t^* = \text{const} + B_c \eta_t - B_c \ln (R'(A_{t-1})) + e_{ct}.$$

This equation is similar to (1) but permits $R'(A_{t-1})$ to differ from 1.

Consider two consumers who have the same value of $\overline{A}_{t-1}$ and are alike in all respects except for the expected income in period t. Consumer 1 learns prior to choice of C_{t-1} 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. (η_{t-1} is negative.) Consequently, consumption in $t-1$ rises above the level that 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 $R'(A_{t-1})$. The coefficient $-B_c$ on ln $R'(A_{t-1})$ is positive, and the anticipated income change does not affect η_t or the other terms in (16). Consequently, Δ 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 Δ ln C_t^* will be smaller than it would have been in the absence of the capital market imperfections, and smaller than Δ ln C_t^* for consumer 1. The consumption response of consumer 1 to the increase in income will be larger in absolute value than the response of consumer 2 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.[26]

We have performed an investigation of the possibility that the response of consumption to the predicted value of Δ ln y_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 were constructed from the regression of Δ ln y_t^* against lagged values of the income determinants (Table II, column 2) and permitted to have separate coefficients in the consumption equation. The relative size of the coefficients will depend upon the shape of the marginal return function and the fraction of the sample whose net wealth is sufficiently low for the marginal return to vary in response to changes in income prospects. The consumption equation is reported in Table IV. The coefficient on the positive change is 0.126, while the coefficient on

26. The above discussion and Appendix I implicitly assume that the marginal tax rate is constant. If this assumption is false, anticipated increases in income may increase the after-tax marginal interest rate. Anticipated decreases might reduce the after-tax marginal interest rate. Since we do not control for the marginal tax in the empirical analysis, we suspect that this mechanism would tend to reinforce the asymmetry that might arise from imperfect credit markets.

TABLE IV
CONSUMPTION RESPONSES TO POSITIVE AND NEGATIVE INCOME CHANGES
(STANDARD ERRORS IN PARENTHESES)

Constant	−0.00209	−0.00237
	(0.00425)	(0.00411)
Positive predicted[a] income change	0.251	
	(0.0740)	
Negative predicted[a] income change	0.204	
	(0.0788)	
Positive predicted[b] income change		0.126
		(0.103)
Negative predicted[b] income change		-0.0346
		(0.176)
R^2	0.0024	0.0002
No. of obs.	9,913	9,913
S.S.E.	1,075.1	1,077.5

a.Predicted income change from column 7 in Table I (current and lagged variables).
b.Predicted income from column 5 in Table I (lagged variables only).

the negative change is −0.0346, suggesting some asymmetry. However, the variables are not significantly different from 0 or from each other and are subject to substantial standard errors.

With 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 IV, column 1). It should be noted that Runkle [1983] and Zeldes [1985] check whether the level of net wealth and the level of income at the beginning of the period are negatively related to the change in consumption, as is implied by the liquidity constraint hypothesis, and have obtained mixed results.[27]

VI. CONCLUSION

We have implemented tests of alternative consumption models that are valid in the presence of measurement error in the income

27. In his innovative paper Runkle finds that the net wealth variable is positive and significant for families with low wealth. However, the positive sign is inconsistent with the liquidity constraint hypothesis, since presumably the marginal interest rate is a 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 $t + 1$.

variable. On the whole, the results are favorable to the RE-lifecycle model, although our tests probably are not sufficiently powerful in the PSID data to detect modest departures from the RE-lifecycle model. We can reject the Keynesian hypothesis that consumption responds to anticipated and unanticipated changes in income in the same way. Treatment of measurement error is important in our analysis, since our results are very favorable to the Keynesian model when measurement error is ignored. Consideration of measurement error also helps reconcile the differences in results of Hall and Mishkin and Bernanke. Nevertheless, our most important conclusion is that taking account of measurement error does not overturn Hall and Mishkin's, Bernanke's, and Hayashi's qualitative finding that the vast majority of households obey the lifecycle model. 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.

APPENDIX: THE LIFECYCLE MODEL WITH RATIONAL EXPECTATIONS

The lifecycle model of consumer behavior under uncertainty is as follows. (See MaCurdy [1983] and Browning et al. [1985] 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 V_t is

$$V_t = \sum_{i=0}^{T-t} \frac{U_{t+i}(C_{t+i}, N_{t+i})}{(1+\delta)^{i+t}}, \tag{A.1}$$

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 (A.1), the consumer must satisfy the constraints,

$$\overline{A}_{t+i+1} = (1 + r_{t+i})R(A_{t+i}), \qquad 0 \leq i \leq T - t \tag{A.2}$$

$$A_T \geq 0, \tag{A.3}$$

where

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

w_t represents the worker's nominal wage at time t, P_t is the price level at t, $\overline{A}_t$ 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 $t + 1$ I, $\overline{A}_{t+1}$, given the base lending rate r_t. For most of the paper we assume that taxes are proportional and absorb the tax rate in the base lending rate. (But see Section 4.1.) Equation (A.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

$$\text{(A.4)} \qquad \frac{\partial V_t}{\partial N_t} = \frac{\partial U_t}{\partial N_t}(1 + \delta)^{-t} + w_t\lambda_t = 0$$

$$\text{(A.5)} \qquad \frac{\partial V_t}{\partial C_t} = \frac{\partial U_t}{\partial C_t}(1 + \delta)^{-t} - P_t\lambda_t = 0,$$

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:

$$\text{(A.6)} \qquad \lambda_t = E_t[\lambda_{t+1}[1 + r_t]R'(A_t)] \text{ for } 0 \le t \le T - 1,$$

where E_t is the expectations operator conditional on information available to the consumer in period t. Equation (A.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 (A.6) for λ_t implies (after backdating one period) that

$$\text{(A.7)} \qquad \lambda_t[1 + r_{t-1}]R'(A_{t-1}) = \lambda_{t-1} + \epsilon_{\lambda t} \qquad (1 \le t \le T),$$

where $\epsilon_{\lambda t}$ 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, $\epsilon_{\lambda t}$ 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

(A.8) $$\frac{\partial U_t}{\partial C_t} = \exp^{\epsilon_{ct}} C_t^{1/B_c}.$$

This equation holds if within-period preferences take the form,

(A.9) $$U_t(C_t,N_t) = [(B_c/(B_c+1)) \exp^{\epsilon_{ct}} C_t^{(1+1/B_c)} - \exp^{\epsilon_{nt}} N_t^{(B_n/(1+B_n))}]^{\gamma},$$

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 that 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 1 constrains preferences to be separable between consumption and leisure within the period. MaCurdy [1983] and Mankiw et al. [1985] have used (A.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.

The intertemporal optimality condition may be expressed in terms of the marginal utility of consumption by combining (A.5) and (A.7), yielding

(A.10) $$[1+\delta]^{-t}\left[\frac{1}{P_t}\right][1+r_t]R'(A_{t-1})\frac{\partial U_t}{\partial C_t} = [1+\delta]^{-t-1}\left[\frac{1}{P_{t-1}}\right]\frac{\partial U_{t-1}}{\partial C_{t-1}} + \epsilon_{\lambda t}.$$

Substituting for $\partial U_t/\partial C_t$ from (A.8) into (A.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 $\ln(1 + r_{t-1}) \simeq r_{t-1}$ leads to the approximation,

(A.11) $$\ln \lambda_t \simeq \ln \lambda_{t-1} - r_{t-1} - \ln R'(A_{t-1}) + \eta_t$$

(A.12) $$\Delta \ln C_t \simeq \text{const} + B_c \Delta \ln P_t + B_c \eta_t - B_c[r_{t-1} + \ln R'(A_{t-1})] - B_c \Delta\epsilon_{ct}$$

(A.13) $$\Delta \ln N_t + \Delta \ln w_t \simeq \text{const} + [1 + B_n]\Delta \ln w_t - B_n[r_{t-1} + \ln R'(A_{t-1})] + B_n \eta_t + B_2 \Delta\epsilon_{nt},$$

where η_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 (A.13) in order to highlight the fact that income from labor is endogenous in the model.

The change in the marginal utility of income η_t summarizes the effects on consumer decisions via the budget constraint of changes in lifetime resources and preferences.

We next project the revision in the marginal utility of income, η_t, onto the scalar variable $h_1 u_{xt}$:

$$\eta_t = b(h_1 u_{xt}) + \xi_t, \tag{A.14}$$

where h_1 is the coefficient vector relating u_{xt} to $\Delta \ln y_t^*$ in (7). We assume in the text that the negative coefficient b depends on the size and degree of permanence in the effects of the components of ΔX_t^* on income. We use this assumption in arguing that b will increase (in absolute value) if transitory income determinants such as hours lost due to illness and unemployment are excluded from ΔX_t^*. Our justification is as follows. 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 η_t and innovations in the exogenous factors entering the lifetime budget constraint. However, since one may easily show in the perfect foresight case that λ_t is a decreasing function of w_{t+i} and $-\epsilon_{Nt+1}$, $i = 0 \ldots T - t$, it is reasonable to assume that permanent shocks to these variables or other variables, which affect earnings (such as spells of unemployment), have larger effects on η_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 η_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.

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 are 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 (A.14) to eliminate η_t from (A.12). With these modifications equation (A.12) becomes

$$\Delta \ln C_t^* = \text{const.} + B_c b h_1 u_{xt} + e_{ct} + B_c \xi_t, \tag{A.15}$$

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

A comparison of (A.15) with (9) establishes that the RE-lifecycle model implies that $\phi_2 = 0$, as was claimed in the text, and that the parameter ϕ_1 is equal to $B_c b$. Essentially, the restriction on ϕ_2 states that income changes 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 (9) 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 (A.15). $h_1 u_{xt}$ is uncorrelated with ξ_t by definition of ξ_t in (A.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 η_t, which implies (given A.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.

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