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THE SENSITIVITY OF CONSUMPTION TO TRANSITORY INCOME: ESTIMATES FROM PANEL DATA ON HOUSEHOLDS

Robert E. Hall

Frederic S. Mishkin

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The Sensitivity of Consumption to Transitory Income: Estimates From Panel Data on Households

ABSTRACT

We investigate the stochastic relation between income and consumption (specifically, consumption of food) within a panel of about 2,000 households. Our major findings are:

1. Consumption responds much more strongly to permanent than to transitory movements of income.
2. The response to transitory income is nonetheless clearly positive.
3. A simple test, independent of our model of consumption, rejects a central implication of the pure life cycle-permanent income hypothesis.
4. The observed covariation of income and consumption is compatible with pure life cycle-permanent income behavior on the part of 80 percent of families and simple proportionality of consumption and income among the remaining 20 percent.

As a general matter, our findings support the view that families respond differently to different sources of income variations. In particular, temporary income tax policies have smaller effects on consumption than do other, more permanent changes in income of the same magnitude.

Robert E. Hall
Hoover Memorial Building
Stanford University
Stanford, California 94305

(415) 497-2215

Frederic Mishkin
Department of Economics
University of Chicago
1126 East 59th Street
Chicago, Illinois 60637

(312) 753-4518

I. Introduction

The stochastic relationship of consumption to income has long been recognized as a critical issue to macro policy analysis. One traditional view of consumers sees them as largely passive agents in the determination of aggregate demand. Changes in real incomes are translated reasonably quickly and fully into changes in consumption. In this view, income tax changes are a powerful tool for countercyclical stabilization policy, as Okun (1971) and Tobin and Dolde (1971) have argued. In contrast, the life cycle-permanent income hypothesis of consumption embodies the opposite view that consumers maximize utility over a long-term horizon. Rather than responding passively to every change in income, consumers will alter their consumption by smaller amounts if they perceive the income change as temporary rather than permanent. Eisner (1969) has argued along this line. With the refinement of rational expectations, the life cycle-permanent income theory (as in Muth (1960), Lucas (1976) and Hall (1978)) casts serious doubt on the usefulness of income tax policy as a stabilization tool. Consumers cannot be relied on to react vigorously when an income tax change goes into effect. Predicting the impact of an income tax change on consumption requires knowledge of consumers' perceptions of its permanence.

This paper tries to shed some light on the stochastic relation between income and consumption (specifically, consumption of food) within a panel of about 2000 households who reported both variables over a seven-year span. Our major findings are:

1. Consumption responds much more strongly to permanent than to transitory movements of income.

2. The response to transitory income is nonetheless vigorous; it is compatible with interest rates of 10 to 20 percent per year but not lower.
3. A simple test, independent of our model of consumption, rejects the pure life cycle-permanent income hypothesis.
4. The observed covariation of income and consumption is compatible with pure life cycle-permanent income behavior on the part of 80 percent of families and simple proportionality of consumption and income among the remaining 20 percent.

These conclusions are derived from evidence about the joint movements of income and consumption. Needless to say, consumption and income frequently rise or fall together in the same year for a particular family. Our model explains the bulk of this correlation as the immediate response of consumption to changes in permanent income. Most of the rest is attributed to departures from life cycle-permanent income behavior by a minority of the sample. We hypothesize that this minority (about a fifth of all families) set consumption to a fraction of current income instead of following the more complicated optimal rule.

II. Stochastic Theory of Consumer Behavior

An important paper by John Muth (1960) on the permanent income hypothesis showed that the marginal propensities to consume out of current and lagged income depend on the stochastic properties of income. An income process with a large transitory component implies a small propensity to consume out of current income. At the other extreme, when most changes in income are permanent--that is, when income is almost a random walk--the propensity to consume out of current income should differ only slightly from the propensity to consume out of permanent income. This point was overlooked in empirical work on consumption long after the publication of Muth's article; Mayer's (1972b) survey does not mention any studies that consider the issue, for example. In recent work using data on individual consumers (Mayer, 1972a), estimates of large propensities to consume out of current income are interpreted as evidence against the permanent income hypothesis without any discussion of the stochastic process of income. The evidence is actually ambiguous because the permanent income hypothesis together with plausible income processes could well imply exactly the degree of sensitivity found.

Recent work by Hall (1978) deals with some of these problems by deriving a theory of the stochastic process of consumption from the life cycle-permanent income hypothesis. Empirical tests then find that one of the important implications of the hypothesis is largely supported by aggregate time-series data.[1] A recent paper by Flavin (1979) examines

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[1]These tests are similar to the ones used in testing the efficient markets hypothesis for financial assets. See Appendix 3 for a discussion of the relation of that body of research to our work on consumption.

aggregate data in a framework similar to the one used here, again with generally favorable results. However, aggregate evidence is not really powerful enough to settle the important questions about the behavior of consumers.

These considerations have led to the research reported here based on data for individual households. We bring a rather specific question to this research: Are consumers more sensitive to current fluctuations in income than they would be if they followed the dictates of the life cycle-permanent income model? We approach the question in the following way: First, we propose a stochastic model of household income. Then, we hypothesize that households choose current consumption so as to maximize expected intertemporal utility, as suggested by the life cycle-permanent income view of consumption. In so doing, they arrive at an estimate of permanent income, based on the information available about the various stochastic components of actual income. Note that permanent income is not one of the components we hypothesize for actual income. Rather, permanent income is an intermediate step in the process by which families determine consumption. In this respect, we expand on earlier microeconomic research on the permanent income hypothesis. The final step makes observed consumption equal to a fraction of permanent income plus a transitory component which can be interpreted as measurement error, inventory accumulation, and the like.

The empirical analysis in this paper focuses on the theoretical implication that consumers should increase consumption by the annuity value of the increase in wealth brought about by a transitory increase in income. We test this implication by estimating the model using panel data on the income and consumption levels of individuals over several years. However, the response of consumption to the transitory component of income is estimated as a free parameter rather than constraining it to equal the expression for the annuity value. We then can evaluate whether consumption is excessively responsive to current income.

The starting point for our work is the life cycle-permanent income theory of consumption. According to the theory, consumers form estimates of lifetime resources and then adopt plans for spreading those resources over the remaining years of their lives. With explicit considerations of uncertainty (Yaari, 1976; Bewley, 1976; and Hall, 1978), this principle becomes: Consumers form estimates of the probability distributions of lifetime resources and adopt sequential policies for spreading the resources. We will consider the hypothesis of rational expectations which asserts that consumers use all available information in estimating the probability distributions of future resources. This hypothesis is more of a sharpening and clarification of assumptions already implicit in the life cycle-permanent income theory rather than a logically independent assumption.

Here we consider the case of a consumer whose real income is the sum of three components:

1. A deterministic component, $\bar{y}_t$, which rises with age until just before retirement, and then falls rapidly.
2. A stochastic component, y_t^L, which fluctuates as lifetime prospects change. Because this lifetime component embodies information about essentially permanent family characteristics, a natural specification is a random walk.

3. A stochastic component, y_t^S, which fluctuates according to transitory influences, and obeys a first-order autoregressive process with parameter ρ.

A key feature of our model is the hypothesis that families observe the two stochastic components separately.

In year t, the consumer will have accumulated assets $\tilde{A}_t$. Then all information available in year t relevant for this year's consumption decision, $\tilde{c}_t$, is contained in y_t^L, y_t^S, and $\tilde{A}_t$ (as well as the information about $\bar{y}_1, \cdots, \bar{y}_t, \bar{y}_{t+1}, \cdots$, denoted by $\bar{y}$, which has always been known). The consumption decision emerging from the consumer's optimal plan can be described by

$$\tilde{c}_t = f_t(\bar{y}, y_t^L, y_t^S, \tilde{A}_t) \tag{1}$$

Note that we do not yet assume that consumers make use of certainty equivalence or even that their preferences over uncertain outcomes can be described by expected utility.

For our present purposes, it will be convenient to assume that the consumption function, f, is linear in its arguments:

$$\tilde{c}_t = \bar{c}_t + \alpha_t y_t^L + \beta_t y_t^S + \gamma_t(\tilde{A}_t - \bar{A}_t) \tag{2}$$

where $\bar{c}_t$ and $\bar{A}_t$ are the deterministic paths of consumption and assets in the absence of surprises in y^L and y^S, and α_t, β_t, and γ_t are the marginal propensities to consume out of y_t^L, y_t^S, and $\tilde{A}_t$ at time t. This will hold exactly for consumers with quadratic utility functions who maximize expected utility, and will serve as a useful approximation in other cases.

Defining c_t and A_t as the deviations from the deterministic paths of consumption and assets, i.e.,

$$c_t = \tilde{c}_t - \bar{c}_t \qquad\qquad A_t = \tilde{A}_t - \bar{A}_t \tag{3}$$

we rewrite (2) as

$$c_t = \alpha y_t^L + \beta y_t^S + \gamma A_t \tag{4}$$

Now, under the assumption about the two components of earnings introduced earlier,

$$y_t^L = y_{t-1}^L + \varepsilon_t \tag{5}$$

and

$$y_t^S = \rho y_{t-1}^S + \eta_t \tag{6}$$

where ε_t and η_t are random innovations in the two components that are completely unpredictable. Further, the evolution of assets around their deterministic path is governed by

$$A_t = (1+r)(A_{t-1} + y_{t-1}^L + y_{t-1}^S - c_{t-1}) \tag{7}$$

We will take the real return to savings, r, as a known, predetermined constant.

With these assumptions and notations, we are prepared to derive an explicit stochastic model for consumption. We could begin with the maximization of the expected value of an intertemporal utility function, but it is simpler to make use of a proposition derived by Hall (1978): Consumers who make consumption plans by maximizing the expected value of an intertemporally separable utility function satisfy the following basic condition: The expected marginal utility of consumption next year depends only on the actual level of consumption this year and on the parameters of the utility function. Again, rational expectations simply sharpens this proposition: No information available to the consumer in year t has any value in predicting next year's marginal utility, beyond the predictive value of this year's consumption. This hypothesis provides constraints on the coefficients of the consumption model. Again, as an approximation, the hypothesis is interpreted as applying to consumption itself, which is exactly true for a quadratic utility function and a reasonable approximation for other cases.

Appendix 1 uses this irrelevance of past data apart from immediate lagged consumption to derive the parameters describing the response of current consumption to the stock of savings and to current values of the two components of income. The conclusions are

$\alpha_t = 1$ for all years t. Changes in the lifetime component of income bring about immediate equal changes in consumption.

$\gamma_t = \dfrac{r}{(1+r)\left(1 - \left(\dfrac{1}{1+r}\right)^{T - t+1}\right)}$ = the annuity value of one unit of wealth, that is, the stream of equal payments over the remainder of the lifetime that can be financed by a unit of wealth. For infinite horizons, γ_t is the real interest rate.

$$\beta_t = \frac{1 - \left(\frac{\rho}{1+r}\right)^{T - t+1}}{1 - \left(\frac{\rho}{1+r}\right)} \gamma_t$$ = the annuity value of the stream of current and future income predicted on the basis of the current value of transitory income.

Some illustrative values at a real interest rate of 5 percent per year and a serial correlation coefficient of transitory income of 0.3 are as follows:

		γ_t, propensity to consume savings	β_t, propensity to consume transitory income
remaining lifetime	20 years	.078	.109
	40 years	.057	.080

Because we lack data on total savings for households, we need an expression describing consumption which eliminates the need for information on household savings. In Appendix 1 we derive the following:[1]

$$\Delta c_t = \varepsilon_t + \beta_t \eta_t \tag{8}$$

[1]Note that this formulation assumes that the consumer's rate of time discount equals the interest rate. Empirical evidence in Hall (1978) does not reject this assumption.

Note that Δc_t depends only on information available in year t, namely, the change in the lifetime component of income, ε_t, and the innovation in transitory income, η_t. Hence, (8) is simply a restatement of the basic hypothesis that all information available in year t-1 is incorporated into c_{t-1}. Assets do not appear in (8) because they are just the residual of income after consumption and observations on A_t would not add information about c_t not already in ε_t and η_t.

Rational consumption behavior is compatible with any degree of sensitivity to the surprise in income (up to $\beta_t = 1$), provided a sufficiently high interest rate faces the consumer. No matter how much they discount the future, consumers should not simply make consumption proportional to current income; rather, the optimal strategy is to make the change in consumption respond only to the surprise in income and not to predictable movements of income. At very high interest rates, it is true that the information about future changes in income contained in today's surprise in income has negligible influence on wealth. However, it is still possible to take steps today that will insulate consumption from any foreseeable future changes in income. Exactly because the return to assets is high, a tiny amount saved from today's temporary increase in income can finance a complete offset of the subsequent decline in income later. In an economy with very high interest rates, consumers make small but lucrative and important asset transactions to achieve the optimal consumption path. Later in the paper, we will consider the behavior of consumers who are constrained against making any transactions in assets. They are prevented from achieving the optimal consumption path, and their actual consumption behaves in a way that is readily detectable in the data. There is a very substantial difference between optimal consumption in the face of very high interest rates and consumption constrained to equal current income.

As a final note on the interpretation of the theory, we emphasize that the lifetime component of income, y^L, is <u>not</u> the same thing as permanent income, although the propensity to consume out of y^L is the same as the propensity to consume out of permanent income. Permanent income includes the annuity values of transitory income and assets, as well as the lifetime component of income. Our research tries to make a clear distinction between the statistical decomposition of income into lifetime and transitory components, on the one hand, and the consumer's inference about permanent income, on the other hand.

III. Statistical Model and Estimation

The data for our investigation are obtained from the University of Michigan's Panel Study of Income Dynamics (PSID) which contains histories of earnings and spending for a large number of families over a span of several years. The PSID reports total annual family income net of estimated federal income taxes, which we then adjusted to take account of estimated FICA (social security) tax payments and changes in the overall cost of living (measured by the Consumer Price Index). The most comprehensive and reliable consumption measure which can be obtained from the PSID is the sum of the annual expenditures on food used at home and the amount spent eating at restaurants. We deflated food expenditures with the food price component of the CPI. Data from the PSID for food consumption are available for the years 1969-1971 and 1973-1975 and for income for all years, 1969-1975. We included all families who reported income and food consumption in all years and whose responses to the food and income questions were deemed accurate by the interviewer.[1] We used data on six first differences of income and five first differences of consumption for 2309 families. One of the first differences of consumption spans two years; Appendix 4 describes how we accommodated this feature of the data.

In the PSID survey, information about food consumption is elicited by the following question: "How much to you spend on food in an average week?" The question is asked sometime in the first half of the year; the average

[1]The survey interviewers were instructed to estimate income and food consumption when an interviewee was unsure of the answers to the questions concerning these items. We excluded all of the cases where this imputation was done.

interview takes place at the end of March. We date the response in the previous year, as does the PSID. For a typical family interviewed in March 1971, for example, data on last year's income and usual food consumption are dated 1970 in our work. Because of the peculiar timing of the question about average food consumption, we found it necessary to extend the model described earlier in the paper in the following way. We assume that the new information about income which the family uses to decide on consumption dated in year t includes a fraction ϕ of the new information that will not be recorded by the survey until the following year. For the simple reason that the consumption question is asked partway into the following year, we might expect a value of ϕ near a quarter. However, a family might have access to additional information about income for the full year at the time that consumption is measured early in the year (Appendix 3 mentions the same issue as it arises in securities markets). For example, in some jobs annual compensation is known with near certainty at the beginning of the year. If this kind of advance information about income is commonplace, our estimate of ϕ should be correspondingly higher. We do not consider the possibility that consumers have information about income in years after t+1, beyond what can be predicted from the history of income itself. Out low estimated value of ϕ tends to confirm our assumption on this point. Further details about the role of future information in the model and the estimation of ϕ appear in Appendix 2.

In addition to the ambiguity about the timing of the question about food consumption, there is a further ambiguity about the length of the period over which consumption is measured. Instead of asking about average consumption over an unstated period, it would be better for our purposes if it were about last year specifically or even about last week.

We investigated the possibility that families averaged food consumption over a period even longer than the entire previous year, but did not find any confirming evidence.

The use of food consumption in place of total consumption obligates us to consider the form of the demand function for food, which differs in two respects from the demand function for total consumption. First, the price of food relative to the overall cost of living influences food consumption. Because all the families in the sample faced roughly the same change in relative prices, and our study relies primarily on the variability of individual family income, the relative price change presents few problems for our work. We posit equal relative price effects among families with similar characteristics, and remove these effects before estimating the model. Details of this adjustment appear later in the paper.

The second consideration is the likelihood that the proportion of income spent on food declines as income rises--the usual view about the Engel curve for food. In the current research, we approximate the Engel curve by a straight line with a positive intercept. Though this does imply a declining expenditure fraction on food, it can be defended only as an approximation. The slope of the line will be called α; it is the marginal propensity to spend permanent income on food. The parameter β introduced in the previous section will be defined as the ratio of the marginal propensity to spend transitory income on food to the marginal propensity to spend lifetime income on food. Thus the units and the expected numerical values for β presented earlier will continue to apply.

Another extension of the basic model is necessary because food consumption is measured imperfectly. Any study of consumption at the level of individual households needs to include a stochastic element of measurement error and transitory consumption. We assume that measured consumption includes a transitory component, c_t^S, which obeys a second-order moving average process with parameters λ_1 and λ_2:

$$c_t^S = \nu_t + \lambda_1 \nu_{t-1} + \lambda_2 \nu_{t-2} \tag{9}$$

We hypothesize that transitory consumption is uncorrelated with both components of income:

$$\mathrm{Corr}(\nu_t, \varepsilon_t) = \mathrm{Corr}(\nu_t, \eta_t) = 0 \tag{10}$$

With these various extensions, our model for the first difference of consumption becomes[1]

$$\Delta c_t = \alpha\varepsilon_t + \alpha\beta\eta_t + \nu_t - (1-\lambda_1)\nu_{t-1} - (\lambda_1-\lambda_2)\nu_{t-2} - \lambda_2\nu_{t-3} \tag{11}$$

The terms involving ν represent the first difference of a moving average process.

A detailed preliminary examination of the serial correlation properties of income revealed that a second-order moving average model was more appropriate than the first-order autoregressive one considered in the theory section. It does not seem useful to present the details of the consumption model with a moving average process for income, as they are a good deal

[1]Here, we are neglecting the issue of advance information about income; the appropriate modifications appear in Appendix 2.

more complex and no more illuminating than for the autoregressive case.[1] It remains true that consumption responds to the innovation in income. With moving-average parameters ρ_1 and ρ_2, the stochastic model for the first difference of income is

$$\Delta y_t = \varepsilon_t + \eta_t - (1-\rho_1)\eta_{t-1} - (\rho_1-\rho_2)\eta_{t-2} - \rho_2\eta_{t-3} \tag{12}$$

Again, the terms involving η are the first difference of a moving average process. This model embodies the strong assumption that income is measured without error. A model augmented with an income measurement error would not be econometrically identified.

Although in the full life cycle model, the propensity to consume out of transitory income depends on age, in the results presented here, we approximate the full model by treating β as constant across the sample. We tried estimating the model separately for families with younger and older heads, but failed to find significant differences. Constancy of β across families has the substantial statistical advantage of making the simple moment matrix over families a sufficient statistic for all of the parameters of the model.

We estimate the parameters of the model by maximum likelihood, under the assumption that ε, η, and ν obey normal distributions. Maximum likelihood achieves the best fit of the variances and covariances predicted by the model to those found in the data; the likelihood function

[1]An earlier set of empirical results based on the autoregressive model of income gave almost exactly the same estimates of the structural parameters as those reported later in the paper.

is a scalar measure of the fit. A formal discussion of the estimation procedure appears in Appendix 4. We confine ourselves here to a heuristic treatment.

The key idea of our approach is to write out the formulas for the variances and covariances of the data implied by our theoretical model, and then solve the resulting system of equations for the parameter estimates. To keep the exposition simple, we will first work out the case where transitory income and transitory consumption are not serially correlated (ρ_1, ρ_2, λ_1, and λ_2 are all taken as zero) and no consumers have advance information about income ($\phi = 0$). First, the variance of the first difference of income is

$$V(\Delta y_t) = \sigma_\varepsilon^2 + 2\sigma_\eta^2 \qquad (13)$$

and the covariance of the first difference of income with its own lagged value is

$$\mathrm{Cov}(\Delta y_t, \Delta y_{t-1}) = -\sigma_\eta^2 \qquad (14)$$

These two formulas give us estimates of the variance of the innovation in transitory income, σ_η^2, and of the variance of the increment in lifetime income, σ_ε^2. Next, the covariance of the first difference of consumption with its own lagged value is

$$\mathrm{Cov}(\Delta c_t, \Delta c_{t-1}) = -\sigma_\nu^2 \qquad (15)$$

This gives us the last of the three variances, that of the innovation in transitory consumption, σ_ν^2.

Information about the structural parameters α and β comes from the covariances of consumption and income. The contemporaneous covariance is

$$C_o = \mathrm{Cov}(\Delta c_t, \Delta y_t) = \alpha\sigma_\varepsilon^2 + \alpha\beta\sigma_\eta^2 \tag{16}$$

and the covariance with future income is

$$C_1 = \mathrm{Cov}(\Delta c_t, \Delta y_{t+1}) = -\alpha\beta\sigma_\eta^2 \tag{17}$$

Solving for α and β gives

$$\alpha = \frac{C_o + C_1}{\sigma_\varepsilon^2} \tag{18}$$

$$\beta = \frac{C_1}{C_o + C_1} \frac{\sigma_\varepsilon^2}{\sigma_\eta^2} \tag{19}$$

It is not surprising that the contemporaneous covariance, C_o, has a central role in estimating the two propensities to consume, α and β. It is perhaps a little surprising that the covariance of the current change in consumption with the future change in income is equally important. The basic finding of the paper is that this covariance is small, so it is not plausible that consumers are excessively sensitive to transitory income. Why would we expect excessive sensitivity to show up as a strong negative correlation between the change in consumption and the future change in income? Because those upward movements in consumption that are associated with the response to transitory income should be followed by a movement of income back toward normal in the following year. The first differences of income are negatively serially correlated (both in the theory and in the data), so the correlation of the change in consumption and the subsequent change in income should reflect this negative serial correlation.

It might appear that the covariance of current consumption and lagged income could provide similar information. That covariance is also free of the effects of changes in the lifetime component of income. However, the optimal use of information hypothesized for consumers in the model implies that the covariance should be exactly zero; no information available in year t-1 should help predict the change in consumption in year t. This is essentially the proposition formulated and tested in Hall (1978). The test will be carried out with the micro panel data of this study in a later section of the paper.

The considerations leading to the introduction of the parameter, ϕ, which indexes the amount of information currently available about future income complicate estimation a little. The parameters α, β, and ϕ are estimated jointly from C_o, C_1, and $C_2 = \mathrm{Cov}(\Delta c_t, \Delta y_{t+2})$. The relations to be solved for the parameters are

$$C_o = (1-\phi)(\alpha\sigma_\varepsilon^2 + \alpha\beta\sigma_\eta^2) \tag{20}$$

$$C_1 = \phi(\alpha\sigma_\varepsilon^2 + \alpha\beta\sigma_\eta^2) - (1-\phi)\alpha\beta\sigma_\eta^2 \tag{21}$$

$$C_2 = -\phi\alpha\beta\sigma_\eta^2 \tag{22}$$

If ϕ is zero, this reduces to the case just worked out, while if it is one, C_1 takes the place of C_o and C_2 the place of C_1. In general, to solve for all three parameters, we start with

$$\alpha = \frac{C_o + C_1 + C_2}{\sigma_\varepsilon^2} \tag{23}$$

The equations for β and ϕ are quadratic and it does not seem worth writing them out explicitly. Provided C_2 is negative (as it is in our data), the equations have a solution with ϕ between zero and one and a positive value of β.

The data whose variances and covariances are the starting point for the estimation process are the deviations of the changes in food consumption and income from deterministic paths. To form the deviations, we need estimates of the deterministic changes in income and consumption for each family in each year based on the family's characteristics in that year. We do this by assuming that the deterministic changes are functions of the family characteristics, then use ordinary least-squares regressions as follows: In the case of income, we regress the change in actual income on an intercept, the age of the household head, the age of the household head squared, the change in the number of adults in the household, the change in the number of children in the household and a linear time trend. Since food is a commodity whose relative price changed substantially over the period of our sample, we need to take account of the downward slope of families' demand functions. Thus the change in food consumption is regressed on the percentage change in the relative price of food (as measured by CPI components) as well as on the variables used in the income regressions. Results for the income and food consumption regressions are given in Appendix 5. The residuals from these regressions are then taken to be the deviations from the deterministic paths of changes in food consumption and income.

The specification of the food and income regressions make little difference to the results obtained for the stochastic model outlined above. For example, if the effect of family characteristics on the deterministic paths of income and food consumption are ignored--i.e., the change in the deterministic components is just assumed to be a constant--we find only very small differences in the estimates of the parameters of the stochastic model.

The residuals from the preliminary regressions showed mild heteroskedasticity, especially in the first difference of consumption. Rather than complicate the model by introducing separate variances for each year, we simply transformed the covariance matrix of the residuals by dividing its rows and columns by suitable constants so that the variances of the first differences of consumption were the same in all years (equal to the average of the original data over the same years). We applied the same transformation to the income data. The spirit of this preliminary treatment of the data is the same as conversion to a correlation matrix, but it preserves the units of the structural parameters. Experiments with the alternative of estimating variances gave essentially the same estimates of the structural parameters.

IV. Results

Estimation by maximum likelihood yielded the results shown in Table 1. In summary, they show:

1. The marginal propensity to consume lifetime income on food, α, is about 0.11, well under the average propensity in the raw data of 0.19.
2. The propensity to consume out of transitory income relative to the propensity to consume out of lifetime income, β, is estimated as 0.29, somewhat above its theoretical value at reasonable discount rates. The hypothesis of equal response to both components, $\beta = 1$, is unambiguously rejected.
3. The fraction of information about next year's income, ϕ, is 0.25, in line with prior expectations.

Table 2 presents a reasonably complete accounting of the success of the model in fitting the pattern of covariation found in the data. For estimation of the key parameters α, β, and ϕ, the covariances of this year's change in consumption with this year's change in income, next year's change, and the subsequent year's change are the most important. All three parameters control the fitted value of the contemporaneous covariance--α and β make it larger, by making the change in consumption more sensitive to surprises in income, while ϕ makes it smaller, by making part of this year's change in consumption depend on next year's surprise in income. For the covariance with next year's income, β makes the fitted value more negative, for the reason explained earlier--if this year's consumption is sensitive to this year's transitory income, it will be negatively related to the change in next year's income when the transitory movement will

Table 1

Results for Basic Model

Parameter	Value (standard error)	Interpretation
α	.107 (.008)	Fraction of permanent income spent on food
β	.292 (.080)	Relative effect of innovation in transitory income compared to effect of innovation in lifetime income
ϕ	.253 (.058)	Fraction of information available in year t about income in year t+1
λ_1	.220 (.014)	First moving average parameter for transitory consumption
λ_2	.104 (.018)	Second moving average parameter for transitory consumption
ρ_1	.294 (.021)	First moving average parameter for transitory income
ρ_2	.114 (.018)	Second moving average parameter for transitory income
σ^2_ε	1.49 (.11)	Variance of innovation in lifetime income (thousands of dollars squared)
σ^2_ν	.154 (.003)	Variance of innovation in transitory consumption
σ^2_η	3.41 (.13)	Variance of innovation in transitory income

Table 2

Actual and Fitted Covariances

	Actual	Fitted
Var(Δc)	.285	.285
Var(Δy)	6.772	6.757
Cov(Δc, Δy)	.234	.200
Cov(Δc, Δy_{+1})	-.004	.003
Cov(Δc, Δy_{+2})	-.021	-.038
Cov(Δc, Δy_{-1})	-.077	.000
Cov(Δc, Δc_{-1})	-.110	-.106
Cov(Δy, Δy_{-1})	-1.948	-1.904
Cov(Δy, Δy_{-2})	-.319	-.339
Cov(Δy, Δy_{-3})	-.383	-.389

Notes: Var(Δc) includes Var($\Delta c_3 + \Delta c_4$); Cov(Δc, Δy) includes Cov($\Delta c_3 + \Delta c_4$, Δy_3) and Cov($\Delta c_3 + \Delta c_4$, Δy_4); Cov(Δc, Δy_{+1}) includes Cov($\Delta c_3 + \Delta c_4$, Δy_5); Cov(Δc, Δy_{+2}) includes Cov($\Delta c_3 + \Delta c_4$, Δy_6); Cov(Δc,Δy_{-1}) includes Cov($\Delta c_3 + \Delta c_4$, Δy_2), and Cov(Δc, Δc_{-1}) includes Cov($\Delta c_3 + \Delta c_4$, Δc_2) and Cov(Δc_5, $\Delta c_3 + \Delta c_4$).

probably be reversed. On the other hand, the fitted covariance is positively related to ϕ. If consumption is partly based on information about next year's surprise in income, this year's change will be positively correlated with next year's change in income. The fitted covariance of almost exactly zero represents cancellation of the two effects, since both β and ϕ are quite positive. The estimation process separates the effects of β and ϕ through the use of the covariance of this year's change in consumption with the change in income two, three, four, and five years from now (of these, the closer ones are relatively more important). Under the hypothesis implicit in our model that consumers have no information about surprises in income more than one year in advance, the only explanation of the negative covariation of current consumption and future income operates through the sensitivity of consumption to transitory income, controlled by β. The estimation process chooses a substantially positive value of β in order to try to match the covariance of -.021; the overstatement in the fitted value of -.038 corresponds to understatements of some of the more distant covariances not shown in Table 2.

The only serious failure of the model revealed in Table 2 is its inability to explain the observed negative correlation of the current change in consumption and the lagged change in income. As we will show, the actual correlation is statistically significantly negative, yet the model holds that it should be exactly zero. The theoretical justification for the fitted correlation of zero is simple: Apart from its transitory component, consumption should respond only to new information, and lagged income cannot contain any new information. The next section of the paper examines the apparent failure of this principle.

V. The Relation Between Consumption and Lagged Income

The model has the straightforward implication that the simple regression of Δc_t on Δy_{t-1} should yield a coefficient on Δy_{t-1} of zero. Instead we find

$$\Delta c_t = \underset{(6.16)}{-4.95} - \underset{(.002)}{0.010}\, \Delta y_{t-1}$$

6926 observations; standard error = \$512; R^2 = .0028

Though the coefficient is quite small, it is statistically unambiguously negative. It would be uninteresting to conclude that the measurement error in Δc_t was negatively correlated with Δy_{t-1}, so we restrict our attention to explanations of a negative relation between the true change in consumption and the lagged change in income.

In this section we investigate the possibility that consumers are actually more sensitive to transitory income than is predicted by theory, but in a way not revealed in our examination of the joint behavior of Δc_t and Δy_t. The results in the previous section did not draw on the observed correlation between Δc_t and Δy_{t-1}--maximum likelihood is blind to covariances whose theoretical values are zero for all values of the parameters. An extended model proposed in Hall (1978) for a similar purpose can be used to examine the lagged relation. Suppose that a fraction $1-\mu$ of families follow the life cycle-permanent income theory and the rest, a fraction μ, simply let consumption track current total income passively and so have an excessive sensitivity to transitory income. A stochastic model expressing the passive behavior of consumers is

$$\Delta c_t = \alpha \Delta y_t + \Delta c_t^S \tag{24}$$

$$= \alpha\varepsilon_t + \alpha\eta_t - \alpha(1-\rho_1)\eta_{t-1} - \alpha(\rho_1-\rho_2)\eta_{t-2} - \alpha\rho_2\eta_{t-3} \tag{25}$$

$$+ \nu_t - (1-\lambda_1)\nu_{t-1} - (\lambda_1-\lambda_2)\nu_{t-2} - \lambda_2\nu_{t-3}$$

The covariance of the change in consumption with last year's change in income implied by this model is

$$\text{Cov}(\Delta c_t, \Delta y_{t-1}) = -\alpha(1-\rho_1)(1-\rho_1+\rho_2)\sigma_\eta^2 \tag{26}$$

which is negative. The logic of the negative covariance is straightforward: If consumption tracks income, then a transitory rise in income this year will typically be followed next year by a decline in income and so also in consumption.

We estimated an extended model in which the fitted covariance matrix gives a weight of $1-\mu$ to the earlier model of optimal information processing and a weight μ to the passive model.[1]

The results of estimating the augmented model are[2]

[1] Appendix 4 explains in detail how the model treats the interaction of future information about income and passive consumption behavior.

[2] These are not strictly maximum likelihood estimates for the model as described. Rather, they are the result of fitting the covariance matrix of the model to the covariance matrix of the data and using the multivariate normal distribution as the metric of fit. They are not precisely maximum likelihood because the distribution implied by the model is a mixture of two multivariate normals, which is not itself exactly multivariate normal. There is no reason to expect any bias on this account.

α	.097 (.009)	Propensity to consume food out of lifetime income
β	.223 (.103)	Propensity to consume out of transitory income relative to propensity out of lifetime income
ϕ	.226 (.054)	Fraction of information available in year t about income in year t+1
μ	.207 (.068)	Fraction of consumption directly proportional to current income

The other parameter estimates are similar to their previous values. The new specification is about halfway successful in matching the covariance of this year's change in consumption with last year's change in income--the predicted value is -.032 against the sample value of -.077. Not surprisingly, the sensitivity of consumption to the innovation in transitory income is found to be smaller in the extended model, as the positive estimate of μ has taken over part of the job of explaining the positive contemporaneous covariation of consumption and income. Further, because μ and β are partly estimated from the same features of the data, joint estimation very substantially raises the sampling variation of the estimate of β, relative to the earlier results. The confidence interval for β now includes the theoretically expected value of about 0.10.

VI. Concluding Remarks

According to our extended model, about 80 percent of the households in the sample obey the life cycle-permanent income hypothesis. They do not adjust consumption in the same mechanical way to every change in income. Instead, they think about the source of a change in income and react vigorously only to those changes that signal a major shift in economic well-being. But the data reject the strong hypothesis that all consumption is governed by the life cycle-permanent income principle. This conclusion is independent of the model developed in this paper; it rests solely on the rather general principle that changes in consumption should not be predictable on the basis of information available to the household. The negative relation between the lagged change in income and the current change in consumption is consistent with constrained consumption behavior on the part of about 20 percent of the families in the sample. We are able to distinguish this symptom of inability (or unwillingness) to borrow and lend from the type of behavior characteristic of consumers who simply face high effective interest rates. The data show signs of both influences. Consumption is somewhat more sensitive to current income than it would be in an economy where every consumer borrowed and lent freely at the Treasury bill rate. Still, it is much less sensitive than in an economy where no consumer ever borrowed or lent at all.

The overwhelming bulk of the movements in income that give rise to our inference from the data are unrelated to the behavior of the national economy; most are probably highly personal. It is purely an inference, though a reasonable one in our opinion, that households respond to income fluctuations attributable to the business cycle or to countercyclical tax policy in the same way they respond to purely personal income fluctuations. Our results cast doubt on the wisdom of tax policies to manipulate aggregate demand by changing disposable income. If, as the results indicate, most consumers react only to the new information about their permanent incomes conveyed by the announcement of a tax change, then policy-makers face the complicated task of inferring consumers' interpretation of the announcement. Lucas (1976) has pointed out the obstacles to policy evaluation in these circumstances.

Our evidence and conclusions refer specifically to food consumption and more generally to the consumption of nondurables. Nothing in our work describes the response of consumer purchases of durable goods to changes in income. Our findings that relatively few consumers behave as if constraints on borrowing were important for food consumption do not rule out important constraints for the acquisition of durables. The sensitivity of durables purchases to transitory income is very definitely a topic for further research, where some of the techniques developed in this paper may be helpful.

Appendix 1

Derivation of the Propensities to Consume Out of Lifetime and Transitory Income

The model is contained in four equations:

$$c_t = \alpha_t y_t^L + \beta_t y_t^S + \gamma_t A_t \tag{A1}$$

$$A_t = (1+r)(A_{t-1} + y_{t-1}^L + y_{t-1}^S - c_{t-1}) \tag{A2}$$

$$y_t^L = y_{t-1}^L + \varepsilon_t \tag{A3}$$

$$y_t^S = \rho y_{t-1}^S + \eta_t \tag{A4}$$

Together these imply the following equation for the first difference of consumption as a function of contemporaneous innovations and lagged variables:

$$\begin{aligned}\Delta c_t = & \left(\alpha_t + (1+r)\gamma_t - (1 + (1+r)\gamma_t)\alpha_{t-1}\right) y_{t-1}^L + \alpha_t \varepsilon_t \\ & + \left(\beta_t \rho + (1+r)\gamma_t - (1 + (1+r)\gamma_t)\beta_{t-1}\right) y_{t-1}^S + \beta_t \eta_t \\ & + \left((1+r)\gamma_t - (1 + (1+r)\gamma_t)\gamma_{t-1}\right) A_{t-1}\end{aligned} \tag{A5}$$

Our conclusions are derived from the theoretical proposition that the coefficients of the lagged variables are all zeros:

1. Set coefficient of y^L_{t-1} to zero:

$$\alpha_t + (1+r)\gamma_t = (1 + (1+r)\gamma_t)\alpha_{t-1} \tag{A6}$$

or

$$\alpha_{t-1} = \frac{\alpha_t + (1+r)\gamma_t}{1 + (1+r)\gamma_t} \tag{A7}$$

Because all income and wealth is consumed in the last year of life (year T), $\alpha_T = 1$. But then by recursion, $\alpha_t = 1$ for all t.

2. Set coefficient of A_{t-1} to zero:

$$\gamma_{t-1} = \frac{(1+r)\gamma_t}{1 + (1+r)\gamma_t} \tag{A8}$$

To explain this, define ϕ_t as the annual income from a \$1 investment paying equal amounts in years t, t+1, ..., T:

$$\phi_t = \frac{r}{(1+r)\left(1 - \left(\frac{1}{1+r}\right)^{T - t+1}\right)} \tag{A9}$$

This is the annuity value of \$1 and it obeys the recursion,

$$\phi_{t-1} = \frac{(1+r)\phi_t}{1 + (1+r)\phi_t} \tag{A10}$$

Now $\gamma_T = 1$ for the reason given above, and $\phi_T = 1$. The coefficients γ_t and ϕ_t obey the same recursion with the same initial values, so they are equal. We conclude that γ_t is the annuity value of \$1 in year t.

3. Set coefficient of y^S_{t-1} to zero:

$$\beta_{t-1} = \frac{\rho\beta_t + (1+r)\gamma_t}{1 + (1+r)\gamma_t} \tag{A11}$$

Let ψ_t be the present value of a stream paying 1 in t, ρ in t+1, ρ^2 in t+2, $\cdots$, ρ^{T-t} in T. Then $\psi_T = 1$ and

$$\psi_{t-1} = \frac{\rho}{1+r}\psi_t + 1 \tag{A12}$$

Suppose it were true that $\beta_t = \psi_t\phi_t$, that is, the propensity to consume out of transitory income is the annuity value of the increment to wealth implied by an innovation in transitory income. Then

$$\begin{aligned} \beta_{t-1} &= \frac{\rho\psi_t\phi_t + (1+r)\phi_t}{1 + (1+r)\phi_t} \\ &= \left(\frac{\rho}{1+r}\psi_t + 1\right)\left(\frac{(1+r)\phi_t}{1 + (1+r)\phi_t}\right) \\ &= \psi_{t-1}\phi_{t-1} \end{aligned} \tag{A13}$$

Because $\beta_T = \psi_T\phi_T = 1$, the recursion establishes $\beta_t = \psi_t\phi_t$ for all t.

With all lagged variables excluded, the change in consumption depends solely on new information,

$$\Delta c_t = \varepsilon_t + \beta_t \eta_t \tag{A14}$$

Appendix 2

Characterization of Information About Future Income

We assume that the annual income innovations ε_t and η_t are the sums of N micron innovations $\varepsilon_{t,\tau}$ and $\eta_{t,\tau}$, $\tau = 1, \cdots, N$. Consumption decisions recorded in year t are based on knowledge of the first M innovations for the following year. Our parameter ϕ is M/N.

Then, in the absence of any discounting within a year, our model is

$$\Delta c_t = \sum_{\tau=1}^{M} (\alpha\varepsilon_{t+1,\tau} + \alpha\beta\eta_{t+1,\tau}) + \sum_{\tau=M+1}^{N} (\alpha\varepsilon_{t,\tau} + \alpha\beta\eta_{t,\tau}) + \Delta c_t^S \quad \text{(A15)}$$

$$\Delta y_t = \sum_{\tau=1}^{N} (\varepsilon_{t+\tau} + \eta_{t+\tau} - (1-\lambda_1)\eta_{t-1,\tau} - (\lambda_1-\lambda_2)\eta_{t-2,\tau} - \lambda_2\eta_{t-3,\tau}) \quad \text{(A16)}$$

We assume $V(\varepsilon_{t,\tau}) = \sigma_\varepsilon^2/N$ and $V(\eta_{t,\tau}) = \sigma_\eta^2/N$ and independence of each $\varepsilon_{t,\tau}$ and $\eta_{t,\tau}$ from the others.

The univariate time-series properties of Δc_t and Δy_t are unchanged in this more elaborate specification, so we examine only the cross-covariances:

$$\text{Cov}(\Delta c_t, \Delta y_{t-i}) = 0 \qquad \text{, all } i > 0 \text{, as before} \quad \text{(A17)}$$

$$\begin{aligned} \text{Cov}(\Delta c_t, \Delta y_t) &= (N-M)\alpha\sigma_\varepsilon^2/N + (N-M)\alpha\beta\sigma_\eta^2/N \\ &= (1-\phi)(\alpha\sigma_\varepsilon^2 + \alpha\beta\sigma_\eta^2) \end{aligned} \quad \text{(A18)}$$

$$\begin{aligned} \mathrm{Cov}(\Delta c_t, \Delta y_{t+1}) &= M\alpha\sigma_\varepsilon^2/N + M\alpha\beta\sigma_\eta^2/N \\ &\quad - (N-M)(1-\lambda_1)\alpha\beta\sigma_\eta^2/N \\ &= \phi(\alpha\sigma_\varepsilon^2 + \alpha\beta\sigma_\eta^2) - (1-\phi)(1-\lambda_1)\alpha\beta\sigma_\eta^2 \end{aligned} \tag{A19}$$

$$\begin{aligned} \mathrm{Cov}(\Delta c_t, \Delta y_{t+2}) &= - M(1-\lambda_1)\alpha\beta\sigma_\eta^2/N \\ &\quad - (N-M)(\lambda_1-\lambda_2)\alpha\beta\sigma_\eta^2/N \\ &= (- \phi(1-\lambda_1) - (1-\phi)(\lambda_1-\lambda_2))\alpha\beta\sigma_\eta^2 \end{aligned} \tag{A20}$$

The vector of Δc and Δy observations for a family is thus multivariate normal with these covariances, and maximum likelihood estimation is appropriate.

In our model, we assume that families are homogeneous with respect to information about income--they all know a fraction ϕ of next year's income in making this year's consumption decisions. The covariances of this model are exactly the same as those for a model of hetergeneous families, where a fraction ϕ are fully aware of next year's income and the rest know nothing about it. The models are not completely the same, however. In the heterogeneous case, the distribution of Δc_t and Δy_t is not multivariate normal, but is a mixture of multivariate normals. Our estimates cannot be said to be maximum likelihood for the heterogeneous model.

Appendix 3

Relation to Research on Efficient Financial Markets

Our work is closely related to the large body of research on the behavior of financial markets under rational expectations. Consumption is the analogue of a stock price, for example, and income is the analogue of the earnings per share of the corporation issuing the stock. Our test of the predictive power of lagged income is the analogue of similar tests for market efficiency in the stock market, in the sense of the unpredictability of changes in stock prices from publicly available information (Fama (1970) and Mishkin (1978)). In contrast to our findings for consumption, the hypothesis of unpredictability is generally supported by the data for security markets.

The issue of advance information which might be available to market participants but not to the econometrician has also been considered in research on financial markets. The problem of the timing of the collection of data which obligates us to consider the issue here is not generally present in data on securities markets, but it may still be true that market participants have information in period t about what the econometrician labels an innovation in period t+1. One supporting piece of evidence is the predictive power of stock prices for future movements of the money stock, found by Rozeff (1974) and Rogalski and Vinso (1977).

The technique developed in our paper could be transplanted directly to securities markets to answer the questions: Do stock prices overreact to current movements of earnings? Do market participants have advance information about earnings?

Appendix 4

Estimation

Our four models for consumption are:[1]

(i) Optimizing, no future information

$$\Delta c_t = \alpha\varepsilon_t + \alpha\beta\eta_t + \Delta c_t^S \qquad \text{(A21)}$$

(ii) Optimizing, full future information

$$\Delta c_t = \alpha\varepsilon_{t+1} + \alpha\beta\eta_{t+1} + \Delta c_t^S \qquad \text{(A22)}$$

(iii) Rule of thumb, no future information

$$\Delta c_t = \alpha\Delta y_t + \Delta c_t^S \qquad \text{(A23)}$$

(iv) Rule of thumb, future information

$$\Delta c_t = \alpha\Delta y_{t+1} + \Delta c_t^S \qquad \text{(A24)}$$

In all cases,

$$\Delta c_t^S = \nu_t - (1-\lambda_1)\nu_{t-1} - (\lambda_1-\lambda_2)\nu_{t-2} - \lambda_2\nu_{t-3} \qquad \text{(A25)}$$

[1] Here, it is convenient to adopt the heterogeneous interpretation of the model of advance information, because it provides a simple way to compute the covariance matrix.

and

$$\Delta y_t = \varepsilon_t + \eta_t - (1-\rho_1)\eta_{t-1} - (\rho_1-\rho_2)\eta_{t-2} - \rho_2\eta_{t-3} \qquad \text{(A26)}$$

Let x be the column vector of unobserved random variables,

$$x' = [\varepsilon_1, \cdots, \varepsilon_7, \nu_{-2}, \cdots, \nu_7, \eta_{-2}, \cdots, \eta_7] \qquad \text{(A27)}$$

We assume that x is multivariate normal, with a diagonal covariance matrix, Σ, and variances

$$V(\varepsilon_t) = \sigma_\varepsilon^2 \qquad \text{(A28)}$$

$$V(\nu_t) = \sigma_\nu^2 \qquad \text{(A29)}$$

$$V(\eta_t) = \sigma_\eta^2 \qquad \text{(A30)}$$

Let z_i be the column vector containing the 5 differences of consumption and 6 first differences of income for family i:

$$z_i' = [\Delta c_1, \Delta c_2, \Delta c_3 + \Delta c_4, \Delta c_5, \Delta c_6, \Delta y, \Delta y_2, \Delta y_3, \Delta y_4, \Delta y_5, \Delta y_6] \qquad \text{(A31)}$$

Let j = 1, $\cdots$, 4 index the four consumption models. Then each model can be stated in the form

$$z_i = A_j x_i \qquad \text{(A32)}$$

(note that the third row of A_j has a special form) and z_i is multivariate normal with covariance matrix $A_j \Sigma A_j'$. The covariance matrix for a family drawn at random from the four types is

$$\Omega(\theta) = (1-\phi)(1-\mu)A_1\Sigma A_1' + \phi(1-\mu)A_2\Sigma A_2' + (1-\phi)\mu A_z\Sigma A_z' + \phi\mu A_4\Sigma A_4' \quad \text{(A33)}$$

Here θ is the vector of parameters,

$$\theta' = [\alpha,\ \beta,\ \lambda_1,\ \lambda_2,\ \rho_1,\ \rho_2,\ \sigma_\varepsilon^2,\ \sigma_\nu^2,\ \sigma_\eta^2,\ \phi,\ \mu] \quad \text{(A34)}$$

Under an interpretation where z_i itself is multivariate normal (homogeneous versions of advance information and rule-of-thumb consumption), the log-likelihood of the sample is

$$L(\theta) = -\frac{N}{2}\log \det\Omega(\theta) - \frac{1}{2}\sum_{i=1}^{N} z_i\Omega^{-1}(\theta)z_i \quad \text{(A35)}$$

plus an inessential constant. We estimate θ by full numerical maximization of the likelihood. Its estimated covariance matrix is computed as the inverse of the information matrix, $\partial^2 L/\partial\theta\partial\theta'$. All computations were carried out by a program written by Bronwyn Hall, which uses analytical derivatives and the method of scoring.

Appendix 5

Regressions to Eliminate the Deterministic Components of Income and Food Consumption

$$\Delta INCOME = \underset{(182.08)}{-433.96} + \underset{(7.89)}{33.23}\ AGE - \underset{(.082)}{.35}\ AGE^2 + \underset{(30.55)}{504.07}\ \Delta CHILD$$

$$+ \underset{(40.99)}{1535.06}\ \Delta ADULT - \underset{(13.04)}{53.44}\ TIME$$

13854 observations $R^2 = .1383$

Standard Error = $2606.4

$$\Delta FOOD = \underset{(32.38)}{-96.67} + \underset{(1.32)}{3.89}\ AGE - \underset{(.014)}{.045}\ AGE^2 + \underset{(6.39)}{166.56}\ \Delta CHILD$$

$$+ \underset{(8.72)}{242.46}\ \Delta ADULT + \underset{(2.65)}{2.00}\ TIME - \underset{(244.85)}{440.62}\ \Delta LOG\ PRICE$$

11545 observations $R^2 = .1438$

Standard Error = $542.02

where

ΔINCOME = change in family income which is adjusted for income and FICA taxes and the cost of living,

ΔFOOD = change in family spending for food at home and in restaurants deflated into real terms,

AGE = age of household head,

AGE^2 = AGE squared,

ΔCHILD = change in the number of children in the household,

ΔADULT = change in the number of adults in the household,

TIME = time trend = 1970=1 ··· 1975=5,

ΔLOG PRICE = change in the log of the relative price of food (measured by the food component of the CPI deflated by the overall CPI),

and standard errors of the coefficients are in parentheses.

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