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PERMANENT INCOME, LIQUIDITY, AND EXPENDITURE ON AUTOMOBILES: EVIDENCE FROM PANEL DATA*

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Several recent papers have tested the permanent income-cum-rational expectations hypothesis using data on nondurable or semidurable consumption. We show how this approach can be extended to the case of durables. An application to panel data on automobile expenditures reveals no evidence against the permanent income hypothesis. This result is unchanged in subsamples segregated by family holdings of liquid assets.

I. INTRODUCTION

The validity of the permanent income-life cycle hypothesis (PIH) as an explanation of consumer spending is an important issue in macroeconomics.[1] Since this hypothesis was posed (separately) by Friedman [1957] and by Modigliani,[2] it has been frequently put to empirical test.[3] Evidence both pro and con has been advanced.

Recently, this question has been illuminated by the realization that the hypothesis of rational expectations, in conjunction with the PIH, imposes strong restrictions on the stochastic properties of consumption conditional on income. In pioneering articles, Hall [1978] and Sargent [1978] used these restrictions to test the joint rational expectations–permanent income hypothesis in the U. S. time series data. Flavin [1981] has shown that, properly interpreted, the Hall and Sargent papers concur in rejecting the joint hypothesis.

Noting the relatively low power of time series tests, Hall and Mishkin [1982] followed by applying these methods (and several innovations) in panel data.[4] The results of their analysis of the relation of food consumption to income change were ambiguous; the PIH could not be clearly accepted or rejected.

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1. For example, it is central to the debate over the effectiveness of temporary income tax changes as countercylical instruments. See Blinder [1981].

2. See, e.g., Modigliani-Brumberg [1954] and Ando-Modigliani [1963].

3. The older research is surveyed in Ferber [1973] and Mayer [1972].

4. Hall-Mishkin used Michigan's Panel Study of Income Dynamics, which contains histories of 2,309 families over the period 1969–1975.

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One feature of this recent research has been the small amount of attention paid to the durables component of consumer expenditure: Of the papers mentioned, only Sargent's does not completely eliminate durables from the measure of consumption. The reason for this neglect is that the theory, as developed, is a predictor of actual consumption; what is observed, however, is not consumption but expenditure. The distinction between the time of buying and the time of using being much less important for nondurables than for durables, it is the former component that has been the focus of the empirical applications.

It would seem that, in the exclusion of durables, an important and interesting part of the story has been left out. The durables component of expenditure is large, the most volatile, and the most cyclically sensitive. Further, if the PIH fails in a quantitatively important way, it is most likely to be revealed in the pattern of durables purchases. For example, as Mishkin [1976] has pointed out, durables (automobiles in particular) are large, primarily debt-financed illiquid assets; moreover, expenditures on durables are more easily rescheduled than expenditures on nondurables. Thus, durables purchases should be relatively more sensitive to liquidity constraints or imperfections in the consumer loan market—the most plausible sources of failure of the PIH.[5]

This paper attempts to fill the lacuna by testing the joint rational expectations and permanent income hypothesis for the case of automobile expenditures. An effective test is permitted by the availability of panel data that record the incomes and car expenditures of 1,434 families over four years. As a bonus, the data also include family holdings of liquid assets for each year. This permits a simple test of Mishkin's "liquidity hypothesis," a principal opposing view to the strict PIH.

The results of this study differ rather sharply from those of previous papers, especially the work using time series. We find no evidence that liquidity constraints or capital market imperfections are important in even the timing of family car purchases. The response of expenditure to transitory income changes is as predicted by the permanent income model.

The plan of the paper is as follows. Section II describes the model to be estimated. Section III outlines the estimation procedure. Results are reported in Section IV. Section V discusses Monte Carlo simulations that tested the robustness of the esti-

5. For this reason Hall-Mishkin single out the extension of their approach to durables as an important topic for further research.

mates to specification error. Section VI takes up some additional issues of specification. Section VII concludes.

II. AUTOMOBILE EXPENDITURES AND REVISIONS TO PERMANENT INCOME

This section presents a model of the response of family automobile purchases and sales to new information about family income. The basic approach is the same as that of Hall and Mishkin's innovative study, to which the reader is referred for additional motivation and clarification.

Let us begin by assuming that families base their consumption plans on their rationally expected level of permanent income. As usual, "permanent income" (Y_t^P) is defined (relative to current-period information) as the flow of income that, if sustained at a constant level for the rest of the family's life, would just exhaust expected earnings and wealth.

An immediate problem is that permanent income is unobservable by the econometrician. In many previous studies, both of automobiles and other consumer goods, permanent income has been proxied for by some weighted average of recent actual incomes. However, as Muth [1960] and Lucas [1976] have shown, the validity of this procedure depends intimately on the stochastic process generating income; in general, using a finite-lag average as a proxy is highly restrictive. Accordingly, the income process should be explicitly modeled.

We shall follow Hall-Mishkin in representing the family's total disposable income in year $t, \tilde{Y}_t$, as being comprised of three parts (which we assume that the family can distinguish).[6] These are as follows:

1. The *deterministic* component $\overline{Y}_t$. This is the pattern of lifetime income that can be projected from the basic demographic characteristics of the family (e.g., age of the head, occupation, family size). We assume that $\overline{Y}_t$ is fixed and known in advance.[7]

6. The Hall, Sargent, and Flavin time series studies treated all income changes as homogeneous; the assumption that families can distinguish different types of income change seems more reasonable. Earlier work tried to operationalize this assumption by breaking income down by source (see, for example, Taylor [1971]); but the identification of, say, capital income with windfalls is arbitrary. The use of an unobservables model here avoids these problems.

7. Alternatively, $\overline{Y}_t$ could be called the nonfamily-specific component. $\overline{Y}_t$ is supposed to capture "standard" income profiles for each demographic group, from which changes in the fortunes of individual families can be measured as deviations.

2. The *lifetime prospects* component Y_t^L. Y_t^L, which is stochastic, depends on the individual family's current evaluation of its talents, special skills, and long-run opportunities. Since any change in this component is (virtually by definition) unanticipated, it is naturally modeled as a random walk:

$$Y_t^L = Y_{t-1}^L + \varepsilon_t, \tag{2.1}$$

where the ε_t are i.i.d., $N(0,\sigma_\varepsilon^2)$.

3. The *windfall* component Y_t^W. Y_t^W, also stochastic, is meant to capture purely transitory changes in income. For our data inspection of the covariogram strongly suggests that Y_t^W can be modeled as simple white noise:

$$Y_t^W = \eta_t, \tag{2.2}$$

where the η_t are i.i.d., $N(0,\sigma_\eta^2)$.[8]

A first step in our estimation below will be to eliminate $\overline{Y}_t$ from the income series. This will allow us to restict our attention to the stochastic part of income Y_t, defined by

$$Y_t \equiv \tilde{Y}_t - \overline{Y}_t. \tag{2.3}$$

We shall also make use of the first difference of stochastic income y_t, given by

$$y_t \equiv Y_t - Y_{t-1} = \varepsilon_t + \eta_t - \eta_{t-1}. \tag{2.4}$$

An issue of interest is the relation between revisions to permanent income and changes in the three components of current income. This relation is easy to find: All changes in the deterministic component $\overline{Y}_t$ are anticipated and do not affect Y_t^P. The current innovation to the lifetime prospects component ε_t represents a permanent increase in expected income and is thus fully reflected in the revision of Y_t^P. In contrast, the current innovation to the windfall component η_t is a one-shot addition to wealth; as such, it will increase Y_t^P only at the rate that an addition to principal increases an annuity. In summary, we can write the current revision to permanent income as

$$Y_t^P - Y_{t-1}^P = \varepsilon_t + \beta\eta_t, \tag{2.5}$$

where β is the rate of payout of an annuity with a term equal to the lifespan of the family.

8. We did experiment with alternative ARMA processes for windfall income; processes with two or less free parameters could be identified in the context of our model. Our findings were not sensitive to these changes.

The standard assumption that consumption is proportional to permanent income, in conjunction with (2.5), gives the Hall [1978] "random walk consumption" result: Under the permanent income and rational expectations hypotheses, changes in consumption flows should be unpredictable.[9] Note also that the covariance of (nondeterministic) consumption and current income changes is proportional to $\sigma_\varepsilon^2 + \beta\sigma_\eta^2$. Thus, when most income changes are permanent ($\sigma_\varepsilon^2/\sigma_\eta^2$ is large), consumption is very sensitive to current income.[10]

The consumption-related variable in which we are specifically interested is family expenditure on automobiles, either purchases or sales, gross of depreciation.[11] As with income, we assume that total expenditure $\tilde{E}_t$ is made of a deterministic (or nonfamily-specific) component and a stochastic component:

$$\tilde{E}_t = \overline{E}_t + E_t. \tag{2.6}$$

Assuming that the deterministic component $\overline{E}_t$ can be eliminated from the data, we concern ourselves here only with the stochastic portion of expenditure E_t.

Under the familiar model of continuous stock adjustment,[12] stochastic expenditure is given by

$$E_t = \lambda(K_t^* - K_t) + \theta_t, \tag{2.7}$$

where λ is the rate of stock adjustment; K_t^* and K_t are desired and actual car stocks (exclusive of the deterministic component) at the beginning of the period; and θ_t (i.i.d., $N(0,\sigma_\theta^2)$) is a white noise term capturing random influences on expenditure.

By assuming smooth adjustment of the car stock, we are ignoring (or at least relegating to the error term) the truncated dependent variable problem raised by Tobin [1958]. While incorporating these considerations into our analysis poses no difficulty in principle, it would transform a computationally easy estimation procedure into one that is extremely burdensome. Section V

9. This assumes that income is exogenous with respect to consumption. Sargent's article has a discussion of the implications of this. The income-exogeneity assumption is more easily avoided in time series than in panel data; see Diewert [1974] for an application to durables.

10. The point that the sensitivity of consumption to current income under the PIH depends on the stochastic process of income is amplified by Flavin and by Blinder.

11. Because of the durable-goods feature of this problem, we depart from the Hall-Mishkin specification at this point.

12. Stone and Rowe [1957]. We use this specification because, like the PIH, it is tractable and descriptively appealing. Also, like the PIH, it can be rigorously derived from a restrictive optimization problem. See Appendix 1.

below discusses the implications of assuming continuous adjustment. The results of Monte Carlo simulations, to be reported, suggest that the biases introduced are small and easily corrected.

To make the desired car stock K_t^* operational, we assume local linearity of the Engel curve for automobile services.[13] This, plus the assumption that services are proportional to stocks, implies that

$$K_t^* - K_{t-1}^* = \alpha(Y_t^P - Y_{t-1}^P), \tag{2.8}$$

where α measures the relation of desired stocks to permanent income. By (2.5), (2.8) is equivalent to

$$K_t^* - K_{t-1}^* = \alpha(\varepsilon_t + \beta\eta_t). \tag{2.9}$$

To close the model, we write the evolution of the automobile stock K_t as

$$K_t = (1 - \delta)K_{t-1} + E_{t-1}, \tag{2.10}$$

where δ is the rate of depreciation.[14] Equations (2.7), (2.9), and (2.10) define a unique stochastic expenditure path, given a history of random disturbances ε, η, and θ, and initial conditions for K and K^*.

Now let us drop the assumption of perfect capital markets. How should the expenditures of a family that is constrained in its borrowing and lending opportunities deviate from the above model? The argument presented by Mishkin [1976] is based on the observation that consumers with unfavorable balance sheets find it difficult to borrow. A series of short-run financial reverses may threaten insolvency and the loss of accumulated equity in debt-financed assets. Thus, the family should try to maintain a buffer of financial assets over debt obligations. This leads to a dependence of car expenditure on the short-run level of financial liquidity, as well as on long-run income.[15]

A second possible effect of imperfect capital markets is drawn

13. At best this is an approximation. Estimation within high- and low-income subsamples showed that in fact the marginal propensity to buy cars is lower for the rich. However, this fact did not affect the estimates of the other parameters, which were about the same in the subsamples as in the total sample.

14. Geometric mortality is a standard assumption. For alternative models of durables stock depletion, see Williams [1972].

15. For an early statement of this idea, see Nugent [1939], especially p. 135. Mishkin's analysis can be viewed as the opposite face of the precautionary demand for money literature (see, e.g., Whalen [1966]). We find this treatment of dynamic liquidity management under uncertainty to be much richer than the older, static model of liquidity constraints, in which spending is affected only when cash reserves literally reach zero.

from the work of Darby [1972]. If consumers do not have good short-run lending opportunities, they may choose to hold part of transitory income as durable goods. Thus, automobile purchases may follow from portfolio considerations.

In the context of our model both of these arguments suggest that car expenditures may be increased (dampened) in the short run by the effects of windfall gains (losses) on current financial holdings. We generalize (2.7) to

$$E_t = \lambda(K_t^* - K_t) + \theta_t + \gamma\eta_t, \tag{2.11}$$

where γ is a parameter that measures the response of expenditure to current windfall income.

Note that the specification (2.11) allows windfall income to affect short-run car stocks only; the long-run target K_t^*, to which K_t converges, does not depend on the $\gamma\eta_t$ term. This is an important and desirable property of this specification.[16]

We would like to test if $\gamma > 0$. The procedure by which this is done is described in the next section.

III. Estimation Procedure

The outline of the estimation approach can be briefly stated. We begin by finding the deviations of each family's car expenditure and changes in income from the corresponding deterministic paths. These deviations can be written as linear functions of unknown parameters and unobservable, family-specific shocks. Under the assumption of normality, it turns out that the average variance-covariance matrix of expenditure and differenced income is a sufficient statistic for the data. A maximum likelihood procedure can be used to extract estimates of the parameters, including the variances of the unobservable shocks.

For the interested reader, the rest of this section provides more detail. Others may wish to go directly to the results in Section IV.

The basic data are the changes in real disposable income and the expenditures (purchases and sales) on automobiles of the families followed by the survey. (See the introduction and part 1 of

16. Specifically, (2.11) implies that expenditures deferred (or moved up) this year are made up at rate λ in future years, leaving no long-run effects. Alternative specifications tried assumed that (1) deferred expenditures are made up completely in the next year, and (2) current deferrals depend on a moving average of past and present windfalls, rather than just the current windfall. The results were not significantly affected by these changes.

the Data Appendix.) The estimation procedure required the data in the form of deviations from the deterministic paths. We assumed that the deterministic components were functions of family demographic characteristics and of year dummies.[17] Ordinary least-squares regressions in the pooled data were run for income change and car expenditure against the explanatory variables. (See Data Appendix, part 2.) The residuals of these regressions for each family and year were used to represent the nondeterministic components of income change and expenditure.

Inspection of these residuals revealed considerable heteroskedasticity across families of different income sizes. Since the estimation will assume that the sample families have identically distributed income innovations, a heteroskedasticity correction was necessary. The Data Appendix, part 3, gives details.[18]

The next step is to write nondeterministic income change (y) and car expenditure (E) solely as functions of unobservables.[19] For y this is easy; we already have (2.4). For E, this task is complicated by the fact that our expenditure data are gross rather than net of depreciation. It is shown in an appendix that current gross expenditure can be expressed, for any k, as

$$(3.1)\qquad E_t = \sum_{i=0}^{k} b_i L^i Z_t + b_{k+1} L^{k+1} (\lambda(K_t^* - K_t) + \theta_t) + a_{k+1} L^{k+1} K_t,$$

where

$$(3.2)\qquad Z_t \equiv \lambda(K_t^* - K_{t-1}^*) + \theta_t - \theta_{t-1} + \gamma(\eta_t - \eta_{t-1}) = \lambda(\alpha(\varepsilon_t + \beta\eta_t)) + \theta_t - \theta_{t-1} + \gamma(\eta_t - \eta_{t-1}).$$

The L^i are lag operators, and the a_i and b_i are parameters depending on λ and δ. Define an arbitrary beginning, or "base," year t'. Let $K_{t'}$ and $(K_{t'}^* - K_{t'})$ be the base year (nondeterministic) car

17. Year dummies were included to eliminate such aggregate influences as the business cycle, interest rates, and the relative price of automobiles; we wanted to avoid the possibility of one or two macroeconomic events dominating the results. Using the year dummies in fact made little difference, confirming the observation that aggregate disturbances explain only a small part of the variation in individual family circumstances.

18. In the original application of this approach, Hall and Mishkin did not make a cross-sectional heteroskedasticity correction. This is a potentially serious omission, since it gives some large-income families as much as one hundred times the average weight in the estimates.

19. The use of income *changes* and car expenditure *levels* is not asymmetrical: Expenditures are the first difference of stocks, which depend on (permanent) income.

stock and the base year difference between desired and actual stocks, respectively. These can be thought of as unobserved random variables with unconditional means of zero and an unspecified covariance. Then, by (3.1), expenditure for any year depends on the history of disturbances and on the base year stock variables.

For a given family i, let x_i be the column vector of unobserved random variables:

$$x_i' = [\varepsilon_{1964}, \ldots, \varepsilon_{1970}, \eta_{1963}, \ldots, \eta_{1970}, \theta_{1963}, \ldots, \theta_{1970}, K_{1963}, (K^* - K)_{1963}]. \tag{3.3}$$

We assume that x_i is multivariate normal with covariance matrix Σ. Σ is supposed to be diagonal, except for the covariance of the last two terms. The variances on the diagonal are

$$\begin{aligned} V(\varepsilon_t) &= \sigma_\varepsilon^2 \\ V(\eta_t) &= \sigma_\eta^2 \\ V(\theta_t) &= \sigma_\theta^2 \\ V(K_{1963}) &= \sigma_k^2 \\ V((K^* - K)_{1963}) &= \sigma_{k^*}^2. \end{aligned} \tag{3.4}$$

Define q_i to be the column vector in which is stacked the ith family's history of income change and expenditure. Then, using (2.4) and (3.1), we may express the model to be estimated in the form,

$$q_i = Ax_i, \tag{3.5}$$

where A is a 7×25 matrix that depends on unknown parameters. The covariance matrix for the representative family is

$$\Omega(P) = A\Sigma A'. \tag{3.6}$$

P is a vector of unknown parameters:

$$P = (\alpha,\beta,\delta,\gamma,\lambda,\sigma_\varepsilon^2,\sigma_\eta^2,\sigma^{2\theta},\sigma_k^2,\sigma_{k^*}^2,\rho_{kk^*}). \tag{3.7}$$

The log-likelihood of a sample of size N is

$$L(P) = -\frac{N}{2}\log\det\Omega(P) - \frac{1}{2}\sum_{i=1}^{N} q_i\Omega^{-1}(P)q_i \tag{3.8}$$

plus an inessential constant. Maximization of (3.8) with respect to the unknown parameters produces estimates with the usual desirable properties. A numerical maximization routine written by Bronwyn Hall [1979] was available for the estimation.

We did not attempt to estimate the full parameter vector P. The annuity rate β was exogenously specified to be equal to 0.03.[20] Following estimates by Cagan [1971], we set the annual rate of stock depreciation δ equal to a constant 0.25.[21]

We found by experiment that, although we could estimate the variance of K_{1963}, the variance of $(K^*_{1963} - K_{1963})$ and its covariance with K_{1963} could not be econometrically identified. Using Monte Carlo simulations as a guide, we tried different exogenous values for these terms. The results were found to be essentially invariant to the treatment of $(K^*_{1963} - K_{1963})$; moving the variance and covariance terms over a reasonable range affected the estimates, except for that of σ_k^2, by 1 percent or less. In the estimates reported in the next section, we simply assumed that

$$K^*_{1963} = K_{1963}. \tag{3.9}$$

That is, families are assumed to have had no gap between desired and actual car stocks in the base year.

IV. Estimation Results

The parameter estimates that maximized (3.8) for the sample are given in Table I. The four variance parameters (1–4) are measured in millions of 1972 dollars; they have been scaled up to offset the cross-sectional heteroskedasticity correction.

The model fits the data well. The variance parameters are of reasonable magnitude[22] and are sharply estimated. We find the variances of innovations to lifetime prospects and windfall components of income to be similar in size.[23] The estimated variance of θ, the expenditure disturbance, is about 80 percent of the total variance of automobile expenditure; presumably this includes the

20. The parameter estimates were not at all sensitive to changes in β. Specifically, the convenient assumption that β is constant across the sample, rather than dependent on the age of the family head, was not a factor in the results.

21. Wykoff [1970] disputes the constant depreciation rate assumption, claiming that depreciation is at a greater rate in the first year. The effects of experimentation with the depreciation rate were confined largely to the estimates of the stock adjustment parameter, λ.

22. σ_k^2 is inflated in some degree by the assumption that the unidentifiable term $\sigma_{k^*}^2$ equals zero.

23. The Hall-Mishkin result that σ_η^2 is about twice σ_ε^2 may be due to the cross-sectional heteroskedasticity in their data. Our uncorrected data also implied a relatively larger variance for windfall income.

TABLE I

PARAMETER ESTIMATES: ENTIRE SAMPLE AND "ADVANCE INFORMATION" MODEL

Parameter		Entire sample estimate (*t*-statistic)	"Advance information" model estimate (*t*-statistic)	Parameter definition
1.	σ_η^2	5.64 (18.26)	5.46 (12.50)	Variance of windfall shocks to income
2.	σ_ε^2	4.79 (11.08)	4.89 (16.64)	Variance of lifetime shocks to income
3.	σ_θ^2	1.96 (19.71)	1.82 (19.61)	Variance of random influences on expenditure
4.	σ_k^2	25.11 (15.22)	24.24 (15.79)	Variance of initial stocks
5.	λ	0.694 (18.55)	0.678 (17.31)	Annual rate of stock adjustment
6.	α	0.259 (6.09)	0.228 (6.26)	Response of desired stock to changes in long-run income
7.	γ	−0.0136 (−0.71)	−0.0200 (−0.72)	Sensitivity of current expenditure to current transitory income
8.	ϕ	—	0.241 (1.04)	Fraction of innovation in next year's income known in advance

effects of noncontinuous stock adjustment and errors of measurement in E_t.

The annual rate of stock adjustment λ is found to be 0.694. Since a given family's car expenditures are nonzero only about one year in three, this may appear high. However, it is probably the case that expenditures are more likely to be made in years in which significant changes in desired stocks have occurred. Thus, λ must exceed one third.

The estimate of α says that a one dollar increase in permanent income will lead, in the long run, to a 25.9 cent increase in the value of the family's car stock. We made several checks of this estimate:

1. Using reported characteristics of car stocks, we were able to construct estimates of each family's car stock value for each year. These values were not used in obtaining the above estimate of α, except in the construction of series for the value of car sales unaccompanied by purchases. Using two-stage least-squares to eliminate transitory income effects, we regressed each family's average real stock value over the period against average disposable income, age of the head, age squared, and a constant. The estimated coefficient of income (a measure of α) was 0.219. See the Data Appendix, part 4.

2. The *Survey of Current Business* has recently reported aggregate constant-dollar automobile stocks for 1964–1979. A simple regression of stocks against real personal disposable income and a constant gave an estimate of α of 0.227.

These confirmations that $\hat{\alpha}$ is in a reasonable range increase our confidence in the model.[24]

The estimate of greatest interest is that of γ, the parameter that measures the "excess" sensitivity of expenditure to windfall income. Recall that, for a family that faces constraints in the capital market, we expect $\gamma > 0$. The actual estimate of γ is negative, small, and insignificantly different from zero. Thus, we have found no evidence of excessive sensitivity of car expenditure to transitory income changes.[25]

24. In addition, Monte Carlo simulations, reported below, found an estimated bias in $\hat{\alpha}$ of approximately 0.03. Correction of $\hat{\alpha}$ by this quantity brings it very close to the alternative estimates. Also, see estimates discussed immediately below.

25. Few previous studies of automobile expenditure have explicitly considered the influence of transitory income. An exception is Katona and Mueller [1968] who, applying a rather different approach to family data, tend to support the no-effect result.

Some readers of an earlier version of this paper were concerned that our results might depend on the assumption that families have no advance information about income innovations. To test this, we estimated a more general model in which advance information about income is permitted. We followed Hall and Mishkin by introducing a new parameter ϕ, which indexes the fraction of the innovation to income in $t + 1$ that is known to the family in period t. (See Hall and Mishkin, Appendix 2 for details.) Estimates of the extended model are also given in Table I.

Comparison of columns 2 and 3 in Table I indicates that the effect of allowing for advance information is small; indeed, the estimate of γ, still insignificant, is slightly *more* negative. The estimate of ϕ suggests that about 24 percent of the innovation to family income is known a year in advance; interestingly, this is almost identical to the estimate found by Hall and Mishkin in their data.

The reported estimates of γ suggest that the capital markets faced by consumers are reasonably "perfect." This conclusion runs counter to the results of the previously mentioned work by Mishkin [1976, 1977], in which time series data were used to find a link between durables expenditure and consumer holdings of liquid assets and debt.[26] We performed an additional test for liquidity effect as follows: Family financial assets including bank deposits and holding of stocks and bonds (but not currency) are available for each year. Real financial assets were regressed against demographic variables to permit the creation of a "fitted" level of financial assets for each family. The sample was ranked by the average level of fitted financial assets over the period. The basic model was then re-estimated for the top third and the bottom third of the sample. The presumption was that, if the liquidity hypothesis is correct, a greater sensitivity to windfall income would be found among those with small financial holdings.[27] The outcome of this exercise is contained in Table II.

Surveying the results, we see that the "rich" are more likely to experience lifetime rather than windfall income changes, while

26. In his comment following Mishkin [1977], Robert Gordon pointed out some difficulties in interpreting the time series tests of the liquidity hypothesis. The use of cross-sectional data helps us avoid those problems in the test reported below.

27. The division of the sample by fitted rather than actual financial assets was done to avoid simultaneity problems, e.g., as when a family accumulates financial assets in anticipation of a car purchase. The estimates of γ were about the same when the sample was divided according to actual financial assets.

TABLE II

PARAMETER ESTIMATES: HIGH FINANCIAL ASSETS SUBSAMPLE AND LOW FINANCIAL ASSETS SUBSAMPLE

Parameter		High financial assets subsample estimate (t-statistic)	Low financial assets subsample estimate (t-statistic)	Parameter definition
1.	σ_η^2	6.61	3.50	Variance of windfall shocks to income
		(8.06)	(12.49)	
2.	σ_ε^2	11.69	1.66	Variance of lifetime shocks to income
		(8.68)	(4.76)	
3.	σ_θ^2	3.79	0.959	Variance of random influences on expenditure
		(13.03)	(10.11)	
4.	σ_k^2	39.12	10.37	Variance of initial stocks
		(8.57)	(5.65)	
5.	λ	0.624	0.687	Annual rate of stock adjustment
		(10.96)	(10.49)	
6.	α	0.237	0.461	Response of desired stock to changes in long-run income
		(4.42)	(4.00)	
7.	γ	0.023	−0.053	Sensitivity of current expenditure to current transitory income
		(0.498)	(−0.96)	

for the "poor" the reverse is true.[28] The high-financial-asset group had larger initial car stocks and more car expenditures, but a lower marginal propensity to buy cars than the low-asset group. The rate of stock adjustment was comparable in the two subsamples, with, surprisingly, slightly faster adjustment by the low-asset people.

Most importantly, estimates from neither subsample can support the hypothesis that $\gamma > 0$. Of the two point estimates, the negative (and marginally significant) one was associated with the low-asset group; the positive one with the high-asset subsample. This is the opposite ordering that would be predicted by the liquidity hypothesis. Again, we have found no reason to believe that liquidity considerations affect even the timing of automobile expenditures.

V. The Discontinuous Adjustment Problem

The well-known desirable properties of maximum likelihood estimation are, of course, contingent on proper specification of the model. However, both experience and theoretical considerations[29] suggest that ML can be an effective approach when the statistical model is only approximately correct. We tested the robustness of our estimates to various specification errors by Monte Carlo simulations, with generally good results.

A possible specification error of particular interest was the assumption of continuous stock adjustment. Since Tobin [1958], it has been standard in cross-sectional studies to model purchases of durable goods as taking place only when the gap between desired and actual stocks exceeds some threshold level.[30] This discontinuous adjustment is consistent with the fact that family purchases of a given durable are zero in most years. While computational considerations forced us to ignore discontinous adjustment, it is important to know what potential biases exist.[31]

In terms of the notation of this paper, the discontinous adjustment model is

28. We had no prior reason to expect this result, but it was obvious even from casual inspection of the autocovariograms of income. Again, variances are scaled to offset the heteroskedasticity correction.

29. For example, see MaCurdy [1981] on ML properties when disturbances are incorrectly assumed to be normal.

30. Dagenais [1975] and others have expanded on the basic Tobin model.

31. Determination of the bias analytically seems intractable. The problem is complicated by the time series aspect and by the inclusion of car sales as well as purchases.

$$(5.1) \qquad E_t^* = \lambda(K_t^* - K_t) + \theta_t + \gamma\eta_t$$

$$E_t = \begin{cases} E_t^* & \text{if } E_t^* > \overline{L} \text{ or } E_t^* < \underline{L} \\ 0 & \text{otherwise.} \end{cases}$$

where $\overline{L}$ and $\underline{L}$ are the thresholds beyond which the family will buy or sell automobiles. The specification is closed by adding equations (2.4), (2.9), and (2.10).

This model, in conjunction with a normal random number generator, was used to create artifical data sets. The variances of the disturbances and the thresholds were chosen so that the purchase frequency and other characteristics of the actual data were approximated. The other parameters were varied over plausible ranges. Each run simulated the behavior of 200, 300, or 400 "families" over fifteen "years." Only the last four years were assumed to be "observed"; the purpose of the first eleven "years" was to generate appropriate random initial conditions. The average income-expenditure covariance matrix for the final four years was input to the basic estimation procedure (which assumes continuous adjustment), and the results were compared to the "true" parameters of the simulation.

While the cost of a completely formal robustness analysis did not seem justified, sixteen simulations and estimations were performed. These seemed sufficient for making the following observations:

1. The sample sizes used (one third or less of the actual sample size) were adequate to allow low-variance estimates of all parameters.

2. Estimates of the income disturbance variances were easy to obtain.

3. We observed a small positive bias in the estimate of α, in the vicinity of 0.03. Twelve of the sixteen simulations led to an estimate of α that was too high. The empirical standard deviation of the estimation of α was about 0.05 for samples of 400.

4. Estimates of γ showed a bias of approximately -0.025. Except for this bias, γ was tightly and reliably estimated: In every simulation and estimation run, even those in which other estimates were unusually inaccurate, $\hat{\gamma}$ fell in the range ($\gamma - 0.01$, $\gamma - 0.04$).

We conclude that violation of the assumption of continuous stock adjustment does not pose a severe problem for our results. Correction of the full-sample estimate of γ for the empirical bias gives a value that is positive but still very close to zero. The marginally significant negative $\hat{\gamma}$ found in the low-asset subsample is shown by the simulation studies to be an artifact. However, no additional explanation can be offered for the positive γ in the high-asset group.

VI. Two Additional Specification Issues

Our work inherits from the Hall-Mishkin framework two additional restrictions on the specification: First, real interest rates are assumed constant over time; second, family income is treated as exogenous. Relaxing these assumptions is a goal of future research. Here we do no more than explain why we would not expect the loosening of these restrictions to affect our results very substantially.

On the constant-real-rate assumption: The real rate in fact did not vary much over the sample period. Given below are the quarterly (nominal) rates charged by banks at this time for short-term loans under $9,000:

1967:	1	6.73	1968:	1	6.82	1969:	1	7.73	1970:	1	9.17
	2	6.61		2	7.18		2	8.22		2	9.05
	3	6.58		3	7.35		3	8.99		3	9.15
	4	6.60		4	7.27		4	9.05		4	8.89

Source. Federal Reserve Bulletin.

Given the steady rise of the inflation rate during these years, no reasonable model of inflation expectations could generate a highly variable real rate from the market rate series above. The only year in which a rise in the real rate might be suspected (1969) was also, according to the *FRB*, the biggest year of the four for new auto loans.

Further evidence for the unimportance of real rate variations in this particular period can be found in the regressions used to remove the deterministic components of income and expenditure (Data Appendix, part 2). The estimated year dummies in these regressions suggest that time-varying variables, such as interest rates or national income, did not create any heterogeneity in the sample.

On the assumed exogeneity of income: Though convenient, this restriction causes statistical problems when family car-purchase plans affect the quantity of income the family chooses to earn. However, given institutional constraints on (or employer determination of) work hours in the short run, and given the fixed costs of obtaining new or additional employment, it seems plausible that, in practice, a family's employment decisions will usually precede its car-expenditure decisions. In those cases where the reverse is true—as when a family member takes a temporary job in order to pay for a car—the resulting bias could be expected to work *against* the permanent income hypothesis, rather than for it.

VII. Conclusion

This study tested the joint rational expectations–permanent income hypothesis using panel data on automobile expenditures. Although it would seem that durables purchases would be especially sensitive to failures of the PIH, no evidence against the joint hypothesis was found.

How can the conclusion that automobile expenditures depend on the consumer's long-run view of his income be squared with the short-run volatility of car sales in the aggregate? While this must be left to future research, it is not anticipated that the reconciliation will be difficult. First, the estimates presented imply that a one-dollar increase in current disposable income that is expected to be permanent will lead to a 17-cent expansion in car sales the first year. (In comparison, average car sales are about 5 percent of disposable income.) This, in conjunction with the fact that aggregate income contains a significant random walk component, leaves room for powerful accelerator effects. Second, by construction our study eliminated some non-income factors that may be important for car sales in the aggregate: Relative prices, interest rates [Hamburger, 1967], and "confidence"[32] all may contribute to observed short-run variations. Thus, we may hope to explain cycles in aggregate automobile purchases without reliance on an "excessive" sensitivity of expenditure to current income.

Appendix 1: Derivation of Optimal Durables Stock Adjustment Rule

We make a set of restrictive assumptions that allow us to derive a form of equation (2.7) as the solution to a dynamic stochastic optimization problem. Assume the following:

32. Hymans [1970] and Juster-Wachtel [1972] have stressed the importance of survey measures of consumer sentiment in predicting short-run car sales. For formal analyses of the "confidence" phenomenon as a result of the interaction of uncertainty and irreversibility, see Cukierman [1980] and Bernanke [1983].

A.1. The instantaneous utility function is of the form,

$$U(c_t, K_t, K_{t-1}) = -\frac{1}{2}(\bar{c} - c_t)^2 - \frac{a}{2}(\overline{K} - K_t)^2 - \frac{d}{2}(K_{t-1} - K_t)^2, \tag{1}$$

where

c_t = consumption of nondurable goods in t,
K_t = beginning-of-period stocks of durable goods in t,

and $\bar{c}$, $\overline{K}$, a, and d are parameters. Stocks affect utility directly because the services of durables are taken to be proportional to stocks. Equation (1) assumes quadratic utility and separability between nondurables and services of durables. The last term in (1) is supposed to capture costs of adjusting the durables stock between t and $t + 1$; this is put in the utility function instead of in the budget constraint to achieve tractability.

A.2. Current income Y_t is a stochastic process of exponential order less than $1/b$, where b is the subjective discount rate.

A.3. The interest rate r is constant. Assume that $b = 1/(1 + r)$, where b is as in (A.2).

A.4. The durable goods stocks do not depreciate. Durables purchased during t become part of the beginning-of-period stock in $t + 1$. (The no-depreciation assumption can be relaxed.)

A.5. The price of durable goods relative to the price of perishable consumption goods is constant. Without further loss of generality, we can normalize this relative price to one.

A.6. The family chooses contingent plans in c_{t+i} and K_{t+i+1} to maximize

$$E_t\left[\sum_{i=0}^{T} b^i U(c_{t+i}, K_{t+i}, K_{t+i+1})\right], \tag{2}$$

subject to the budget constraint,

$$\sum_{i=0}^{T}\left(\frac{1}{1+r}\right)^i (c_{t+i} + (K_{t+i+1} - K_{t+i}) - Y_{t+i}) = A_0, \tag{3}$$

where A_0 = initial family assets.

The solution to the problem in (A.6) begins with the necessary conditions,

$$\begin{aligned}(\bar{c} - c_{t+i}) &= \beta E_{t+i}(\bar{c} - c_{t+i+1})(1 + r)\\ &= E_{t+i}(\bar{c} - c_{t+i+1})\end{aligned} \tag{4}$$

$$(5)\qquad \begin{aligned} -d(K_{t+i+1} - K_{t+i}) + ba(\overline{K} - K_{t+i+1}) \\ + bdE_{t+i}(K_{t+i+2} - K_{t+i+1}) \\ - rbE_{t+i}(\bar{c} - c_{t+i+1}) = 0. \end{aligned}$$

Condition (4) is the familiar "random walk in marginal utility" result. It says that one dollar spent on nondurable consumption today must, along the optimal path, provide the same expected marginal utility as $1 + r$ dollars spent tomorrow.

Condition (5) says that, along the optimal path, the marginal return to the following strategy must be zero: Increase durable goods investment by one unit today; reduce durable goods investment tomorrow by one unit and perishable consumption tomorrow by r units. Note that this satisfies the budget constraint and leaves expected durable goods holdings at the end of tomorrow unchanged.

Assuming that an infinite-horizon approximation may be used, methods discussed in Sargent [1979] allow us to find a stochastic difference equation in K that satisfies (5). Rewrite (5) as

$$(6)\qquad bE_{t+i}K_{t+i+2} - \left[\frac{ba + d(1+b)}{d}\right]K_{t+i+1} + K_{t+i} = \frac{b}{d}(r(\bar{c} - c_{t+i}) - a\overline{K}).$$

Equation (6) uses the fact that $E_{t+i}(\bar{c} - c_{t+i+1}) = (\bar{c} - c_{t+1})$.

Define

$$(7)\qquad K^*_{t+i} = -(1/a)(r(\bar{c} - c_{t+i}) - a\overline{K}).$$

This definition will be rationalized shortly. Using (7), we see that (6) becomes

$$(8)\qquad bE_{t+i}K_{t+i+1} - \left[\frac{ba + d(1+b)}{d}\right]K_{t+i+2} + K_{t+i} = \frac{-baK^*_{t+i}}{d}$$

The difference equation that solves (8) can easily be verified to be

$$(9)\qquad K_{t+i+1} = X_1K_{t+1} + \frac{X_1X_2}{X_2 - 1}\left[\frac{ba}{d}\right]K^*_{t+i},$$

where X_1 and X_2 are the roots of the characteristic polynomial in (8). We know [Sargent, 1979, pp. 197–198] that X_1 and X_2 are real. If X_1 is the smaller root, we also know that $0 < X_1 < 1 < (1/b) < X_2$, and that

$$(10) \qquad 1/b = X_1 X_2$$
$$(1/b)\,[(ba/d) + (1 + b)] = X_1 + X_2.$$

Define durable goods expenditures $EXP_{t+i} = K_{t+i+1} - K_{t+i}$, and let $\lambda = 1 - X_1$. Thus, $0 < \lambda < 1$. Using (10), we may write (9) as

$$(11) \qquad EXP_{t+i} = \lambda(K^*_{t+i} - K_{t+i}),$$

which is of the same form as equation (2.7).

All that remains is to rationalize our definition of K^*_{t+i} in (7), and to show the relation of this concept of desired capital stock to the one used in the main text.

The usual notion of a "desired" capital stock K^* is the level of stock that would be held in the absence of adjustment costs. Accordingly, set the adjustment cost parameter d equal to zero in (5). Solving for K_{t+i+1}, we see that the level of stocks "desired" as of $t + i$ for the beginning of the next period (call this K^*_{t+i}) is just as is given in (7).

To see the connection of (7) to the definition of K^* used in the text, first-difference (7) to get

$$(12) \qquad K^*_{t+i} - K^*_{t+i-1} = r/a(c_{t+i} - c_{t+i-1}).$$

Like c, K^* is a random walk that responds only to innovations in Y. Now suppose that there is an innovation in the income process at t. Denote the corresponding change in the annuity value of lifetime wealth as ΔY^P_t. The linear expenditure rule (11) allows us to write the annuitized value of expenditures associated with ΔK^*_t as $m\Delta K^*_t$, where

$$(13) \qquad m \equiv r \sum_{i=t}^{\infty} \left(\frac{1}{1 + r}\right)^{i-t} \left[(1 - \lambda)^{i-t} - (1 - \lambda)^{i-t+1}\right].$$

The flatness of the optimal nondurable consumption plan and satisfaction of the new budget constraint require that

$$(14) \qquad \Delta c_t + m\Delta K^*_t = \Delta Y^P_t$$

or

$$(15) \qquad \Delta c_t = (1 + m(r/a))^{-1}\, \Delta Y^P_t.$$

Finally, we have

$$(16) \qquad \Delta K^*_t = \alpha \Delta Y^P_t.$$

where $\alpha \equiv r/(a + rm)$. Equation (16) corresponds to equation (2.8) in the text.

APPENDIX 2: DERIVATION OF THE EXPRESSION FOR GROSS AUTOMOBILE EXPENDITURES

The model for gross expenditures (using the notation of the text) is

$$E_t = \lambda(K_t^* - K_t) + \theta_t + \gamma\eta_t, \tag{1}$$

where E_t, K_t^*, and K_t are defined to be net of their deterministic components. K evolves as

$$K_t = (1 - \delta)K_{t-1} + E_{t-1}. \tag{2}$$

Differencing (1) gives

$$E_t = \lambda(K_t^* - K_{t-1}^*) - \lambda(K_t - K_{t-1}) + \theta_t - \theta_{t-1} + \gamma(\eta_t - \eta_{t-1}) + E_{t-1}. \tag{3}$$

Differencing (2) and substituting gives

$$E_t = \lambda(K_t^* - K_{t-1}^*) - \lambda(E_{t-1} - \delta K_{t-1}) + \theta_t - \theta_{t-1} + \gamma(\eta_t - \eta_{t-1}) + E_{t-1} \tag{4}$$

or

$$E_t = Z_t + (1 - \lambda)E_{t-1} + \lambda\delta K_{t-1}, \tag{5}$$

where

$$Z_t \equiv \lambda(K_t^* - K_{t-1}^*) + \theta_t - \theta_{t-1} + \gamma(\eta_t - \eta_{t-1}).$$

Using (5) we may show that, for any $k \geqslant 1$,

$$E_t = c_{k-1} + b_k L^k E_t + a_k L^k K_t, \tag{6}$$

where

$$c_j \equiv \sum_{i=0}^{j} b_i L^i Z_t,$$
$$a_0 = 0,$$
$$b_0 = 1,$$
$$a_{j+1} = a_j (1 - \delta) + \lambda\delta b_j,$$
$$b_{j+1} = a_j + (1 - \lambda)b_j,$$

and L is the lag operator.

Proof of (6) is by induction. For $k = 1$, (6) reduces to (5). Now suppose that (6) is true for k. Substitute (5) and (2) into (6) to get

$$E_t = c_{k-1} + b_k L^k (Z_t + (1 - \lambda) L E_t + \lambda \delta L K_t) + a_k L^k ((1 - \delta) L K_t + L E_t). \tag{7}$$

This implies that

$$E_t = (c_{k-1} + b_k L^k Z_t) + (a_k + b_k (1 - \lambda)) L^{k+1} E_t + (a_k (1 - \delta) + \lambda \delta b_k) L^{k+1} K_t, \tag{8}$$

which is just

$$E_t = c_k + b_{k+1} L^{k+1} E_t + a_{k+1} L^{k+1} K_t. \tag{9}$$

Q.E.D.

Equation 9 is equivalent to

$$E_t = \sum_{i=0}^{k} b_i L^i Z_t + b_{k+1} L^{k+1} (\lambda (K_t^* - K_t) + \theta_t) + a_{k+1} L^{k+1} K_t, \tag{10}$$

which is used in the text.

DATA APPENDIX

This appendix describes data sources and construction, and provides details on some preliminary steps in the estimation procedure.

The primary source of data was the Hendricks-Youmans [1976] four-year panel study of consumer behavior. Their study was conducted at the University of Michigan's Survey Research Center as an adjunct to the annual *Survey of Consumer Finances*. Fourteen hundred and thirty-four families, representing a national cross-section, were interviewed each year from 1967 to 1970.

1. Data construction. The basic variables in our study were real family disposable income and gross expenditures on automobiles. These were constructed as follows:

Total income is reported each year in current dollars. It includes capital and mixed labor-capital income, as well as wages and salaries. Unrealized capital gains do not appear to be included. Federal taxes were estimated from the family data by the survey-taking group. We estimated Social Security and state income taxes for each family:

1. Total family income was allocated into wages, nonwage taxable, and nontaxable income. The appropriate Social Security

tax rate, subject to the legislated ceiling, was applied to each of the first two categories to estimate Social Security taxes.

2. For each state and each year, we found the ratio of state personal income taxes to Federal personal income taxes paid by inhabitants of the state.[33] The applicable ratio was applied to each family's estimated Federal taxes to calculate the family's state taxes for that year.

Sales taxes and property taxes were not deducted, on the grounds that they should be treated as part of the price of the associated consumer good.

Income measures were converted to 1972 dollars by the implicit deflator for the personal consumption expenditures component of GNP.

The survey contained annual data on gross expenditures on automobiles for each family. However, car sales that were not trade-ins were not reported. We augmented the expenditure data with a car sales series constructed from data on family car stocks.

Each family reported the number of cars owned in each year and a list of characteristics of the primary car. We estimated the value of the primary car in a manner to be described. When the number of cars owned was unaccountably too low, based on previous stocks and expenditures, it was assumed that a sale had taken place. If it could be determined that the primary car had been sold without an accompanying purchase, the value of the primary car was included in the sales series. If it was not the primary car that was sold, we assumed that the "last" of the n cars owned by the family was sold. This car was valued at $1/n$ times the value of the primary car.

Valuation of the primary car was achieved by fitting a regression of the purchase prices of cars bought during the sample period against the characteristics of those cars. By using the characteristics of the primary cars, the regression predicted primary car values.

The predicting regression was

$$\begin{aligned} RPCAR = {} & \underset{(66.7)}{2{,}635} - \underset{(-74.8)}{364}\, AGECAR + \underset{(3.86)}{310}\, CONV \\ & + \underset{(2.74)}{220}\, MIDSIZE + \underset{(16.0)}{658}\, LGSIZE; \quad R^2 = 0.732. \end{aligned} \tag{DA.1}$$

33. Sources were (1) for federal personal income taxes by state: Internal Revenue Service, *Statistics of Income: Individual Income Tax Returns;* (2) for state personal income taxes, Commerce Clearing House, *State Tax Handbook,* various years.

Variables are defined as follows:

$RPCAR$ = real purchase price of car;

$AGECAR$ = age of the car in years, if age < 10; otherwise $AGECAR = 10$;

$CONV$ = 1, if the car is a convertible; otherwise $CONV = 0$;

$MIDSIZE$ = 1, if the car is intermediate-sized; otherwise $MIDSIZE = 0$;

$LGSIZE$ = 1, if the car is large-sized; otherwise $LGSIZE = 0$.

The t-statistics are in parentheses.

Automobile expenditures were deflated by the automobiles component of the Consumer Price Index.

2. *Elimination of deterministic components.* A first step in the estimation procedure is to remove the "deterministic" components of family income and autombile expenditure. As in Bhalla [1980], our approach was to extrapolate time series profiles from the essentially cross-sectional data. The prediction regressions for the first difference of real disposable income and for real automobile expenditures were

$$\text{(DA.2)} \quad \begin{aligned} DY_t = & \underset{(-1.08)}{-52.3\, AGE_t} + \underset{(0.74)}{0.434\, (AGE_t)^2} \\ & + \underset{(11.30)}{1{,}491\, DADULT_t} + \underset{(0.22)}{32.8\, OCCMED_t} \\ & + \underset{(0.58)}{89.4\, OCCHI_t} + \underset{(1.90)}{1{,}843\, YR1} \\ & + \underset{(1.65)}{1{,}598\, YR2} + \underset{(1.71)}{1{,}658 YR3}; \\ R^2 = & \ 0.045 \end{aligned}$$

and

$$\text{(DA.3)} \quad \begin{aligned} EXP_t = & \underset{(0.76)}{13.0\, AGE_t} - \underset{(-0.86)}{0.176\, (AGE_t)^2} \\ & + \underset{(2.65)}{96.3\, ADULT_t} + \underset{(4.02)}{215\, OCCMED_t} \\ & + \underset{(5.53)}{298\, OCCHI_t} - \underset{(0.06)}{18.9\, YR1} + \underset{(0.10)}{34.5\, YR2} \\ & - \underset{(-0.05)}{15.8\, YR3}; R^2 = 0.156. \end{aligned}$$

The variable definitions are

DY_t = change in real disposable income between years t and $t+1$

EXP_t = real automobile expenditures in year t

AGE_t = age of head of household at end of year t

$ADULT_t$ = number of adults in household at end of year t

$DADULT_t = ADULT_{t+1} - ADULT_t$

$OCCMED_t$ = 1 if $30 \leqslant OCC_t \leqslant 59$, 0 otherwise

$OCCHI_t$ = 1 if $60 \leqslant OCC_t$, 0 otherwise,

where OCC_t equals the Duncan socioeconomic status score of occupation of family head. The scale is 0–100, with higher scores corresponding to higher status. Because the score is not reported for 1970, we assumed that $OCC_{1970} = OCC_{1969}$ for each family.

$YR1$, $YR2$, and $YR3$ are year dummies, 1968–1970.

Pooled data were used. The "deterministic" components of income change and expenditure were taken to be the predictions of these regressions for each family.

3. Heteroskedasticity adjustment. The data were adjusted for heteroskedasticity in the innovations to income. A simple Wald approach was used: First, the four-year average disposable income for each family was calculated. The range of average incomes was then broken up into $5,000 intervals. (The large interval size was chosen in order to keep induced bias at a minimum.) The normalizing factor assigned to each family was the mean of all incomes falling in the same interval as the income of the family. Income and expenditure were divided by the normalizing factor before estimation.

4. Alternative estimate of α. To find an alternative estimate of the sensitivity of long-run car stocks to permanent income, we ran the following regression:

$$\text{(DA.4)} \quad \begin{aligned} CARSTOCK = \underset{(8.02)}{2{,}625} + \underset{(26.0)}{0.219}\, YPERM - \underset{(-8.84)}{152}\, AGE_{1968} + 1.67\,(AGE_{1968})^2; \\ R^2 = 0.116, \end{aligned}$$

where $CARSTOCK$ is the estimated value of family's car stock, averaged over the sample period, and $YPERM$ equals a proxy for permanent income, from a first-stage regression of average disposable income against age, age squared, the number of adults in the hosuehold, occupational dummies, and a constant.

5. Partitioning the sample by liquidity levels. The sample was subdivided in order to do the estimation reported in Section IV. First, the holdings of real, liquid financial assets for each year in the sample period were calculated for each family. Pooling years 1968–1970, liquid assets was fitted against demographic data as follows:

$$\text{(DA.5)} \quad \begin{aligned} FIN_t = {} & \underset{(-0.79)}{-2{,}116} + \underset{(0.01)}{1.64}\, AGE_t + \underset{(1.68)}{2.60}\, (AGE_t)^2 \\ & - \underset{(0.85)}{230}\, ADULT_t + \underset{(9.22)}{3{,}760}\, OCCMED_t \\ & + \underset{(17.7)}{7{,}200}\, OCCHI_t; \qquad R^2 = 0.121. \end{aligned}$$

Predicted liquid assets for each family were averaged over the sample period. Families were then ranked according to average predicted liquid assets, and the sample broken into thirds.

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