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Liquidity Constraints and Intertemporal Consumer Optimization: Theory and Evidence from Durable Goods

THE PROPOSITION that individuals arrange their saving and spending based on intertemporal optimization has both theoretical and intuitive appeal. Unfortunately, most tests of the strongest form of this proposition—the life cycle–permanent-income hypothesis with rational expectations—reject the theory. Researchers frequently appeal to liquidity constraints to explain the discrepancy between theoretical and actual behavior.[1] Efforts to formalize the notion of liquidity-constrained consumers have not to date produced testable implications as striking as those derived for the permanent-income hypothesis (for example, Robert Hall 1978). The difficulty in deriving testable implications stems from the unobservability of the key variable in the model—the shadow price of borrowing. Most investigators have dealt with this difficulty by using some proxy for liquidity constraints, either splitting the sample by some indicator of the likelihood of binding liquidity constraints (for example, Zeldes 1989; Jappelli 1990; Runkle 1991; Flavin 1994) or controlling directly for the likelihood of facing liquidity contraints in a regression context (for example, Flavin 1985). Flavin (1985), Zeldes (1989), and Jappelli (1990) find some evidence for borrowing constraints, while Runkle (1991) and Flavin (1994) find no evidence for borrowing constraints.

This paper develops a theory of optimal consumption behavior in the presence of

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1. See, for example, Flavin (1981), Hall and Mishkin (1987), Hayashi (1987), and Wilcox (1989).

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borrowing constraints, and tests that theory using aggregate data on the stock of durable goods and purchases of nondurable goods. We assume households are forward-looking and maximize expected lifetime utility, subject to current assets, current income, and expected future income. Households are assumed to be unable, however, to borrow the necessary amounts to smooth all consumption over time. We show that liquidity constraints induce a distinctive relationship between household stocks of durable goods and consumption of nondurable goods. Durable goods provide services over an extended time period, so capital market imperfections affect the timing of durable goods expenditures differently from nondurable goods expenditures. Our test focuses on the relationship between the marginal utility of household *durable* good holdings and the marginal utility of *nondurable* consumption. If capital markets are perfect, then these two variables will always be in an equilibrium relationship relative to one another. In the presence of capital market imperfections, however, the lagged value of the discrepancy between these two variables will have predictive power for the current change in nondurable goods consumption.

If durable goods expenditures cannot be debt-financed, then forecastable increases in income are preceded by reductions in expenditures on durables. Consumers temporarily run down their durables stocks and reallocate expenditures to current nondurable consumption; they anticipate a subsequent increase in sustainable expenditure levels and they plan a future augmentation in durable goods stocks and expenditures. Alternatively, if durable goods expenditures, but not nondurable consumption, can be debt-financed, then forecastable increases in income are preceded by a rise in durables expenditures anticipating the increase in debt-service capacity. In either case, the theory implies that the level of durable goods holdings relative to the level of nondurable goods purchases should have predictive power for changes in nondurable consumption expenditure.

The predictions of the theory are sharp enough to distinguish between a liquidity constraint model and a "Keynesian" rule-of-thumb model, where consumption varies directly with current income. Hall (1978), Hayashi (1987), and Campbell and Mankiw (1989) have suggested that the excess sensitivity of consumption to predictable changes in income might be attributable to a fraction of the population following a Keynesian nonoptimizing rule of thumb. Borrowing constraints do not, in general, imply Keynesian rule-of-thumb behavior. Liquidity constrained forward-looking consumers smooth consumption *within* stages of their lives, these stages being defined endogenously by the level of consumption sustainable without debt (Heller and Starr 1979; Zeldes 1989). The typical optimal program is characterized by several relatively smoothly changing segments of consumption with abrupt transitions between them. Along the smooth segments, the usual marginal equivalences are fulfilled. If the consumers anticipate relaxation of liquidity constraints at date t (presumably with an increase in current income), they arrange their expenditures in prior periods to run assets down to their lower bound at $t - 1$. Upon relaxation of the constraint, consumption levels rise, forming the abrupt transition. If consumers face liquidity constraints, but are forward-looking optimizers, then predictable changes in income should not be statistically significant predictors of consumption, once the effects of liquidity constraints have been accounted for through lagged values of the marginal utility of durables and nondurables as explanatory variables. Alternatively, if some consumers are Keynesian, then predictable changes in income should remain significant. The model and empirical results below suggest that consumers behave as rational forward-looking optimizers in a liquidity constrained environment.

1. THEORY

Optimal Consumption Paths with Liquidity Constraints: Simple Case

We first develop intuition in the context of a simple model (Chah 1990). To highlight the effect of liquidity constraints, we assume that interest rates and relative prices are constant, and that the interest rate equals the rate of time preference. The next section will relax these assumptions.

Consider a consumer who faces a stochastic income stream and chooses consumption and asset holdings to maximize expected lifetime utility subject to the constraint that assets must be nonnegative. The problem to be solved is

$$\max_{C,K,A} E_0 \sum_{t=0}^{\infty} (1 + \rho)^{-t} U(C_t, K_t) \qquad \text{subject to}$$

$$A_t = (1 + r)A_{t-1} + Y_t - C_t - P_d(K_t - (1 - \delta)K_{t-1})$$

$$A_t + \varphi P_d K_t \leq 0, \qquad \text{where } A_{-1}, K_{-1} \text{ given}, \qquad t = 0, 1, 2, \ldots$$

where A_t is financial wealth at the end of period t, C_t is consumption of nondurables during period t, K_t is the stock of durables at the end of period t, Y_t is labor income during period t, P_d is the (constant) relative price of durables in terms of nondurables, r is the (constant) real interest rate, ρ is the subjective rate of time preference, δ is the physical depreciation rate of durables, φ is the fraction of durables that can be financed, U is increasing and concave in C and K with $U_c(0, K) = U_k(C, 0) = \infty$, and E_0 is the expectation based on period 0 information.

The only nonstandard feature of our model is the second constraint, which restricts a particular definition of the consumer's net assets to be nonnegative in every period. The parameter φ in the constraint represents the fraction of durables that the consumer is allowed to finance. If φ is zero, the consumer cannot borrow against future income to finance current expenditures for durable consumption; the consumer is constrained to have nonnegative financial assets. At the other extreme, if φ is unity, durables purchases are fully financeable, and only total assets—the sum of financial assets and the value of the durable stock—need be nonnegative. The purchase of a durable in this case does not adversely affect current liquidity since the increase in financial liabilities is offset by the increase in physical assets. In such an environment, the consumer is constrained only to have positive total net worth. Finally, if φ is between zero and unity, then durables are partially financeable. We expect φ to be close to unity since financing is available for most durable goods. Note that in no case is spending on nondurable goods financeable.

Solving the asset evolution equation for C_t and substituting, the Lagrangean and first-order conditions for the problem are

$$L = E_0 \sum_{t=0}^{\infty} (1 + \rho)^{-t}\{U[(1 + r)A_{t-1} + Y_t - P_d(K_t - (1 - \delta)K_{t-1}) - A_t, K_t]$$

$$+ \mu_t[A_t + \varphi P_d K_t]\} .$$

$$E_t U_c(t + 1) = U_c(t) - \mu_t , \tag{1}$$

$$U_k(t) = P_d \left[U_c(t) - \frac{1 - \delta}{1 + r} E_t U_c(t + 1) \right] - \varphi P_d \mu_t , \tag{2}$$

$$\mu_t \geq 0 , \tag{3}$$

$$(A_t + \varphi P_d K_t)\mu_t = 0 . \tag{4}$$

U_c denotes the derivative of the utility function with respect to C, and U_k denotes the derivative with respect to K. μ_t is the shadow price at date t of the nonnegativity constraint on the household asset position. μ_t assumes positive values only in those periods t where the asset position fulfills the constraint with equality. Typically, the nonnegativity constraint will be binding at some dates in the program, and this affects the optimal path throughout the program, even at dates where $\mu_t = 0$ and the constraint is not currently binding. In the absence of a liquidity constraint, that is, with $\mu_t = 0$ for all t, equation (1) would be the usual relationship between marginal utilities across periods. With a perfect capital market, the expected marginal utility of consumption is constant over time since $\rho = r$ and μ_t is always zero. In contrast, the expected marginal utility will not be constant in the presence of liquidity constraints binding at some dates of the program. In conjunction with equation (3), equation (1) implies that in the presence of liquidity constraints the expected marginal utility of nondurable consumption cannot be rising over time (Heller and Starr 1979). If the liquidity constraint is binding in period t, so that μ_t is strictly positive, then the expected marginal utility of nondurable consumption declines from period t to period $t + 1$.

The information contained in equation (2) is much more apparent if equation (2) is combined with equation (1). This combination yields

$$U_c(t) = \frac{1 + r}{r + \delta} \frac{1}{P_d} U_k(t) + \frac{\varphi(1 + r) - (1 - \delta)}{r + \delta} \mu_t . \tag{5}$$

When μ_t is zero in equation (5), we obtain the usual equality between the marginal rate of substitution between nondurable and durable goods and their relative price,

$(1 + r)/(r + \delta)P_d^{-1}$. Nonzero values of μ_t affect the intratemporal relationship between the two goods in period t because they alter the shadow price of durables relative to the shadow price of nondurables. How that shadow price is altered depends on the degree to which durables can be financed. If φ is zero the coefficient on μ_t is negative. Hence, during a period when the consumer runs his financial assets to zero, the marginal utility of nondurables will be low relative to the marginal utility of durables; equivalently nondurable consumption will be high relative to durable consumption. This result reflects the nature of durables (that they yield their services slowly) and the assumption that they are not counted as assets. With borrowing constraints, durable goods must be paid for "up front," even though the utility yield of durables extends over many periods. When the borrowing constraint is binding, the current user cost of durables is very high because durables employ liquid assets that could be used to increase consumption of nondurables. Thus, durable good consumption falls temporarily in anticipation of a rise in income.

The nature of the optimal path changes dramatically for φ equal to unity. When durables are fully financeable, the coefficient on μ_t in equation (5) is equal to one. In this case, the consumer *increases* his ownership of durables in the period before the increase in income. The consumer finds it optimal to do this because he can begin to enjoy the benefits of the durables one period before he begins to pay the rental cost (consisting of interest and depreciation).

Equations (1) and (5) can be combined to produce an expression for the change in marginal utility from the consumption of nondurables in terms of the discrepancy between marginal utility from durables and nondurables:

$$\begin{aligned} U_c(t+1) - U_c(t) &= -\mu_t + \epsilon_{t+1} \\ &= -\frac{r+\delta}{\varphi(1+r) - (1-\delta)} \\ &\quad \cdot \left[U_c(t) - \frac{1+r}{r+\delta}\frac{1}{P_d} U_k(t) \right] + \epsilon_{t+1}\,, \end{aligned} \tag{6}$$

where ϵ_{t+1} is an expectational error and is uncorrelated with information available at time t. If liquidity constraints are never binding, so that μ_t is always equal to zero and the term in brackets in equation (6) is always equal to zero, no information available in period t can predict the change in the marginal utility between periods t and $t + 1$ (Hall 1978). If, however, liquidity constraints are binding in some periods, then the deviations from the lagged linear combination of $U_c(t)$ and $U_k(t)$ will have predictive power for $\Delta U_c(t + 1)$; these deviations, in fact, are proportional to the value of the Lagrange multiplier on the borrowing constraint. Equation (6) is the key theoretical result and testable implication of this paper.

Generalization of the Theory

We now discuss how changes in the model affect the implications derived in the last section. We begin by briefly discussing the relevance of the results in a general equilibrium setting. We then analyze how generalizations of the model change the results.

The implications of perfect capital markets versus liquidity constraints also hold in a general equilibrium context. Under the pure permanent-income hypothesis, the lagged behavior of durable goods should not predict the change in the marginal utility of the consumption of nondurable goods, even in a general equilibrium model. Any lagged information that affects expected income should already be incorporated in consumption behavior. Using an example from Baxter's (1992) general equilibrium model, if there is a shock to consumers' desired holdings of durable goods, and if that shock is known to affect future income and wealth, then the consumption of nondurable goods should respond immediately. Thus, the finding that lagged information about the marginal utility of durable goods predicts the change in the marginal utility of nondurable goods is contrary to the assumption of perfect capital markets.

A second issue of interest is the effect of adjustment costs. Bernanke (1985) and Startz (1989) both study the joint behavior of the consumption of durable goods and nondurable goods in a framework with a nonseparable utility function and with adjustment costs for durable goods. Bernanke uses this framework to determine whether these changes can explain rejections of the permanent-income hypothesis for nondurable goods. Among his findings are that (1) separability is a good approximation, and (2) nondurable consumption is still excessively sensitive to changes in income. Startz, on the other hand, uses the framework to determine whether the changes can explain the rejections of the permanent-income hypothesis for durable goods. He finds that the exercise is generally successful, but the lack of rejection may be due to low power of the tests.

Their results raise the question of whether adjustment costs may be mistaken for liquidity constraints. If utility is separable in durables, nondurables, and adjustment costs, which is consistent with Bernanke's findings, then adjustment costs do not have the same implications as liquidity constraints. To see this, simply augment the utility function with an adjustment cost, so that it is written $U(C_t, K_t, K_t - K_{t-1})$. Without borrowing constraints, the first-order condition for nondurable consumption is $E_t U_c(t + 1) = U_c(t)$. Since adjustment costs on durable goods do not affect the marginal utility of nondurable goods, the model still has the implication that all relevant information available in period t is incorporated in $U_c(t)$. The presence of adjustment costs in the borrowing constraint model will make it more difficult to detect borrowing constraints, but will not lead to false acceptance of the liquidity constraint hypothesis.

We now derive implications of liquidity constraints under the more general conditions of nonconstant relative prices and variable interest rates, which will be useful for our empirical test. The Lagrangian for the more general model is

$$L = E_0 \sum_{t=0}^{\infty} (1 + \rho)^{-t}\{U[(1 + r_t)A_{t-1} + Y_t - P_{dt}(K_t - (1 - \delta)K_{t-1}) - A_t, K_t] + \mu_t[A_t + \varphi P_{dt}K_t]\} .$$

The variable r_t is the real interest rate on financial assets held between periods $t - 1$ and t. In the general problem, the necessary conditions are

$$E_t \frac{1 + r_{t+1}}{1 + \rho} U_c(t + 1) = U_c(t) - \mu_t \, , \tag{1'}$$

$$U_k(t) = P_{dt} \left[U_c(t) - \frac{1 - \delta}{1 + \rho} E_t((1 + \pi_{t+1}) \, U_c(t + 1)) \right] - \varphi P_{dt} \mu_t \, , \tag{2'}$$

where $1 + \pi_{t+1}$ equals P_{dt+1}/P_{dt}, the gross inflation rate of the relative price of durables.

The slackness conditions are identical to the ones in the preceding section. Equations (1′) and (2′) are similar to those presented earlier. The key difference is that the relationships between the marginal utilities of consumption have variable coefficients that depend on relative prices and interest rates.

In order to derive implications without specifying a general equilibrium model, we assume that both r_{t+1} and P_{dt+1} are known at time t.[2] With these assumptions, equations (5) and (6) from the simple case presented above become

$$U_c(t) = \frac{1 + r_{t+1}}{R^k_{t+1}} \frac{1}{P_{dt}} U_k(t) + \frac{\varphi(1 + r_{t+1}) - (1 - \delta)(1 + \pi_{t+1})}{R^k_{t+1}} \mu_t \, . \tag{5'}$$

$$\begin{aligned} U_c(t + 1) - \frac{1 + \rho}{1 + r_{t+1}} U_c(t) &= \frac{1 + \rho}{1 + r_{t+1}} \mu_t + \epsilon_{t+1} \\ &= - \frac{1 + \rho}{1 + r_{t+1}} \frac{R^k_{t+1}}{\varphi(1 + r_{t+1}) - (1 - \delta)(1 + \pi_{t+1})} \\ &\quad \cdot \left[U_c(t) - \frac{1 + r_{t+1}}{R^k_{t+1}} \frac{1}{P_{dt}} U_k(t) \right] + \epsilon_{t+1} \end{aligned} \tag{6'}$$

where $R^k_{t+1} = 1 + r_{t+1} - (1 - \delta)(1 + \pi_{t+1})$. These equations yield the same basic insight: when liquidity constraints are binding, the lagged relationship between durable stocks and nondurable flows has predictive power for the future change in the marginal utility of nondurables. The relationship is the term in square brackets, now stated to include variable prices. When φ is unity, the relationship should enter with a time-varying coefficient of negative $(1 + \rho)/(1 + r_{t+1})$, since the expression involving φ is equal to R^k_{t+1}; when φ is zero, the relationship should enter with a time-varying positive coefficient.

2. EMPIRICAL TEST

The theoretical section above suggests a simple empirical exercise: determine whether the deviations from the long-run relationship between durable stocks and

2. Without this assumption, we would have to specify the conditional covariances between r and P_d on one hand, and the marginal utility of nondurables on the other.

nondurable flows have predictive power for future changes in nondurable consumption. Although this test is simple in principle, complications arise in the empirical implementation. We will discuss these complications in the following sections.

Empirical Specification

We assume that the utility function takes the CES form $U = \eta_t C_t^{1-1/\alpha} + \nu_t K_t^{1-1/\beta}$, where α and β are parameters, and η and ν are possible random shocks to the utility function, observable to households but unobservable to the econometrician. If we substitute this functional form into the key equations from the last section, we obtain

$$\frac{1 + r_{t+1}}{R_{t+1}^k} \frac{1}{P_{dt}} \frac{(1 - 1/\beta)\nu_t K_t^{-1/\beta}}{(1 - 1/\alpha)\eta_t C_t^{-1/\alpha}}$$

$$= 1 - \frac{\varphi(1 + r_{t+1}) - (1 - \delta)(1 + \pi_{t+1})}{R_{t+1}^k} \frac{\mu_t}{\eta_t(1 - 1/\alpha)C_t^{-1/\alpha}}, \qquad (5'')$$

$$\frac{1 + r_{t+1}}{1 + \rho} \frac{\eta_{t+1}}{\eta_t} \left\{\frac{C_{t+1}}{C_t}\right\}^{-1/\alpha} = 1 - \frac{\mu t}{(1 - 1/\alpha)\eta_t C_t^{-1/\alpha}} + \epsilon_{t+1} . \qquad (6'')$$

For convenience, we take logarithms of the equations above and use the approximation $\ln(1 + x) \cong x$ for small x. The model thus becomes

$$\ln C_t = \text{constant} + \alpha/\beta \ln K_t + \alpha \ln P_{dt} + \alpha \ln R_{t+1}^k - \alpha\, r_{t+1} + Z_t . \qquad (7)$$

$$\Delta\ln C_{t+1} = \theta_0 + \alpha\, r_{t+1} + \theta_{2t+1} Z_t + \alpha\Delta\ln \eta_{t+1} - \alpha\epsilon_{t+}1 \qquad (8)$$

where

$$\theta_{2t+1} = -\frac{R_{t+1}^k}{\varphi(1 + r_{t+1}) - (1 - \delta)(1 + \pi_{t+1})}, \quad \text{and}$$

$$Z_t = \alpha\ln \eta_t - \alpha\ln \nu_t - \alpha \frac{\varphi(1 + r_{t+1}) - (1 - \delta)(1 + \pi_{t+1})}{R_{t+1}^k} \frac{\mu_t}{\eta_t(1 - 1/\alpha)C_t^{-1/\alpha}} .$$

This system has the form of an error correction model. Many studies, such as Engle and Granger's (1987), have shown that consumption is well-described as a unit root process, so that the growth rate of consumption is stationary. This empirical fact implies that the terms on the right-hand side of equation (8), including Z, should be stationary.[3] Since Z is the error term in equation (7), equation (7) is essentially a cointegrating relationship between durable stocks and nondurable flows and Z is an error correction term. Z, which is a function of the Lagrange multiplier μ, predicts future changes in nondurable consumption, as is seen in equation (8). The coeffi-

3. Of course, it is possible that each of the components is nonstationary, but cointegrated with each other. This case is very unlikely.

cient on Z, denoted θ_{2t+1}, is a function of φ. If φ is unity, then θ_2 will be a constant, equal to minus one. For other values of φ, the coefficient will be a function of time as interest rates and rental costs vary. If φ is near unity, the average value of the coefficient will be negative, whereas if φ is close to zero, the average value of the coefficient will be positive. Testing for statistical significance of θ_2 in equation (8) is equivalent to testing for the presence of binding liquidity constraints affecting consumption.

The formulation is precise enough to distinguish the predictions of alternative models. For example, the pure permanent-income model with no unobservable shocks predicts that variables dated t or earlier should have no predictive power for ΔC_{t+1}. A Keynesian rule-of-thumb model, on the other hand, predicts that forecastable variation in disposable income should have predictive power for ΔC_{t+1}.

The unobservables in the utility function, η_t and ν_t, complicate the analysis. The cointegrating relationship between durables and nondurables still holds, as long as the unobserved elements are stationary, but the error term of the cointegrating equation will be a function not only of μ_t but also of η_t and ν_t. The presence of the additional elements will not affect the consistency properties of the estimates of the cointegrating vector, but will affect the inferences derived from the error correction equation. To be specific, even in the absence of binding liquidity constraints, the error correction term may have predictive power for the change in the consumption of nondurables, because the error correction term, which contains $\ln\eta_t$, may be correlated with the error term in equation (8), which contains $\Delta\ln\eta_{t+1}$. If $\ln\eta_t$ is white noise, the correlation between $\ln\eta_t$ and $\Delta\ln\eta_{t+1}$ will be -0.5. Thus, if we allow for the presence of unobservables in the utility function, we must estimate the error correction equation (8) using instruments for the error correction term that are not correlated with $\Delta\eta_{t+1}$ or ϵ_{t+1}.

In the estimation, we will use a general error correction model, augmented by lagged differences in the consumption and durable stock variables. The inclusion of these lags can account for any additional dynamics resulting from adjustment lags. The estimating equation is specified as follows:

$$\Delta\ln C_{t+1} = \text{constant} + \theta_1 r_{t+1} + \theta_{2t+1} Z_t + \theta_3 \Delta\ln C_t + \theta_4 \Delta\ln K_t + \tau_{t+1} , \tag{9}$$

where τ_{t+1} is the error term containing ϵ_{t+1} and $\Delta\ln\eta_{t+1}$. We estimate two versions of equation (9): first, under the assumption that θ_2 is a constant, and then assuming θ_2 is significantly different from zero, using a nonlinear estimator, treating φ as a parameter. The reason for estimating the linear relationship first to determine whether the coefficient is nonzero is that there exists no value of φ for which θ_2 is zero.

Data Description

We use monthly data from 1959:1 to 1989:12 for real per capita personal consumption expenditures and disposable income, as well as the real per capita net

TABLE 1

UNIT ROOT TESTS (p-values)

Variable (in logs)	ADF test on levels no trend	ADF test on levels trend	ADF test on differences no trend	ADF test on differences trend
Services	0.26	0.96	0.00	0.71
Nondurables	0.86	0.78	0.00	0.05
Income	0.82	0.92	0.00	0.17
Durable Stock	0.98	0.09	0.17	0.04
Motor Vehicles	0.96	0.46	0.03	0.16
Other Durables	0.99	0.00	0.37	0.01

Four lags were included in each test.

stock of durables, split into motor vehicles and parts and all other. Motor vehicles and motor vehicle parts are combined into a single aggregate denoted *cars*. Non-auto durables constitute the aggregate *other durables*. See the data appendix for details on the construction of the data. We treat expenditures on nondurables and services separately. We use monthly data because the monthly frequency corresponds to the frequency at which debt service on consumer debt is paid. The effect of variation in the immediacy of the liquidity constraint should be evident at this frequency.

The other variables used are the commercial paper rate, the implicit price deflators for nondurables expenditures, services expenditures, new car expenditures, and durable goods expenditures, and the real price of refined petroleum. All variables were taken from Citibase. All variables except the interest rate are in logarithms.

As a preliminary step, we established the time series properties of the variables. This step is important for determining the order of integration of the variables, as well as the nature of the unobservable shocks. We first ran standard tests for unit roots, which are shown in Table 1. The results of the augmented Dickey-Fuller tests suggest that nondurable consumption, services, income, and the stock of "cars" all have one unit root. On the other hand, the stock of durables other than cars seem to have only a deterministic trend or two unit roots. Because non-car durables have different types of trends, we exclude them from further analysis.

We then tested (separately) whether the nondurables and services were cointegrated with the stock of motor vehicles and parts. In the basic specification, we regressed services or nondurables on a constant, a deterministic linear trend, the stock of cars, and the price of cars relative to the price of nondurables or services. The results were as follows:[4]

$$\begin{aligned}\log(\textit{services}) = \underset{(14.7)}{2.81} + \underset{(12.5)}{0.0015}\ \textit{trend} + \underset{(14.7)}{0.362}\log(\textit{cars}) \\ - \underset{(-9.2)}{0.424}\log(\textit{relative price})\ . \qquad (10)\end{aligned}$$

$R^2 = 0.998$; Test statistic for null of no cointegration: -4.46; $p -$ value $= 0.02$

4. t-statistics were calculated using a heteroskedastic autocorrelation consistent estimator of the standard errors. A Parzen kernel with twelve lags was used. The cointegration tests included four lags.

$$\log(nondur) = \underset{(13.8)}{2.46} - \underset{(-1.6)}{0.0002}\ trend + \underset{(11.2)}{0.441}\log(cars) - \underset{(-8.0)}{0.312}\log(relative\ price)\ . \quad (11)$$

$R^2 = 0.985$; Test statistic for null of no cointegration: -3.06; p − value = 0.46

All the coefficients in the regressions have the predicted signs, with nondurables or services moving positively with the stock of cars, and negatively with the relative price of nondurables or services to cars. According to the test statistics, one can reject noncointegration in favor of cointegration in the case of services. Thus, except for a deterministic trend, the marginal rate of substitution between services and cars is equal to the relative price in the long run. On the other hand, one cannot reject noncointegration at the usual significance levels for nondurables. This result might be attributable to a nonstationary unobservable shock to the marginal utility of nondurables, or to the notorious low power of cointegration tests.[5]

Empirical Results

Tests for Liquidity Constraints. We now test the permanent-income hypothesis against the liquidity constraint alternative by estimating equation (9). The error correction terms are the residuals from the estimated equations (10) and (11).

As discussed in the previous section, we must extract only that part of the error correction term that is correlated with μ_t and uncorrelated with the shocks to utility. If we assumed that the shock was not serially correlated, then any variables lagged one period or more would be valid as instruments. We are not, however, willing to make such a strong assumption. Instead, we proceed under the following assumption: the current shocks to nondurable (or service) utility are uncorrelated with lagged shocks to durable good utility and financial variables. The instruments used are lags one through five of (1) the log change in real disposable income; (2) the commercial paper rate; (3) the real interest rate, measured as the difference between the commercial paper rate and the inflation rate of either nondurables or services; and (4) the log change in the stock of cars. Note that we do not use lagged values of the change in nondurables, services, or the error correction term as instruments.

Table 2 presents both the linear and nonlinear estimates of equation (9) for services and for nondurables. Consider first the results of the linear estimation reported in Part A. In both equations, the error correction term enters significantly with a negative coefficient, the coefficient on the lagged dependent variable is negative,

5. When other variables such as real oil prices, interest rates, and inflation rates are entered, the results are virtually unchanged.

TABLE 2

TESTS FOR LIQUIDITY CONSTRAINTS; INSTRUMENTAL VARIABLES ESTIMATION

	Dependent Variables	
	Δ log services (t + 1)	Δ log nondurables (t + 1)
A. Linear Estimation		
Constant	0.0022 (3.25)	−0.0017 (−1.58)
Error correction term (t)	−0.159 (−2.11)	−0.196 (−2.21)
Real interest rate (t + 1)	−0.334 (−1.96)	0.350 (1.84)
Dependent variable (t)	−0.238 (−1.04)	−0.175 (−0.92)
Δlog cars (t)	0.338 (3.23)	0.666 (2.89)
p-value for test of overident. restrict.	0.03	0.07
B. Nonlinear Estimation		
Constant	0.0022 (3.18)	−0.0016 (−1.57)
φ [from error correction term (t)]	1.18 (12.1)	1.14 (14.5)
Real interest rate (t + 1)	−0.336 (−1.97)	0.343 (1.82)
Dependent variable (t)	−0.267 (−1.17)	−0.186 (−0.98)
Δlog cars (t)	0.346 (3.30)	0.645 (2.88)
p-value for test of overident. restrict.	0.04	0.05

t-statistics are in parentheses. The error correction term is from the relevant cointegrating equation reported in the text. The instruments used are lags one through five of: the log change in real disposable income, the commercial paper rate, the real interest rate (described in the text), and the log change in the stock of cars.

but not significantly different from zero, and the coefficient on the lagged change in cars is positive and very significant. The implications of these results are twofold. First, even after extracting the effects of unobservable shocks to the utility function, the lagged behavior of cars and nondurables have predictive power for the change in nondurable consumption. Thus, we can reject the permanent-income hypothesis in favor of the liquidity constraint alternative. Second, the sign of the coefficients suggests that the stock of cars rises in anticipation of an increase in nondurable and service consumption. As discussed earlier, this pattern of behavior suggests a high value of φ.

Part B of Table 2 presents the results of the nonlinear estimation. The estimate of φ is almost identical in both cases, with a value of 1.18 for services and a value of 1.14 for nondurables. The point values are greater than one, the presumed maximum value of φ, but both are within two standard deviations of one. A possible technical explanation for the high estimated value of φ is the manner in which φ enters the time-varying coefficient. The absolute value of the coefficient is decreasing in φ and is very steep near the point where φ equals $(1 - \delta)(1 + \pi)/(1 + r)$, since the denominator vanishes at that point. Thus, any misspecification that biases the coefficient toward zero will bias the estimate of φ upward. Alternatively, a value of φ greater than one may be consistent with the credit arrangements for financing new cars. Cars depreciate faster than the loans financing them are amortized, resulting in more than 100 percent financing of the outstanding stock of cars and a value of φ greater than unity.

In sum, when we test the permanent income null hypothesis against a precisely specified alternative hypothesis of liquidity constraints, we can reject the null hypothesis. Furthermore, the values of the coefficients are generally consistent with the alternative theory, and suggest that a large fraction of durables is financeable.

Tests for Rule-of-Thumb Behavior. The next step is to determine whether the liquidity constraint hypothesis or the Keynesian hypothesis is a better description of the data. Hall (1978), Hayashi (1987), and Campbell and Mankiw (1989) suggest a model in which a certain percent of the consumers follow permanent-income behavior, while the rest follow Keynesian behavior. According to their model, when the change in consumption is regressed on the predictable change in income, the coefficient gives the percent of the consumers who are Keynesian.

We first reproduce the results obtained by Campbell and Mankiw using our data definitions and instruments. We estimate the effect of the current growth rate of real disposable income on the growth rate of services and nondurables, separately, using the instruments employed above. The results are given in columns 1 and 3 of Table 3. In the case of services, the coefficient estimate is 0.203 with a *t*-statistic of 2.67; in the case of nondurables, the coefficient estimate is 0.288 with a *t*-statistic of 1.85. These estimates are somewhat lower than those obtained by Campbell and Mankiw, most likely because our data are higher frequency. The estimates we obtain, however, support the hypothesis that consumption is excessively sensitive to predictable changes in income.

TABLE 3

Test of Rule-of-Thumb Behavior versus Liquidity Constraints Instrumental Variables Estimation

	Dependent Variables			
Explanatory Variables	Δ log services ($t+1$) 1	2	Δ log nondurables ($t+1$) 3	4
Constant	0.002	0.0021	0.0005	−0.0015
	(7.50)	(3.14)	(1.06)	(−1.32)
Δ log dispos. income ($t+1$)	0.203	0.092	0.288	0.062
	(2.67)	(1.06)	(1.85)	(0.305)
Real interest rate ($t+1$)		−0.292		0.328
		(−1.74)		(1.64)
Error correction term (t)		−0.130		−0.172
		(−1.71)		(−1.45)
Dependent variable (t)		−0.219		−0.189
		(−1.00)		(−0.978)
Δlog cars (t)		0.292		0.601
		(2.69)		(1.94)

t-statistics are in parentheses. The error correction term is from the relevant cointegrating equation reported in the text. The instruments used are lags one through five of: the log change in real disposable income, the commercial paper rate, the real interest rate (described in the text), and the log change in the stock of cars.

Are predictable changes in income still significant when we include them in the liquidity constraint model? The Campbell-Mankiw model would suggest a positive answer, but in a rational forward-looking liquidity constraint model, predictable changes in disposable income should not be significant after the effects of liquidity constraints have been taken into account fully. Columns 2 and 4 of Table 3 present estimates of the linear model estimated in Table 2, with the log change in disposable income added. In each case the coefficient on income drops precipitously compared to columns 1 and 3, and is no longer significant. On the other hand, the coefficients on the liquidity constraint terms fall only slightly in absolute value, and generally remain significantly different from zero. Hence we reject the Keynesian rule-of-thumb model in favor of a liquidity constraint model. It is neither necessary nor useful to characterize household behavior as rule of thumb to account for the data.

We should add that these results are entirely consistent with Wilcox's (1989) tests using increases in Social Security benefits. In all of his specifications, he includes lagged changes in durables and nondurables when he tests for the significance of predictable changes in benefits. According to his Table 2, durable good expenditures (but not nondurable goods) are sensitive to predictable changes in benefits. Furthermore, his estimates show that lagged changes in durables expenditures predict the change in nondurables.

3. CONCLUSIONS

We have developed and tested the stochastic implications of a forward-looking model of rational optimizing consumers subject to liquidity constraints. This paper should be viewed as a contribution to the body of evidence including Flavin (1985), Zeldes (1989), and Jappelli (1990) that argues that liquidity constraints dominate myopia as an explanation for the excess sensitivity of consumption to predictable changes in income. The theory and the results provide the following description of the behavior of consumers. Most consumers are forward looking in their behavior: they smooth consumption as much as capital markets permit. When they receive news of a future increase in income, they increase their durable goods holdings in anticipation. They cannot, however, increase their nondurables or services consumption because they cannot finance the increase. The anticipatory movement of durables contains more information about the future change in the marginal utility of nondurables and services than does the predicted change in income.

On the other hand, the results provide evidence against Keynesian rule-of-thumb behavior in favor of forward-looking behavior with liquidity constraints. The addition of predictable changes in income to the model show them to have no significant additional predictive value. Consumers are forward looking, but the horizon over which they can smooth their consumption is limited by capital market imperfections. The excess sensitivity of consumption to predictable changes in income is attributable to liquidity constraint.

DATA APPENDIX

In this appendix we describe construction of the durables stock. For both the case of total durables and motor vehicles and parts, we used the Bureau of Economic Analysis estimates of the end of the year stock. We consider the BEA estimates to be superior to those obtained using investment series and assuming constant exponential depreciation. In the case of motor vehicles and parts, the BEA data are quite accurate because they use the Polk data on the number and age of autos registered. For all types of durables, straight-line depreciation schedules are used.

We estimated monthly stocks of durables as follows. In all cases, we used straight-line depreciation. The within-year rate of depreciation of new purchases was assumed constant for all years. We chose the monthly rate of 0.003 for both total durables and motor vehicles and parts because this was the only value that did not generate spurious seasonality. We allowed the rate of depreciation of carry-over stock from the year before to vary year to year. The value was chosen so that the estimated value of the stock by year end was equal to the BEA value. The estimated monthly straightline depreciation ranged from .0170 to .0191 for all durables, and from .0214 to .0280 for motor vehicles and parts. The stock of durables other than motor vehicle and parts was set equal to the difference of total durables and motor vehicles and parts.

In the theoretical model, we assume exponential depreciation for simplicity. The only case when we must have a value for this depreciation rate, δ, is when we perform the nonlinear estimation. For cars, we choose a value of δ of .028 per month, which is the exponential rate that is the closest approximation to the straight-line rates for within and across years that we estimate from the BEA data.

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