

# EXPENDITURE ON DURABLE GOODS: A CASE FOR SLOW ADJUSTMENT\*

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For more than a half a decade the fact that expenditure on durables can be well approximated by a random walk has remained a hidden puzzle, challenging almost any theory in which agents smooth the use of their wealth. This paper shows that once a nonparsimonious approach is used, or lower frequencies of the data are examined, the fact itself disappears; changes in expenditures on durables reveal a degree of reversion consistent with the permanent income hypothesis (PIH), although this reversion occurs at a rate significantly slower than what is suggested by a frictionless PIH model.

## I. INTRODUCTION

Few mainstream economists would strongly object to the implications of the life cycle-permanent income hypothesis (henceforth LCH/PIH); denying this hypothesis is tantamount to denying many of the basic principles used by economists in their modeling efforts. It is not surprising, then, that the seminal works of Modigliani and Brumberg [1954] and Friedman [1957] were followed by innumerable attempts to test the validity of the LCH/PIH theory and to amend its empirical failures, while preserving the same general framework.

The advent of rational expectations spurred a whole new literature starting with the Sargent [1978] and Hall [1978] papers that tested the joint LCH/PIH-rational expectations hypothesis. Hall's paper has been especially important for the consumption literature in the last decade. He noticed that the rational expectations hypothesis implies that consumers should use all the information available to them at each moment in time to make their consumption decisions. The LCH/PIH, on the other hand, implies that expected marginal utilities of consumption should be equalized across time. The interaction of these two implications—plus some standard assumptions on the specification of preferences and the sources of uncertainty—makes today's consumption a sufficient

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statistic to forecast tomorrow's consumption; this is the now famous random walk hypothesis for the consumption of nondurables.

Mankiw [1982] noticed that when Hall's insight is applied to durables, the disturbance in a regression of current expenditure on lagged expenditure should exhibit a first-order moving average (MA(1)) structure (as opposed to the nondurables case in which this disturbance should be white noise). Furthermore, the MA coefficient should be negative, and its absolute value equal to one minus the rate at which the stock of durables depreciates, reflecting the fact that durable purchases provide services for more than one period. The empirical implementation of this model has brought about strong rejection not only of the implications of the LCH/PIH model, but also of most models advocating some degree of intertemporal smoothing—in fact, much stronger than the thoroughly studied rejection observed in the nondurables (and services) case. Mankiw used quarterly U. S. postwar data and found that contrary to the theory, the disturbance in the equation for expenditures on durables behaved as white noise. In other words, the time series behavior of durables expenditures exhibited the same type of behavior as expenditures on nondurables, and it should not. Caballero [1987b] showed that this unpleasant result holds even when the model is expanded to allow for the possibility of very general substitution effects, so that only the wealth component of the shocks—the component most clearly related to the LCH/PIH—is subjected to the MA(1) structure.

This paper shows that once a moderate amount of slowness in the response of some consumers to news about the economic environment is admitted, a clear difference between the time series behavior of durables and nondurables arises. Furthermore, this difference points strongly in the direction suggested by the LCH/PIH: the sum of the autocorrelations of changes in nondurables expenditures remains positive and close to zero, whereas the same statistic is decreasing and negative for the case of durables, reflecting the reversion (although delayed) implied by the theory. The cumulative adjustment of durables to wealth and taste shocks matching the data seems to be around 55 percent after the first year, and 90 and 100 percent one and two years later, respectively.

This introduction is followed by three sections. Section II presents the frictionless model and preliminary nonparsimonious evidence on the compatibility of the differences between the time series processes of durables and nondurables with the implications of the LCH/PIH for such differences. Section III models and estimates slow adjustment, and highlights the effects of "slowness"

on U. S. postwar consumption fluctuations. Section IV presents concluding remarks.

## II. PRELIMINARY EVIDENCE

The model is presented in full detail in the Appendix. It basically consists of the standard intertemporal optimization model used in macroeconomic studies of consumption, but adds two less common features: first, durables and nondurables are jointly modeled;<sup>1</sup> and second, a distribution shock that affects (permanently<sup>2</sup>); the allocation of resources between durables and nondurables. The latter captures substitution effects omitted by the basic model and introduces a second source of uncertainty that avoids singularities in the joint representation of durables and nondurables.

This structure, complemented with well-known assumptions about preferences, discount, and interest rates, yields the random walk (or martingale) representation of nondurables consumption:

$$(1) \quad \Delta cn_{t+1} = a_0 + e_{t+1}^n,$$

with  $\Delta cn_{t+1}$  the change in nondurables consumption from  $t$  to  $t + 1$ ,  $a_0$  a constant, and  $e_{t+1}^n$  a white noise disturbance independent of all information available at time  $t$ .

The intuition behind equation (1) was given in Hall's [1978] seminal paper: agents use all the information available at time  $t$  to form their consumption decisions *and* according to the LCH/PIH, attempt to smooth consumption; hence  $cn_t$  is a sufficient statistic for forecasting  $cn_{t+1}$ . Empirically, such a simple relationship has held remarkably well, although it is certainly not flawless. Excess sensitivity of nondurables consumption to lagged variables (income in particular) and excess smoothness with respect to wealth innovations are among the most studied puzzles in the empirical literature of the 1980s.

It is surprising, however, that so much empirical and theoretical work has been devoted to nondurables consumption and so little to durables. As was said before, the latter has shown rejection of the basic implications of the LCH/PIH that is orders of magnitude stronger than that found in the case of nondurables. This was

1. Bernanke [1985] and Startz [1986] also modeled the joint process of durables and nondurables.

2. The persistence of these shocks is tested through cointegration tests and is not rejected (see Caballero [1987c]).

brought to light by Mankiw [1982], who noticed that in the absence of friction, services provided by durables should follow a process similar to that of nondurables consumption. Furthermore, if these services are proportional to the stock of durables  $k$ , it is possible to write

$$(2) \quad \Delta k_{t+1} = a_1 + e_{t+1}^d,$$

where  $a_1$  is a constant and  $e_{t+1}^d$  is an innovation disturbance with properties similar to those of  $e_{t+1}^n$ .

The fundamental difference between nondurables and durables is that the latter last for more than one period; thus, the stock is not equal to current purchases. In fact, if depreciation is exponential, the stock and purchases of durables are related through the accumulation equation:

$$(3) \quad k_{t+1} = (1 - \delta)k_t + cd_{t+1},$$

where  $\delta$  is the depreciation rate and  $cd$  is the expenditure on durable goods.

Finally, putting together equations (2) and (3) yields a description of expenditures on durable goods comparable to that of nondurables in equation (1):

$$(4) \quad \Delta cd_{t+1} = a_2 + e_{t+1}^d - (1 - \delta)e_t^d,$$

where  $a_2 = a_1\delta$ .

Equation (4) indicates that if the time interval is short enough (so  $\delta \approx 0$ ), the level of durable expenditures should be approximately white noise, contrasting sharply with the random walk behavior implied by the LCH/PIH for nondurables. Or in terms of the first differences, as presented in equation (4), changes in expenditure on durables should follow an MA(1) process, with a large and negative MA coefficient. That is, most of the initial impact of a shock on changes in durables expenditures should be undone during the first period after this shock. Again, this contrasts sharply with the white noise behavior implied by the LCH/PIH for changes in nondurables purchases.

Mankiw [1982] used quarterly U. S. data and showed that contrary to what is implied by the theory, durables expenditures seem to follow a random walk. That is, there is no evidence whatsoever of a strong reversion of the initial impact of the shock on changes in durables expenditures. The stochastic behavior of durables purchases appeared to be too similar to that of nondurables purchases to be consistent with the lifetime smoothing implied by the LCH/PIH. Caballero [1987c] showed that in fact this

TABLE I  
NONPARSIMONIOUS ESTIMATES: DURABLES (QUARTERLY DATA)

$MA_1$	$MA_2$	$MA_3$	$MA_4$	$MA_5$	$MA_6$	$MA_7$	$MA_8$	$\Sigma_i MA_i$
-0.092	0.123	-0.170	0.008	0.019	-0.082	-0.068	-0.279	-0.541
(0.081)	(0.083)	(0.083)	(0.086)	(0.086)	(0.086)	(0.086)	(0.087)	(0.234)

The table reports the MA coefficients of an MA(8) process (estimated).  
Standard errors are in parentheses.

conclusion is robust to important relaxation of the simplifying assumptions involved in Mankiw's derivation.

This paper confirms that the process followed by durables expenditures is not close to a white noise, but shows that the reversion implied by the theory for changes in durables expenditures is indeed present in the data, although with an important delay. In fact parsimonious approaches like Mankiw's are not likely to detect the subtle and spread-out reversion. Table I shows the results of a nonparsimonious representation of the process for quarterly changes in durables expenditures. It is apparent that the first MA coefficient is very far from minus 0.95 (a value that would be consistent with 5 percent quarterly depreciation), and that individual MA coefficients are small. However, the sum of them is important and negative, as seen in the last column of Table I. This evidence is reinforced by Figure I, where the sum of the quarterly autocorrelations<sup>3</sup> for changes in expenditures on nondurables (and services) and durables is presented. The solid line corresponds to nondurables and shows that the sum of the autocorrelations remains positive and close to zero. Conversely, the sum of the autocorrelations in the case of durables is declining, almost always negative, and converges to a number close to minus 0.5, precisely what corresponds to a sum of MA coefficients converging to a number close to minus one.

In other words, disregarding the "abnormal" spreading out of the reversion of changes in expenditure on durables, the evidence is much more in line with the basic implications of the LCH/PIH for the difference between the behavior of durables and nondurables expenditures, than previously suspected. The next section provides a more revealing characterization of the delayed response of durables expenditures.

3. This is just a monotonic transformation of Cochrane's [1988] statistic.

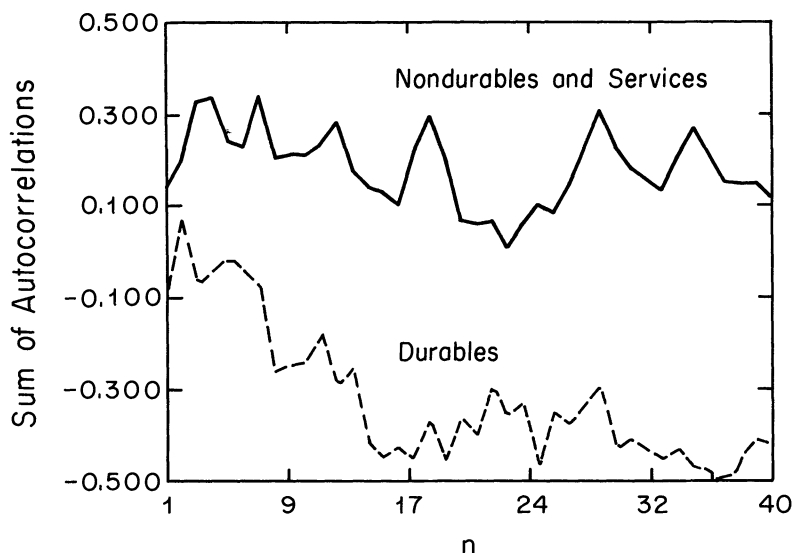


FIGURE I

### III. SLOW ADJUSTMENT

This paper, and this section in particular, does not attempt to explain why consumers seem to adjust their expenditures—especially in durable goods—slowly, but only to show that slow adjustment is consistent with the autocorrelations shown in the previous section. Furthermore, allowing for slow adjustment permits summarizing the time series behavior of expenditure on durables and nondurables in a way that highlights the fact that the difference in the expenditure process for the two goods is consistent with the basic implications of a LCH/PIH-type model.

Bearing this in mind, slowness is introduced by assuming that everybody faces the same shocks but reacts to (or perceives) them with different delays. For example, if the maximum delay for nondurables purchases is  $dn$  periods, a consumer with  $i \leq dn$  periods of delay exhibits a consumption process equal to

$$\Delta cn_{t+1}^i = a_0 + e_{t+1-i}^n$$

Aggregating over consumers yields

$$(5) \quad \Delta CN_{t+1} = a_3 + \sum_{i=0}^{dn} \theta_i^n e_{t+1-i}^n$$

with  $CN$  aggregate expenditure on nondurables,  $\theta_0^n \equiv 1$ ,  $\theta_i^n \geq 0$  for all  $i \leq dn$ , and  $\theta_i^n / \Sigma_i \theta_i^n$  represents the fraction of people adjusting their nondurables purchases with delay  $i$ .

The same can be said about durables, yielding an aggregate equation equal to

$$(6) \quad \Delta CD_{t+1} = a_4 + \theta_0^d e_{t+1}^d + 1[dd > 0] \sum_{i=1}^{dd} \{\theta_i^d - \theta_{i-1}^d (1 - \delta)\} e_{t+i-1}^d - \theta_{dd}^d (1 - \delta) e_{t-dd}^d,$$

where  $CD$  is the aggregate expenditure on durable goods,  $\theta_0^d \equiv 1$ ,  $\theta_i^d \geq 0$  for all  $i \leq dd$ ,  $dd$  is the maximum delay for durables purchases, and  $\theta_i^d / \Sigma_i \theta_i^d$  represents the fraction of people adjusting their durables purchases with delay  $i$ .

It is important to notice that delays in both goods have not been constrained to be equal (see below for a formal test of this hypothesis). This seems realistic since durables purchases often involve more expensive and complex purchases. This raises a technical issue since discrepancies in the adjustment period for different goods are likely to induce short-run cross-equation (goods) effects. However, Bernanke's [1985] finding of separability between durables and nondurables expenditures, together with the numerical simulations in Lam [1986], suggest that this only introduces a parameter of excess sensitivity in the good with a shorter adjustment period. This is irrelevant for the main hypothesis tested in this paper, and is therefore disregarded (see Caballero [1987c] for an explicit treatment of this problem).

Before reporting the results, it is convenient to mention that what follows uses annual instead of quarterly data. Although this is likely to make the time aggregation problem more severe,<sup>4</sup> it seems better able to detect small MA coefficients of the same sign, by summarizing their effects in a smaller set of coefficients.<sup>5</sup> The data correspond to nondurables and services, and durables expenditures as reported by the National Income and Product Accounts for the period 1947–1986. All the series were previously exponentially

4. See the working paper version of this paper for a proof that the fundamental conclusion of this paper is not affected by time aggregation problems [Caballero, 1987c].

5. Call  $x_a$  the annual change in expenditure on durable goods between periods  $t - 1$  and  $t$ , and  $xq_{tq}$  the quarterly change in expenditure on durable goods between periods  $tq - 1$  and  $tq$ , then  $x_a = \sum_{j=0}^6 a_j xq_{tq-j}$ , with  $a_0 = a_6 = 1$ ,  $a_1 = a_5 = 2$ ,  $a_2 = a_4 = 3$ , and  $a_3 = 4$ . Using Proposition 4 in Engel [1984], it is possible to show the relation between the annual autocovariances,  $r_{x_a}(k)$ , and the quarterly autocovariances,  $r_{xq}(k)$ :  $r_{x_a}(k) = \sum_{j=0}^6 \sum_{i=0}^6 a_i a_j r_{xq}(4k + j - i)$ .

TABLE II  
THE MA STRUCTURE

	$MA_1$	$MA_2$	$MA_3$	1. Durables		$\Sigma_i MA_i$	Q(8)	LLF
				$MA_4$	$MA_5$			
WN	—	—	—	—	—	—	5.69	-119.3
MA(1)	0.124 (0.165)	—	—	—	—	0.124 (0.165)	4.54	-119.0
MA(2)	0.073 (0.169)	-0.217 (0.171)	—	—	—	-0.144 (0.244)	4.11	-118.3
MA(3)	-0.064 (0.173)	-0.275 (0.174)	-0.375 (0.177)	—	—	-0.714 (0.338)	2.45	-115.8
MA(4)	-0.028 (0.177)	-0.290 (0.178)	-0.332 (0.181)	-0.336 (0.182)	—	-0.913 (0.417)	1.59	-114.3
MA(5)	-0.048 (0.179)	-0.330 (0.181)	-0.354 (0.184)	-0.295 (0.185)	0.076 (0.184)	-0.951 (0.460)	0.90	-114.3
			2. Nondurables and services					
	$MA_1$	$MA_2$	$MA_3$	$MA_4$	$MA_5$	$\Sigma_i MA_i$	Q(8)	LLF
WN	—	—	—	—	—	—	4.38	-130.2
MA(1)	0.393 (0.164)	—	—	—	—	0.393 (0.164)	0.58	-127.4
MA(2)	0.391 (0.167)	-0.069 (0.168)	—	—	—	0.322 (0.236)	0.49	-127.3
MA(3)	0.391 (0.169)	-0.070 (0.170)	-0.044 (0.170)	—	—	0.277 (0.293)	0.42	-127.3
MA(4)	0.390 (0.172)	-0.071 (0.172)	-0.038 (0.173)	-0.031 (0.174)	—	0.250 (0.343)	0.45	-127.3
MA(5)	0.387 (0.174)	-0.064 (0.175)	-0.045 (0.175)	-0.017 (0.176)	-0.065 (0.180)	0.196 (0.388)	0.35	-127.3

Columns 1 to 5: moving average coefficients.

Column 6: sum of moving average coefficients.

Column 7: Portmanteau statistic (8 degrees of freedom).

Rows: estimated processes (e.g., WN: white noise).

Standard errors are in parentheses.

(deterministic) detrended. In order to check whether the detrending procedure is responsible for the results, all the tests were rerun using per capita data. Also the restriction on the lagged expenditure coefficient (equal to one) was relaxed. These modifications left the main results and conclusions unchanged.<sup>6</sup>

### III.1. Differences in the MA Structures

Table II confirms the evidence found in quarterly data and reported in Figure I: the time series behavior of durables and

6. These results are available from the author upon request.



nondurables differs in the direction indicated by the LCH/PIH. The rows of this table represent the MA process estimated for changes in expenditure on durables and nondurables, respectively, whereas the first five columns report the value of the corresponding MA coefficients. Column (6) shows the sum of these MA coefficients, whereas columns (7) and (8) present the Portmanteau statistic and log likelihood, respectively. A “quasi-parsimonious” approach hints at an MA(3) process for changes in expenditure on durables changes and an MA(1) process for changes in expenditure on nondurables. According to equations (5) and (6) this suggests that  $dd = 2$  and  $dn = 1$ . It is worth noticing that the positive MA coefficient in nondurables could be reflecting time aggregation problems as suggested by Working [1960], instead of slow adjustment.<sup>7</sup> Which one is the right interpretation is not very important for the main result of this paper; the fact that both goods behave very differently—and that this difference is consistent with the implications of the LCH/PIH—is independent of the interpretation of the MA coefficient in the nondurables series.

Table II also shows, as the quarterly data did, that the first MA coefficient for durables does not reflect the reversion required by a frictionless LCH/PIH model. However, the presence of large and negative MA coefficients after the first lag is also apparent.

It is possible to obtain from equations (5) and (6) an expression for the sum of the MA coefficients. Indeed,

$$\sum_{i=1}^{dn} MA_i^n = \sum_{i=1}^{dn} \theta_i^n,$$

and

$$\sum_{i=1}^{dd} MA_i^d = -(1 - \delta) + \delta \sum_{i=1}^{dd} \theta_i^d.$$

These expressions suggest that except for very extreme cases of slow adjustment, the sum of MA coefficients should be positive for nondurables and very negative for durables. This is precisely what column (6) of Table II reveals. For the preferred models this sum is

7. Note that most of the slow adjustment in nondurables and services comes from services, perhaps through imputed rent on housing. The distinction between the speed of adjustment of these two types of goods, however, is not the main concern of the paper.

equal to minus 0.72 in the case of durables and plus 0.39 for nondurables.<sup>8</sup>

### III.2. Deep Parameters

This subsection starts with the assumption—based on the evidence in subsection III.1—that the adjustment is completed in two or fewer periods after the shock.

The system formed by equations (5) and (6) is estimated by maximum likelihood. The prediction errors to construct the likelihood are formed using a Kalman filter. (The details can be seen in Caballero [1987c].)

Table III presents the results. Column (1) corresponds to equation-by-equation estimates of equations (5) and (6). The results of the joint estimation that are equivalent to those of column (1) are shown in column (2). It is possible to see that the value of the likelihood function is substantially larger in the latter. From here on, the analysis concentrates on the joint estimation results.

Column (2) shows the results with no cross-equation restrictions. The first very promising result is that the estimate of the annual rate of depreciation of durables is 0.35. This is still high; however, it is much more reasonable than the rates of depreciation above 0.95 *per quarter* obtained in previous studies (e.g., Mankiw [1982] and Caballero [1987b]). The second important result is that the correlation between the innovations of durables and nondurables and services is 0.7, considerably higher than what was found before (Startz [1986] found a correlation coefficient of the innovations of his model equal to 0.38), and closer to what one would expect if the elements highlighted by the LCH/PIH are the driving forces of consumption decisions. The estimates of  $\theta_1^d$  and  $\theta_1^n$  are large and significant. The estimates of  $\theta_2^d$  and  $\theta_2^n$ , on the other hand, do not appear very significant. However, the results in column (5) show that the restriction  $\theta_2^d = \theta_2^n = 0$  can be rejected at the 5 percent significance level. It is also encouraging to see that all the estimates of the  $\theta$ s are positive as suggested by the slow adjustment model.

Column (3) imposes the constraint of equal speed of adjustment in both goods; the likelihood ratio statistic (LR) for this hypothesis is 4.4 and therefore cannot (marginally) be rejected at the 10 percent significance level. However, the implicit rate of depreciation rises, becoming less reasonable. In fact, when the rate

8. As was said before, an important part of this positive MA term could come through time aggregation problems. I disregard this issue here (see Caballero [1987c]).

TABLE III  
STATE SPACE MODEL (DURABLES/NONDURABLES SHOCKS DECOMPOSITION)

	(1)	(2)	(3)	(4)	(5)
$\theta_1^d$	0.701 (0.204)	0.682 (0.148)	0.439 (0.130)	0.507 (0.118)	0.077 (0.228)
$\theta_2^d$	0.319 (0.260)	0.178 (0.183)	0.060 (0.139)	0.124 (0.125)	0.000 —
$\theta_1^n$	0.363 (0.164)	0.338 (0.133)	$\theta_1^d$ —	$\theta_1^d$ —	0.362 (0.114)
$\theta_2^n$	-0.074 (0.182)	0.068 (0.134)	$\theta_2^d$ —	$\theta_2^d$ —	0.000 —
$\sigma_{ud}$	5.022 (0.582)	5.075 (0.594)	5.048 (0.582)	5.162 (0.607)	5.122 (0.580)
$\sigma_{un}$	6.311 (0.719)	6.439 (0.756)	6.398 (0.733)	6.431 (0.741)	6.343 (0.719)
$\tau_{ud,un}$	— —	0.700 (0.089)	0.647 (0.097)	0.634 (0.100)	0.619 (0.099)
$\delta$	0.350 (0.245)	0.348 (0.131)	0.513 (0.227)	0.348 —	1.077 (0.228)
<i>LFF</i>	-173.4	-162.0	-164.2	-165.9	-165.5

Columns (1) to (5): state space estimates under different assumptions.  
Standard errors are in parentheses.

of depreciation is kept fixed at 0.35 (see column (4)), these equality restrictions ( $\theta_1^d = \theta_1^n$  and  $\theta_2^d = \theta_2^n$ ) can be rejected at the 2 percent significance level.

Table IV presents the speed of adjustment implied by the set of models shown in Table III. The columns represent the models reported in the corresponding columns in Table III; whereas the rows represent the degree of delay. The speeds of adjustment of the preferred model are reported in column (2). Overall, the results are

TABLE IV  
SPEED OF ADJUSTMENT

Lags	1. Durables				
	(1)	(2)	(3)	(4)	(5)
(0)	0.51	0.54	0.67	0.61	0.93
(1)	0.33	0.37	0.29	0.31	0.07
(3)	0.16		0.04	0.08	0.00
2. Nondurables and services					
(0)	0.73	0.71	0.67	0.61	0.73
(1)	0.27	0.24	0.29	0.31	0.27
(3)	0.00	0.05	0.04	0.08	0.00

The columns correspond to the models represented in Table III.

sensible: people seem to adjust their stock of durables more slowly than their level of consumption of nondurables and services. For durable goods the adjustment takes three periods. Approximately 55 percent of the adjustment is completed during the year of the shock, 90 percent one year later, and 100 percent after two years. Nondurables and services, on the other hand, show numbers around 70, 95, and 100 percent, respectively.

### *III.3. Slow Versus Fast Regimens*

This last subsection compares the actual path of postwar total expenditures<sup>9</sup> in consumption goods with the path that would have been observed, *ceteris paribus*, had the same shocks occurred but the adjustment of expenditures occurred at the speed indicated by the frictionless LCH/PIH (fast regime).

The estimates of the underlying disturbances were constructed with a fixed interval smoother fed with the parameters of the preferred model estimated above (column (2) in Tables II and III).<sup>10</sup> The actual path of changes in total expenditures is depicted in Figure II with the solid line, whereas the fast regime's path is illustrated by the dashed line. Not surprisingly, a fast regime would have led to much wider but less persistent fluctuations of consumption expenditures (or interest rates).<sup>11</sup> This also highlights the fact that slow adjustment could potentially rationalize the excess smoothness and excess sensitivity puzzles.

## IV. CONCLUSION

For more than half a decade the fact that expenditure on durables can be well approximated by a random walk has prevailed as an almost unchallenged puzzle. This is particularly intriguing considering that such findings go against almost any theory in which agents optimize intertemporally; even if the effective horizon is only a few years, as suggested by Carroll and Summers [1989]. Barring aggregation problems, this finding suggests, for example,

9. Similar experiments for individual consumption categories can be seen in Caballero [1987c].

10. See Anderson and Moore [1979] for a thorough explanation of filtering and smoothing.

11. A by-product of the smoothing exercise presented above is that it is also possible to recover (based on the model presented in the Appendix) estimates of the influences of wealth and distribution shocks (i.e., shocks that move consumption of durables and nondurables in the same and opposite direction as consumption in each good, respectively). This exercise is reported in Caballero [1987c] showing that wealth shocks are the main driving force of both durables and nondurables. Furthermore, distribution shocks are almost irrelevant for nondurables fluctuations.

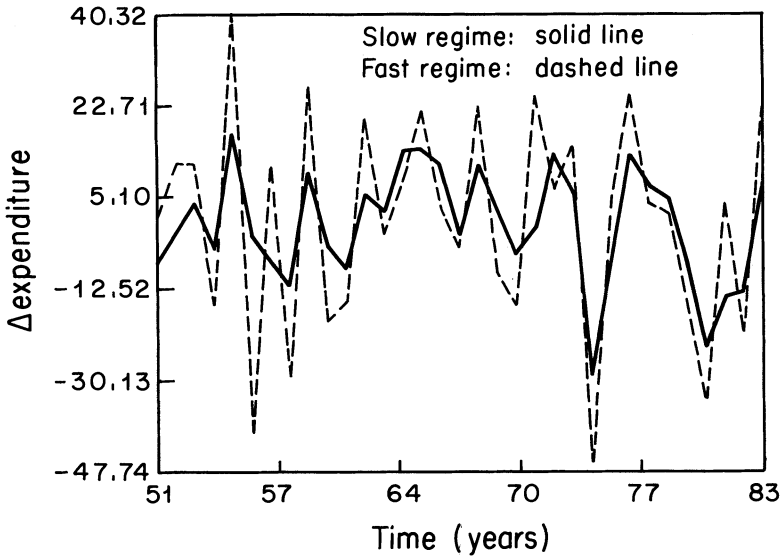


FIGURE II

that a consumer facing a large wealth shock does not buy a new large car, but prefers to buy one small car and add an equally important investment to the car every year. . . . It is certainly possible to manufacture dubious habit formation mechanisms yielding such behavior, but it does not seem worth doing it.

This paper, instead, has challenged the fact itself by looking, first, at nonparsimonious representations of quarterly consumption expenditures, and second, at lower frequency data able to detect more sharply features of the data blurred by a slow and irregular adjustment. Both approaches have shown that indeed expenditure on durables *does not* follow a random walk. In fact, the data show a clear reversion of the impact of initial shocks on durable purchases, a feature very much consistent with a framework in which consumers do some smoothing.

On the other hand, the fact that the frictionless LCH/PIH is unable to account for expenditure on durables is fully confirmed in this paper. However, this type of model complemented with slow adjustment provides a fairly good description of the differences between the stochastic processes followed by nondurables and durables expenditures.

Still, this paper should not be interpreted as a claim for

complete consistency between the data and the LCH/PIH. Moreover, the paper has not even addressed many of the well-known puzzles of nondurables (although slow adjustment provides at least a partial explanation for excess smoothness and sensitivity). Furthermore, the fact that durables expenditures seem to adjust more slowly is perhaps a reflection of liquidity constraints and other departures from the basic LCH/PIH. The paper has claimed, however, that one of the grossest violations of the basic implications of smoothing theories is not such.

#### APPENDIX

This Appendix describes the model underlying the equations used in the main text. For this, denote by  $V(W_t, y_t, k_{t-1}, z_t)$  the value function of the representative consumer, with  $W$ ,  $y$ ,  $k$ , and  $z$ , financial wealth, labor income (exogenous), stock of durables, and distribution shock (representing substitution effects), respectively. Assume also that the utility function is separable across goods and time, and that it can be well approximated by a constant absolute risk aversion felicity. Thus, the problem solved by the consumer is

$$V(W_t, y_t, k_{t-1}, z_t) = \max_{\{cn, cd\}} - \left( \frac{e^{-\gamma cn_t} + e^{-\gamma k_t} e^{z_t}}{\gamma} \right) + \beta E_t[V(W_{t+1}, y_{t+1}, k_t, z_{t+1})]$$

subject to

$$\begin{aligned} cn_{t+i} + cd_{t+i} &= (1+r)W_{t+i-1} + y_{t+i} - W_{t+i}, \\ k_{t+i} &= (1-\delta)k_{t+i-1} + cd_{t+i}, \\ \lim_{i \rightarrow \infty} \beta^i (W_{t+i} + k_{t+i}) &= 0, \end{aligned}$$

where  $r$  is the (constant) interest rate,  $\gamma$  the coefficient of absolute risk aversion, and  $\beta < 1$  the discount factor.

The driving processes are assumed to have a moving average representation, so

$$z_t = \Theta_z(L)v_t$$

and

$$y_t = \Theta_y(L)w_t,$$

where  $L$  is the lag operator,  $\Theta_z$  and  $\Theta_y$  are polynomials, and  $v$  and  $w$  are innovation disturbances.

The first-order conditions of such a problem (besides the

complementary slackness conditions) are

$$(A.1) \quad e^{-\gamma cn_t} = \beta(1+r)E_t[e^{-\gamma cn_{t+1}}],$$

$$(A.2) \quad e^{z_t} e^{-\gamma k_t} = \beta(1+r)E_t[e^{z_{t+1}} e^{-\gamma k_{t+1}}]$$

and

$$(A.3) \quad (1 - \alpha(1 - \delta))e^{-\gamma cn_t} = e^{z_t} e^{-\gamma k_t},$$

where  $\alpha \equiv (1+r)^{-1}$ .

Following the solution approach proposed in Caballero [1987a], it is convenient to guess the form of the stochastic processes followed by  $cn$  and  $k$ :

$$(A.4) \quad cn_{t+1} = a_{0t} + b_{1t}cn_t + e_{t+1}^n$$

and

$$(A.5) \quad k_{t+1} = a_{1t} + b_{2t}k_t + e_{t+1}^d.$$

The next step is to use the first-order conditions described above, together with the intertemporal budget constraint, to find  $a_{0t}$ ,  $a_{1t}$ ,  $b_{1t}$ ,  $b_{2t}$ , and the innovations  $e^n$  and  $e^d$ . It is also necessary to check whether (A.4) and (A.5) are feasible solutions.

Replacing (A.4) and (A.5) in (A.1) and (A.2), respectively, yields

$$e^{(-\gamma cn_t(1-b_{1t}))} = \beta(1+r)e^{-\gamma a_{0t}}E_t[e^{-\gamma e_{t+1}^n}]$$

and

$$e^{z_t} e^{(-\gamma k_t(1-b_{2t}))} = \beta(1+r)e^{-\gamma a_{1t}}E_t[e^{z_{t+1}} e^{-\gamma e_{t+1}^d}].$$

These equations imply (under the identification assumption that  $a_{0t}$  and  $a_{1t}$  are not linear functions of  $cn_t$  and  $k_t$ , respectively) that  $b_{1t} = b_{2t} = 1$ ; otherwise  $cn_t$  and  $k_t$  would be determined by the Euler equations, *regardless* of the budget constraint. Given that the exponential utility exhibits no satiation, this would almost surely violate the first-order conditions. Furthermore, imposing these conditions permits us to find expressions for  $a_{0t}$  and  $a_{1t}$  that make (A.4) and (A.5) consistent with the Euler equations:

$$a_{0t} = (1/\gamma) \log \beta(1+r) + (1/\gamma) \log E_t[e^{-\gamma e_{t+1}^n}]$$

and

$$a_{1t} = (1/\gamma) \Theta_z^+(L)v_t + (1/\gamma) \log E_t[e^{(v_{t+1} - \gamma e_{t+1}^d)}],$$

where  $\Theta_z^+ = [(\Theta(L)/L)_+ - \Theta(L)]$ , with  $(\cdot)^+$  denoting the positive powers of  $L$ .

Here we assume that the distribution shock follows a random walk; the unit root part of this assumption was tested through cointegration tests and not rejected (see Caballero [1987c] for details), whereas the lack of serial correlation of the increments is an identification assumption. This assumption implies that all the elements of  $\Theta_z^+$  are equal to zero, hence it is sufficient to prove that  $e^d$  and  $e^n$  are i.i.d. to show that  $a_{0t}$  and  $a_{1t}$  are constants, as assumed in the main text.

Using the procedure suggested in Caballero [1987a], it is possible, although tedious, to show that

$$e_t^n = \Phi_1 w_t - \Phi_2 v_t$$

and

$$e_t^d = \Phi_1 w_t + \Phi_3 v_t,$$

where

$$\Phi_1 = \left( \frac{1 - \alpha}{2 - \alpha(1 - \delta)} \right) \sum_{i=0}^{\infty} \alpha^i \theta_{yi},$$

$$\Phi_2 = [1 - \alpha(1 - \delta)] / [\gamma(2 - \alpha(1 - \delta))]$$

and

$$\Phi_3 = 1 / [\gamma(2 - \alpha(1 - \delta))].$$

Given that  $v$  and  $w$  are i.i.d., so are  $e^n$  and  $e^d$ , hence  $a_{0t}$  and  $a_{1t}$  are constants.

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