A Study of the Stochastic Behavior of Durable Goods Consumption

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A STUDY OF THE STOCHASTIC BEHAVIOR OF DURABLE GOODS CONSUMPTION

A Thesis

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In Partial Fulfillment
of the Requirements for the Degree
Master of Arts

by

Alexander Lebedinsky

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A STUDY OF THE STOCHASTIC BEHAVIOR OF
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The author of this thesis examines the stochastic behavior of durables consumption in the rational expectations/permanent income hypothesis framework. The testing in this paper parallels the studies conducted by other researchers, who basing their work mainly on quarterly data rejected the frictionless rational expectations/permanent income hypothesis. The distinctive feature of this thesis is that the models are examined using monthly instead of quarterly data. The results of the estimation are compared to the results based on quarterly data. The results show that estimates obtained using monthly data seem to be more consistent with the frictionless rational expectations/permanent income hypothesis than the estimates from quarterly data. Then, by using two subsets of the monthly data representing the first and the last twelve years of a 37 year period, the models are reexamined to explore the possibility of change in the stochastic behavior of personal expenditures on durable goods over time. This results suggest a change in influence of liquidity constraints on the time series behavior of durable goods consumption over the last four decades.
CHAPTER I
INTRODUCTION

Most of the contemporary research on the theory of consumption is based upon the implications of the life cycle - permanent income hypothesis (LC/PIH). This theory is widely accepted as the proper application of theory to the problem of consumption optimization over time. According to the hypothesis, consumers form estimates of their ability to consume in the long run and then set current consumption to the appropriate fraction of that estimate. The rational expectations hypothesis (REH) implies that most consumers are forward-looking, and they do not commit systematic mistakes. Consumers utilize all available information to estimate their lifetime income and augment their consumption decisions (subject to constraints) when new information becomes available. Therefore, in a simple, zero information cost world the only useful predictor of consumption is its lagged value, and inclusion of other lagged variables such as income should not improve forecasts.

Hall (1978) developed a simple model to test the validity of the LC/PIH in the rational expectations framework and found little reason to cast doubt on the LC/PIH. Hall’s research was followed by the work of other researchers who expanded upon his model with several modifications. Subsequent studies that employed stronger testing techniques led mainly to the rejection of the versions of rational expectations/permanent income hypothesis (REPIH) that did not account for liquidity constraints and adjustment costs. The rejection of such frictionless models came primarily from the fact that there were variables other than
lagged consumption with statistically significant predicting power\textsuperscript{1}.

In this thesis the author re-examines the performance of the models based on the one developed by Hall. The testing in this thesis parallels the research conducted by Mankiw (1982) and by Startz (1989). The distinctive feature of this thesis is that the models are examined using monthly data, and the results of the estimation are compared to those obtained using quarterly data. This comparison is conducted in order to explore the reasons for the lack of success of previous research, which is mainly attributed to the influence of liquidity constraints. As it will be shown later in the thesis, monthly data seems to fit the model much better than quarterly data, showing that the influence of liquidity constraints may have been overstated. The models are also re-examined with two subsets of monthly data representing (approximately) the first and the last twelve years of a 37-year period. This examination yields results that suggest a change in the stochastic behavior of durable goods consumption over the last four decades.

This thesis is divided into four sections. This section is a brief introduction to the thesis. Chapter II summarizes the results of the previous studies in this field of research. Chapter III contains the mathematical representation of the models. Chapter IV presents the empirical results of the testing of the models discussed in this thesis. Chapter V is a conclusion.

\textsuperscript{1} Seater (1993) noted that underlying assumptions of Hall’s model are “quite demanding.” As he wrote, “...if financial portfolios, or stocks of physical assets are costly to adjust, then current consumption will depend on lagged variables other than consumption.”
CHAPTER II

REVIEW OF THE LITERATURE

A. RATIONAL EXPECTATIONS/PERMANENT INCOME HYPOTHESIS AND THE THEORY OF CONSUMPTION.

Most of the contemporary research on the theory of consumption is based upon the implications of the LC/PIH. This theory is widely accepted as the proper way to address the problem of dividing consumption between the present and the future. It is not surprising that the works of Modigliani and Brumberg (1954) followed by Friedman (1957) generated a number of attempts by other economists to test the validity of the LC/PIH and to amend its apparent empirical failures. According to the hypothesis, consumers form estimates of their ability to consume in the long run and then set current consumption to the appropriate fraction of that estimate. The estimate may be stated in the form of wealth, according to Modigliani, in which case the fraction is the annuity of wealth, or as permanent income, following Friedman, in which case the fraction should be close to one.

The emergence of the rational expectations hypothesis (REH) brought about a whole new literature that tested the joint LC/PIH - REH (or REPIH). One of the first and the most significant papers was written by Hall (1978). He noted that the REH implies that consumers should use all the information available to them at each moment in time to make their consumption decisions, and that the LC/PIH suggests that the expected marginal utilities from consumption should be equalized across time. The interaction of these two
implications makes today’s consumption a sufficient information set in order to forecast tomorrow’s consumption. Hall argued that when consumers maximize expected future utility, the conditional expectation of the future marginal utility is a function of today’s level of consumption - all other information is irrelevant. In other words, apart from the trend, marginal utility follows a random walk. If marginal utility is a linear function of income, then consumption should also obey a random walk, again apart from the trend. Hall established a test of the stochastic implication of the LC/PIH in the form of estimating a conditional expectation \( E(c_t|c_{t-1}, x_{t-1}) \), where \( x_{t-1} \) is a vector of data known in period \( t-1 \). According to the theory, tests should show that the conditional expectation is actually not a function of \( x_{t-1} \). The error term reflects new information regarding permanent income available at \( t \). If consumers form their estimates of permanent income rationally, then this error must be serially uncorrelated. The empirical results stated in Hall's paper contradict the REPIH. Although he showed that including lagged income and lagged consumption beyond \( t-1 \) does not improve the results of regression, he found that the stock market is a valuable predictor for one quarter in the future. Fauvel and Samson (1991) also researched the relationship between the consumption of durable goods and the real rate of return on savings. Using data for the Canadian economy, they found that consumer expenditure on durable goods is very responsive to the real rate of return. The model used in their research is the intertemporal optimization model suggested by Hansen and Singleton (1982).

\[ \text{Footnote by Hall [A.L.]} \]

The authors took on the issue from a somewhat different prospective - they were researching the fluctuations in intertemporal substitution in relation to business cycles. Their idea was that fluctuations of real returns on savings can impact the economy via their influence on the purchase of durable goods.
Although Hall found a predictor other than $C_{t,1}$, he concluded that there is little reason to doubt the REPIH, because any variable that is correlated with permanent income in $t-1$ will help in predicting the change in consumption in period $t$, since part of the contemporaneous change in the level of consumption is the lagged response to the previous changes in permanent income. With the help of his test, Hall tried to detect two principal departures from the REPIH. One argument holds that consumers are unable to smooth consumption over transitory fluctuations in income because of liquidity constraints and other practical considerations. The second proposition holds that a reasonable measure of permanent income is a distributed lag of past actual income. So the consumption function should relate actual consumption to such a distributed lag.

Several further tests have been sought to investigate the structural relation between innovations in income and consumption (Flavin [1981, 1985], Hall and Mishkin [1982]). Typically, real income is modeled as a mixed autoregressive moving average stochastic process, which is then used to decompose current income movements into anticipated and unanticipated elements. Flavin's (1981) test is known as the “excess sensitivity test.” She investigates the anticipated income component, and where that component has explanatory power over current consumption, it (consumption) is excessively responsive to current income. Flavin reported a decisive rejection of REPIH - the hypothesis that consumption exhibits no excess sensitivity to the contemporaneous changes in income could be rejected at the .5 % level.

Noting that aggregate evidence is not powerful enough to settle the question about the behavior of consumers, Hall and Mishkin (1982) conducted another study using panel data. The major findings presented in their paper are as follows: a) consumption responds
much stronger to permanent than to transitory movements of income; b) the response to transitory income is still strong - requiring interest rates of 20% or more for the theoretical model to explain the movements; c) a simple test (a regression of change in consumption on change in income lagged by one period) rejects the REPIH; d) observed covariation of income is compatible with pure REPIH behavior for 80% of consumption and simple proportionality for the remaining 20%.

The notion that the sensitivity of consumption to income is greater than predicted by the REPIH has long been associated with the idea that households are unable to dissave during periods of abnormally low income. Instead of continuing a normal level of consumption by borrowing, they must reduce consumption. As Hall (1989) noted, such households face liquidity constraints because they do not hold liquid assets or collateral suitable for borrowing. Runkle (1991) and Zeldes (1989) examined liquidity constraints in panel data for individual households. Zeldes tested a basic REPIH against the alternative hypothesis that consumers optimize subject to a well-specified sequence of constraints (i.e., a liquidity constrained version of REPIH). Implications for consumption in the presence of borrowing constraints were tested using time-series/cross-section data on families from the Panel Study of Income Dynamics. His results support the hypothesis that the inability to borrow against future labor income affects the consumption of a significant portion of the population. He found that the consumption optimization principle is violated in the low income/wealth group (where the liquidity constraints are likely to be more binding) but holds

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4The authors wrote in conclusion, "...Consumption is somewhat more sensitive to current income than it would be in an economy where every consumer borrowed and lent freely at the Treasury bill rate. Still it is much less sensitive than in an economy where no consumer ever borrowed or lent."
for the remaining observations. Zeldes, however, using the same data set as Runkle, found strong empirical evidence supporting the REPIH and showed that panel data do not support the view that certain consumers are liquidity-constrained and others are not. Runkle found that the rate of growth of consumption is positively related to net worth in families with assets below $1,500. Zeldes found that consumption growth is negatively related to real disposable income. The latter finding was also reported by Hall and Mishkin (1982).

Flavin (1985) also dealt with the issue of liquidity constraints in time-series data in an extended version of her earlier model. She considered two explanations of her earlier finding that the innovation in consumption is excessively sensitive to the innovation in income. First, consumers may be myopic - that is, they may behave as if they faced extremely high interest rates at all times. Second, some consumers at some time face liquidity constraints. She noted that the two alternative explanations can be distinguished by studying the relation of excess sensitivity to variables that measure the incidence of liquidity constraints. For this purpose, she used the unemployment rate as an indicator of liquidity constraints. Flavin found that when the unemployment rate is included in the model as an additional variable to forecast income but is constrained to have no direct effect on consumption, the excess sensitivity of consumption to current income is large and statistically significant. However, when the unemployment rate, interpreted as an indicator of liquidity constraints, is permitted to have a direct impact on consumption, the measured excess sensitivity of consumption to income falls substantially and becomes insignificant.

Chan, Ramey and Starr (1995) developed a theory of optimal consumption behavior in the presence of borrowing constraints and tested their theory using data on the stock of durable goods. The authors noted that 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 stock and reallocate expenditures to current nondurables consumption; they anticipate a subsequent increase in sustainable expenditure levels, and they plan a future augmentation of durable goods stocks and expenditures. Alternatively, if durable goods, but not nondurable consumption, can be debt-financed, then forecastable increases in income are preceded by a rise in durables expenditures. In either case, their theory implies that the level of durable goods purchases should have a predictive power for changes in nondurable consumption expenditure. Chah’s et al. conclusions were in line with those of Flavin (1985) and of Zeldes (1989) - the excess sensitivity of consumption to predictable changes in income is attributable to liquidity constraints. Their results show that most consumers are forward-looking in their behavior. They smooth consumption as much as the capital markets permit. When they receive the news of a future increase in income, they increase their holdings of durable goods in anticipation of the rise in income. 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 income.

B. CONSUMPTION OF DURABLE GOODS IN THE RATIONAL EXPECTATIONS/PERMANENT INCOME HYPOTHESIS FRAMEWORK

For the most part, the theory of durables consumption is no different from the theory of nondurables consumption. Households consume a flow of services from durables, and that flow should be determined in the same way as the flow of other types of consumption. Several authors (Mankiw [1982,1985], Bernanke [1984,1985], Bar-Ilan and Blinder [1987],
Caballero [1990,1995] and Startz [1989]) conducted research on the consumption of durable goods ranging in complexity and approaches.

Mankiw (1982) developed the most basic model in a time series setting. He noted that the stock of durables should evolve according to the same Euler equation as the flow of consumption of nondurables. Hall (1978) argued that consumption should obey a first-order autoregressive process AR(1). Mankiw expanded Hall’s theory to durable goods and suggested that expenditures on durable goods should follow a first-order autoregressive-moving average process [ARMA (1,1)] if the frictionless REH treatment of the LC/PIH is true. The parameter of the moving average (MA) term depends only on the rate of depreciation. It should be negative, and its absolute value equal to one minus the rate at which the stock of the durable goods depreciates. Mankiw obtained a strong rejection of that hypothesis. He found that the stochastic process for durables purchases is close to a random walk, which implies that the quarterly depreciation rate for durables is about 100%.

Bernanke’s (1985) work is another undertaking to test the consumption of durables in the REPIH setting. He noted that the lack of success of previous works might be a result of the problem that lagged stock adjustment and accelerator effects concealed in the expenditures on durable goods may lead to an incorrect rejection of the REPIH. The principal novelty of his model was that the consumer's optimal spending patterns on durables and nondurables are jointly, rather than separately determined. Bernanke argued that such

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5 The Euler equation \( E_U(K_{t+1}) = \frac{1}{1-\gamma} U'(K_t) \), where \( E_t \) is the mathematical expectation conditional on all information available in \( t \), \( \gamma \) is the rate of subjective time preference, \( r \) is real rate of interest, assumed constant over time, \( U() \) is one period utility function, strictly concave, \( K \) is stock of goods providing services to the consumer, is identical to Hall's (1978) Euler equation describing optimization principle for nondurables.
treatment of consumption has several advantages over other approaches. First, the model that employed data on durables and nondurables in a single integrated procedure should increase the power of the REPIH test. Second, he tested, rather than assumed as in earlier works, the separability of utility of durables and nondurables. A particular consequence of allowing for non-separability is that nondurables consumption is no longer predicted by a random walk but “mirrors” the sluggish behavior of durables purchases caused by adjustment costs. Therefore, nondurables can potentially “overreact” to an unanticipated wealth increase. However, the findings based on the aggregate data reinforced those of previous work.

Bernanke’s paper supported the conclusion of Flavin (1981), who suggested that there is substantial excess sensitivity of consumer spending to income changes in the short run. Bernanke’s results suggest that durables and nondurables are neither strong substitutes nor strong complements. The “mirror” effect may not be important, although costs of durables stock adjustment are found to be substantial. Furthermore, the REPIH restrictions were rejected through excess sensitivities in both durables and nondurables. Bernanke also noted that aggregate data always seem to do worse than the tests on the micro-level panel data. He referred to his own study [Bernanke (1984)] where he studied the data on income and automobile expenditures for 1,400 families over four years. In that study, he concluded that estimated consumer behavior in the sample could be well-described by the REPIH. Attempting to explain the differences in performances of the aggregate and micro-data, he referred to Blinder (1983), who argued that econometric models of the sort used in this
thesis are particularly susceptible to the aggregation problem. Mankiw (1985) studied durables in a framework that considers substitution between durables and nondurables and also intertemporal substitution. He found evidence of high elasticities of substitution in both dimensions. The estimates indicated that consumer expenditures on durables is very responsive to changes in the real interest rate. As a result, movements of real interest rates are an important influence, making durables depart from the predictions of a model that assumes constant interest rates.

Following Mankiw's (1982) approach, Caballero (1990) showed that once a moderate amount of slowness of response of some consumers to news about economic environment is admitted, a clear difference appears between the time series behavior of durables and nondurable goods. The sum of autocorrelations of changes in nondurables expenditures remains close to zero, whereas the same statistic is decreasing and negative for the case of durables. The data show a clear reversion of the initial impact of shocks on durables purchases, a feature very much consistent with a framework in which consumers' decisions are subject to liquidity constraints. His paper supports an already proven fact that a frictionless REPIH is unable to account adequately for expenditures on durable goods.

While Hall (1982) showed that a univariate representation for nondurables matches the data reasonably well, the analogous univariate representation of durables is widely rejected. Startz (1989), however, presented evidence supporting this stochastic model and supporting the idea that forecasts are efficient in the same sense as those originally made by Hall. Startz noted that inclusion of adjustment costs and nonseparability suggests a specific

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6 The problem of the data choice will be discussed later in the thesis.
bivariate time series process for durables - one in which lags of nondurables and services enter on the right hand side. The data for durable goods are consistent with a bivariate representation suggested by nonseparability, in particular with services. The results also showed no evidence in favor of adjustment.

Bar-Ilan and Blinder (1992) developed a hypothesis that also may be a missing link between the LC/PIH, REH and empirical results. They argued that the best policy for a rational optimizing consumer is to do nothing for some period of time, even if new, relevant and unexpected information becomes available. The authors assume that there are lumpy costs in the durables transaction. Therefore, consumers choose a finite range instead of a single level for their durable goods stock. The boundaries of this range change with new information and are associated with the permanent income hypothesis. However, as long as the stock is within the chosen region, the consumer does not change his or her durables stock. Hence, individuals make transactions involving durables infrequently, and their consumption may differ significantly from the prediction of the pure REPIH, which ignores transaction costs. Bar-Ilan and Blinder use the model of inventory management known as \((s,S)\) to explain this kind of behavior. When the durables stock depreciates to some lower bound \(s\), a purchase is made to increase the durable stock to \(S\). If the stock remains above the trigger \(s\), no action is taken. Both \(S\) and \(s\) are proportional to permanent income. Thus, durables consumptions can be described by a range \(s,S\) whose boundaries follow the prediction of the REPIH. But when the durable goods stock is in the desired range, the consumer is inactive.

Another important suggestion they made in their paper is that when analyzing the aggregate data one should look separately at the average expenditure per purchase and at
the number of transactions. The prediction of the REPIH should hold for the former but not for the latter. If the \((s,S)\) theory is correct, then one can describe more precisely how behavior of the number of purchases should differ from random walk. Total consumption expenditures on durables in period \(t\) is equal to the product of average expenditures and the number of transactions. The number of transactions is a function of the density of consumers with durables holdings near \(s\). Therefore, total expenditure on durables should not obey the standard REPIH pattern of consumption, since the number of transactions does not follow this pattern. Bar-Ilan and Blinder's paper is one of the few works on durable goods that focuses on explaining the reasons for the slowness of adjustment in the consumption of durable goods.

Caballero (1993) used an approach similar to that of Bar-Ilan and Blinder. He acknowledged that at the microeconomic level durables purchases are often discontinuous and relatively large. He examined the problem of dynamic aggregation of stochastically heterogeneous units, which would help to analyze the connection between microeconomic behavior and aggregate dynamics in the presence of nonconvex adjustment costs. Caballero's results provide further support for the view that lumpy microeconomic purchases play an important role in explaining the time series behavior of aggregate expenditure on durable goods.
CHAPTER III
THE MODELS

From the previous chapter one can see that most of the contemporary research on the LC/PIH emphasized two characteristics of consumption. First, in the frictionless world the consumption of nondurable goods should follow a random walk. Second, forecasts of consumption conditioned on lagged consumption should be efficient in the sense that they cannot be improved by using any other lagged variable. The process determining consumption depends mainly on the process determining income through expectations of future income. All previously available information has been incorporated into preceding consumption. Thus, the change in consumption can be described by a random disturbance reflecting new information as it becomes available. Although Hall (1978) stated that these major implications of REPIH are mainly supported by empirical results, other researchers\(^7\), who extended these characteristics onto durables consumption, found strong evidence leading to the rejection of simple versions of REPIH. The failure of the model was attributed to several factors among which the most influential are liquidity constraints and high adjustment costs of the stock of durable goods.

In this chapter, several of the major theoretical developments for intertemporal consumption that have just been surveyed are presented in an explicit, mathematical framework.

\(^7\) Mankiw(1982), Bernanke(1985), Caballero (1990) are among those who rejected REPIH using Hall’s test applied to durable goods.
A. CONSUMPTION OPTIMIZATION

Hall's test of the REPIH can be described as follows: the simplest implication of the REPIH is that consumption lagged more than one period has no predictive power for current consumption. Furthermore, consumption is unrelated to any other economic variable observed in earlier periods. The optimization model of life-cycle consumption can be represented as follows: maximize

$$E_t \sum_{\tau=0}^{T-t} (1+\gamma)^{-\tau} u(c_{t,\tau})$$

subject to

$$\sum_{\tau=0}^{T-t} (1+r)^{-(c_{t,\tau} - w_{t,\tau})} = A_t,$$

where $E_t =$ mathematical expectation conditional on all information available in $t$;

$\gamma =$ rate of subjective time preference;

$r =$ real rate of interest, assumed constant over time;

$T =$ length of economic life;

$u =$ one period utility function;

$c_t =$ consumption;

$w_t =$ earnings;

$A_t =$ assets apart from human capital.

Hall noted that earnings $w_t$ are the only source of uncertainty. In each period $t$, the consumer seeks to maximize the expected lifetime utility using all information available then. The principal theoretical result obtained by Hall is the following Euler equation:
Thus, marginal utility obeys the regression relation:

\[ Eu'(c_{t+1}) = \frac{1+\gamma}{1+r} u'(c_t) . \]  

(3)

Thus, marginal utility obeys the regression relation:

\[ u'(c_{t+1}) = \delta u'(c_t) + \varepsilon_{t+1} . \]  

(4)

where \( \varepsilon_{t+1} = \) uncorrelated error term and \( \delta = (1+y)/(1+r) \).

Therefore, as Hall concluded, consumption obeys the exact regression

\[ c_{t+1} = \beta_0 + \delta c_t + \varepsilon_{t+1} . \]  

(5)

According to Hall, no variable added to this equation should have a nonzero coefficient. Assuming that the change in the marginal utility from one period to another is small, \( i.e. \), if the interest rate is close to the time preference rate, consumption itself obeys a random walk.

B. CONSUMPTION OPTIMIZATION PRINCIPLE FOR DURABLE GOODS

Mankiw (1982) expanded Hall’s framework to deal with consumer expenditures on durable goods. Mankiw noted that since utility is derived from the stock of durable goods rather than current consumption as it is in case of nondurables, the maximization constraint should be as follows:
where $K =$ stock of durable goods providing services to the consumer and $\rho =$ depreciation rate of the stock $K$.

If $\rho = 1$, then equation (6) looks exactly like the Hall's, where no goods are durable.

Mankiw's Euler equation representing the optimization principle is given by

$$E u'(K_{t+1}) = \frac{1+\gamma}{1+r} u'(K_t),$$

and it is similar to the one derived by Hall, with only one difference. Instead of current consumption, consumers optimize the stock of durable goods. Therefore, the stock of durable goods should obey the following regression:

$$K_{t+1} = \alpha_0 + \delta K_t + \epsilon_{t+1}$$

where $\delta = (1+\gamma)/(1+ r)$ and $\epsilon_{t+1}$ is an uncorrelated error term.

Thus, if the change in intertemporal marginal utility is small, then $K$ obeys a first order autoregressive process - AR(1). The fundamental identity between the stock of durable goods $K$ and their flow - expenditures on durable goods $CD_t$ can be described as

$$K_{t+1} = (1-\rho)K_t + CD_{t+1}.$$
He showed that consumer expenditures on durables should obey an autoregressive-moving average process - ARMA(1,1), in which the moving average parameter is related to the rate of depreciation.

One of the key assumptions of both Hall and Mankiw is that utility is separable in the sense that consumption decisions about one good or group of goods do not affect the utility received from some other good or a group of goods. Startz (1989) noted that if the flow utility function is nonseparable in durables and nondurables, then the ARMA(1,1) representation suffers from an omitted variable that may be highly correlated with the innovations in the moving average process. He stated that the marginal utility for durables can be rewritten in the following form:

\[ u'(K_{t+1}) = \alpha_0 - \alpha_1 K_{t+1} + kC_{t+1} \]

Thus, the Euler Equation looks as follows:

\[ \alpha_0 - \alpha_1 K_{t+1} + kC_{t+1} = \frac{1 + \gamma}{1 + r} \left( \alpha_0 - \alpha_1 K_t + kC_t \right) + \epsilon_t \]

Substituting the Euler equation for nondurables (3) into (12) and rearranging the equation to represent the consumption of durables, Startz obtained the following equation:

\[ CD_{t+1} = \rho \alpha_0 + \delta CD_t + \epsilon_{t+1} - (1 - \rho) \epsilon_t \quad (10) \]
where \( r^d \) = rate of interest for durable goods and \( r^c = \) rate of interest for nondurable goods.

As one can see from equation (13), Startz recognizes the possibility that consumers may face different rates of interest when purchasing nondurables and durables. He also noted that the variable that represents the consumption of nondurable goods should be highly correlated with the innovation in the moving average. If the change in \( c \) is positive, then \( \varepsilon_t \) should also be positive. Thus, when estimating this modification of an ARMA(1,1) model \( \varepsilon_t \) and \( c_t \) should offset each other, leaving the AR component and making MA insignificant.

To examine the influence of the adjustment costs on the consumption of durable goods, Startz used an approach suggested by Bernanke (1985), who argued that adjustment costs arise because purchases of durables require leisure expenditure. Adding adjustment costs to the model requires the modification of the marginal utility equation, which now is written:

\[
 u'(K_{t+1}) = \alpha_0 - \alpha_1 K_{t+1} - aCD_{t+1} \tag{14}
\]

where \( a \) represents the adjustments costs associated with purchases of durables. The null hypothesis of no adjustment costs is \( a = 0 \). The modified Euler equation is as follows:

\[
 \alpha_0 - \alpha_1 K_{t+1} - aCD_{t+1} = \frac{1+\gamma}{1+r} (\alpha_0 - \alpha_1 K_{t} - aCD_{t}) + \varepsilon_t \tag{15}
\]

Substituting \( CD_{t} + (1-\rho)K_{t} \) for \( K_{t+1} \) and collecting terms, Startz obtained the following time series representation of durable goods consumption:
\[ CD_{t+1} = \delta \left( 1 - \frac{1 + \gamma}{1 + r} \right) \frac{\alpha_0}{\alpha_1 + \alpha} + \left( \frac{1 + \gamma}{1 + r} + \frac{\alpha}{\alpha_1 + \alpha} (1 - \rho) \right) CD_t - \frac{\alpha}{\alpha_1 + \alpha} \frac{1 + \gamma}{1 + r} CD_{t-1} + \frac{1}{a + \alpha_1} \varepsilon_{t+1} - \frac{1 - \rho}{a + \alpha_1} \varepsilon_t \]  \hspace{1cm} (16)

With presence of adjustment costs the time series representation of durable goods should obey an ARMA(2,1) process.

Startz also noted that it is possible that both adjustment costs and nonseparability exist. Then the estimating equation for expenditures on durable goods should look as follows:

\[ CD_{t+1} = \left( \frac{1 + \gamma}{1 + r} + \frac{\alpha}{\alpha_1 + \alpha} (1 - \rho) \right) CD_t - \frac{\alpha}{\alpha_1 + \alpha} \frac{1 + \gamma}{1 + r} CD_{t-1} + \frac{k}{\alpha_1} \left( \frac{1 + \gamma}{1 + r} \varepsilon - \frac{1 + \gamma}{1 + r} \varepsilon_{t+1} \right) (1 - \rho) e_{t+1} + \varepsilon_{t+1} - (1 - \rho) \varepsilon_t \]  \hspace{1cm} (17)

The last equation is an ARMA(2,1) model, with the two lags of nondurable goods consumption included in the model.
CHAPTER IV
EMPIRICAL RESULTS

This chapter presents empirical evidence that there is a difference in the estimation results of the described models when they are tested using quarterly versus monthly data. The results presented in previous studies of durables consumption (most of which were obtained using quarterly data) stated that models based upon frictionless REPIH were unsuccessful due to the influence of optimization constraints faced by consumers. Therefore, if the assumption of the presence of constraints is true, the estimation results of models based on the frictionless REPIH obtained with the monthly data should be essentially the same as those obtained using quarterly data. Otherwise, an improvement in performance of the models estimated with monthly data, compared to the quarterly results, would suggest that the influence of optimization constraints may have been overstated. The difference between the performance of quarterly and monthly data, as demonstrated in this thesis, suggests that the influence of optimization constraints might indeed have been overstated.

Another set of empirical results presented in this thesis explores the possibility of change in the degree of influence of the optimization constraints over time. Optimization constraints are associated mainly with liquidity constraints. If capital markets become more complete, allowing consumers to borrow and lend more freely, then the influence of liquidity constraints faced by consumers will be less significant. Thus, if during one period of time the liquidity constraints were more important than during another period, the estimation
results of the models based upon a frictionless REPIH would be different for these two periods. The estimation results obtained from the data representing the time period with a weaker influence of liquidity constraints would be more in line with the results implied by the REPIH. Therefore, if the degree of importance of liquidity constraints has changed, a comparison of the estimation results obtained from two subsets of data representing different time periods would provide information about the direction of the change.

The empirical results demonstrated in this thesis are presented in a form similar to that of Startz (1989). Startz's strategy was to test the significance of increases in explanatory power resulting from adding new variables representing the costs of adjustment and nonseparability. The results are presented in a sequence starting with a basic autoregression model and subsequently including additional variables to allow for various constraints.

Table 1 (page 27) consists of two parts that show the results of the empirical test using monthly and quarterly data. Table 2 (page 33) is also divided into two parts that contain the evidence obtained from the tests of the subsets of the monthly data. The first line in each part of both tables shows the result of the regression of personal consumption expenditures on durables on their lagged value. The second line presents the result of the ARMA (1,1) equation estimation, which is identical to equation (10). As implied by the theory, the MA component should have a negative sign and should be equal to one minus the rate of depreciation of the stock of durables. Comparing the results of AR(1) and ARMA(1,1) models (using a Log-likelihood test) provides information about the importance of the MA component.

The third line of the table presents the estimation results of equation (13). This ARMA (2,1) specification is designed to test the significance of the adjustment costs
represented by the second lag of personal expenditures on durable goods and is a modified form of the equation that includes four lags of disposable personal income. Comparing the estimation results of this model with ARMA(1,1) yields information about the significance of the adjustment costs.

The following line of the table presents the results of a modification of an ARMA (2,1) model, which includes four lags of disposable personal income. The primary interest for obtaining these estimation results is to test (using the Log-likelihood statistic) whether the model can be improved by adding four lags of disposable income.

Next, the estimation results of equation (16) designed to test the hypothesis of nonseparability are presented. This model is an ARMA(1,1) specification modified to include nondurables and services. The results of this model are compared to the results of an ARMA (1,1). The Log-likelihood statistic provides information about whether allowing for nonseparability improves the performance of an ARMA(1,1) model. Then, the estimation results of equation (17) are presented to examine the possibility of the presence of both nonseparability and adjustment costs. The estimation results comparing the performance of monthly versus quarterly data are discussed in Sections C of this chapter. Section D presents the estimation results of two subsets of monthly data.

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8 Since the main idea behind this test is to find out if the models can be improved by including lagged income, the individual coefficients on lagged income variables are not the object of interest and are not reported.
A. DATA

In addition to the problems of liquidity constraints, adjustment costs and separability which can potentially influence the results of the tests of the consumption theory in the REPIH framework, the choice of the data is another concern. As noted by Speight (1990, 122), aggregate economic shocks tend to induce correlated responses in aggregate variables, with a resulting high degree of multicollinearity. While aggregate consumption evidence may be valuable in forecasting macroeconomic fluctuations, it does not provide enough information on the validity of the underlying economic structure.

A specific issue related to data aggregation for consumption theory concerns the data characterization of nondurable consumption expenditures. Speight noticed that the distinction between durable and nondurable goods is mainly associated with their price. Therefore, such long-lasting items as books and clothing fall into the category of nondurable goods. Although the author favored panel data, he noted that a measurement error due to misreporting is potentially serious. The studies by Hall and Mishkin (1982), Runkle (1991), Zeldes (1989) and Bernanke (1984) produced mixed results showing that some consumers behave according to the postulates of the LC/PIH and some do not. Other researchers based their work on the results of quarterly aggregate data. Some researchers (Caballero [1990]) even used annual data for their empirical investigation of the consumption of durable goods.

All empirical results in this thesis cover the period of 1959 through 1997 and are based on the aggregate data from the Bureau of Economic Analysis\(^9\). The data consist of two sets: one containing monthly and the other containing quarterly data on personal

\(^9\) The data was obtained from Saint Louis Federal Reserve Bank Economic Database (http://www.stls.frb.org/ fred/dataindx.html).
expenditures on durable goods, nondurable goods, services and disposable personal income. All data are seasonally adjusted and measured in current dollars. Monthly data extend from January 1959 to April 1997 and have a total of 459 observations. Quarterly data extend from the first quarter of 1959 to the first quarter of 1997 and have a total of 152 observations. Quarterly data are computed as the average of monthly figures.

B. PRELIMINARY EXAMINATION OF THE DATA SETS

As a preliminary test of the theoretical implications, the residuals of the autoregression of personal expenditures on durable goods are examined for the presence of autocorrelation. According to REPIH, the time series behavior of durable goods stock in frictionless economies can be described as a random walk, which also can be presented as an AR(1) process. If the rate of depreciation is small, then the first difference of the stock of durable goods is equal to the purchase of durable goods. Thus, the purchases of durable goods can be expressed as ARMA (1,1) process with a large negative MA coefficient. Therefore, the residuals of the autoregression of personal expenditures on durable goods should exhibit MA(1) characteristics. The first few lags of the residual should show negative autocorrelation, which should appear on the autocorrelation function (ACF) plot.

As one can see from the ACF plots (see appendix), the residuals obtained using quarterly data (Table A.1) exhibit much weaker correlation than the ones from monthly data (Table A.2). The null hypothesis of no autocorrelation at the first lag can be rejected (using Ljung-Box statistic) at only a 10% confidence level for quarterly data, while the results for monthly data yield a much higher significance level for the rejection of the same null. These results suggest that empirical tests using monthly data may yield outcomes that will be more
in line with the REPIH than the results of the test based on quarterly data.

Monthly data for different time periods also produce different results. Tables A.3 and A.4 in the appendix present the residual ACF plots from the first and last 150 observations of the data set containing monthly observations that correspond to the time periods extending from July 1959 to December 1971 and from October 1984 to April 1997, respectively. As one can see from the correlograms, the results obtained from earlier observations are different from the results from the later ones. First, the nature of autocorrelation appears to be different. The earlier data show autocorrelations of the residuals in second, third and fourth lags and the later data show a strong autocorrelation in the first lag. The estimation results obtained with the later data set exhibit stronger ARMA(1,1) characteristics implied by the theory. Second, the probability values of the Ljung-Box statistic indicate a higher significance level at first two lags for the last 150 observations. A comparison of autoregression residuals of these two subsets of monthly data suggests that the empirical results based on the later observations may be more statistically significant and may yield results that support the frictionless REPIH.

C. ESTIMATION RESULTS: QUARTERLY VS. MONTHLY DATA

The results presented in Table 1 show a significant difference in the performance of monthly and quarterly data. If adding an MA term to the univariate model does nothing to improve estimates based on quarterly data, the MA term for monthly data is statistically significant. The log likelihood statistic for the ARMA (1,1) model shows a significant improvement over an AR(1) model estimated with monthly data. The coefficient of the MA term obtained with monthly data is also closer to the expected value implied by the theory.
Table 1. Regression results of personal expenditures on durable goods
(quarterly and monthly data)*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Quarterly data</th>
<th>Monthly data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CD_{t-1}</td>
<td>CD_{t-2}</td>
</tr>
<tr>
<td>AR(1)</td>
<td>1.0140</td>
<td>(0.0022)</td>
</tr>
<tr>
<td>ARMA(1,1)</td>
<td>1.0141</td>
<td>(0.0019)</td>
</tr>
<tr>
<td>Adjustment cost</td>
<td>0.8822</td>
<td>(0.6264)</td>
</tr>
<tr>
<td>4 lags disposable income</td>
<td>0.8421</td>
<td>(0.5751)</td>
</tr>
<tr>
<td>Nonseparability</td>
<td>0.9262</td>
<td>(0.0356)</td>
</tr>
<tr>
<td>4 lags disposable income</td>
<td>0.9179</td>
<td>(0.0377)</td>
</tr>
<tr>
<td>Nonseparability &amp; adjustment cost</td>
<td>0.1129</td>
<td>(1.0650)</td>
</tr>
<tr>
<td>4 lags disposable income</td>
<td>0.8818</td>
<td>(1.2798)</td>
</tr>
</tbody>
</table>

*Numbers in parentheses are standard errors.
The MA coefficient should reflect the depreciation rate and should be equal to \((1-\rho)\), where \(\rho\) is the rate of depreciation. According to estimation results, the quarterly depreciation rate is 87.7% and the monthly depreciation rate is 48.2%. However, both results are out of the range of depreciation rates accepted in the macroeconomic or accounting literature, which is normally believed to be 5% to 20% per annum.

Introduction of the second lag of personal expenditures on durable goods to reflect the presence of adjustment costs improves the models estimated with both monthly and quarterly data (third line in the Table 1). When the model is estimated with monthly data, it does better because, unlike in the estimate with quarterly data, the MA term remains significant. Also, the coefficient on the MA component becomes zero for quarterly estimates but improves for the monthly estimates. After the introduction of the second lag, the implied depreciation rates are 100% for quarterly data and 41.4% for monthly data. One can also see that after including the second lag into the equation estimated with quarterly data, the standard errors of the coefficients increase significantly. These results suggest that either the adjustment costs may be insignificant, or they cannot be captured with quarterly data.

The next set of results parallels similar tests by Hall (1978), Mankiw (1982) and Startz (1989), who compared the performance of the ARMA model modified to include four lags of disposable personal income with the basic ARMA(1,1) specification. The estimation results presented here are similar for both models. Although the coefficient on the AR and MA components do not seem to change significantly, the likelihood ratio test suggests that the models are improved with the inclusion of four lags of disposable personal income.

The following set of estimation results allows for both durables and services to enter the ARMA model for durable goods. The results demonstrate strong support for
nonseparability. Using the likelihood ratio test, the ARMA(1,1) specification can be rejected in favor of equation (13) at better than a 0.005 level of significance for both quarterly and monthly data. Estimation of the model with the quarterly data still does not change the value of the MA component, which is now estimated to be -.08, which corresponds to the quarterly rate of depreciation of 92%. Startz (1989) also pointed out that if the durables consumption variable is entered into the equation, it should cancel out the effect of the MA component. That is because both of them contain information on the innovation in income, and they enter the equation under opposite signs. However, as one can see from Table 1, the MA coefficient estimated with either quarterly or monthly data does not change significantly after the nondurables and services are entered into the equation. Modification of equation (13) that includes four lags of disposable personal income yields a numerically small but statistically significant (based on the log-likelihood statistic) change in the estimated coefficients.

Finally, the last group of results is the estimation of the equation that allows for both nonseparability and adjustment costs. When estimated with the quarterly data, the nonseparability model can be rejected in favor of the nonseparability-adjustment cost model at only a .05 level of significance, according to the likelihood ratio test. The same statistic for the monthly data estimates leads to the rejection of the nonseparability model at better than a 0.005 level of significance. The standard errors of the coefficients obtained with the quarterly data are large and make the AR(2) and MA components statistically insignificant. Similar to previous results, including lagged disposable income in the equation improves the results, suggesting that income can be a valuable predictor. Quarterly results show that including income significantly changes the coefficients on the second lag of durables
expenditures and the MA term compared to the results of the estimates of the restricted (without lagged income) version of the model. The estimation results with the monthly data show that once lagged income is introduced into the equation, the influence of the nondurables component becomes much smaller. These two variables may have canceled each other out, because they both can represent information on innovations in permanent income.

Thus, estimation of the models with the monthly rather than quarterly data yields more significant statistical results, which are also more in line with the theoretical implications of REPIH. The most significant difference between the results of monthly and quarterly data is that the MA component in the ARMA(1,1) specification obtained with monthly estimates is statistically significant and is much closer to the expected value \((1-\rho)\) than the one obtained from quarterly data. Comparing the performance of ARMA(1,1) one can see that the results obtained with monthly data are more in line with the implications of frictionless REPIH than the results of quarterly data. If the assumption that models based on frictionless REPIH cannot perform well due to distortion caused by liquidity constraints were true, then there would not be a significant difference between the results obtained with quarterly and monthly data. The results presented here suggest that the role of liquidity constraints may have been overstated. However, as suggested by the estimation results of the models that included lagged income the influence of liquidity constraints may be small but is still statistically significant.

The data for durable goods are consistent with the nonseparability hypothesis for estimates based on both quarterly and monthly observations. The empirical results also show the presence of the adjustment costs.

This section presents the empirical results of the estimation conducted on two subsets of the monthly data to examine if the influence of the liquidity constraints has changed over time. If the degree of importance of liquidity constraints has changed, a comparison of the estimation results obtained from two subsets of data representing different time periods would provide information about the direction of the change. Both subsets contain 150 observations and extend from July 1959 to December 1971 and from October 1984 to April 1997 (henceforth they will be referred to as the “first” and “second” subset respectively). The estimation procedure is the same as the one used previously to compare the performance of quarterly versus monthly data. The estimation results are compared to find out which data set yields estimates that are more in line with frictionless REPIH. Empirical results are presented in Table 2.

The first group of results compares the performance of the AR(1) and ARMA(1,1) models. The estimates obtained with the second subset provide enough evidence to reject an AR(1) in favor of an ARMA(1,1) specification. For the first subset, the likelihood ratio test does not yield a value that would allow one to make the same decision even at a 0.1 significance level. These results show that the stochastic behavior of personal expenditures on durable goods for the period of 1984-1997 can be well described by an ARMA(1,1) process. The data subset representing the period of 1959-1971 produces results showing that personal expenditures on durable goods does not follow the implied theoretical stochastic process. The results obtained with the second data set are more in line with implications of frictionless REPIH. This may have resulted from the decreased influence of liquidity...
constraints.

Estimating the equation allowing for adjustment costs yields similar results for both subsets. The ARMA(1,1) specification could not be rejected for the first or for the second subsets at any acceptable level of significance in favor of the model including the second lag of durables expenditures.

Including four lags of disposable personal income produces mixed results. For the first subset, the presence of lagged income did not improve the results significantly. The estimate of the second subset, however, showed that income has statistically significant predicting power. The restricted (without lagged income) specification can be rejected at better than a 0.005 level of significance.

The test of nonseparability is also more supported by the estimates obtained from the second rather than the first subset. The ARMA specification can be rejected in favor of the equation allowing for nonseparability at a 0.025 significance level for the first subset, when the same statistic for the second subset has a 0.005 significance level. Contrary to the results of the comparison of quarterly and monthly data, the coefficients on the nondurables and service variables do not differ significantly between the subsets. Modifying the nonseparability equation specification to include four lags of disposable income does not improve the estimates of the first subset but, according to the log-likelihood statistic, but does for the second one.

The last set of estimation results presents a test of the composite nonseparability-adjustment costs hypothesis. The results show that the nonseparability model cannot be rejected in favor of the composite specification for the second subset. The results for the first subset show that the nonseparability model can be rejected at a 0.05 level of significance.
Table 2. Regression results of personal expenditures on durable goods
(subsets of the monthly data)*

<table>
<thead>
<tr>
<th>Variable Model</th>
<th>$CD_{t1}$</th>
<th>$CD_{t2}$</th>
<th>MA(1)</th>
<th>$c_{t1}$</th>
<th>$c_{t2}$</th>
<th>$S_{t1}$</th>
<th>$S_{t2}$</th>
<th>Log-likelihood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monthly data (observations 1-150) July 1959 - December 1971</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AR(1)</td>
<td>1.0056</td>
<td></td>
<td>0.1201</td>
<td>0.0244</td>
<td>0.2211</td>
<td>0.0417</td>
<td>-295.47</td>
<td></td>
</tr>
<tr>
<td>ARMA(1,1)</td>
<td>1.0056</td>
<td>0.2047</td>
<td>0.3181</td>
<td>0.0244</td>
<td>0.2211</td>
<td>0.0417</td>
<td>-294.62</td>
<td></td>
</tr>
<tr>
<td>Adjustment cost</td>
<td>0.7876</td>
<td>-0.00609</td>
<td>0.2011</td>
<td>0.0244</td>
<td>0.2211</td>
<td>0.0417</td>
<td>-293.83</td>
<td></td>
</tr>
<tr>
<td>4 lags disposable income</td>
<td>0.8590</td>
<td>-0.0609</td>
<td>0.2011</td>
<td>0.0244</td>
<td>0.2211</td>
<td>0.0417</td>
<td>-285.25</td>
<td></td>
</tr>
<tr>
<td>Nonseparability</td>
<td>0.8307</td>
<td>0.1922</td>
<td>0.0280</td>
<td>0.2211</td>
<td>0.0417</td>
<td>-287.90</td>
<td></td>
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</tr>
<tr>
<td>4 lags disposable income</td>
<td>0.8195</td>
<td>0.2514</td>
<td>0.0271</td>
<td>0.2470</td>
<td>0.0115</td>
<td>-286.22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nonseparability &amp; adjustment cost</td>
<td>0.8564</td>
<td>-0.0207</td>
<td>0.1683</td>
<td>0.2470</td>
<td>0.0115</td>
<td>-285.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 lags disposable income</td>
<td>0.8445</td>
<td>-0.0159</td>
<td>0.2315</td>
<td>0.2756</td>
<td>0.0323</td>
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</tr>
<tr>
<td>AR(1)</td>
<td>1.0039</td>
<td></td>
<td>-0.6076</td>
<td>0.0271</td>
<td>0.0383</td>
<td>0.2470</td>
<td>-591.68</td>
<td></td>
</tr>
<tr>
<td>ARMA(1,1)</td>
<td>1.0049</td>
<td>-0.6076</td>
<td>0.1683</td>
<td>0.0240</td>
<td>0.2275</td>
<td>0.0445</td>
<td>-591.50</td>
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</tr>
<tr>
<td>Adjustment cost</td>
<td>1.0766</td>
<td>-0.0726</td>
<td>-0.6476</td>
<td>0.0240</td>
<td>0.2275</td>
<td>0.0445</td>
<td>-591.50</td>
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</tr>
<tr>
<td>4 lags disposable income</td>
<td>1.0761</td>
<td>-0.0949</td>
<td>-0.6326</td>
<td>0.0240</td>
<td>0.2275</td>
<td>0.0445</td>
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</tr>
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<td>Nonseparability</td>
<td>0.9820</td>
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<td>0.0128</td>
<td>0.1242</td>
<td>-0.0179</td>
<td>0.1550</td>
<td>-583.83</td>
<td></td>
</tr>
<tr>
<td>4 lags disposable income</td>
<td>0.9797</td>
<td>-0.5756</td>
<td>0.0115</td>
<td>0.1583</td>
<td>-0.0103</td>
<td>0.1532</td>
<td>-573.95</td>
<td></td>
</tr>
<tr>
<td>Nonseparability &amp; adjustment cost</td>
<td>1.0789</td>
<td>-0.0938</td>
<td>-0.6444</td>
<td>0.1583</td>
<td>-0.0103</td>
<td>0.1532</td>
<td>-583.58</td>
<td></td>
</tr>
<tr>
<td>4 lags disposable income</td>
<td>1.1039</td>
<td>-0.1189</td>
<td>-0.6646</td>
<td>0.1240</td>
<td>-0.0101</td>
<td>0.1081</td>
<td>-573.55</td>
<td></td>
</tr>
</tbody>
</table>

*Numbers in parentheses are standard errors.
To summarize, the estimates obtained from the second subset yield results that provide more empirical support for the theoretical implications of the models based on frictionless REPIH. The moving average component has the anticipated sign and is statistically significant when estimated using the second subset. These results suggest that the influence of liquidity constraints may have declined over time, since the stochastic behavior of later data fits frictionless REPIH better than earlier data.

The evidence for the presence of adjustment costs was not found in either of the subsets, except when the first subset was estimated allowing for both nonseparability and adjustment costs. The nonseparability hypothesis is supported by the estimates of both subsets of the data, with the stronger evidence obtained from the second subset. Including four lags of disposable income did not yield any significant results for the estimates of the first subset but did for the second.

To sum up the empirical results presented in last two sections, one can conclude that monthly data provides more support for the theoretical implications of REPIH. The most significant difference between the results of monthly and quarterly data is that the results obtained with monthly data are more in line with frictionless REPIH than the results from quarterly data. If the assumption that the models based on frictionless REPIH cannot perform well due to the impact of liquidity constraints were true, then there would not be a significant difference between the results obtained with quarterly and monthly data. The results presented in this thesis show that the role of liquidity constraints may have been overstated, because the difference between the performance of monthly and quarterly data exists. The estimates obtained using both monthly and quarterly data support the nonseparability hypothesis. They also provide evidence for the existence of adjustment
costs. Including lagged income into the estimated equations also can be statistically justified.

The results obtained from comparing two data sets representing the periods of 1959.07 - 1971.12 and 1984.10 -1997.04, respectively, suggest that the influence of liquidity constraints may have declined over time, since the stochastic behavior of the later data fits the frictionless REPIH better than does the earlier data. Other empirical results are similar to the results obtained with the undivided monthly data set - the estimates support the hypotheses of nonseparability and adjustment costs. Only the first data set did not provide strong statistical evidence supporting the existence of adjustment costs. Also, compared to other test estimates, the results obtained from the subset representing earlier data show a much weaker response to adding the lagged disposable personal income variable.
CHAPTER V
CONCLUSIONS

The author of this thesis re-examines the tests conducted by other researchers who analyzed the time-series behavior of the consumption of durable goods in the REPIH framework. The models proposed by Mankiw(1982) and Startz(1989) are estimated using monthly and quarterly data, and the results are compared. One of the key results presented in this thesis is that monthly data seem to fit models better than quarterly data. The importance of these results is that they suggest that the role of the liquidity constraints may have been overstated in previous research. If the assumption that the models based on the frictionless REPIH do not perform well due to the distorting influence of liquidity constraints were true, then there should not be significant differences between the results obtained using monthly versus quarterly data. The results presented here show that such differences exist.

Including a lagged income variable improves the performance (based on the likelihood ratio test) of the models estimated with both quarterly and monthly data, even after allowing for nonseparability. Even if the consumption of nondurables contains some information relevant for the estimation of real income, the model still can be improved by including income, possibly due to the influence of liquidity constraints. Thus, although the role of liquidity constraints may be small it is still statistically significant.

In the absence of adjustment costs, the REPIH predicts that purchases of durable goods should be approximated by an ARMA(1,1) process. The difference in performance of quarterly and monthly data can be observed from the results of the ARMA(1,1) specification.
of expenditures on durable goods. Although the coefficients on the moving average term have a correct sign when estimated with both quarterly and monthly data, the value obtained from the monthly data is closer to the one implied by theory.

Estimating the equation allowing for nonseparability of utility derived from durables, nondurables and services yields similar results for both quarterly and monthly data, rejecting the null hypothesis of separability.

The null hypothesis of no adjustment costs also can be rejected for both quarterly and monthly estimates. Although allowing for adjustment costs does not change the coefficients on the AR and MA components when estimated with monthly data, the results obtained with quarterly data show a significant increase in standard errors of the coefficients, which lessens the predictive power of the model.

By dividing monthly data into subsets, it can be seen that the stochastic behavior of the personal expenditures on durable goods may have changed over time. From the results obtained with the subset covering the earlier period, one can see that the MA component from an ARMA (1,1) specification has an unexpected sign. The estimation results based on later observations seem to be more in line with the implications of frictionless REPIH than the results obtained using earlier observations. These results may imply that the influence of liquidity constraints has decreased over time, and a larger part of consumption can be approximated by a frictionless REPIH.

The estimation results obtained from the two subsets of the data are mainly the same as for the whole monthly data set. The only exception is that the null hypothesis of no adjustment costs could not be rejected by the results of either subset. The results obtained from examining the models with the data covering the years 1959-1971 are less conclusive,
due to smaller statistical significance of the estimates. Another interesting result, which appears in the estimates of both subsets, is that after allowing for nonseparability, including income into the equation does not produce a significant improvement in the performance of the models.

Thus, comparing performance of monthly and quarterly data, one can say that the empirical results obtained with monthly data provide more support for the type of REPIH tests presented in this thesis. Although, the tests discussed here are usually deemed to be statistically weak, the use of the monthly data for the test of consumption models may deserve further consideration.
## APPENDIX

Table A.1 Autocorrelation function plot of autoregression residual of personal expenditures on durable goods (Quarterly data. 152 observations)

<table>
<thead>
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