TESTING RATIONAL EXPECTATIONS BEHAVIOR IN CANADIAN AGGREGATE CONSUMPTION

by

Chae Kon Chong

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A thesis submitted to the Faculty of Graduate Studies of
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DOCTOR OF PHILOSOPHY

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ABSTRACT

Consumer behavior has been one of the most important areas of research in economics. By applying the rational expectations approach to consumer behavior, Hall argues that the life cycle-permanent income hypothesis implies that consumption follows a random walk with drift. The random walk model of consumption indicates that the best forecast of future consumption is today's level of consumption adjusted for trend. Since this argument has a great influence on designing macro policies, there has been much research to test the hypothesis. However, in spite of the large volume of research to test the hypothesis during the past decade, the research is inconclusive.

The purpose of this study is to shed some light on the controversy in order to understand the Canadian aggregate consumption behavior. To accomplish this, the findings from recent research on this subject are reviewed and the random walk hypothesis is reexamined using Canadian aggregate data. Since the random walk is a special case of nonstationary time series, the recent developments on nonstationary time series analysis, such as Box-Jenkins' ARIMA model analysis in time domain and spectral analysis in frequency domain, are used to test the theory in this thesis. Specifically,

this thesis tests the theory by estimating a combined model of the random walk hypothesis and the Keynesian consumption function using transitory income calculated by all available detrending procedures. The detrending procedures applied here are traditional linear detrending, differencing, detrending by state space model, and detrending by spectral analysis. For estimation of the combined model in this study, the two stage least squares method is applied to avoid possible simultaneous equation bias. The estimated results from this model are not subject to the spurious regression problem since only differenced series are used. This thesis also tests the random walk hypothesis by estimating this model based on the specification of the error correcting model of consumption.

The test results, using Canadian data, support the random walk hypothesis of consumption, indicating that optimal decisions of Canadian consumers induce a stochastic trend in the consumption series. The test results of this thesis will help policy makers understand consumers behavior when they design economic policies which affect consumers' decision making on expenditures.

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I dedicate this study to Mija and our children, Eugene and Lee, for their understanding and love.

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Chapter I

INTRODUCTION

1.1 Statement of the Problem

The study of the relationship between consumer spending and income has been considered one of the most important topics in macroeconomics. Keynesian macroeconomists argue that a direct relationship exists between consumption and the current level of income. However, the Keynesian consumption function failed to explain the stylized fact: over short periods of time, consumption changes less than the amount by which income fluctuates; over long periods of time, real GNP and consumption expenditures grow at about the same rate so that consumption expenditures maintain, on the average, roughly a two-thirds share of the GNP.[1] Furthermore, economists wished to find theoretical bases for the basic postulates of Keynes and have provided a micro foundation for macroeconomics. Consumption functions can be derived from the basic microeconomic principle that consumers behave to maximize utility subject to the constraint of lifetime available resources. For these reasons, Franco Modigliani's life-cycle hypothesis (1954, 1963) and Milton Friedman's permanent income hypothesis

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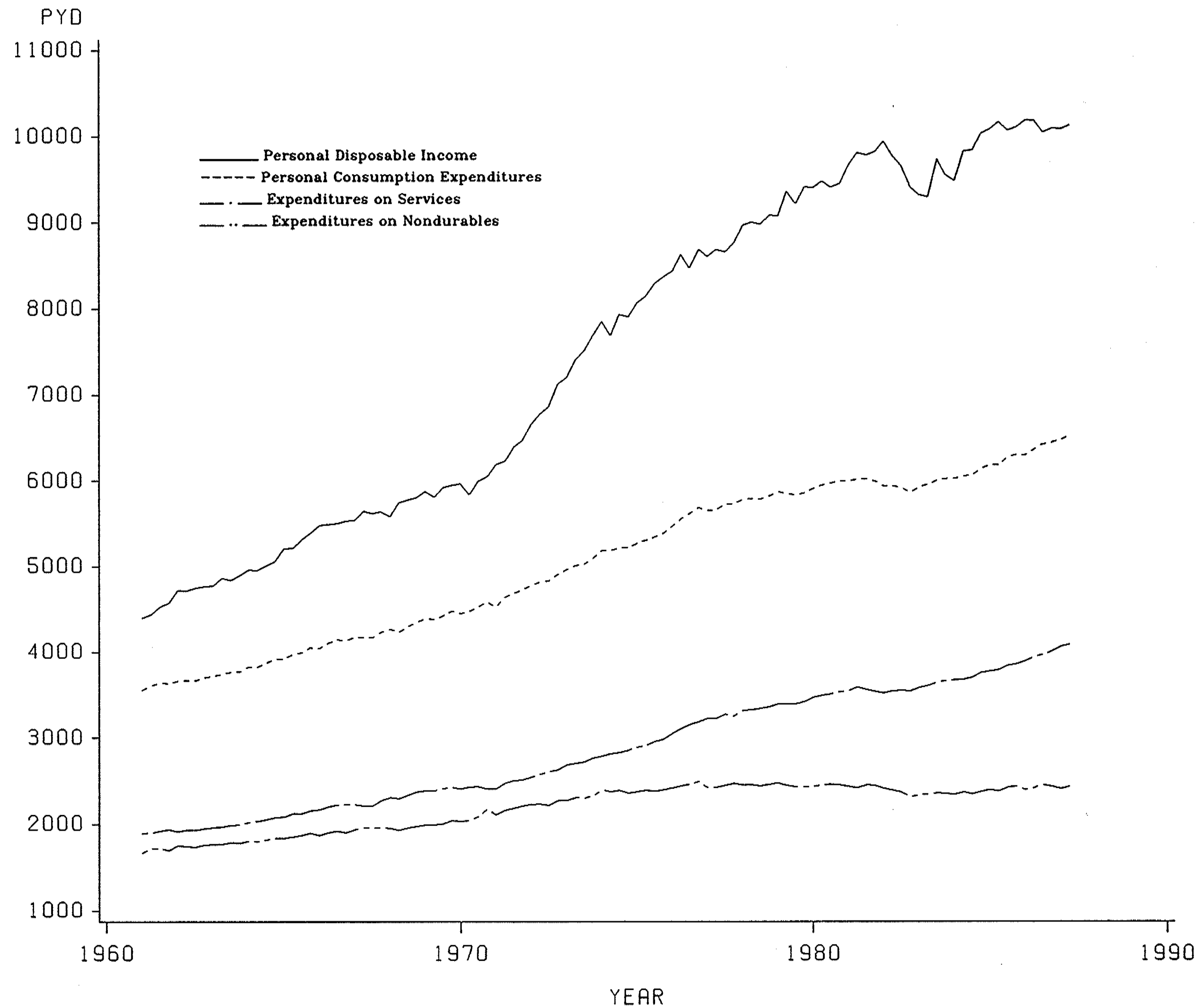
[1] This stylized fact is well shown in figure 1.1. All figures in this thesis are drawn by the SAS/GRAPH system.

Figure 1.1: Consumption and Income



(1957) were widely accepted as the theoretical derivation and the econometric form of the aggregate consumption function. For example, consumption was regressed on a distributed lag of current and past income. Muth (1960) showed that a geometric distributed lag was optimal under rational expectations with a certain special stochastic process for income.

The practice of estimating the aggregate consumption function in the above way has been challenged since the emergence of rational expectations literature in early of 1970s. Lucas (1976) criticized that the consumption function specified by the permanent income hypothesis asserts a stable structural relation between observed income and permanent income, but the relationship may be altered by the change in stochastic policy and we can not rely on policy analysis based on that consumption function.

To solve the Lucas' critique and the exogeneity problem of income in consumption function, Hall (1978) derived the Euler equation for the implication of aggregate consumption behavior under the life cycle-permanent income hypothesis with rational expectations. By assuming a quadratic utility function and a constant real interest rate, Hall showed that the Euler equation characterizes that consumption follows a random walk with drift. Hall reported that the postwar U.S. quarterly seasonally adjusted data supports the model. However, Flavin's (1981) test results, which used the same data, did not support the model. The difference between Hall's and Flavin's test was that the latter included more lagged values of income and used detrended data derived by regressing the natural logarithms of consumption and income on the time variable.

Further testing on the Hall's random walk of consumption model has followed, but no clear conclusion has been derived from the testing of the theory, although more research reported the rejection of the pure life cycle-permanent income hypothesis under rational expectations. At the same time, many suggestions have been provided to save the life cycle-permanent income hypothesis under rational expectations. They argued that the excess sensitivity of consumption to current income may be caused by one of the following: inappropriate detrending procedure for nonstationary income, existence of liquidity-constrained individuals, use of a different data set, causality from consumption to income, nonseparability of utility function, or misspecification of model.

The controversy surrounding the testing of the random walk hypothesis has not been settled yet even if there has been a large volume of research on the topic. Nevertheless, this issue is very important in analyzing the effectiveness of stabilization policy and in discriminating new classical theory against traditional Keynesian theory.

1.2 Objectives of the Study

The stochastic relationship between consumer expenditure and income is an important issue in macro policy analysis. The effect of change in macro policy on income can be measured through the multiplier, which is determined by the marginal propensity to consume out of disposable income. A simple Keynesian view of consumers believes the stability of the multiplier effect, since consumption is a direct function of income in the Keynesian model. In this view, the income changes caused by the macro policy tool have powerful effects on countercyclical stabilization since the income changes cause change in the large component of aggregate demand (consumption).

In contrast, the life cycle-permanent income hypothesis of consumption considers that consumers revise their optimal consumption plan only when they perceive income changes as permanent rather than temporary. This alternative view sees that the income changes by anticipated stochastic policy have no role as a countercyclical stabilization tool, especially under rational expectations. Thus, the effectiveness of a policy depends on how sensitively consumers respond to changes in income.[2] If the life cycle-permanent income hypothesis explains consumer behavior better than the Keynesian model, policy makers must know how consumers perceive the permanence of income variations in

[2] Note that liquidity-constrained consumers show an excessively sensitive response to change in income.

order to predict the effect of policy.

Therefore, the validity or invalidity of the life cycle-permanent income hypothesis under rational expectations has very important implications for the design of macro economic stabilization policies. If consumers behave following traditional Keynesian theory, the government can affect aggregate demand by a transitory income change, for example via a transitory change in taxes. On the other hand, if consumers behave according to the life cycle-permanent income hypothesis under rational expectations, the transitory change in fiscal policy has only a negligible effect on aggregate demand. Although the practical importance of discriminating one theory from the other is enormous, the empirical test results by a large volume of research have not achieved a unanimous conclusion yet. This fact provides the motivation for this study.

The purpose of this study is to shed some light on the issue using Canadian aggregate data. Specifically the Hall's random walk model of consumption is tested against the Keynesian consumption function in a nested model. Considering that most empirical tests have been done with U.S. data, the formal test on the theory using Canadian data provides not only another test result for different data set, but also a profound understanding of Canadian aggregate consumption behavior. By testing the theory, we can find whether Canadian consumers are forward looking and what proportion of Canadian, if any, are liquidity-constrained or myopic consumers. The results on this research provides important implications for future Canadian government policies, such as social security, fiscal, and monetary policy, which affect consumers' decision making on expenditures.

1.3 Scope of the Study

In this study, the twin disciplines of rational expectations and cleared markets will be embodied to analyze the stochastic relationship of consumption to income. This general equilibrium approach avoids internal inconsistencies and provides a better understanding of the real world as it has already shown its successful performance in microeconomics. By building macro models based on micro foundations, we can acquire insights about the laws of the motion of economic aggregates. By solving the consumer's intertemporal optimization problem with the dynamic programming method,[3] the optimal control rule for consumers, which reflects an individual's intertemporal preferences and the expectations held by consumers, can be easily derived.

[3] Dynamic programming is a recursive method for solving a special class of constrained-optimum problems applying the "principle of optimality". The principle of optimality states that an optimal rule has the property that, whatever the initial state and decision are, the remaining decisions must constitute an optimal rule with regard to the state resulting from the first decision. See Bellman (1957) for the details of the method.

For the problem of a representative consumer who seeks to maximize expected lifetime utility subject to lifetime income stream constraint, Hall (1978) derived the Euler equation solution.[4] The Euler equation shows the equality of the marginal rate of substitution between consumption this year and consumption next year to the present discount cost of a unit of future consumption. By assuming a quadratic utility function and constant real interest rates, Hall argued that consumption obeys a random walk, apart from trend: $\Delta C(t) = \mu + \nu(t)$,[5] where μ is drift and $\nu(t)$ is a random variable whose expectation at time t is zero.

The random walk model of consumption is the model used to test the life cycle-permanent income hypothesis under rational expectations. In order to make the general equilibrium model tractable enough for macroeconomic models, the random walk model of consumption was derived by imposing restrictions on preferences, technologies, and endowments patterns in a particular way. Since a variety of such restrictions can be made, it is questionable whether the theory can be tested based on estimated results of the model derived with specific assumptions. However, we can interpret any rejection of the model as a failure of the

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[4] For mathematical derivation of the Euler equation, see section 2.2 or see Hall (1978) and Sargent (1987) for the details.

[5] Flavin (1981) elaborated this model and showed that $\Delta C(t) = \mu + a\epsilon(t) + \eta(t)$, where $\epsilon(t)$ is the innovation between time t-1 and t period in consumers' assessment of permanent income and $\eta(t)$ is consumption disturbance.

underlying theory, although only a particular simple version of the dynamic optimization problem can be tested. The reason for this is that the utility of a theory as a framework for understanding economy will be called into question if the theory fails when expressed simply.

Probably the best way to test the theory is by tracing sample households' consumption behavior over a sufficient time period as in the Hall and Mishkin (1982) and Hayashi (1985) studies. However, testing the theory by this kind of research is not easy since we face practical difficulties to get such micro data. One advantage of using the random walk model of consumption is that it enables us to test the theory using aggregate time series data, which can be easily obtained. Furthermore, recent advancements in time series analysis, such as ARIMA model analysis in time domain and spectral analysis in frequency domain, provide very useful techniques for analyzing the random walk model. To summarize, this study tests the life cycle-permanent income hypothesis under rational expectations by estimating the random walk model of consumption using Canadian aggregate time series data.

1.4 Organization of the Study

The organization of this thesis is as follows. Chapter II reviews recent research on the subject. First, it reviews the Lucas' critique on the pure life cycle-permanent income hypothesis and then shows Hall's random walk model of consumption as a solution to the critique. This chapter also discusses the other researchers' empirical test results and some explanations for the rejection of the life cycle-permanent income hypothesis under rational expectations.

Chapter III reports the Canadian evidence on the random walk model of consumption. Since the modern rejections of life cycle-permanent income hypothesis began with Flavin's (1981) findings, my starting point is to examine her argument carefully. The puzzle is why Flavin reported very strong rejection using formally equivalent to Hall's test. Following the arguments of Nelson and Kang (1981), Mankiw and Shapiro (1985), and Nelson (1987), this chapter investigates whether, in fact, Flavin's rejection of the theory simply reflects an appropriate sensitivity of consumption to current income along with the effects of an inappropriate detrending procedure. Recently Dickey and Fuller (1981) and Schwert (1987) found that most macroeconomic variables show nonstationary behavior. If income process is a random walk, the coefficient of lagged income in Flavin's (1981) paper can not be identified. Furthermore, the significance of the coefficient is attributed to the spurious regression problem of Nelson and Kang (1981), since Flavin applied trend-stationary processes instead of difference-stationary processes for detrending the data. This issue is discussed in the chapter. Finally, an alternative test on rationality of consumers behavior is also performed.

Chapter IV develops a nested model to avoid the spurious regression problem involved in testing the theory. Following the suggestion of Davidson and MacKinnon (1981), the random walk hypothesis and Keynesian consumption function are combined into a single model to test the theory, and the model is estimated by a two stage least squares method. By estimating the model based on different detrending procedures, it is possible to achieve a conclusion which is not sensitive to detrending procedures.

Chapter V reviews a cointegrating and error correcting model of consumption as an atheoretical approach to aggregate consumption behavior and shows that the random walk model of consumption encompasses the atheoretical model. The theory is also tested by estimating the model of chapter 4 based on the specification of the error correcting model.

Chapter VI presents the thesis' summary and conclusion as well as some suggestions for further study.

Chapter II

REVIEW OF THE LITERATURE

2.1 Lucas Critique on the Pure Life Cycle-Permanent Income Hypothesis

According to the pure life cycle-permanent income hypothesis,[6] consumers plan to spend an appropriate fraction of the estimate of their entire future lifetime's income stream. In practice, the expected future income in the hypothesis has been estimated by relating past and current observed income in the form of a geometric distributed lag. Specifically, as Friedman (1963) proposed, Friedman's permanent income is taken to be a weighted average of past and present income, assumed to decline geometrically backwards in time, if the weight used in average past incomes is the same as the discount factor used in averaging future incomes.

What Lucas (1976) criticized about this practice is that consumption based on the estimate of future income by the process of past and current incomes may not be affected by the change in stochastic policy, whereas the variance of consumption is affected. Since change in the policy

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[6] Friedman's permanent income is considered to be the same as the annuity value of total lifetime incomes in Modigliani model, so the two hypotheses are combined.

increases the variance of transitory income and lowers the weight used in averaging past income,[7] the correct estimate of expected future income, including stochastic policy effect, requires the revision of the weight used in averaging past incomes. Failure to do so results in prediction error of consumption with response to policy change. Thus, the relationship between consumption and income, shown by Friedman's permanent income hypothesis, should be changed whenever the stochastic policy changes the estimate of expectations of future income.

The Lucas' critique means that the parameters of the consumption function are related to the parameters of the permanent income generating function. Since the reduced-form equations are derived from structural equations, the parameters of reduced-form equations will change if the parameters of structural equations change. In fact, the parameters of the consumption function of Friedman's permanent income hypothesis are functions of the parameters of the permanent income generating function.

Another problem with the estimation of the life cycle-permanent income hypothesis consumption function is the "exogeneity" of the income variable. When it is not clear whether income causes consumption or vice versa, there is no reason to specify that consumption is a function of past and

[7] According to Muth's (1960) formula, the weight used in averaging past incomes depends negatively on the variance of transitory income.

current income.[8] Sargent (1978) showed an ambiguous result that, in the Granger (1969) "causality" sense,[9] income is exogenous with respect to consumption for the seasonally adjusted postwar U.S. data, and income is not exogenous with respect to consumption for the seasonally unadjusted postwar U.S. data.

Application of the simultaneous-equations econometric techniques may be suggested for estimation of consumption function, but it is not easy to find instrument variables which have close relationships with income and yet are exogenous in respect to consumption at the same time.

Hall (1978) developed an alternative econometric approach to the study of the life cycle-permanent income hypothesis consumption function where none of the right-hand variables is exogenous.

About the same time, Sargent (1978) also developed, by imposing rational expectations on time-series models, another econometric estimation technique for Friedman's consumption function under rational expectations for the cases of income as exogenous variable and income as endogenous variable.

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[8] Haavelmo (1943) and Friedman and Becker (1957) showed that consumption function would be distorted if income was treated as exogenous.

[9] According to Granger's (1969) definition, a process X is said to cause a process Y if, given past values of Y, past values of X help predict future Y.

2.2 The Hall's Random Walk Model of Consumption

Lucas and Sargent (1981) referred to models of optimizing agents as "rational expectations models".[10] Application of rational expectations to consumption function means that consumers make intertemporal optimizing decisions and maximize the expected future discounted utility function subject to the expected discounted lifetime income. Recently, following pioneering work of Hall (1978), many researchers have begun to emphasize explicit modelling of intertemporal optimization[11] in consumption function to solve Lucas (1976) critique.

To review Hall's (1978) results, we begin by setting up the following intertemporal optimization problem. The consumer maximizes

$$E(t) \sum_{t=0}^{T} (1 + \delta)^{-t} U[C(t)] \qquad (2.1)$$

subject to the intertemporal budget constraint

$$A(t) = \sum_{t=0}^{T} (1 + r)^{-t} [C(t) - Y(t)] \qquad (2.2)$$

---

[10] Historically speaking, the original definition of rational expectations is from Muth (1961). He defined expectations to be "rational" if expectations of individuals tend to be distributed, for the same information set, about the prediction of the theory.

[11] Intertemporal optimizing behavior has also been applied to investment function and asset market analysis by many researchers.

where $E(t)$ = conditional expectation at time period t

δ = rate of time preference

T = length of lifetime

U = strictly concave utility function

C = consumption

A = amount of asset

r = interest rate

Y = labor income

The solution for the above maximization problem by dynamic programming will be the following Euler equation

$$E(t)U'[C(t+1)] = \left(\frac{1 + \delta}{1 + r} \right) U'[C(t)] \qquad (2.3)$$

$$\text{for all } t=0,\ldots,T-1$$

The Euler equation shows that the conditional expectation of future marginal utility of consumption is a function of today's level of consumption alone. If the utility function for the consumer is quadratic and the interest rate equals the rate of time preference, then consumption itself obeys a random walk with a trend (Hall 1978, p.975 and 1987, p.6-7).

$$C(t) = \lambda C(t-1) + \epsilon(t) \qquad (2.4)$$

where $\lambda=[(1 + \delta)/(1 + r)]$ and equals one. This Hall's striking result of the "random walk" hypothesis came from replacing the assumption of an ad hoc nonoptimal distributed lag of adaptive expectations with the assumption of rational expectations in the expectation formation of future incomes. Under rational expectations, all other variables are irrelevant in predicting the level of consumption, since the value of previous consumption incorporated all information about the consumer at that time. Therefore, lagged values of actual income have no explanatory power once one lagged consumption variable is included. The "random walk" hypothesis can be tested without any assumptions about exogeneity by checking whether only consumption lagged one period has a nonzero coefficient in the regression of the consumption function and all other lagged variables do not.

To find empirical evidence, Hall (1978) examined seasonally adjusted quarterly U.S. data on the consumption of non-durable goods and services for the period 1948 to 1977. First, he regressed consumption on its own past values, and reported

$$\begin{aligned} C(t) = \underset{(8.3)}{8.2} + \underset{(0.092)}{1.130}\, C(t-1) - \underset{(0.142)}{0.040}\, C(t-2) + \underset{(0.142)}{0.030}\, C(t-3) \\ - \underset{(0.093)}{0.113}\, C(t-4) \qquad (2.5) \end{aligned}$$

$$R^2 = 0.9988 \quad SER = 14.5 \quad DW = 1.96$$

where the standard error of coefficients is given in parentheses. In the above equation, only the coefficient of C(t-1) is statistically significant. It means that consumption does not have a definite cyclical pattern and only the first lagged value of consumption helps predict current consumption.

Secondly, Hall examined the following equation to assess whether information from lagged period levels of disposable income, Y(t-i), helps explain current consumption.

$$C(t) = -\underset{(11)}{25} + \underset{(.054)}{1.113}\, C(t-1) + \sum_{i=1}^{12} \beta(i) Y(t-i), \quad (2.6)$$

$$\sum_{i=1}^{12} \beta(i) = \underset{(0.040)}{0.077}$$

$R^2 = 0.9988$ SER = 14.6 DW = 1.92

The result of an F-test for above equation tells us that 12-quarter Almon lag cannot compete with one lagged consumption as a predictor for current consumption. From these empirical findings, Hall concluded that disposable income has no predictive power in the regression of consumption on its own lagged value and lagged disposable income. Therefore, the "random walk" hypothesis of consumption was shown as a surprisingly good approximation.[12]

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[12] Hall (1978) discovered that lagged market value of corporate stock as a measure of wealth had a statistically significant coefficient in the consumption function, but its additional contribution to the explanation of consumption was quite minor.

Although Hall's test supported the life cycle-permanent income hypothesis with rational expectations, his consumption function was not completed, in the sense that no equation for permanent income has been developed in his model. The policy implication of his result is that policy affects consumption only through changes in permanent income. However, we cannot predict the policy effect on consumption without having an explicit definition of permanent income. The next section will review some more tests on life cycle-permanent income hypothesis models with rational expectations, in which permanent income is explicitly defined.

2.3 Tests of Life Cycle-Permanent Income Hypothesis under Rational Expectations

2.3.1 Introduction

Sargent (1978) defined permanent income as the average discounted value of expected current and future disposable income,[13] and proposed the following simultaneous-equations system.

$$C(t) = BYP(t) + u(t), \quad B>0 \qquad (2.7)$$

$$YP(t) = (1 - a) \sum_{i=0}^{\infty} a^{i} E(t)Y(t+i), \quad 0<a<1 \qquad (2.8)$$

[13] This definition of permanent income is originated from Muth (1960).

where YP is permanent income. He estimated the consumption function by assuming that consumption and disposable income are generated by a bivariate autoregressive process. A likelihood ratio test is used to test the restrictions implied by the permanent income hypothesis with rational expectations. The result of Sargent's test was that consumption was related only to contemporaneous income.

This Sargent's result contradicts Hall's random walk hypothesis. To reconcile the conflicting empirical evidence of Hall's and Sargent's papers, Flavin (1981) developed a structural model of consumption on which she believed Hall's reduced form was based. As Flavin has shown, Sargent's definition of permanent income cannot be derived from intertemporal optimizing consumer's behavior, since future disposable income includes returns from savings which should not affect current consumption decisions. Therefore, she defined permanent income as the annuity value of net worth.

$$YP(t) = r[A(t) + \sum_{i=0}^{\infty} \{1/(1 + r)\}^{i+1} E(t)Y(t+i)] \tag{2.9}$$

Flavin showed that application of this particular definition of permanent income to Sargent's formulation of restrictions led to the same parameter restrictions tested by Hall. This means that the different results of Sargent came from his incorrect definition of permanent income.

Next, she tested the validity of Hall's random walk hypothesis. An autoregressive-moving average model was specified for income series to quantify the revision in permanent income induced by the innovation in the current income process. She elaborated Hall's random walk model of consumption as follows:

$$\Delta C(t) = \mu + \nu(t), \qquad (2.10)$$
$$\nu(t) \equiv \alpha\epsilon(t) + \eta(t)$$

where $\epsilon(t)$ is the innovation between time t-1 and t period in consumers' assessment of permanent income and $\eta(t)$ is consumption disturbance. To test the theory she added the change in income $\Delta Y(t)$ as a regressor for the above equation.

$$\Delta C(t) = \mu + \beta\Delta Y(t) + \nu(t) \qquad (2.11)$$

If the coefficient of the change in income, β, is significant, the theory is rejected. This indicates that consumption is excessively sensitive to current income, since innovations in income which provide new information about future income and signal changes in permanent incomes is already included in the equation and change in income $\Delta Y(t)$ should not have any explanatory power to change in consumption. For the empirical test, using multivariate least squares method, she regressed income series by AR(8) model and regressed change in consumption on change in current income and changes in seven lagged incomes, and found that the coefficient of $\Delta Y(t)$ is 0.355 and is significant for the detrended U.S. data by the linear detrending procedure. From these test results, she concluded that consumption is excessively sensitive to current income.

This excess sensitivity of consumption to current income does not necessarily mean that consumers are "myopic" or non-rational. Recently, a large number of researchers have provided some reasons why an individual's consumption behavior is excessively sensitive to current income rather than following what the life cycle-permanent income hypothesis predicts. They argued that excess sensitivity of consumption to current income may be caused by (1) inappropriate detrending procedure for non-stationary income, (2) existence of liquidity-constrained individuals, (3) use of a different data set, (4) causality from consumption to income, (5) non-separability of the utility function, and (6) misspecification of the model. In this section, we will review several occasions where life cycle-permanent income hypothesis with rational expectations can be reconciled with the excess sensitivity phenomenon.

2.3.2 Nonstationarity of Income

First, the "excess sensitivity" of consumption to current income has been criticized, since the result of Flavin's (1981) analysis can be accepted only when the income process is stationary. Nelson and Kang (1981) have shown that if a fitted trend is removed from a random walk, then the resulting detrended data will appear to be an autocorrelated stationary time series. Since Flavin imposed stationarity on the income process by removing a fitted trend, this may cause the excess sensitivity of consumption to income. Mankiw and Shapiro (1985) pointed out that inappropriate detrending could make consumption appear to be excessively sensitive to income when it is actually not. Further, Nelson (1987) argued that the coefficient of lagged income may simply reflect the effects of an inappropriate detrending procedure rather than an appropriate sensitivity of consumption to current income. However, McCallum (1986) revealed that income is, in fact, stationary in a multivariate income forecasting model for the Canadian postwar data, and concluded that marginal propensity to consume out of current income is "excessive" in terms of the permanent income hypothesis.

2.3.3 Liquidity-constrained Consumers

Second, some researchers argued that the empirical rejection of life cycle-permanent income hypothesis with rational expectations reflects liquidity constraints rather than myopic or non-rational behavior. In his pioneering paper, Hall (1978) discussed the issue of excess sensitivity of consumption to transitory fluctuations in income by liquidity-constrained individuals as follows. If a fraction of the population is liquidity-constrained, that fraction of the population will consume all of its disposable income. The total consumption of the population is the sum of consumption from liquidity-constrained consumers, $C^1(t)$, and consumption followed by Euler equation rule, $C^2(t)$. That is,

$$C(t) = C^1(t) + C^2(t) \quad (2.12)$$

$$C(t) = \alpha Y(t) + \lambda[C(t-1) - \alpha Y(t-1)] + \epsilon(t) \quad (2.13)$$

where α is a proportion of total income earned by the liquidity-constrained fraction of the population. If disposable income is given a univariate autoregressive process of second order, i.e. $Y(t) = \rho_1 Y(t-1) + \rho_2 Y(t-2) + u(t)$, then total consumption will be

$$E[C(t)] = \lambda C(t-1) + \alpha(\rho_1 - \lambda)Y(t-1) + \alpha\rho_2 Y(t-2) \quad (2.14)$$

Hall's empirical result of regression of C(t) on C(t-1), Y(t-1), and Y(t-2) was that the coefficient of lagged income was shown to be statistically insignificant. This means that $\rho_1 = \lambda$ and $\rho_2 = 0$. That is, consumption and disposable income obey exactly the same stochastic process, random walk, and observed income is equal to permanent income. Therefore, consumption of all its disposable income by liquidity-constrained individuals,[14] does little more than

[14] Using a panel data of U.S. households, Hall and Mishkin (1982) reported that about 20 percent of households fall into this category. Thus, consumption is somewhat more sensitive to change in disposable income than it would be

to follow the life cycle-permanent income hypothesis.

Hayashi (1982) formulated the following optimal consumption rule for the household's intertemporal optimization problem.

$$C(t) = \beta[A(t) + H(t)] + u(t) \tag{2.15}$$

where β = the propensity to consume out of total income

A = real nonhuman wealth

H = real human wealth

This formulation of the hypothesis is more general than Flavin's (1981) since the discount rate for future labor income is not constrained to be equal the rate of return from nonhuman wealth. He considered the above consumption function for "wealth-constrained" individuals. To include consumption for liquidity-constrained individuals, Hayashi generalized the above consumption function as:[15]

$$C(t) = \beta[A(t) + H(t)] + \alpha Y(t) + u(t) \tag{2.16}$$

where α is the liquidity-constrained individuals' proportion of disposable income. In the above equation, the coefficient of disposable income α should be zero not to reject the pure life cycle-permanent income hypothesis. Estimating the equation by nonlinear instrumental variable

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in an economy without liquidity constraints.

[15] Davidson and Mackinnon (1981) discussed this "artificial nesting" to choose one hypothesis from among alternatives.

technique to avoid the explicit treatment of human wealth, Hayashi reported the high estimate of the coefficient of current income. The estimated result of significant coefficient of disposable income indicates that a sizable fraction of the population is liquidity-constrained individuals.[16] Therefore, he concluded that the high correlation between aggregate consumption and aggregate disposable income does not necessarily mean that consumption is a function of disposable income, and may reflect an imperfect capital market in which the borrowing rates are substantially higher than the lending rates.

Bernanke (1984) found no evidence that the life cycle-permanent income hypothesis needs to be modified for liquidity constraints or capital market imperfections in his application to panel data on automobile expenditures. The response of expenditures on automobiles to transitory income change is as predicted by the permanent income hypothesis. He concluded that relative prices, interest rate, and "confidence" may contribute to observed short-run variations.

Flavin (1985) argued that excess sensitivity of consumption to current income can be traced to the operation of liquidity constraints. If individuals are liquidity

[16] Hayashi (1982) found that liquidity-constrained consumers account for about 17.1 percent of all personal consumption expenditures on services and nondurables, plus the value of service flows from consumer durables in postwar U.S. data.

constrained by capital market imperfections, the non-zero marginal propensity to consume out of transitory income may be consistent with a broadly defined life cycle-permanent income hypothesis with rational expectations. She compared the random walk model of consumption with the Keynesian consumption function to see whether the observed excess sensitivity of consumption arises from capital market imperfections or myopia. To test the life cycle-permanent income hypothesis against the Keynesian consumption function she specified the following equation in which the two hypotheses are combined.

$$\Delta C(t) = \lambda \Delta YP(t) + a[\Delta Y(t) - \Delta YP(t)] + \gamma \Delta Z(t) \qquad (2.17)$$

The above equation can be rewritten as follows:

$$\Delta C(t) = (\lambda - a)\Delta YP(t) + a\Delta Y(t) + \gamma \Delta Z(t) \qquad (2.18)$$

If the estimate of the coefficient of $\Delta Y(t)$, a, is non-zero, then it may indicate that there is some element of truth to the Keynesian view of consumption. For a specification test for the Keynesian consumption function, an additional variable Z, aggregate unemployment rate,[17] was included as a proxy for liquidity constraints. If the additional variable has a statistically significant coefficient, then we conclude that the Keynesian consumption function is incomplete or incorrect.

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[17] McCallum (1986) noted that the power of Flavin's test may be ruined because unemployment rate and detrended income has a high collinearity.

According to Flavin's empirical result, the estimate of the excess sensitivity of consumption to current income drops from 0.368 to 0.146 and becomes statistically insignificant after including the unemployment rate as a proxy for liquidity constraints. Furthermore, the coefficient of the unemployment rate is significantly negative, meaning that the unemployment rate is a good proxy for liquidity constraints and the Keynesian consumption function with non-zero marginal propensity to consume out of transitory income is an incomplete model. From this analysis, Flavin concluded that excess sensitivity of consumption can be explained by liquidity constraints.

Hubbard and Judd (1986) analyzed the liquidity constraint arising from a nonnegativity constraint on net worth[18] in the life cycle model. Young and low-income households who earned less than $15,000 a year had especially low levels of financial assets so that they were not permitted to borrow against income to be received in the future. Therefore, their consumption cannot exceed current resources. Hubbard and Judd found that, in the case where the elasticity of substitution in consumption is 0.25, for example, the constrained capital stock is 35 percent larger than the unconstrained capital stock, with borrowing constraints binding on 19 percent of the population receiving 11

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[18] This notion of liquidity constraints reflects large transaction costs and the possibility of bankruptcy in explaining borrowing restrictions. In Hayashi's (1982) and Flavin's (1985) analysis, liquidity constraints were caused by imperfect information in the loan market.

percent[19] of disposable income. From this prediction, they concluded that liquidity constraints may have an important role as a preexisting distortion in the determination of consumption in a life cycle model.

In contrast, McCallum (1986) argued that a broadly defined permanent income hypothesis should be rejected even with liquidity constraints. As Blanchard (1981) noted, liquidity constraints do not imply that anticipated decreases in income lead to anticipated movements in consumption.[20] Liquidity-constrained individuals would not reduce consumption by less than the amount predicted by the permanent income hypothesis. That is, consumption should not respond to anticipated decreases in income. To test the hypothesis, consumption is specified as follows and estimated.

$$\Delta C(t) = a_0 + a_1\Delta C(t-1) + a_2\,\Delta UY(t) + a_3\Delta AY^{+}(t) + a_4\Delta AY^{-}(t) + a_5\Delta Xi(t) + u(t) \qquad (2.19)$$

where ΔUY = unexpected change in income

ΔAY^{+} = positive value of anticipated change in income

ΔAY^{-} = negative value of anticipated change in income

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[19] This result is lower than Hayashi's (1982) estimate of 17.1 percent for the fraction of disposable income earned by liquidity-constrained individuals.

[20] This is because the responses of consumption to positive and negative changes in income are asymmetric.

ΔXi = change in government purchases, M1, and oil price

For the postwar Canadian data, he reported that the coefficient for $\Delta AY^{-}(t)$ is 1.36, while the coefficient for $\Delta UY(t)$ and $\Delta AY^{+}(t)$ are only 0.12 and 0.14, respectively. From this result, he concluded that if liquidity constraints are the only source to save the theory, the permanent income hypothesis should be rejected in favor of the "non-rational hypothesis".[21]

2.3.4 Data Set

Third, the inadequate treatment of data, for example, durables expenditure and measurement error, might lead to incorrect rejection of the life cycle-permanent income hypothesis.

Mankiw (1982) expanded Hall's (1978) framework to show that durable good expenditure should follow a mixed autoregressive moving average process, ARMA(1,1), instead of an autoregressive process AR(1). He derived the Euler equation for durable goods as:

$$C(t+1) = \delta a_0 + a_1 C(t) + u(t+1) - (1 - \delta)u(t) \qquad (2.20)$$

[21] However, with $\Delta Xi(t)$ (current-dated) in the equation (2.19), the permanent income hypothesis already has been rejected in favor of some unspecified alternative.

where δ is the depreciation rate of the consumer's stock of durable goods. From the above equation we observe that if the depreciation rate of durable goods is one, i.e. $\delta = 1$, then the consumption function will be AR(1), which is the special case that Hall considered. Estimating this equation for the postwar U.S. data of nondurable goods, he reported that the depreciation rate of durable goods is 1.038, with a standard error of 0.082. This means that consumer expenditure on durable goods does not follow the ARMA(1,1) process derived by Mankiw, but an AR(1) process, the same stochastic process as Hall found for nondurable goods and services. He suggested that this result may be caused by the similarity in the stochastic structure between expenditure on durables and expenditure on nondurables and services. It may be possible to consider that some nondurable goods and services are actually partly durable. A good example is a pleasure trip.[22] It is physically perishable, but it is also durable in the sense that the good memories of a trip may have a lasting psychological effect.

Bernanke (1984) also tested the joint rational expectations-permanent income hypothesis for durable goods using panel data on automobile expenditures. By maximizing the quadratic utility function in respect to intertemporal budget constraints, he derived a necessary condition and generalized it to include the effect of transitory changes

[22] Hayashi (1985), p1084.

in income as follows:

$$E(t) = \lambda[K^*(t) - K(t)] + \theta(t) + \gamma\eta(t) \qquad (2.21)$$

where E = family expenditure on automobiles

K^* = desired car stock

K = actual car stock

λ = rate of stock adjustment

θ = random influences on expenditures

γ = response of expenditure to change in current income

η = change in transitory income

He reported the estimate of the coefficient of change in transitory income is negative, small, and insignificantly different from zero. Thus, he found the results that expenditures on car are not excessively sensitive to changes in transitory income, and that the capital market faced by consumers is reasonably "perfect" and no liquidity constraints exist.[23] This result was unchanged in subsamples segregated by family holdings of liquid assets.[24]

Hayashi (1985) made the distinction between consumption and expenditure since consumption and expenditure cannot be equated. He took the durability issue into account by assuming consumption to be a Koyck distributed lag function

[23] Hubbard and Judd (1986) argued that this result is expected because automobile loans are self-collateralized.

[24] For entire sample estimate, $\gamma = -0.0136$, for high financial assets subsample estimate, $\gamma = 0.023$, and for low financial assets subsample estimate, $\gamma = -0.053$.

of expenditure. He derived the multi-commodity version of Hall's random walk hypothesis for the quadratic utility function as follows:

$$C(t+1) - C(t) = d(t+1) + e(t+1), \qquad (2.22)$$
$$d(t+1) \equiv \eta(t+1) - \eta(t)$$

where C = a vector of consumption of n commodities

e = forecast error

η = a vector of preference shocks

We can state the above Euler equation in terms of expenditure changes and also generalize to test the theory against the alternative model of "liquidity constraints".[25]

$$E(t+1) - E(t) = (1 - \lambda)[\{d(t+1) - \rho d(t)\} + \{e(t+1) - \rho e(t)\}] + \lambda[Y(t+1) - Y(t)] \qquad (2.23)$$

where E = a vector of expenditure

ρ = distributed lag coefficient

λ = a fraction of liquidity-constrained population

By estimating the above equation using a panel data of about 2,000 Japanese households for several commodity groups, he found that there is around 15 percent of liquidity-constrained households in the population. Thus, only a small fraction of consumer changes is explained by change in disposable income.

[25] Hayashi referred to this model as the "augmented model".

Bernanke (1985) considered the integrated procedure for the joint behavior of nondurable and durable expenditure to increase the power of the test of the permanent income hypothesis. He derived the decision rules for nondurable and durable goods under the two assumptions that the utility function is non-separable in respect to nondurable and durable goods and that there are adjustment costs in changes in stock of durable goods. His empirical test, based on the U.S. aggregate data, supported the Flavin's (1981) conclusion that consumer expenditure is excessively sensitive to disposable income. Thus, he concludes that the assumption in the past works that nondurable and durable goods are separable in utility function; is not a source of bias in testing of the theory.

Miron (1986) examined seasonal fluctuations in consumption expenditures as one of the possible explanations for rejecting the life cycle-permanent income hypothesis of consumption. The stylized facts show that there are large seasonal fluctuations in aggregate consumption purchases. He derived the stochastic Euler equation for the consumer's optimal consumption plan, including the seasonal fluctuations. By estimating the Euler equation for the U.S. aggregate data, he found no evidence against the life cycle-permanent income hypothesis. From this analysis, he concluded that seasonally adjusted or annual data gives a bias toward rejecting the theory. He explained that the reason why seasonal fluctuations are well described by a rational expectations model is because they are predictable so that individuals can adjust their behavior accordingly.

Altonji and Siow (1987) brought the measurement error in income into consideration when testing the rational expectations life cycle-permanent income hypothesis of consumption against the Keynesian model and the "liquidity constraints" model. They argued that the rejection of the theory from the estimated results using micro panel data sets, which may contain substantial measurement errors, may be an artifact of measurement error in the income data. To test their argument, they checked whether consumption responds to the past values of variables, such as wage changes, unemployment, and layoffs, and whether only the change in unanticipated income matters to change in consumption. From studying the micro data set of the Panel Study of Income Dynamics Individuals tape, they found that, in the presence of measurement error in income, the test results are favorable to the rational expectations life cycle-permanent income hypothesis, and are against the Keynesian model and the "liquidity constraints" model. In their analysis, measurement error played an important role to save the theory since their results accepted the Keynesian model if the measurement error in income is ignored.

2.3.5 Causality from Consumption to Income

Fourth, the excess sensitivity of consumption to disposable income may in fact show the response of income with respect to exogenous change in consumption. The stylized fact of relatively smooth behavior of consumption expenditures compared to income may reflect the income endogeneity. Sargent (1978) found that income does not seem to be Granger-caused by consumption for the seasonally adjusted data. However, McCallum (1986) rejected the rational expectations life cycle-permanent income hypothesis for the Canadian data even after considering the income endogeneity problem.

2.3.6 Assumption on Utility Function

Fifth, the rejection of the theory may be attributable to the assumption of separability in the utility function. To simplify estimation, the utility function assumed in most empirical research is additively separable in nondurable and durable goods, additively separable in consumption and leisure, and additively separable over time. The relaxation of one of these assumptions may change the test results not to reject the life cycle-permanent income hypothesis. King (1983) argued that consumption itself does not follow a random walk unless consumption and leisure are separable in utility function.

However, from Bernanke's (1985) analysis, we have already seen that the separable assumption of nondurable and durable goods did not cause a bias in testing the theory.

Mankiw, Rotemberg, and Summers (1985) also found from examining postwar aggregate data, that taking account of the utility function to be nonseparable in consumption and leisure does not change the result that the seasonally adjusted data rejects the life cycle-permanent income hypothesis.

Barro and King (1984) discussed the time-separability[26] of the utility issue, and concluded that separability in utility did not restrict the size of the intertemporal substitution effect. They could not accept that the habit persistence model of non time-separable utility predominates over the intertemporal substitution model of time-separable utility.

2.3.7 Misspecification of Model

Sixth, there are some other reasons suggested by researchers to save the rejection of the theory. Sargent (1978) noted that consumers should be confronting not incomes but prices at which they consume if their behavior followed the equilibrium theories of business cycle. Thus, the Euler equation used in most research may be a

[26] This means that past consumption does not influence current and future preferences since past consumption is treated as bygones.

misspecified redued form to express consumer's optimizing behavior.

For the convenience in empirical estimation, the utility function is usually assumed to be a quadratic form or constant relative risk aversion form. However, the actual functional relationship might not be one of these forms, so that the real reduced form for the intertemporal optimization problem for consumers may be different from the random walk model of consumption used in most empirical research. Therefore, the observed rejection of the life cycle-permanent income hypothesis may not be necessarily rejection of the theory, but rejection of the functional forms assumed for utility function.

Bernanke (1985) and Mankiw, Rotemberg, and Summers (1985) suggested that the econometric methods of the representative consumer approach used in the analyses are susceptible to aggregation problem. This aggregation problem may explain the rejection of the theory in aggregate data.

Chapter III

CANADIAN EVIDENCE ON THE RANDOM WALK MODEL OF CONSUMPTION

3.1 Introduction

The permanent income hypothesis under rational expectations has been tested by many researchers since the seminal work of Hall (1978). By maximizing the intertemporal utility function subject to life-time income stream, Hall derived the Euler equation solution for the consumer's optimization problem. Given the assumption that utility is quadratic, he showed that the Euler equation implies that consumption follows a random walk with drift since the conditional expectation of future marginal utility is a function of today's level of consumption alone. The random walk hypothesis of consumption implies that any deviation of consumption from its trend is permanent and unexpected, and today's level of consumption adjusted for trend is the best forecast of future consumption.

As Cooley and LeRoy (1985) argued, Hall tested the theoretical implication by checking whether lagged income and consumption lagged more than one period fail to Granger-cause consumption. To support the permanent income hypothesis under rational expectation, Granger-causality should be absent; lagged income and consumption lagged more than one period should have no explanatory power with respect to consumption. The assumption of rational expectations holds that any economic variable that is observed in earlier periods should have no additional explanatory power once one lagged consumption is included. The theory was well supported by Hall's empirical F-test, which used the U.S. postwar data; consumption obeys first-order autoregression and the sum of the lagged income coefficients is slightly negative in the presence of past consumption.

However, subsequent structural analysis by Flavin (1981) revealed that consumption is excessively sensitive to disposable income.[27] Flavin's rejection of the theory is a puzzle because her test is formally equivalent to Hall's test, except for the use of detrended data to avoid nonstationarity problem of the time series data. Nelson (1987) argued that the Flavin's rejection may reflect an appropriate sensitivity of consumption to current income, along with the effects of an inappropriate detrending procedure.

The recent work of many time series analysts suggests that most economic time series are nonstationary and, in fact, have unit roots. Nelson and Kang (1981) showed that

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[27] Flavin (1981) reported that the point estimate of the excess sensitivity of consumption to the contemporaneous change in income is 0.355.

inappropriate detrending of nonstationary time series data, which is a stochastic process with no tendency to return to a trend line, can produce spurious periodicity although the underlying data have no cyclical properties. Therefore, understanding of nonstationary behavior of consumption and income process is necessary for aggregate time series analysis of permanent income hypothesis.

Since the modern rejections of life cycle-permanent income hypothesis were begun with Flavin's (1981) findings, it is very important to see whether her argument is still valid after applying the recent developments of time series analysis. The main purpose of this chapter is to show Canadian evidence of Hall's and Flavin's test results and to investigate whether, in fact, the contradiction between Hall's and Flavin's results is attributable to the detrending of nonstationary income series. Although this chapter concludes that Flavin's rejection of the theory is caused by the inappropriate detrending of data, this does not necessarily mean that the theory should be accepted. Therefore, an alternative test procedure,[28] which applies the anticipated-unanticipated paradigm proposed by Barro (1977), is also used in this chapter to test the rationality of aggregate consumption behavior.

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[28] This test procedure was applied to test the theory for U.K. and Germany by Weissenberger (1986). The reason why we used this test procedure is that the test results using detrended data and first differenced data are the same.

The organization of this chapter is as follows. The next section reviews Canadian evidence of Hall's and Flavin's test on the life cycle-permanent income hypothesis under rational expectations. This will serve as a starting point for later arguments since this research is intended to understand aggregate consumption behavior in Canadian context by figuring out the different results of the two tests and testing the theory by an alternative method which gives the same test results for detrended data and first differenced data. In section 3, Flavin's test results are reappraised based on the nonstationary behavior of income series. In section 4, the test results of Weissenberger's version are discussed. Section 5 presents conclusions.

3.2 Hall's and Flavin's Test Using Canadian Data

3.2.1 Data

In this section the stochastic implications of Hall's and Flavin's model of the life cycle-permanent income hypothesis under rational expectations are tested using Canadian quarterly data from 1961:I to 1987:II. The data for this study was obtained from Income and Expenditures Accounts in "CANSIM University Base" data bank.

To include only the component of consumption which is easily and rapidly adjustable to change in permanent income, the consumption variable used is the sum of personal expenditure on consumer non-durable goods (data bank number

D20147) and services (data bank number D20141). Both the expenditure on non-durable goods and services are in millions of 1981 year dollars and adjusted for seasonal variations. To express in real per capita terms, the sum of the two are divided by population (data bank number D1).

The income variable used in the estimation is personal disposable income in real per capita terms. To construct this variable personal disposable income (data bank number D20111), which was in millions of current dollars and adjusted for seasonal variations, was divided by implicit price indexes (data bank number D20338) and multiplied by 100, then divided by the population. The same definition of consumption and income as Hall's and Flavin's papers, i.e. seasonally adjusted data in real per capita terms, is used in the estimation to make the test results comparable to those of Hall and Flavin.

3.2.2 Hall's Test

Hall ran the regression of consumption on four lagged values to test whether consumption can be predicted from its own past values. To support the theory, the estimated result should have a positive intercept, a coefficient insignificantly different from one for one period lagged consumption, and coefficients of zero for any additional lags.

The same model is estimated for Canada using the SAS system for regression and obtains the result shown in table 3.1.

TABLE 3.1

Consumption Function with Lagged Consumption

dependent var: C(t)

Equation	Const.	C(t-1)	C(t-2)	C(t-3)	C(t-4)	SER	R^2
(1)	50.970 (2.18)	0.996 (224.8)				34.98	0.998
(2)	43.97 (1.82)	0.973 (9.45)	0.004 (0.03)	0.247 (1.71)	-0.227 (-2.22)	34.60	0.998

Note: The t-ratios are in parentheses below coefficients. Standard error of regression is shown in dollars. Sample size is 105 for equation (1) and 102 for equation (2).

The t-values for the corresponding coefficients are given in parentheses. The 5 percent critical t-value is approximately 1.98. The coefficients of two and three lagged consumption are not statistically significant at the 5 percent level of significance, whereas the coefficient of C(t-4) is significant at the 5 percent level.[29] The F-statistic for the test on the joint significance of the added variables is 1.68 for the equation (2), which is close

[29] The significant coefficient of C(t-4) can be considered reflecting the remaining seasonal factors to cause the relationship.

to Hall's test statistic of 1.7 for the U.S. data, and well below the critical value of 2.7 at the 5 percent level of significance. From this result the conclusion is that Canadian evidence supports the theory and the result is similar to Hall's, using the U.S. data.

The implication of Hall's random walk model is that consumption should not obey a second order difference equation which is capable of generating stochastic cycles. Hall (1978, p.981) argued that rational consumers ought to be able to offset any cyclical pattern and restore the noncyclical optimal behavior of consumption predicted by the theory. This means that the theory can also be tested by examing whether changes in consumption are autocorrelated or not. That is, to support theory the values of $a(i)$s in the following equation should be insignificant.

$$\Delta C(t) = \mu + a_1\Delta C(t-1) + a_2\Delta C(t-2) + a_3\Delta C(t-3) + \epsilon(t) \quad (3.1)$$

This test is exactly the same as Hall's, since the above equation can be rewritten as follows:

$$C(t) = \mu + (1+a_1)C(t-1) + (a_2-a_1)C(t-2) + (a_3-a_2)C(t-3) - a_3C(t-4) + \epsilon(t) \quad (3.2)$$

Since estimating the above equation by ordinary least squares method has a multicollinearity problem, for the same test on the theory, the first differenced consumption equation can be estimated by ARIMA(3,1,0) model. The estimated result of the model using the SAS system is:[30]

$$\Delta C(t) = \underset{(6.92)}{28.23} - \underset{(-0.15)}{0.015}\Delta C(t-1) - \underset{(-0.13)}{0.013}\Delta C(t-2) + \underset{(2.49)}{0.241}\Delta C(t-3) \qquad (3.3)$$

SER=33.17 AIC=1037.23 Q(24)=25.02

where Δ is the difference operator. The estimation of consumption by the ARIMA(3,1,0) model produced about $1.43 per person per year improvement in standard error of regression compared with equation (2) in table 3.1. Since the Q-statistic of 25.02 is insignificant at the 5 percent level,[31] the model fits reasonably well according to the Box-Pierce portmanteau test.[32] Also, the Akaike Information Criterion (AIC) value[33] of the model is the smallest compared with the ARIMA(1,1,0), ARIMA(2,1,0), and ARIMA(4,1,0) models of consumption, meaning that ARIMA(3,1,0) is the best specified model to describe the data compared to the other models. To test the implication of the theory, the significance of the estimated

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[30] The conditional least squares estimation method is applied.

[31] The upper and lower critical values of Q-statistic for 24 degrees of freedom at the 5 percent significance level are 12.40 and 39.38, respectively.

[32] See Harvey (1981) p148-150 for the test.

[33] See Harvey (1981) p19-20.

coefficients were checked and only the coefficient of difference value of three lagged consumption variable was slightly significant at the 5 percent level of significance. The meaning of the significant coefficient of $\Delta C(t-3)$ in the above equation as well as $C(t-4)$ in the equation (2) of table 3.1 at the 5 percent level for the Canadian data can be interpreted as showing that there may still remain some seasonal factors to cause the relationship, even though the seasonally adjusted data is used.

Hall (1978) also tested the theory by checking whether lagged income helps predict consumption. If consumers were rational, they should use all available information, including information on income, to make their best consumption decision and lagged income should not have substantial predictive power beyond that of lagged consumption. To make the Canadian results comparable to the U.S. evidence, the same number of lagged income variables as Hall's model is used in estimating the consumption equation for Canada. The estimated results are shown in table 3.2.

As shown in the table, the test F-statistics are far away from the 5 percent critical value of F-statistic. Therefore, the above analysis results in the same conclusion of supporting the theory for Canadian data as that of Hall's U.S. result. In this subsection we have seen that, following Hall's test, aggregate consumption behavior in Canada also obeys the life cycle-permanent income hypothesis

TABLE 3.2

Consumption Function with C(t-1) and Y(t-i)

dependent var: C(t)

	(1)	(2)	(3)
Constant	31.80	-31.64	-17.69
	(0.07)	(0.08)	(0.08)
C(t-1)	1.007	1.037	1.032
	(0.04)	(0.04)	(0.04)
Y(t-1)	-0.005	0.009	0.013
	(1.89)	(3.44)	(3.56)
Y(t-2)		0.006	0.008
		(4.12)	(4.23)
Y(t-3)		0.009	-0.012
		(4.10)	(4.35)
Y(t-4)		-0.041	-0.066
		(3.21)	(4.29)
Y(t-5)			0.103
			(4.26)
Y(t-6)			-0.067
			(4.28)
Y(t-7)			-0.032
			(4.29)
Y(t-8)			0.087
			(4.28)
Y(t-9)			0.001
			(4.36)
Y(t-10)			-0.087
			(4.43)
Y(t-11)			0.017
			(4.31)
Y(t-12)			0.020
			(3.38)
$\bar{R}^2$	0.998	0.998	0.998
SER	35.16	34.09	34.30
F	0.08	0.22	1.31
F*	3.95	2.46	1.88

Note: F is the test F-statistic for the null hypothesis that all other coefficients than C(t-1) variable equals zero. F* is the critical value of F-statistic at the 5 percent level. The standard error of coefficients is shown in parentheses below coefficients.

under rational expectations. However, this is the result from the reduced-form model, as Flavin (1981) showed. In the next subsection the theory will be tested following Flavin's structural model.

3.2.3 Flavin's Test

Flavin (1981) expanded Hall's test of the life cycle-permanent income hypothesis by formulating a structural relationship between consumption and lagged values of income. She defined permanent income as the annuity value of net worth. From this definition she showed that the permanent income hypothesis holds that change in consumption depends upon revision in permanent income. Using a general ARMA representation of the income process, she also showed how innovation in current income signals to revise the consumers' expectations of future income and, therefore, their permanent income.

If the actual current income change were added to the change in the consumption equation,[34] the coefficient of the variable should have a zero value since rational consumers have already included the information about income into their consumption decision making. If the coefficient of the added change in income variable has a significant value, then this will measure the "excess sensitivity" of

[34] Note that the current innovation in income is included in the random variable term of the change in consumption equation.

consumption to current income, that is, sensitivity in excess of the response attributable to the new information contained in current income, as argued by Flavin (1981, p.990).

To simplify her discussion, if we assume that income process is a simple AR(1), then the unrestricted system can be shown as:

$$Y(t) = \mu_1 + \rho Y(t-1) + \epsilon_1(t) \tag{3.4}$$

$$\Delta C(t) = \mu_2 + k\Psi\epsilon_1(t) + \beta\Delta Y(t) + \epsilon_2(t) \tag{3.5}$$

where $\Psi=1/[1-\{\rho/(1+r)\}]$ and k represents the marginal propensity to consume out of wealth. This unrestricted model is a nested model to test the economic theory, suggested by Davidson and MacKinnon (1981). The coefficient β in the equation measures the excess sensitivity and should be zero to support the theory. From the above structural model, the reduced form of Hall's model can be obtained as follows:

$$\begin{aligned}\Delta C(t) &= \mu + \beta(\rho-1)Y(t-1) + \epsilon_2(t) \\ &= \mu + \pi Y(t-1) + \upsilon(t)\end{aligned} \tag{3.6}$$

where $\upsilon(t)=k\Psi\epsilon_1(t)+\epsilon_2(t)$ and $\pi=\beta(\rho-1)$. If income is a random walk, i.e. $\rho=1$, then the theory can not be tested by estimating the above reduced form model since the coefficient π equals zero whether or not there is excess sensitivity of consumption to current income. Besides, testing the theory is not related to the trend of consumption, but to the fluctuations in consumption level. Therefore, Flavin used detrended data, calculating deviations from its estimated exponential trend,[35] to impose stationarity on the income series.

To compare the test results using Canadian data with that using U.S. data, the following model, which was specified by Flavin, is estimated for Canadian detrended quarterly data.

The structural model:

$$Y(t) = \mu_1 + \rho_1 Y(t-1) + \rho_2 Y(t-2) + \ldots + \rho_8 Y(t-8) + \epsilon_1(t) \quad (3.7)$$

$$\Delta C(t) = \mu_2 + \beta_0[(\rho_1-1)Y(t-1) + \ldots + \rho_8 Y(t-8)] + \beta_1 \Delta Y(t-1) + \ldots + \beta_7 \Delta Y(t-7) + \epsilon_2(t) \quad (3.8)$$

The semi reduced-form model:

$$\Delta C(t) = \mu + \pi_1 Y(t-1) + \pi_2 Y(t-2) + \ldots + \pi_8 Y(t-8) + \upsilon(t) \quad (3.9)$$

The results estimated by the SAS system are shown in table 3.3. The theory can be tested by investigating the hypothesis that $\beta_0=\beta_1=\ldots=\beta_7=0$ in the unrestricted model and $\pi_1=\pi_2=\ldots=\pi_1=0$ in the restricted model of consumption. Since testing these hypotheses is nothing more than testing the global usefulness of the estimated model, the F-test can

[35] Including the time variable in the equation has the same effect as removing a fitted trend.

be applied to test the theory. The test F-statistic of the estimated model was 7.30.[36] Since the critical value of the F distribution at the 5 percent significance level is 2.04, the hypothesis is very decisively rejected. The decisive rejection of the theory for Canadian data is the same as Flavin's test results for the U.S. data. Thus, the analysis in this subsection shows that using Canadian data instead of the U.S. data does not affect the test results of Hall's and Flavin's model.

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[36] Since equation (3) in table 3.3 is a restricted model of equation (2), the test F-statistics are the same for the two estimated equations.

TABLE 3.3

Estimates of Flavin's Model

dependent var: Y(t) (1)		dependent var: ΔC(t) (2)		(3)	
μ_1	-0.00 (-0.59)	μ_2	-0.00 (-0.13)	μ	-0.00 (-0.13)
ρ_1	0.69 (-6.60)	β_0	1.54 (0.72)	π_1	-0.14 (-2.05)
ρ_2	0.39 (3.05)	β_1	0.34 (0.51)	π_2	0.07 (0.87)
ρ_3	-0.06 (-0.49)	β_2	-0.19 (-0.97)	π_3	0.15 (1.84)
ρ_4	0.51 (4.15)	β_3	0.05 (0.63)	π_4	0.23 (2.94)
ρ_5	-0.40 (-3.31)	β_4	-0.50 (-0.44)	π_5	-0.26 (-3.35)
ρ_6	-0.39 (-3.06)	β_5	-0.15 (-0.50)	π_6	-0.20 (-2.40)
ρ_7	0.12 (0.92)	β_6	0.26 (0.56)	π_7	-0.07 (-0.81)
ρ_8	0.13 (1.20)	β_7	0.00 (0.01)	π_8	0.20 (2.84)
R^2	0.931		0.396		0.396
SER	0.016		0.010		0.010
F	150.26		7.30		7.30

Note: Sample size is 98. The t-ratios are shown in parentheses below coefficients.

3.3 A Reappraisal of Flavin's Test

3.3.1 Interpretation of the Different Test Results

As shown in the previous section and in Flavin's paper (1981), Hall's test, based on the single equation reduced form, and Flavin's test, based on the bivariate unrestricted equations, yield numerically identical values of the likelihood ratio statistic for comparable specification. The Canadian evidence in the previous section shows that the life cycle-permanent income hypothesis under rational expectations was supported by Hall's test and rejected by Flavin's test. The question is why there are two different conclusions from in fact the same test. Considering the significance of the difference between the two test results, it is not likely that the contradictory results were caused by differences in the specification of the model in terms of the number of lagged values of income included.[37] Instead, the difference in the test statistic may be attributed to a difference in the data sets in terms of the treatment of the trend in income.[38]

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[37] Flavin (1981) used eight lagged values of income in the estimation whereas Hall (1978) tested the theory using two, four, and twelve lagged values of income in the three different regressions. Since Hall's conclusion was from using three different numbers of lagged values of income, it can be inferred that his conclusion is not sensitive to the number of lagged values of income in the equation.

[38] This was pointed out by Mankiw and Shapiro (1985) and Nelson (1987).

According to Maddala (1988) there are two procedures used for detrending:

1. Estimating regressions on time.

In this case the series of Y(t) is assumed to be generated by the mechanism[39]

$$Y(t) = \alpha + \beta t + u(t) \tag{3.10}$$

where u(t) is a stationary series with mean zero and constant variance.

2. Successive differencing.

In this case it is assumed that Y(t) is generated by the following model

$$Y(t) - Y(t-1) = \beta + u(t) \tag{3.11}$$

in which u(t) is a stationary series.

Nelson and Plosser (1982) call the former, trend-stationary processes and the latter, difference-stationary processes. Flavin (1981) followed the trend-stationary processes type to detrend the nonstationary data in her paper. This detrending procedure of regressing the time series on time has been often used by many macroeconomists since they believed that the trend does not fluctuate much over short periods of time, but rather moves slowly and smoothly, and follows a deterministic path. Flavin used the

[39] In general we could regress time series on a polynomial in time.

residuals from fitted time trend to test the theory.

However, as Nelson and Plosser argued, if the secular movement in macroeconomic time series is of a stochastic rather than deterministic nature, then a model based on time trend residuals is misspecified. In fact, we will get nonstationary residuals from fitted time trend if the first difference of the time series is stationary with mean.[40] To see this problem, the following equation is derived from difference-stationary processes by accumulating Y(t) starting with an initial value Y(0)

$$Y(t) = Y(0) + \beta t + \sum_{j=1}^{t} u(j) \qquad (3.12)$$

The residuals from estimating the above equation are not stationary since the variance of the equation increases over time. Nelson and Kang (1981) clarified this point by showing that the autocorrelation function of the residuals from regression of a random walk series on time is a statistical artifact in the sense that it is determined entirely by sample size and it implies strong pseudo periodic behavior at long lags. This means that inappropriate detrending may cause misleading genuine dynamic properties in the series. Furthermore, Nelson and Kang (1984) argued that regression of one random walk on another, with time included for trend,[41] is strongly subject

[40] This model is known as a "random walk" with drift.

to the spurious regression phenomenon. That is, the conventional t-test will tend to indicate a significant relationship between the variables when none is present. This section reviews whether Flavin's rejection of the theory belongs to this spurious regression phenomenon.

3.3.2 Nonstationarity of Income Series

To see whether the inappropriate detrending of nonstationary data is the cause of Flavin's rejection of the theory based upon the spurious regression results, we need to review nonstationary behavior of income series.[42] Table 3.4 presents sample autocorrelations of income series in real per capita terms for the quarterly Canadian data from 1961:I to 1987:II.

The estimated sample autocorrelations r(j) in the table shows the normalized values of the estimated autocovariance sequence C(j) computed by the following equation:

$$r(j) = C(j)/C(0) \tag{3.13}$$

The estimated autocovariance C(j) is the sample covariance between Y(t) and Y(t+j) and is defined as follows:

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[41] Inclusion of a time trend in a regression has the same effect as detrending the series by regressing it on time.

[42] Income series is clearly nonstationary in the sense that the mean and variance depend on time, and they tend to depart ever further from any given value as time goes on. Since this movement is predominantly in upward direction, it is said that the income series exhibits a "trend".

TABLE 3.4

Sample Autocorrelations of Personal Disposable Income

Number of Lags	Simple Autocorrelation	Partial Autocorrelation
1	0.98	0.98
2	0.96	0.01
3	0.93	-0.04
4	0.91	0.00
5	0.89	-0.06
6	0.86	-0.03
7	0.84	-0.01
8	0.81	-0.03
9	0.78	-0.01
10	0.76	-0.03
11	0.73	-0.02
12	0.70	0.01
13	0.68	-0.03
14	0.66	0.02
15	0.63	-0.03
16	0.60	-0.04
17	0.58	0.03
18	0.56	-0.02
19	0.53	-0.03
20	0.50	-0.04
21	0.48	-0.06
22	0.45	-0.06
23	0.41	-0.02
24	0.39	-0.03

Note: The data is from 1961:I to 1987:II and contains 106 observations.

$$C(j) = \sum_{j=1}^{n-j} [Y(t)-\bar{Y}][Y(t+j)-\bar{Y}]/n \qquad (3.14)$$

where $\bar{Y}$ is the mean of the entire series. To be stationary, the means and autocovariances of the series should be the same for every t. Therefore, the simple autocorrelations of personal disposable income in the table 3.4, which is dropping off slowly as lag length increases, suggests nonstationarity. Since the partial autocorrelation[43] of only the first lag is large, the income series Y(t) can be well explained by one lagged value of the series Y(t-1). In fact the partial autocorrelations decline to almost zero after the large value of first lag. Since this is known as a property of a random walk, difference-stationary processes should be applied for detrending rather than trend-stationary processes. As discussed above, if the trend-stationary processes are applied for detrending the income series when the appropriate method of eliminating the trend is difference-stationary processes, then the residuals from fitted time trend will show nonstationary behavior whereas the change in income will be a white noise.

The autocorrelations for the time trend residuals and the first difference of the income series are presented in table 3.5. Since the simple autocorrelations of the time trend

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[43] The partial autocorrelation shows the values of the last coefficient of Y(t-j) variable in regression of Y(t) on Y(t-1), Y(t-2), ... , Y(t-j).

TABLE 3.5

Simple Autocorrelations of Residuals and ΔY(t)

Number of Lags	Series Residuals	ΔY(t)
1	0.91	-0.21
2	0.86	0.20
3	0.82	-0.01
4	0.80	0.11
5	0.71	0.04
6	0.65	-0.10
7	0.61	0.10
8	0.58	-0.22
9	0.51	0.13
10	0.45	0.04
11	0.41	-0.02
12	0.39	-0.01
13	0.31	0.09
14	0.23	0.01
15	0.18	-0.01
16	0.15	0.06
17	0.05	0.08
18	-0.02	-0.09
19	-0.07	-0.04
20	-0.09	-0.00
21	-0.15	-0.01
22	-0.18	0.02
23	-0.19	0.03
24	-0.20	-0.08

Note: Residuals are calculated from the equation $\ln Y(t) = \alpha + \beta t + u$. Sample size is 105 for the residuals and 104 for ΔY(t) series.

residuals also drop off slowly, it suggests that nonstationarity may still exist after detrending the series by regressing it on time. In contrast, the simple autocorrelations of the change in income are all small. The Q-statistic of the change in income series for the null hypothesis that the first twenty-four autocorrelations are zero is 25.07, which is not significant even at the 1 percent level of significance. Thus, the result of Box-Pierce portmanteau test tells us that the first difference of income is approximately white noise. To clarify this point, the spectral density function for residuals from fitted time trend and first difference of income series are shown in figure 3.1 and 3.2, respectively. The spectral density function of the time trend residuals shows nonstationarity of the series since the spectral density is very large at frequency zero. The spectral density function of first differenced series indicates that it is almost white noise. The shape of the spectral density function in figure 3.1 and 3.2 is similar to that of the spectral density function from experimental data in Nelson and Kang's figure 3 (1981, p.748). This implies that autocorrelations in the time trend residuals series are an artifact and that Flavin applied a wrong detrending procedure.

More formally, the test developed by Dickey and Fuller (1981) can be applied to test the hypothesis that the income series belongs to the difference-stationary processes

Figure 3.1: Spectral Density of Time Trend Residuals

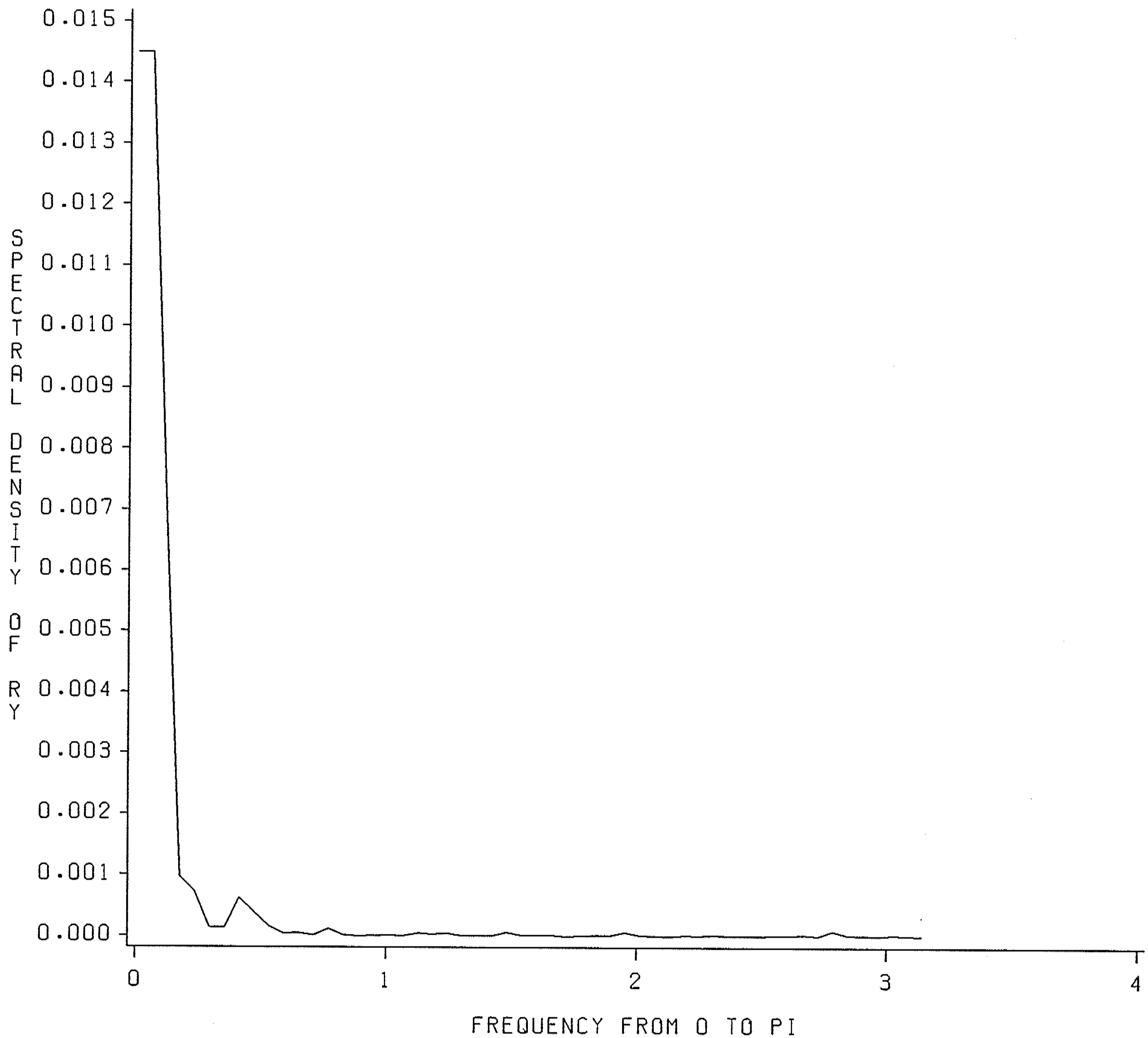
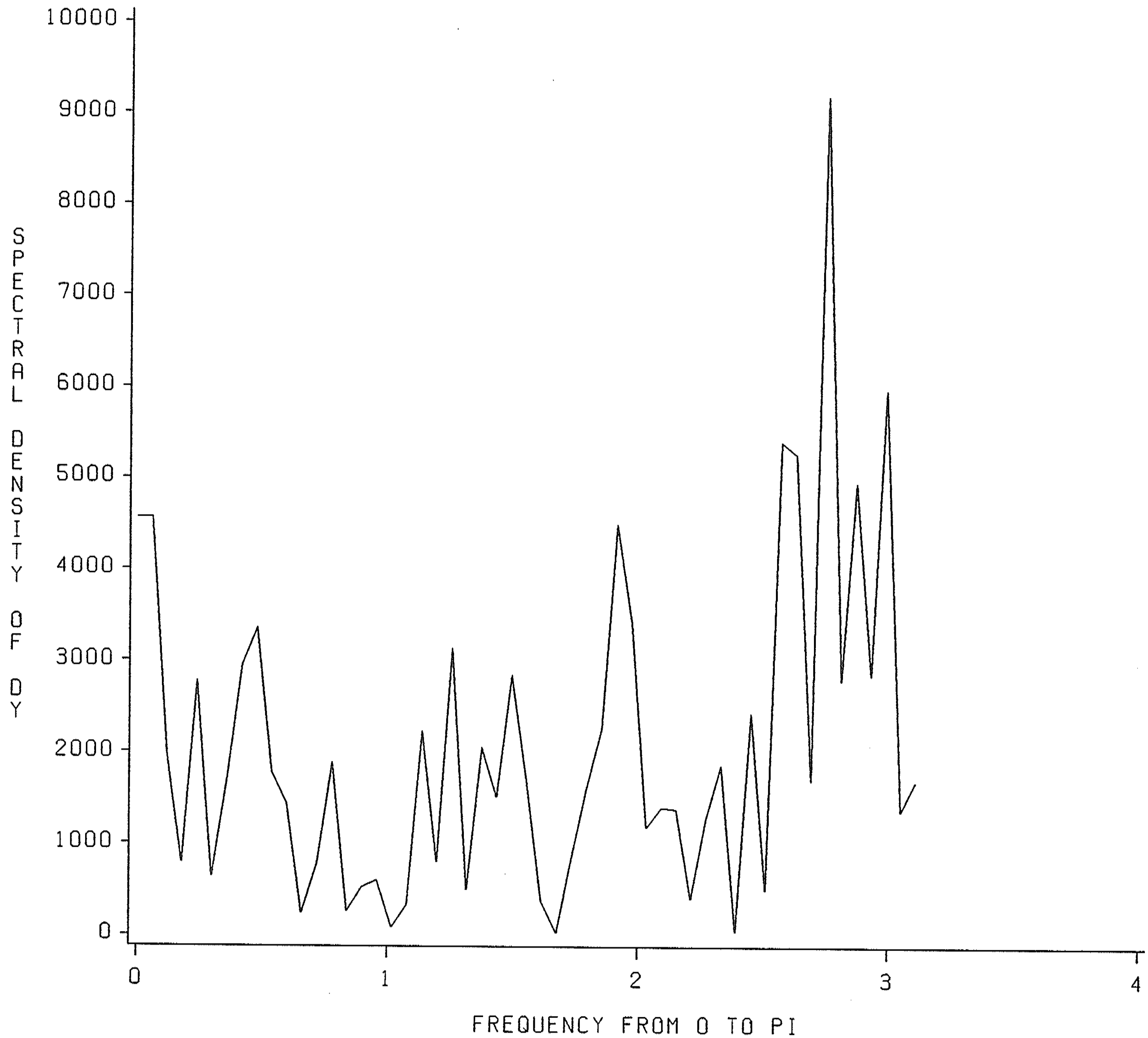


Figure 3.2: Spectral Density of First Differenced Series



class[44] instead of the trend-stationary processes class. Following Dickey and Fuller, the time series X(t) is assumed to be adequately represented by the following model.

$$X(t) = \beta_0 + \beta_1 t + \rho X(t-1) + \sum_{i=1}^{k} \alpha(i)\Delta X(t-i) + \epsilon(t) \qquad (3.15)$$

To investigate the existence of a unit root in the time series, the null hypothesis that X(t) follows a random walk with drift, i.e. $(\beta_1,\rho)=(0,1)$, is tested against the alternative hypothesis, $(\beta_1,\rho)\neq(0,1)$, by estimating the above equation with k=0. Since the conventional tests are inadequate if the time series follows a random walk, the Dickey and Fuller's test is applied. Table 3.6 presents the Dickey and Fuller's test statistic Φ_3 for this case. The null hypothesis, $(\beta_1,\rho)=(0,1)$, is also tested against the alternative hypothesis, $(\beta_1,\rho)\neq(0,1)$, in a more general model, by allowing the difference of time series $\Delta X(t)$ to follow an AR process. The test statistic Φ_3 for AR(2) model of $\Delta X(t)$, i.e. k=2, is also reported in table 3.6. From Dickey and Fuller's table VI (1981, p.1063), the critical value of the Φ_3 statistic at the 5 percent is approximately 6.49. For the levels of income series and the time trend residuals, the test statistic Φ_3 does not reject the null hypothesis $(\beta_1,\rho)=(0,1)$ at the 5 percent level. For first difference of income series, the null hypothesis is, as we

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[44] This means that the income series has a unit root.

TABLE 3.6

Dickey-Fuller Test Results

X(t):	Y(t)	Residuals	ΔY(t)
No lags (k=0)			
β_0	212.0	0.004	84.36
	(1.61)	(1.42)	(3.56)
β_1	1.95	-0.00	-0.33
	(0.95)	(-1.95)	(-0.90)
ρ	0.96	0.99	-0.21
	(30.1)	(39.0)	(-2.20)
SER	113.94	0.014	111.96
Φ_3	0.45	1.99	78.02
Two lags (k=2)			
a_1	-0.15	-0.34	-0.24
	(-1.48)	(-3.25)	(-1.51)
β_0	-15990.1	1.11	2078.8
	(-0.99)	(2.19)	(0.69)
β_1	8.27	-0.00	-1.03
	(1.00)	(-2.20)	(-0.67)
ρ	0.96	1.00	0.05
	(30.1)	(28.3)	(0.25)
a_1	-0.15	-0.34	-0.24
	(-1.48)	(-3.25)	(-1.51)
a_2	0.19	-0.08	-0.06
	(1.84)	(-0.78)	(-0.60)
SER	111.41	0.019	112.52
Φ_3	0.91	2.45	13.00

Note: The t-ratios are in parentheses below coefficients. The statistic Φ_3, calculated like the F-statistic, tests the null hypothesis $(\beta_1,\rho)=(0,1)$, against the alternative $(\beta_1,\rho)\neq(0,1)$.

expected, rejected at the 5 percent level by the test statistic Φ_3. The results of the unit root test and the spectral analysis of the series support the impression, based on the sample autocorrelation analysis of table 3.5, that nonstationary behavior of income series should be detrended by the difference-stationary processes procedure. The analysis of nonstationary behavior of the income series in this subsection suggests that there is enough reason to suspect that Flavin's rejection of the theory is attributable to inappropriate detrending of nonstationary data.

3.3.3 Testing the Theory with Unit Root

From the above analysis we have seen that there is a strong possibility that the income series has a unit root nonstationarity. Besides, as argued by Plosser and Schwert (1978), there is a good reason why it is better to work with differenced data rather than data in levels. If we estimate the first difference equation, when the levels equation included time variable as one of the regressors for detrending is correctly specified, then at worst we will have inefficient but consistent estimates. However, if we estimate the levels equation when indeed the data series are of the difference stationary processes type, then the statistical inference for the estimated model will be invalid.

Therefore, to see whether Flavin's rejection of the theory was caused by inappropriate detrending, in this section the rational expectations life cycle-permanent income hypothesis model of Flavin (1981) is estimated, using the first differenced data, under the assumption of the existence of a unit root nonstationarity in income series.

For simplicity, if we assume that income series can be well explained by the following IMA(1,1) model,[45]

$$Y(t) - Y(t-1) = \mu + \epsilon(t) - \beta\epsilon(t-1) \quad (3.16)$$

then by repeated back substitution

$$\epsilon(t) = \mu' + [Y(t)-Y(t-1)] + \beta[Y(t-1)-Y(t-2)] + \beta^2[Y(t-2)-Y(t-3)] + \ldots \quad (3.17)$$

or[46]

$$Y(t) = \mu' + (1-\beta)[Y(t-1)+\beta Y(t-2)+\beta^2 Y(t-3)+\ldots] + \epsilon(t) \quad (3.18)$$

The above equation shows that income series Y(t) can be forecasted by an exponentially weighted sum of past Ys.[47] The derived results from the estimation of the IMA(1,1) model of income series by the SAS ARIMA Procedure is

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[45] The specification of this model is supported later by the Box-Jenkins' model selection procedure and the Akaike Information Criterion. Refer to section 3.4.2.

[46] The relationship between Flavin's specification of Y(t) model and this equation is $\mu=\mu'$, $\rho_1=1-\beta$, $\rho_2=(1-\beta)\beta$, $\rho_3=(1-\beta)\beta^2, \ldots$.

[47] This is called simple exponential smoothing. The inclusion of more MA terms results in high-order exponential smoothing and does not affect our conclusion for testing of the theory.

$$Y(t) = \mu' + 0.85Y(t-1) + 0.13Y(t-2) + 0.02Y(t-3) + 0.003Y(t-4) + 0.0004Y(t-5) + 0.00006Y(t-6) + 0.00001Y(t-7) + 0.00000Y(t-8) + \ldots \quad (3.19)$$

Given the values of ρs from the above equation, the following Flavin's model of change in consumption is estimated for quarterly Canadian data from 1961:I to 1987:II.

$$\Delta C(t) = \mu_2 + \beta_0[(\rho_1-1)Y(t-1)+\ldots+\rho_8 Y(t-8)] + \beta_1\Delta Y(t-1) + \ldots + \beta_7\Delta Y(t-7) + \epsilon_2(t) \quad (3.20)$$

The estimated results of the model are shown in table 3.7.

TABLE 3.7

Estimation of Flavin's Model with Unit Root

μ_2	β_0	β_1	β_2	β_3
34.59 (15.30)	0.033 (0.049)	0.017 (0.031)	0.036 (0.031)	0.026 (0.031)

β_4	β_5	β_6	β_7
-0.031 (0.032)	0.068 (0.032)	-0.002 (0.032)	-0.044 (0.032)

Note: The standard error of coefficients are given in parentheses.

The coefficient of β_0, which measures the excess sensitivity of consumption to current income, has small amount. Besides, the joint null hypothesis $\beta_0=\beta_1=...=\beta_7=0$ is not rejected by the F test, since the test F-statistic of 1.42 is far below than the 5 percent critical value of 2.04. This means that the theory is well supported, as was Hall's conclusion, when the nonstationary income series is detrended by difference-stationary processes procedure.

3.4 An Alternative Test on the Rationality of Consumer behavior

Analysis of the above section shows that Flavin's rejection of the theory reflects an inappropriate detrending of the data, as argued by Mankiw and Shapiro (1985) and Nelson (1987). Although the rejection of the theory by Flavin may be attributed to an inappropriate detrending of data, this should not be interpreted directly as support for the theory, since the theory has only been tested by a model derived with some restricted assumptions. Therefore, we test the life cycle-permanent income hypothesis under rational expectations with an alternative approach in which the rationality of consumers' behavior is formally examined.

In this subsection, the Weissenberger (1986) version of Flavin's (1981) model is applied to test the theory. Weissenberger, first, tested the theory by comparing the calculated value of the marginal propensity to consume out of income innovations, as implied by the theory, with the coefficient obtained by regressing the current consumption innovations on the current income innovations. Since this test depends on the assumption that the individual's time horizon is infinite, the test result may not be valid for an individual with a finite time horizon where the inequality can be caused by the difference between the annuity rate and the quarterly interest rate.

Therefore, Weissenberger's second test of the theory which is derived by applying the anticipated-unanticipated paradigm proposed by Barro (1977) is more applicable to our purpose. Specifically, the life cycle-permanent income hypothesis under rational expectations can be tested by either investigating whether past innovations that are known in current period affects current consumption innovations, or by investigating whether the coefficient of the anticipated income variable is significant. The theory will be rejected if either the past innovations or the anticipated income variable has an explanatory power.

For the empirical analysis for U.K. and Germany, Weissenberger used detrended data which was obtained by regressing the natural logarithm values of income series and consumption series on a trend. To find income innovations and consumption innovations from the detrended series, he identified and estimated ARMA models along the lines suggested by Box and Jenkins.[48] In this section, first the theory is tested, based on consumption innovations and income innovations derived by the ARMA model following Weissenberger. Then the theory is also tested, based on consumption innovations and income innovations derived by the ARIMA model, following the suggestion of Plosser and Schwert (1978) and the evidence of unit root of the series in subsection 3.3.2.

This section serves not only to show the results of a different version of Flavin's test on the theory, but also to see whether the application of the different detrending procedures also plays a key role for the conclusion of the test on the theory in the alternative test. For this purpose, the test results of the theory using ARMA models with detrended data are compared with the test results of the theory using ARIMA models with original data.

3.4.1 Analysis of ARMA Model

Following Flavin and Weissenberger, the series is detrended and the ARMA model is estimated for the detrended data to find consumption innovations and income innovations. To detrend the consumption series and the income series, the two series are regressed on time. Autocorrelation, partial

[48] From the ARMA analysis, using detrended data, Weissenberger (1986) rejected the theory for the United Kingdom and Germany.

autocorrelation, and inverse autocorrelation functions of the resulting residuals of the regression are checked to identify a model for the detrended data of the consumption series and the income series.[49] Since the Box-Jenkins model selection procedure suggests several specifications, the Akaike Information Criterion (AIC),[50] was also applied. In AIC, the decision rule is to select the model for which

$$AIC = \tilde{\sigma}^2 \exp[\ \log|V| + 2(p+q)/T\ ] \tag{3.21}$$

is a minimum; $\tilde{\sigma}^2 V$ is the covariance matrix of the series, p is the number of order in the AR process, and q is the number of order in the MA process. The term $2(p+q)/T$ assigns a penalty to models which are not suitably parsimonious.

From the above criteria, we estimate the following ARMA(1,5) model for both detrended consumption series and detrended income series.

$$X(t) - \phi_1 X(t-1) = \epsilon(t) + \theta_1\epsilon(t-1) + \theta_2\epsilon(t-2) + \theta_3\epsilon(t-3) + \theta_4\epsilon(t-4) + \theta_5\epsilon(t-5) \tag{3.22}$$

[49] Brocklebank and Dickey (1986) suggested to check the Autocorrelation Function (ACF), Inverse Autocorrelation Function (IACF), and Partial Autocorrelation Function (PACF) to identify a model. If ACF drops to 0 after q lags, this indicates a MA(q) model. If IACF or PACF drops to 0 after p lags, this indicates an AR(p) model.

[50] See Harvey (1981, p.157).

The estimated results of the above equation using the SAS ARIMA system are shown in table 3.8. Since the first few autocorrelations are small and the Q(24) statistics are below than the 5 percent critical value of 36.4 for 24 degrees of freedom, we may assume that the two series are

TABLE 3.8

ARMA Model of Consumption and Income Series

	(1) Consumption	(2) Income
ϕ_1	0.954	0.952
	(0.04)	(0.05)
θ_1	-0.013	-0.160
	(0.11)	(0.11)
θ_2	0.017	0.248
	(0.10)	(0.10)
θ_3	0.283	0.045
	(0.10)	(0.11)
θ_4	0.112	0.298
	(0.10)	(0.10)
θ_5	0.032	-0.030
	(0.11)	(0.11)
SER	32.97	109.28
Q(24)	23.26	13.17

Note: Sample size is 106. Standard error of coefficients is shown in parentheses. Q(24) shows Box-Pierce portmanteau statistic when p=24.

just white noise and the ARMA(1,5) model is well identified. To apply Weissenberger's test to testing the theory, consumption innovations and income innovations are derived by subtracting forecasted values of consumption and income based on the estimated ARMA model from the actual value of consumption and income.

We test the theory by investigating whether innovations in earlier periods or anticipated income in the previous period affects consumption innovations in the current period. Since information from past periods is already considered in consumers' decision making, if consumers are rational, those variables known in past periods should have no additional explanatory powers and consumption innovations should be determined entirely by income innovations in the current period. For the purpose of testing the theory, the obtained consumption innovations are regressed on income innovations, lagged income innovations, lagged consumption innovations, and anticipated income variable, as shown in the following models:[51]

$$\xi C(t) = \alpha_1 \xi Y(t) + \nu(t) \tag{3.23}$$

$$\xi C(t) = \alpha_1 \xi Y(t) + \alpha_2 \xi Y(t-1) + \alpha_3 \xi Y(t-2) + \nu(t) \tag{3.24}$$

$$\xi C(t) = \alpha_1 \xi Y(t) + \alpha_2 \xi Y(t-1) + \alpha_3 \xi Y(t-2) + \alpha_4 \xi C(t-1) + \alpha_5 \xi C(t-2) + \nu(t) \tag{3.25}$$

$$\xi C(t) = \alpha_1 \xi Y(t) + \alpha_2 \xi Y(t-1) + \alpha_3 \xi Y(t-2) + \alpha_4 FY(t) + \nu(t) \tag{3.26}$$

where ξC = consumption innovations

ξY = income innovations

[51] The same numbers of lagged variables as in Weissenberger's paper (1986) are used to compare the Canadian test results with the U.K. and the German test results.

FY = anticipated income

ν = disturbances

and time periods are shown in parentheses.

Table 3.9 contains the estimated results of the above

TABLE 3.9

Estimates of Consumption Innovations: I

dependent var: $\xi C(t)$	equation (1)	(2)	(3)	(4)
$\xi Y(t)$	0.306*	0.268*	0.069*	0.269*
	(0.02)	(0.07)	(0.03)	(0.07)
$\xi Y(t-1)$		0.072	-0.024	0.072
		(0.08)	(0.04)	(0.08)
$\xi Y(t-2)$		-0.034	-0.047	-0.034
		(0.07)	(0.03)	(0.07)
$\xi C(t-1)$			0.897*	
			(0.10)	
$\xi C(t-2)$			0.069	
			(0.11)	
FY(t)				0.094
				(0.30)
SER	74.49	74.94	33.31	75.28

Note: Standard error of coefficients is shown in parentheses. * denotes that the corresponding coefficient is statistically significant at the 5 percent level.

equations. The first column shows that the estimated marginal propensity to consume out of income innovations is about 0.31.[52] In the second column, although adding two

[52] This value is close to the calculated value of marginal propensity to consume out of income innovations as implied by the rational expectations life cycle-permanent income hypothesis with quarterly rate of interest 2% or

lagged income innovations variables as the regressors reduces the marginal propensity to consume from 0.31 to 0.27, we cannot reject the theory because lagged income innovations do not influence the consumption innovations.[53] However, as shown in the third column, once lagged consumption innovations are added, the marginal propensity to consume is drastically reduced from 0.31 to 0.07, and the F test shows the significance of the coefficients of lagged innovations variables.[54] In the fourth column, to see whether anticipated income matters in determining consumption innovations, the current anticipated income variable is included, and the estimated result shows that the variable is statistically insignificant at the 5 percent level, as shown in table 3.9 equation (4). From the above analysis of the ARMA model using Canadian detrended data, one might conclude that the theory is rejected only when the lagged consumption innovations variable is included.[55] However, since all the lagged income innovations have insignificant coefficients at the 5 percent level, the

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annual rate of interest approximately 8.2%.

[53] The F-statistic to test the significance of coefficients of two lagged income innovations is 0.38, which is far below the 5 percent critical value of 3.10. Therefore, the coefficients of lagged income innovations in equation (2) of table 3.9 are not significant the 5 percent level.

[54] The test F-statistic is 103.01 whereas the critical value at the 5 percent is 2.47.

[55] This rejection of the theory by Canadian data is weaker than that by the U.K. and Germany data. Weissenberger (1986) reported for U.K. and Germany data that every lagged variables and anticipated income variable are statistically significant at the 5 percent level.

significance of the coefficient of lagged consumption innovations may be due to defects of the ARMA model specification used to obtain innovations.[56] To be innovations, they are supposed not to be autocorrelated. The significant coefficient of $\xi C(t-1)$ indicates that consumption innovations are not a white noise series, although the ARMA model is specified following an ARMA search. The difficulty involved in the measurement of innovations weakens the power of Weissenberger test.

3.4.2 Analysis of ARIMA Model

Following the suggestion of Plosser and Schwert (1978) and the evidence of the unit root of the series in subsection 3.3.2, the theory is tested in this subsection using the first differenced series instead of the detrended series. The Box-Jenkins' model selection procedure also suggests to difference the series once before identifying the model for the consumption series and the income series. The Akaike Information Criterion (AIC) is applied to select the best model among several specifications suggested by Brocklebank and Dickey.[57] From this model selection procedure, the ARIMA(0,1,1) models for both the consumption

[56] An other possibility is that the significance may be caused by a generated regressors problem. Since $\xi C(t-1)$ is a generated regressor, the inference may not be correct as discussed in Pagan (1984, 1986). The standard error of the coefficient of $\xi C(t-1)$ may be underestimate and the test t-statistic upwardly biased.

[57] See footnote 49 (p.72).

series and the income series are estimated and the results are as follows:

$$\Delta C(t) = (1 - 0.018L)\xi C(t) \tag{3.27}$$

SER=33.85   Q(24)=34.14

$$\Delta Y(t) = (1 - 0.150L)\xi Y(t) \tag{3.28}$$

SER=112.01   Q(24)=18.96

where ξC = consumption innovations

ξY = income innovations

L = lag operator

Although the Q statistics show the two series may be white noise, the test statistics are higher than those of the ARMA model estimation using detrended data. The standard error of estimates for the consumption series and the income series is also higher in the ARIMA model using first differenced data than the standard error of estimates in the ARMA model using detrended data. Therefore, the estimated results indicate that the estimates of the ARMA model using detrended data is slightly better than the estimates of the ARIMA model using first differenced data.

Table 3.10 shows the results of regressing the consumption innovations on the income innovations, lagged income innovations, lagged consumption innovations, and anticipated income variable. The specified models are the same as in the ARMA model analysis case. The estimated

TABLE 3.10

Estimates of Consumption Innovations: II

dependent var: ξC(t)	equation (1)	(2)	(3)	(4)
ξY(t)	0.260* (0.02)	0.283* (0.07)	0.071* (0.03)	0.278* (0.07)
ξY(t-1)		0.063 (0.09)	-0.027 (0.04)	0.072 (0.09)
ξY(t-2)		-0.088 (0.07)	-0.044 (0.03)	-0.038 (0.07)
ξC(t-1)			0.899* (0.10)	
ξC(t-2)			0.065 (0.10)	
FY(t)				-0.024* (0.01)
SER	83.46	83.70	33.54	77.98

Note: Standard error of coefficients is shown in parentheses. * denotes that the corresponding coefficient is statistically significant at the 5 percent level.

results of the consumption innovations equation based on the ARIMA model are almost the same as the estimated results based on the ARMA model, except that the coefficient of the anticipated income variable is significant at the 5 percent level. However, the significant coefficient of -0.024 for the anticipated income variable in the ARIMA model analysis is not strong enough to reject the theory because the value of the coefficient has a wrong negative sign.[58]

[58] This significant coefficient of FY(t) variable may reflect troubles with measurement of innovations or spurious regression problem caused by misspecification of equation (4) in table 3.10.

3.5 Summary and Conclusion

In this chapter, we have tested the life cycle-permanent income hypothesis under rational expectations using the Canadian data. The models tested were Hall's and Flavin's specifications of the random walk hypothesis of consumption and Weissenberger's model of anticipated-unanticipated paradigm. Using the same concepts of consumption and income in their papers, we obtained the following test results:

1. Hall's test results using the Canadian data supported the theory that consumption is determined by one lagged consumption variable only and the coefficient of the variable is statistically insignificantly different from one. This random walk behavior of consumption for the Canadian data is the same result as Hall's conclusion for the U.S. data.

2. The Canadian evidence for Flavin's structural model test on the theory rejected the theory when the detrended data was used. The result of Flavin's test for the Canadian data is again the same as Flavin's test result using the U.S. data.

3. Following the arguments of Mankiw and Shapiro (1985) and Nelson (1987), Flavin's test results for Canadian data (1987) were reappraised, and it was shown that the rejection of the theory can be attributed to the inappropriate detrending procedure.

4. To avoid the problem involved in detrending the data, an alternative test on the theory, suggested by Weissenberger (1986), was applied. The innovations of the consumption series and the income series were calculated by both the ARMA and the ARIMA model specifications, and these innovations were used to examine whether consumers behave following the prediction of the theory. Since the innovations series are used in estimating the model to test the theory, the different detrending procedures does not affect our conclusion on the test. In fact, the estimated results were almost the same for both the ARMA analysis and the ARIMA analysis. The test results using Weissenberger's version of Flavin's test showed that the theory is supported, even though the coefficient of the consumption variable lagged one period is significant in both the ARMA and the ARIMA model analysis and the coefficient of the anticipated income variable is significant in the ARIMA analysis. The reason is that the significance of lagged consumption may be caused by problems of ARMA and ARIMA specifications for innovations, and the coefficient of anticipated income has a wrong negative sign.

Chapter IV

SOME TESTS ON THE THEORY BY TSLS ESTIMATION

4.1 Introduction

During the past decade, there has been much effort to test the Hall's (1978) random walk model of consumption, which is the implication of life cycle-permanent income hypothesis under rational expectations. As shown in chapter 3, Hall's test results using the level of consumption and the level of income support the theory. However, the response of consumption to income is inconsistent with the theory in Flavin's test, which is nothing more than the structural model test of Hall's test. Following the arguments of Mankiw and Shapiro (1985) and Nelson (1987), it was shown that Flavin's detrending procedure may cause a bias towards rejection of the theory in her test results, since nonstationary income series has approximately a unit root.[59]

However, the argument that the income series has a unit root is not settled yet and we can not totally depend on a unit root of the income series to refute Flavin's rejection

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[59] The term "unit root" refers to the unit coefficient on one lagged variable in its autoregressive representation. Therefore, this means that income series is approximately a random walk with drift.

of the theory. The purpose of this chapter is to test the theory, based on all available detrending procedures. The model used in testing the theory is Hall's random walk hypothesis of consumption, which was elaborated later by Flavin. To test the theory, following the suggestion of Davidson and MacKinnon (1981), this chapter investigates whether change in consumption can be explained by change in transitory income in the combined model of the random walk hypothesis and the Keynesian consumption function. The reason why the theory is tested in this nested model is that if the empirical results show that the marginal propensity to consume out of transitory income is non-zero, then the theory is rejected and it can be interpreted that consumers are irrational or myopic.[60]

To extract the transitory income from income series, the detrending procedures used are the traditional detrending procedure of linear trend, differencing, detrending by state space model, and detrending by spectral analysis. The trend is assumed to be constant in linear detrending procedure, but is variable and stochastic in the other detrending procedures. In a deterministic linear time trend, the time series increases by some fixed amount every quarter, whereas in a stochastic variable trend, the series increases each quarter by some fixed amount on the average but the change in the trend deviates from its average by some unforecastable random amount. From the general recognition

[60] This was pointed out by Flavin (1985).

by econometricians that many macroeconomic series appear to be integrated of order one,[61] there has been much research[62] on the variable trend recently. The reason why we consider the trend to be variable is, as explained by Stock and Watson (1988), that the sources of trend, for example, in a one-sector neoclassical growth model, such as the capital-labor ratio, the labor force participation ratio, and the technical progress have cyclical as well as trend components and this cyclical component can cause the trend to be stochastic. However, in spite of a large volume of research on the trend issue, the arguments between a deterministic linear time trend and a stochastic variable trend have not been settled yet.[63] Therefore, in this chapter the theory is tested using the transitory income calculated by all available detrending procedures. By doing so, it is possible to arrive at a conclusion for testing the theory which is insensitive to the detrending procedures.

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[61] This means that the series needs differencing once to achieve stationarity.

[62] Beveridge and Nelson (1981), Watson (1986), Campbell and Mankiw (1987), Clark (1987), and Stock and Watson (1988) are some examples to mention.

[63] There has been some recent research against the variable trend. McCallum (1988) showed that time-adjusted GNP is stationary when output is allowed to respond to monetary and non-monetary shocks. Perron (1987) argued that fluctuations around a deterministic trend are indeed stationary if the break in the trend line at the time of the oil shock of 1973 is considered.

Estimating the model using the Ordinary Least Squares (OLS) method may have a simultaneous equation bias problem since we can not exclude the correlation between change in transitory income and innovation in permanent income. Therefore, the Two Stage Least Squares (TSLS) method will be applied for the estimation of the model.

The organization of this chapter is as follows. Section 2 describes the nested model to be used for testing the theory in this chapter. Sections 3 to section 6 report the empirical test results of the model based on transitory income calculated by four different detrending procedures. Section 7 presents the summary and conclusion of this chapter.

4.2 A TSLS Estimation Approach to Test the Theory

The life cycle-permanent income hypothesis under rational expectations is represented as

$$C(t) = a\ YP(t) \tag{4.1}$$

where a is the marginal propensity to consume out of permanent income (YP). From the above equation we have

$$\Delta C(t) = a\ \Delta YP(t) \tag{4.2}$$

To test the theory, following Flavin (1985), the above model is nested with an alternative hypothesis that consumption is influenced by transitory income, as shown in the following equation:[64]

$$\Delta C(t) = a\ \Delta YP(t) + \lambda\ \Delta YT(t) \qquad (4.3)$$

or

$$\Delta C(t) = a\ \Delta YP(t) + \lambda\ [\Delta Y(t) - \Delta YP(t)] \qquad (4.4)$$

where YT is transitory income. This approach is more useful for testing the theory than Watson's (1986) test, in which $\Delta C(t)$ was regressed on the lagged values of transitory income level, because this approach avoids the possible regression problem of Granger (1986). Granger noted that a regression makes no sense unless the number of differences to achieve stationarity is the same for the regressand and regressor since, otherwise, the independent and dependent variables have such vastly different temporal properties. The model used in this chapter is subject to this problem because the regressand of change in consumption is integrated of order zero, whereas the regressor of transitory income can be integrated of order one,[65] depending on the detrending procedure applied. Using the first differenced series of transitory income as the regressor also has the following statistical advantages in testing the theory. The stationarity of the first differenced series allows one to invoke the asymptotic

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[64] This test procedure is motivated by the suggestions of Davidson and MacKinnon (1981), and Campbell and Mankiw (1987).

[65] This means that since the transitory income can be nonstationary and may have a unit root, the first difference of the series is stationary.

distribution theory and the test results of the theory using the differenced data are valid. According to Plosser and Schwert (1978) and Campbell and Mankiw (1987), estimating the equation using differenced data does not give biased estimates, but consistent estimates, even if the series in fact does not have a unit root but is stationary around a time trend. Therefore, the test, using first differences of transitory income as regressor rather than the levels of the series, is more powerful since it is still valid whether or not transitory income has a unit root. Besides, if the coefficient λ in the model is statistically significant and the value is the same as the value of coefficient a, then consumption is determined by current income and the result can be interpreted as rejection of the random walk hypothesis in favor of the Keynesian theory.

Following the arguments of Hall (1978) and Flavin (1981), if consumers with rational expectations maximize the expected value of an intertemporally separable utility function subject to the life time income stream, then the change in the aggregate consumption equation to be estimated, $\Delta C(t) = a\,\Delta YP(t)$, can be shown as follows:[66]

$$\Delta C(t) = \mu + \nu(t) \qquad (4.5)$$

[66] Refer to section 2.2 and 2.3.1 for the derivation of this equation.

where μ is the drift of consumption series and $\nu(t) = a\epsilon(t) + \eta(t)$, in which $\epsilon(t)$ is the innovation between time t-1 and t period in the consumers' assessment of permanent income and $\eta(t)$ is the consumption disturbance. Therefore, the nested model to be tested can be rewritten as follows:

$$\Delta C(t) = \mu + \lambda\, \Delta YT(t) + \nu(t) \qquad (4.6)$$

After running the above equation, the theory is tested by investigating the hypothesis that $\lambda = 0$.[67] However, if the Ordinary Least Squares (OLS) method is used to estimate the above equation, then it is possible to have upwardly biased estimates of λ in the case that change in transitory income $\Delta YT(t)$ is positively correlated with current innovation in income $\epsilon(t)$. To avoid this problem, estimating the equation by the Two Stage Least Squares (TSLS) method is suggested. In the first stage, ΔYT is estimated by instrumental variables and ΔC is regressed on the estimated value of ΔYT in the second stage. To be good instrumental variables, it is well known that they must be correlated with ΔYT but not with ν. Campbell and Mankiw (1987) argued that the lagged values of ΔY are valid instruments for ΔY[68] since a time series can be explained by its history according to the time series analysis. Campbell (1987) emphasized that the lagged

[67] This means that change in the transitory component of income should have no influence on the change in consumption to support the theory.

[68] Campbell and Mankiw (1987) showed that even if the income series has a unit root, lagged values of ΔY are still valid instruments but they do not explain a large fraction of the variance of ΔY.

values of consumption could be good instrumental variables for income because consumption summarizes consumers' information about the future income stream, providing the permanent income hypothesis holds. It is also considered that, following the traditional business cycle theory, changes in government fiscal and monetary policies may provide good instruments for change in transitory income, ΔYT. From the above arguments, the instrumental variables to be used in the present model are summarized as follows:

1. lagged values of ΔYT(t)
2. lagged values of ΔC(t)
3. lagged values of ΔG(t), ΔT(t), or ΔM(t)[69]

where ΔC(t) = change in consumption

ΔG(t) = change in government expenditure

ΔT(t) = change in taxation

ΔM(t) = change in money supply

Therefore, the corresponding nested model, which is to be estimated using the above instrumental variables, for testing the theory can be specified in the following three different models:[70]

[69] The estimated results with the highest F-statistic in estimation of ΔYT(t) using any one of these ΔG(t), ΔT(t), or ΔM(t) will be used for the second stage estimation.

[70] Four lagged values are used for instruments following Watson (1987).

1. $\Delta C(t) = \mu + \lambda\ \Delta \hat{Y}T(t) + \nu(t)$ (4.7)

$$\Delta YT(t) = \beta_0 + \beta_1 \Delta YT(t-1) + \beta_2 \Delta YT(t-2) + \beta_3 \Delta YT(t-3) + \beta_4 \Delta YT(t-4) + \omega(t)$$

2. $\Delta C(t) = \mu + \lambda\ \Delta \hat{Y}T(t) + \nu(t)$ (4.8)

$$\Delta YT(t) = \beta_0 + \beta_1 \Delta C(t-1) + \beta_2 \Delta C(t-2) + \beta_3 \Delta C(t-3) + \beta_4 \Delta C(t-4) + \omega(t)$$

3. $\Delta C(t) = \mu + \lambda\ \Delta \hat{Y}T(t) + \nu(t)$ (4.9)

$$\Delta YT(t) = \beta_0 + \beta_1 \Delta X(t-1) + \beta_2 \Delta X(t-2) + \beta_3 \Delta X(t-3) + \beta_4 \Delta X(t-4) + \omega(t)$$

where $\Delta \hat{Y}T$ is the estimated value of ΔYT, $\omega(t)$ is the disturbance term, and X can be G, T, or M.

The data used in this chapter for estimation is the same as the data used in the analysis of chapter 3. The income series is personal disposable income in real per capita terms, and the consumption series is the sum of personal expenditure on non-durable goods and personal expenditure on services in real per capita terms. The sample period of the data is from 1960:I through 1987:II.

4.3 Test Results Based on Linear Detrending

The distinguishing feature of income series or similar macroeconomic is that its movement is predominantly in an upward direction and it has a trend. Most macroeconomic analysis concerns explaining the cyclical component of those series. To find the cyclical component of the income series, the traditional approach used until now[71] was that the natural logarithm value of the series is regressed on time and the resulting residuals from the regression are considered as the transitory income.[72] The assumption behind this detrending procedure is that the residuals in the following equation are a well behaved stationary series:[73]

$$\ln Y(t) = \alpha + \beta t + u(t) \qquad (4.10)$$

By regressing the above equation,[74] the transitory income series, YT, is obtained, and the change in transitory income, ΔYT, is calculated from the YT series. The trend and cycle components of the income series decomposed by the linear detrending procedure are shown in figure 4.1 and 4.2, respectively. From figure 4.1 it can be observed that the actual income series is greatly deviated from the forecast of the trend and these deviations may be strongly positively autocorrelated. The behavior of this cycle component is clearly shown in figure 4.2.

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[71] For example, Flavin (1981) and Blanchard (1981) applied this approach in their papers for detrending the time series.

[72] We can also include a time variable in a regression model for the same effect.

[73] The problem of using this detrending procedure for the income series with a unit root was already discussed in section 3.3.1 of chapter 3 related with differencing.

[74] The estimated results using the SAS system are that α=8.416(0.011), and β=0.009(0.000). The standard error of the coefficients are given in parentheses.

Figure 4.1: Trend Component of Income Series by Linear Trend

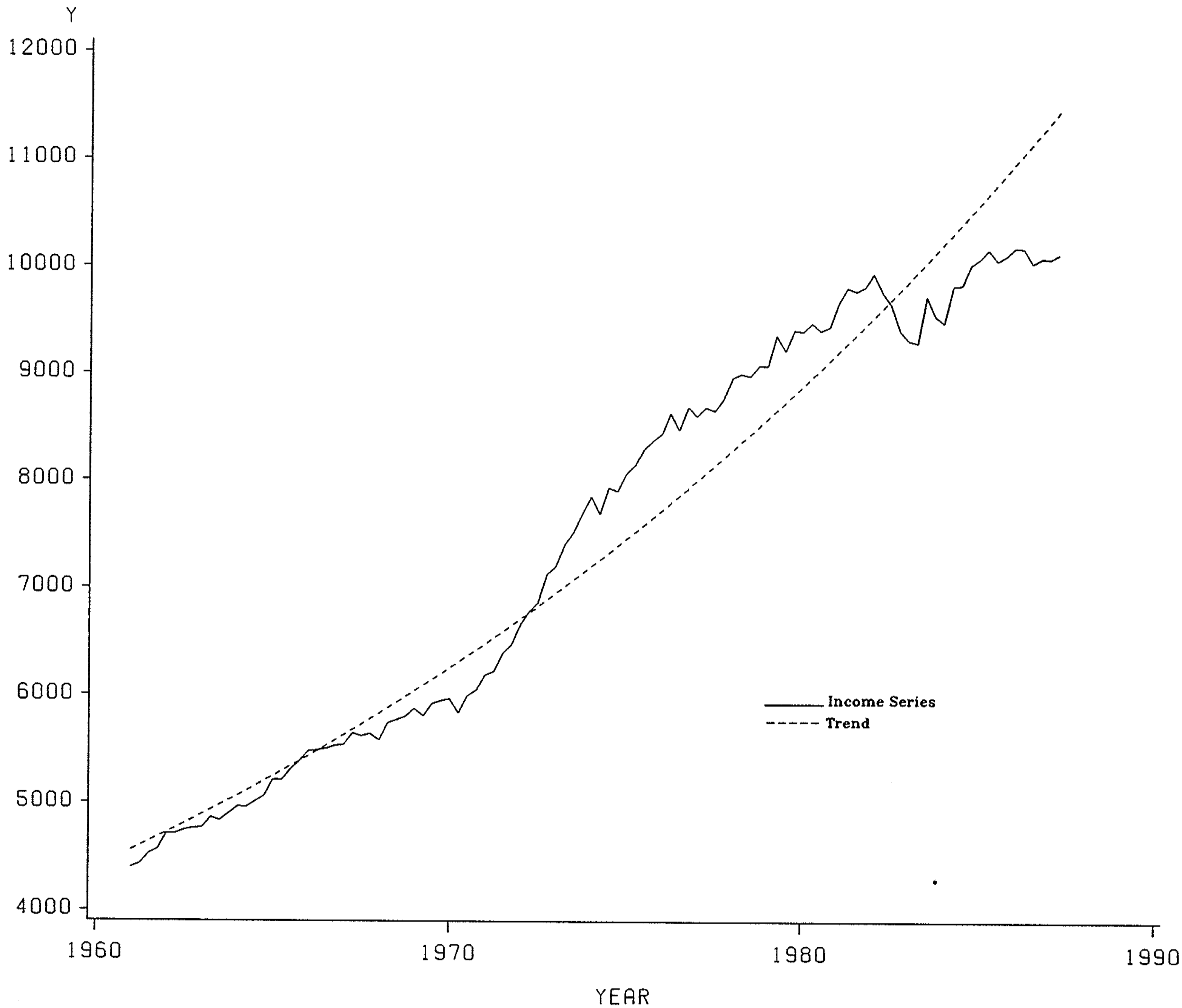

Figure 4.2: Cycle Component of Income Series by Linear Trend

Using the transitory income calculated by the linear detrending procedure, the model specified in section 2 is estimated by the SAS SYSLIN system and the estimated results are shown in table 4.1. The first, second, and third column in the table give the TSLS estimation results of the present model using instrumental variables of the lagged values of $\Delta YT(t)$, $\Delta C(t)$, and $\Delta T(t)$, respectively. The first stage estimation results show that the F-statistic of the equation (3) only is larger than the 5 percent critical value of 2.47, indicating that the change in transitory income can be explained by change in the taxation policy. Following the explanation of Campbell and Mankiw (1987), the first stage estimation result of equation (1), that a large fraction of the variance of $\Delta YT(t)$ is not well explained by lagged values of $\Delta YT(t)$, can be interpreted that the transitory income series by detrending procedure of linear trend is nonstationary and has approximately a unit root.[75] The estimated results in the table also show that the lagged values of change in consumption can not explain the variations of $\Delta YT(t)$ either. This is expected since, under the theory, consumption changes only with change in permanent income, not with change in transitory income. Thus, consumption has no relationship with transitory income and $\Delta C(t)$ should not have any influence on $\Delta YT(t)$. In that sense, both small value of R^2 and strong insignificance of the equation by the F test in the first stage estimation of

[75] The nonstationarity of the detrended series of income was shown in section 3.3.2 of chapter 3.

TABLE 4.1

Estimated Results Based on Linear Detrending

	(1)	(2)	(3)
β_1	-0.155	0.389	0.711
	(0.10)	(0.35)	(0.16)
β_2	0.205	0.644	0.301
	(0.10)	(0.34)	(0.18)
β_3	0.125	0.090	0.064
	(0.10)	(0.34)	(0.18)
β_4	0.126	0.244	-0.267
	(0.10)	(0.35)	(0.16)
SER	114.28	116.72	107.86
R^2	0.09	0.06	0.19
F	2.51	1.41	5.76
μ	28.24	28.96	28.28
	(3.64)	(3.71)	(3.52)
λ	-0.005	0.050	-0.002
	(0.09)	(0.12)	(0.07)
SER	34.37	33.69	34.29
R^2	0.00	0.00	0.00
F	0.00	0.17	0.00

Note: For the equation (1), the lagged values of $\Delta YT(t)$ are used as instrumental variables. For the equation (2), the lagged values of $\Delta C(t)$ are used as instrumental variables. For the equation (3), the lagged values of $\Delta T(t)$ are used as instrumental variables. The standard error of coefficients is given in parentheses.

equation (2) can be considered as an evidence to support the theory.

The estimated results of the second stage estimation support the theory more strongly by showing zero R^2, small F-statistics which are far below the 5 percent critical value of 3.95,[76] and the insignificant coefficient of the change in transitory income variable, λ.

From the above results, we can conclude that the theory is well supported even with detrended data and there is no evidence of excess sensitivity of current income as argued by Flavin (1981). This conclusion is rather contradictory with her rejection of the theory. The difference between this approach and Flavin's approach is mainly that the consumption series is also detrended by the linear detrending procedure in her paper.[77] This might cause the significant coefficient of change in current income in her model since the residuals from regressing the consumption series on the time variable is regressed on the lagged values of the residuals from regressing income series on the time variable. Therefore, the significant coefficient in her test may show nothing but a significant relationship

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[76] Note that strong support for the theory with the smallest value for the coefficient of $\Delta YT(t)$ and the lowest F-statistic in equation (3) was by the best instruments $\Delta T(t)$, in the sense that the instruments well explain $\Delta YT(t)$ with the highest F-statistic.

[77] One more difference is that Flavin (1981) used lagged level values of the detrended income series for instruments in her test.

between transitory consumption[78] and transitory income. The difference between Hall's and Flavin's test results can be explained by interpreting Flavin's results this way.

4.4 Test Results Based on Differencing

An alternative procedure for detrending the time series data often used in the literature is to difference the series. Removing the nonstationarity of the series by first differencing, rather than using the linear detrending of the above section, means that the trend is assumed to be a stochastic process rather than a straight line. This differencing method for detrending the data is especially useful when the series has a unit root.

Beveridge and Nelson (1981) show that any ARIMA process for which the first differences are a stationary process of autoregressive-moving average form can be represented as a random walk with drift trend plus a stationary component. Based on the nonstationary behavior of the income series described in chapter 3, the ARIMA(0,1,1) model[79] was specified for the series and the representation for it can be shown as the following equation:

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[78] The trend is interpreted as the permanent component of the series and the deviations of the trend as the cycle or the transitory component of the series. Therefore, the residuals from regressing the series on the time variable are considered as the transitory component of the series.

[79] For the trend and cycle component decomposition of general ARIMA(p,1,q) model see Beveridge and Nelson (1981).

$$Y(t) = YP(t) + YT(t) \tag{4.11}$$

$$YP(t) = \mu + YP(t-1) + (1 + \beta)\epsilon(t)$$

where μ is the drift in the trend, $\epsilon(t)$ is the random disturbance term[80] with mean zero and constant variance, and β is the coefficient of the one lagged disturbance term $\epsilon(t-1)$ in the ARIMA(0,1,1) model.

To decompose the trend and cycle components from income series, the ARIMA(0,1,1) model of income series is rewritten as follows:[81]

$$\Delta Y(t) = \mu + \epsilon(t) + \beta\epsilon(t-1) \tag{4.12}$$

or

$$\begin{aligned} Y(t) &= \mu + Y(t-1) + \epsilon(t) + \beta\epsilon(t-1) \\ &= 2\mu + Y(t-2) + [\epsilon(t) + \beta\epsilon(t-1)] \\ &\quad + [\epsilon(t-1) + \beta\epsilon(t-2)] \\ &= \mu t + \sum_{i=1}^{t} \epsilon(i) + \beta \sum_{i=1}^{t-1} \epsilon(i) \\ &= \mu t + (1 + \beta)[\sum_{i=1}^{t} \epsilon(i)] - \beta\epsilon(t) \end{aligned} \tag{4.13}$$

---

80 The $\epsilon(t)$ is often referred to as 'innovation' since it is the part of YP(t) and Y(t) which is unpredictable from the past.

81 It is assumed that $\epsilon(0)=0$.

From the above equation, YP(t) and YT(t) can be rewritten as follows:

$$YP(t) = \mu t + [(1 + \beta) \sum_{i=1}^{t} \epsilon(i)] \qquad (4.14)$$

$$YT(t) = -\beta\epsilon(t) \qquad (4.15)$$

The trend and cycle components for income series were calculated by applying the above formula to the estimated result of ARIMA(0,1,1) model, and are shown in figures 4.3 and 4.4, respectively.

From this transitory income, the model in section 4.2 is estimated by the SAS SYSLIN system and the results are reported in table 4.2. The estimated results in the table show that for the second stage equation, R^2 is zero, the F-statistics are far below the critical value of 3.95 at the 5 percent level, and furthermore the coefficient of the change in transitory income, λ, is not significant at all for any estimation using different instruments. Therefore, the test results based on the differencing detrending procedure again support the theory.

Figure 4.3: Trend Component of Income Series by Differencing

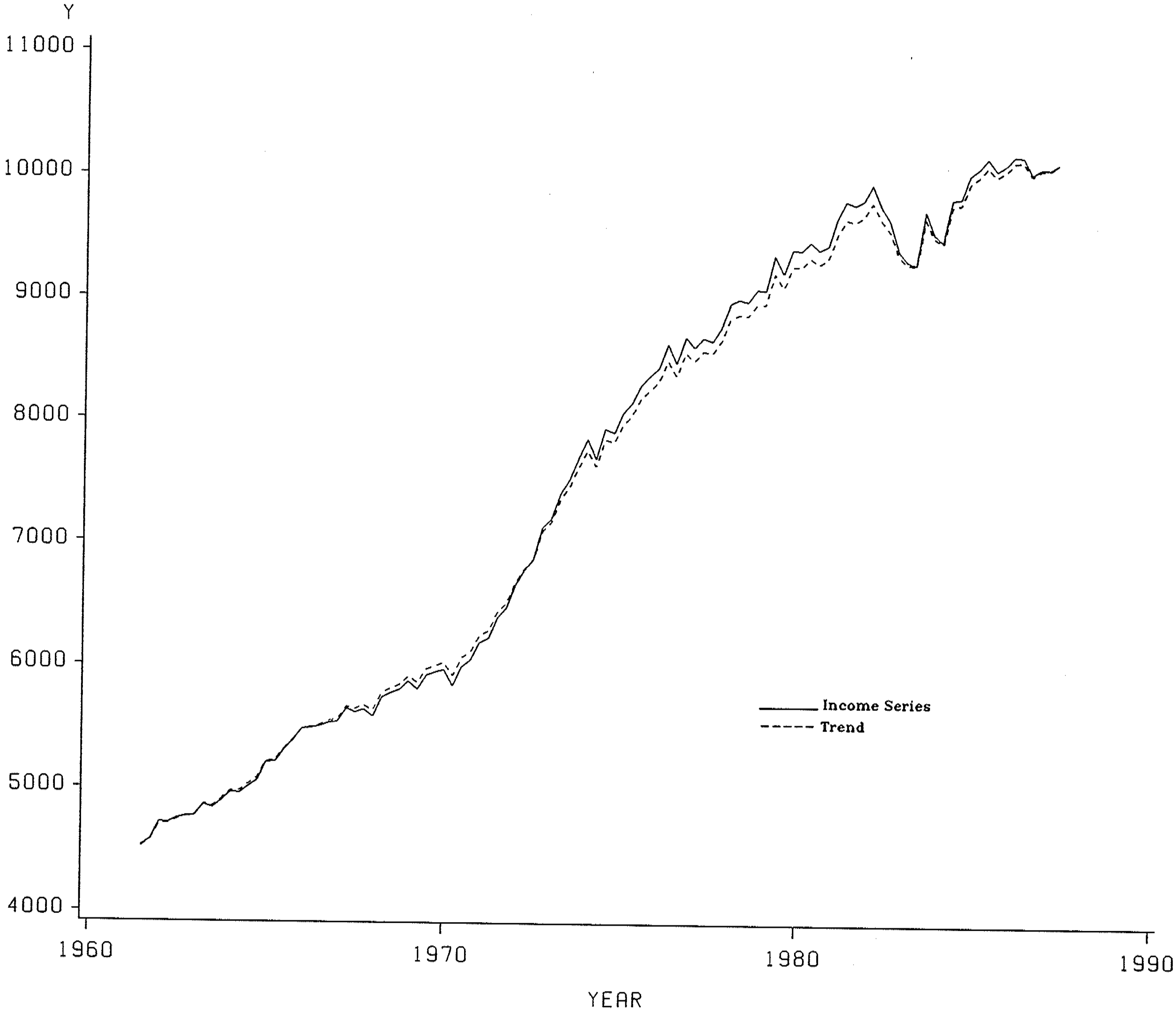

Figure 4.4: Cycle Component of Income Series by Differencing

TABLE 4.2

Estimated Results Based on Differencing

	(1)	(2)	(3)
β_1	-0.188	0.055	0.106
	(0.10)	(0.05)	(0.02)
β_2	0.165	0.092	0.045
	(0.10)	(0.05)	(0.03)
β_3	0.085	0.011	0.010
	(0.10)	(0.05)	(0.03)
β_4	0.095	0.034	-0.040
	(0.10)	(0.05)	(0.02)
SER	17.03	17.31	15.90
R^2	0.08	0.05	0.20
F	2.12	1.30	5.90
μ	28.85	28.87	28.86
	(3.52)	(3.41)	(3.46)
λ	-0.178	0.248	-0.030
	(0.71)	(0.86)	(0.45)
SER	35.05	33.88	34.47
R^2	0.00	0.00	0.00
F	0.06	0.08	0.01

Note: For the equation (1), the lagged values of $\Delta YT(t)$ are used as instrumental variables. For the equation (2), the lagged values of $\Delta C(t)$ are used as instrumental variables. For the equation (3), the lagged values of $\Delta T(t)$ are used as instrumental variables. The standard error of coefficients is given in parentheses.

4.5 Test Results Based on State Space Model

Although a random walk with drift for the trend in the above section was strongly supported by Beveridge and Nelson (1981), it is possible that a deterministic nonlinear trend or some other form of stochastic trend may be just as good as or even better than a random walk model, as argued by Clark (1987). Specially, if the autocovariance function for the first differenced series is not exactly zero after lag one, then a wide variety of processes for the trend is consistent with the series, as indicated by Harvey (1985).

In this section, to allow for a smoothed trend rather than an irregular trend of the differencing detrending procedure in the above section, the state space model is applied to extract the trend from the income series. For the state space model, following Watson (1986) and Clark (1987), it is assumed that the trend component is a nonstationary stochastic process of a random walk with drift and the cyclical component is a stationary process with second autocorrelation. The dynamic behavior of the trend and the cyclical components assumed in the above can be represented in the following state space model:

measurement equation:

$$Y(t) = YP(t) + YT(t) \tag{4.16}$$

$$\Phi(L)YT(t) = \upsilon(t)$$ [82]

[82] For second-order autocorrelation this can be written as $YT(t)-\phi_1 YT(t-1)-\phi_2 YT(t-2)=\upsilon(t)$.

transition equation:

$$YP(t) = YP(t-1) + d + \omega(t) \tag{4.17}$$

where Y = income series

YP = trend

YT = cyclical component

d = drift

υ, ω = white noise processes, assumed to be mutually uncorrelated

$\Phi(L)$ = a finite polynomial in the lag operator L

In the above state space model, the income series Y(t), which is actually observable, is related to the state variable of the unobserved trend component YP(t) in the measurement equation. Even if the trend component YP(t) is not directly observable, its movements are assumed to be governed by a random walk with drift process in the transition equation.

The unobserved component of the trend in the above state space model can be estimated by the Kalman filtering. The Kalman filter provides an optimal solution for estimating the trend by recursively applying a set of equations:[83] the prediction, updating and smoothing equations. The optimal predictor of the trend component for the income series, YP(t), is estimated by the prediction equation with a given

[83] For the detailed mathematical form of the equations, see Clark (1987) p.801-803.

initial guess for the state variable and its variance.[84] Then, given an observation Y(t+1), YP(t+1) is estimated by updating the estimated value of YP(t) in the updating equation. When all the observations have been processed, the filtered estimates are smoothed by the smoothing equation. The smoothed estimators use all information, whereas the updating equation gives the best estimators of the state variable based on the information available at that time.

Figure 4.5 presents the actual income series and the optimal estimates for the trend using the Kalman filtering subroutine FTKALM of IMSL (International Mathematical and Statistical Library) edition 9. The trend in the figure smooths the series considerably, compared with the irregular trend of the differencing detrending procedure, but it is far from a linear curve of linear detrending procedure. Once the trend of the series is found, the cycle component can be easily calculated by subtracting the trend component from the actual income series. Figure 4.6 shows the cycle component of the income series.

Using the cycle component of income series, the model specified in section 4.2 is estimated by the SAS SYSLIN system and the estimated results are reported in table 4.3. The estimated results in the table show that the test F-

[84] The first observation of income series is used for the initial value of the trend and the variance of income series for its initial variance.

Figure 4.5: Trend Component of Income Series by State Space Model

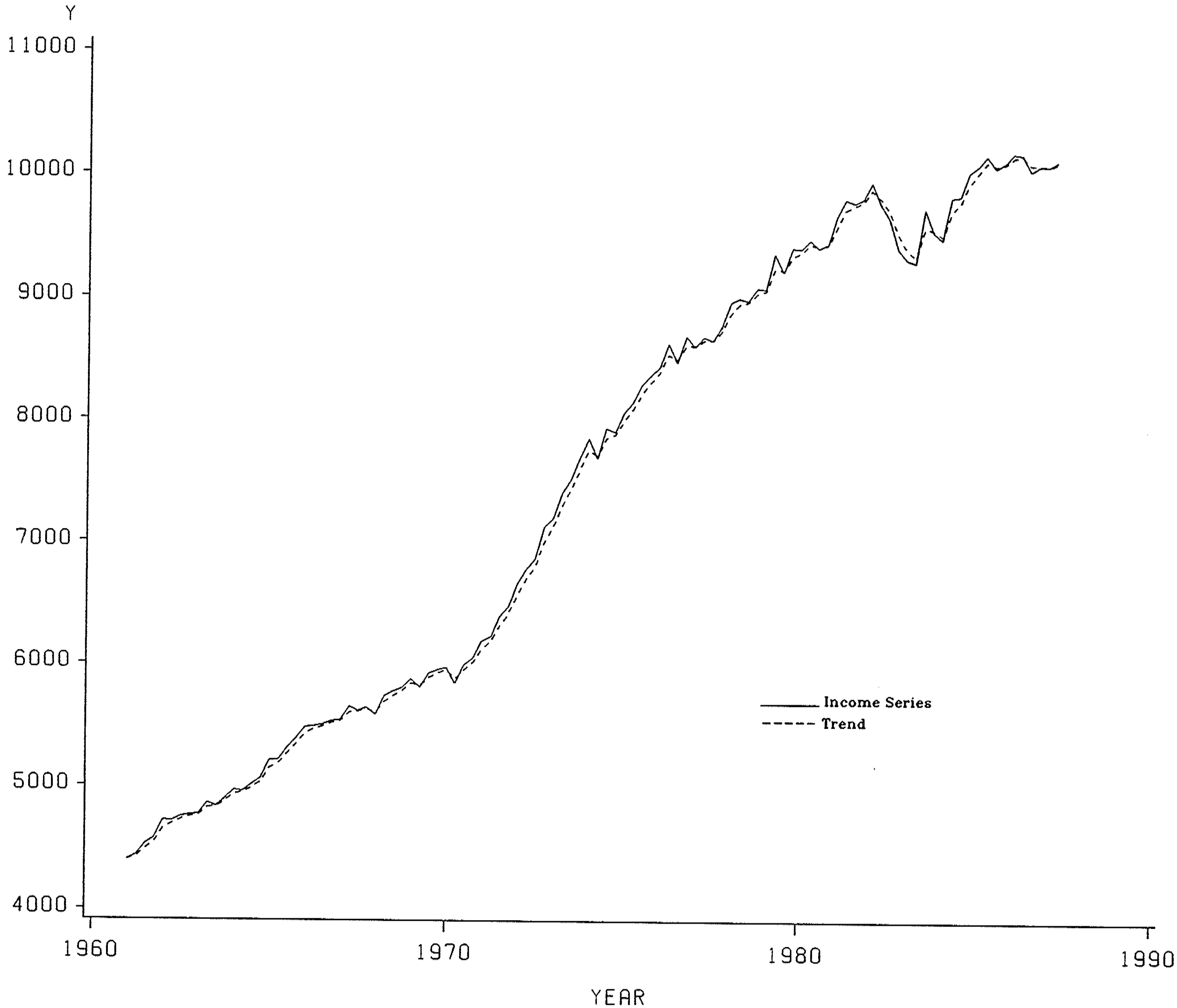

Figure 4.6: Cycle Component of Income Series by State Space Model

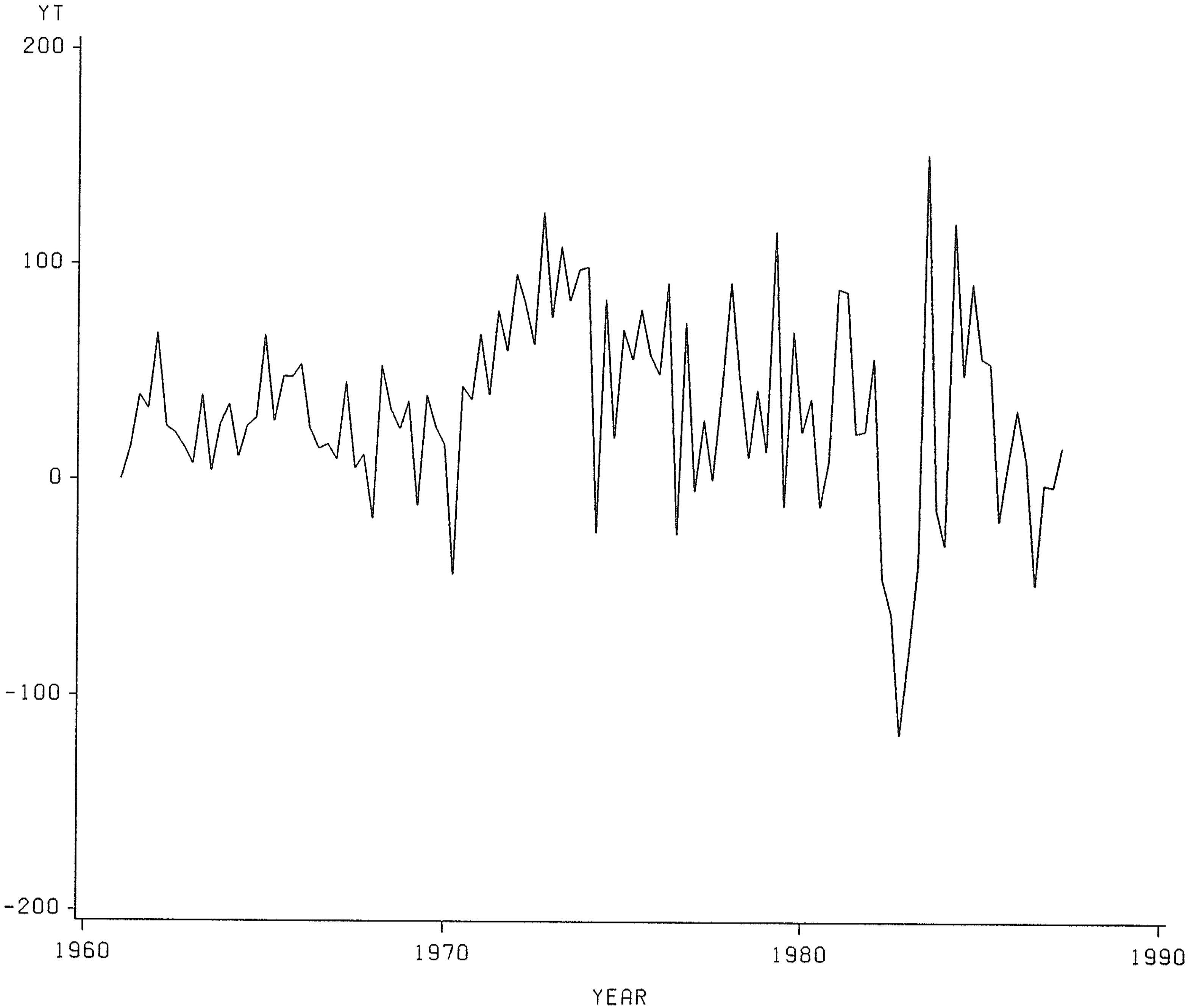

TABLE 4.3

Estimated Results Based on State Space Model

	(1)	(2)	(3)
β_1	-0.699	-0.029	0.413
	(0.10)	(0.17)	(0.07)
β_2	-0.370	0.072	0.072
	(0.12)	(0.16)	(0.08)
β_3	-0.277	-0.182	-0.031
	(0.12)	(0.16)	(0.08)
β_4	-0.103	0.018	-0.153
	(0.10)	(0.17)	(0.07)
SER	45.30	55.63	46.47
R^2	0.35	0.02	0.31
F	12.76	0.38	10.94
μ	28.29	27.75	28.32
	(3.43)	(7.06)	(3.40)
λ	-0.039	-1.070	0.025
	(0.11)	(1.07)	(0.11)
SER	34.50	70.79	34.16
R^2	0.00	0.01	0.00
F	0.13	1.07	0.05

Note: For the equation (1), the lagged values of $\Delta YT(t)$ are used as instrumental variables. For the equation (2), the lagged values of $\Delta C(t)$ are used as instrumental variables. For the equation (3), the lagged values of $\Delta T(t)$ are used as instrumental variables. The standard error of coefficients is given in parentheses.

statistics for change in the consumption equations are far below the 5 percent critical value of 3.95 and the coefficient of change in transitory income is statistically insignificant at the 5 percent level. Therefore, we conclude that the test results using the cycle component of income series calculated by the state space model as transitory income in the present model support the theory.

4.6 Test Results Based on Spectral Analysis

The detrending procedures discussed in the above section were based on special assumptions about the trend. Specifically, the trend is assumed to be either linear in the linear detrending procedure or random walk with drift in the differencing detrending procedure and the detrending procedure by the state space model. Considering that a generally acceptable definition for the trend is not obvious, there is no reason to suppose that the trend can be approximated by a monotonic expression such as linear or random walk with drift. As argued by Granger (1966), a curve that would be considered as a "trend" in a short series would not be so considered if the series were longer.[85] Therefore, the proper definition of the trend is likely to depend on the amount of data available.

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[85] Granger used temperature readings as an example. If a temperature series was gathered every minute for four hours during the day, then the daily fluctuation would appear as a trend in the series. However, it would not be considered as a trend if the data were available for a period of three months, since in such case the annual fluctuation would appear as a trend.

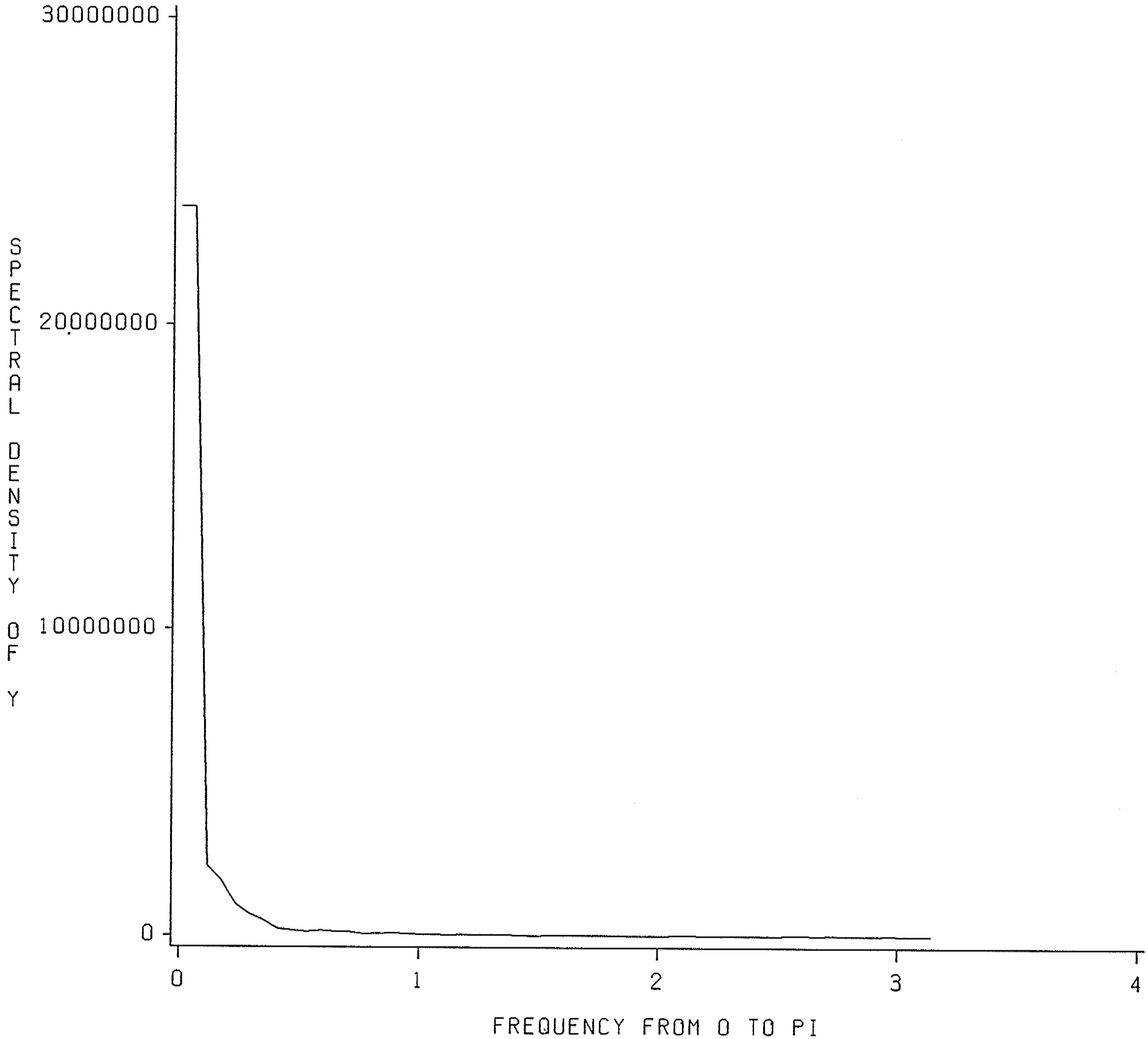
In this section, we decompose the trend and cycle component of the income series more generally by spectral analysis[86] rather than depending on the assumption of either a constant rate of income growth or a specific form of ARIMA model for the income series. An advantage of using spectral analysis is that the difficulty involved in identifying the ARIMA model of time domain analysis can be easily avoided. Besides, spectral analysis is very useful for the purpose of decomposing trend and cycle component from the income series since the analysis provides the information on the cyclical movements of the series.

Granger (1966) observed that the majority of power spectra estimated from macroeconomic data are of a similar shape. A number of power spectra of economic series displayed the typical shape of its maximum at zero frequency and the overpowering importance of the low frequency[87] components, indicating that the series is strongly positively autocorrelated. It is well known that the trend contained in the economic time series raises the value of the power spectrum at the low frequencies. The spectral density of the income series is of course not an exceptional case of this typical shape, as well shown in figure 4.7 of

[86] This is also known as analysis in the frequency domain. For the easiest explanation on this analysis see Harvey (1981).

[87] In the spectral analysis, the lower frequency means that the period of cycle for the components is longer since the period of cycle is equal to $2\pi/\omega$, where ω is frequency.

Figure 4.7: Spectral Density of Income Series



power spectra of the income series. The spectrum $f(\omega)$ in the figure is defined by the following continuous function and calculated as the Fourier transform of the autocorrelation function $\gamma(t)$ using the SAS SPECTRA system:

$$f(\omega) = (2\pi)^{-1}[\gamma(0) + 2 \sum_{t=1}^{\infty} \gamma(t)\cos\omega(t)] \qquad (4.18)$$

where the frequency in radians ω can take any value in the range $(-\pi, \pi)$. From the estimated spectral density of income series shown in the figure, it is known that power spectra have their peak at zero frequency and are concentrated at low frequencies. Following the arguments of Granger (1966) and Singleton (1988), this proportion of spectral densities at low frequencies is interpreted as the trend component. Granger defined the trend as all components of the series whose wave length equals or is greater than the length of the series.[88] This means that the trend consists of all frequency components with $\omega \leq 2\pi/n$,[89] where n is the sample size.

The filtering technique enables us to decompose the trend and the cycle components of the series by extracting low frequency components of the trend from the power spectra. A

[88] This gives more flexibility to define the trend which depends on the amount of data available. As longer period of data become available, the trend for longer period can be easily defined.

[89] The frequency $\pi/16$ was arbitrarily chosen by Kydland and Prescott (1982) for detrending.

low-pass version of the Butterworth filter[90] is applied to extract the trend component from the series. As shown in figure 4.8, the filter has the effect of truncating the high frequency components of the cycle component of income series.

Using the computer program for the Butterworth filter in Kanasewich (1981), the trend component is calculated and the trend and actual income series are shown in figure 4.9. From the trend component, the cycle component of income series is calculated and figure 4.10 presents the behavior of the cycle component. The trend in figure 4.9 displays a smoother line than the trend from the state space model in figure 4.5. Accordingly, the cycle component from spectral analysis is greater than that from the state space model.

To test the theory, the present model specified in section 4.2 is estimated using the SAS SYSLIN system and the estimated results are shown in table 4.4. From the low test F-statistics and the insignificant coefficient of the variable $\Delta YT(t)$, we conclude that the test results support the theory.

[90] This low-pass filter passes low frequency components but blocks or attenuates high frequency components. See Kulhanek (1976) for the more details of the filter.

Figure 4.8: Butterworth Filter

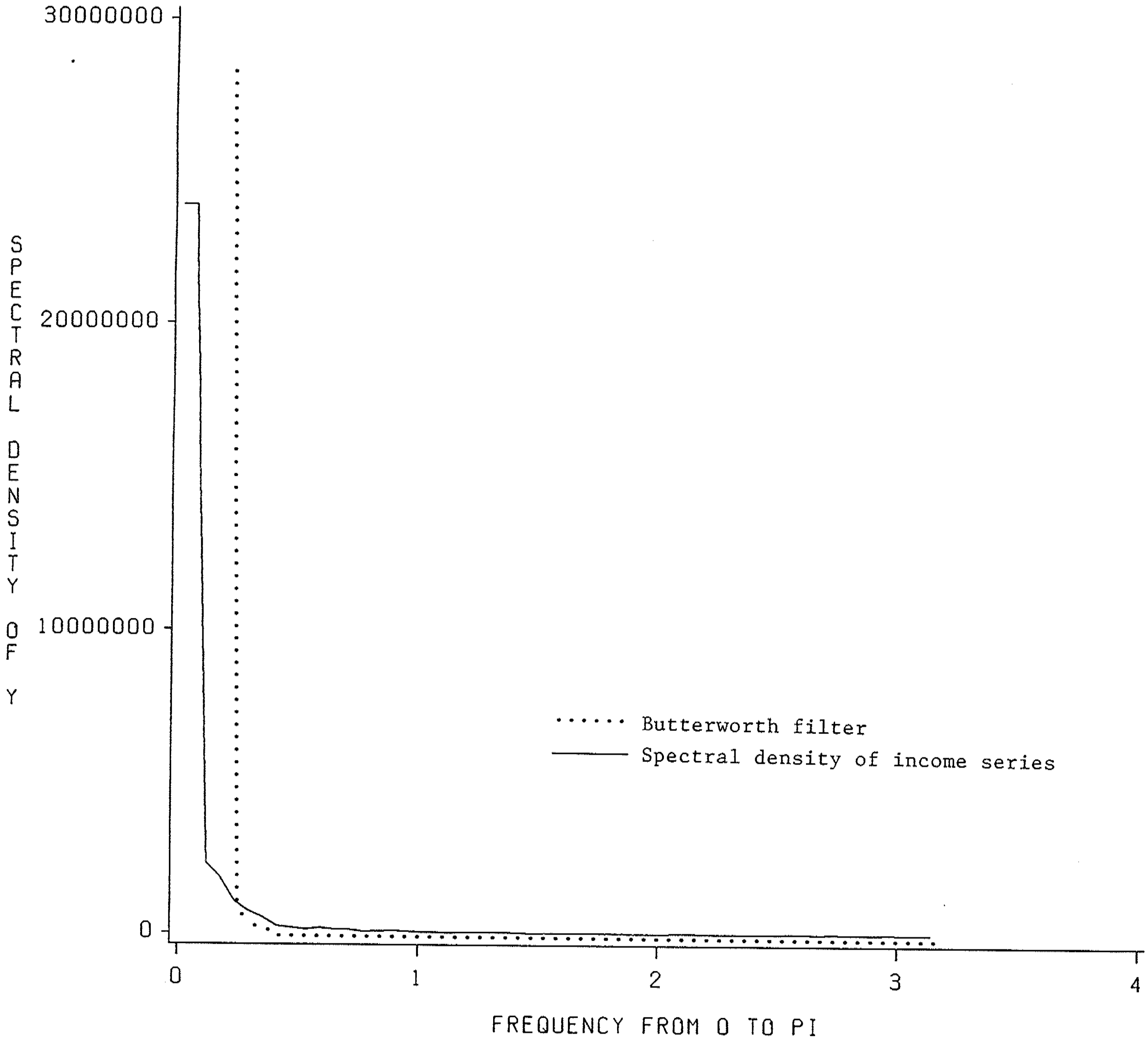


Figure 4.9: Trend Component of Income Series by Spectral Analysis

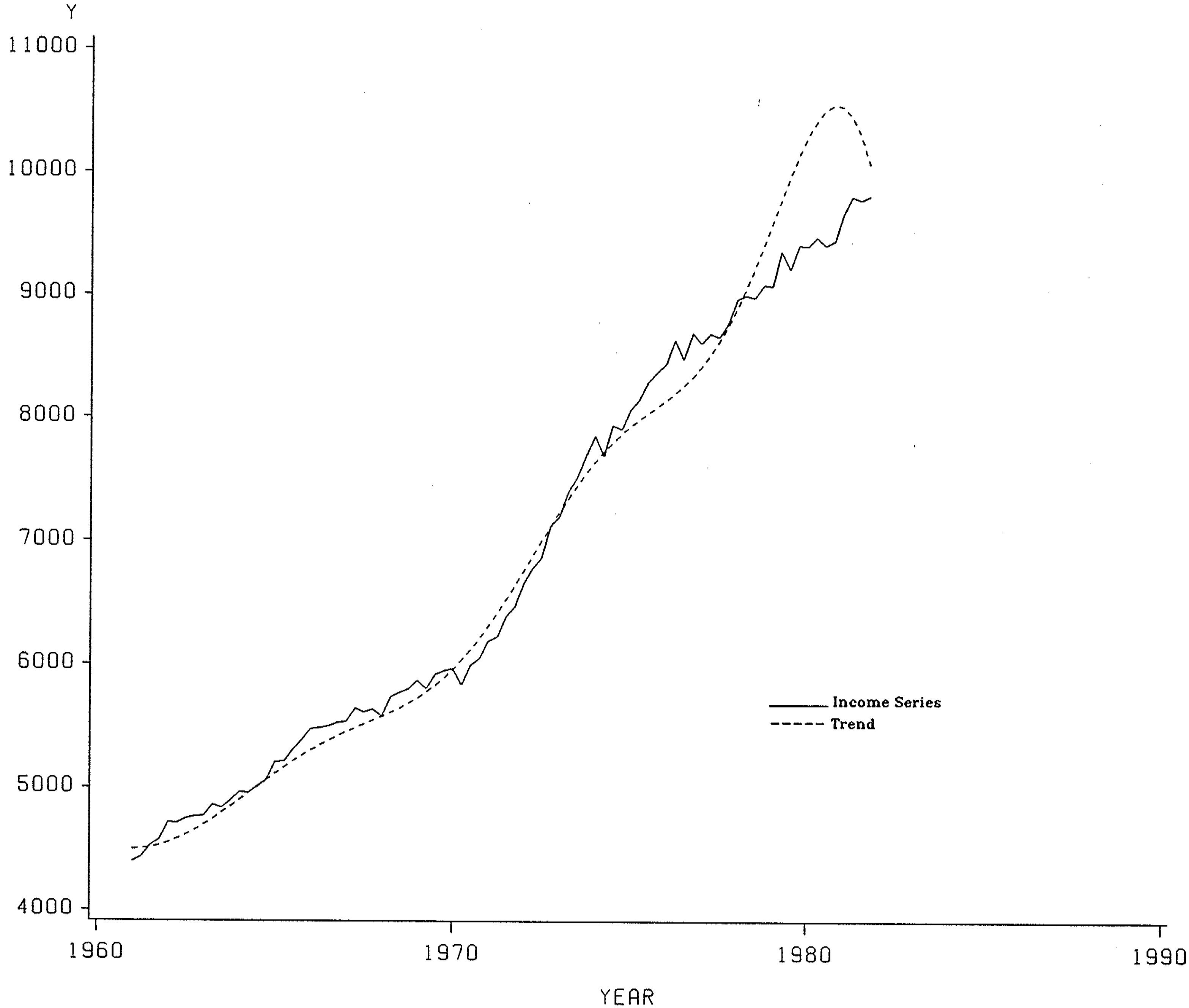


Figure 4.10: Cycle Component of Income Series by Spectral Analysis

TABLE 4.4

Estimated Results Based on Spectral Analysis

	(1)	(2)	(3)
β_1	-0.093	0.045	0.795
	(0.12)	(0.40)	(0.19)
β_2	0.501	-0.001	0.264
	(0.12)	(0.40)	(0.20)
β_3	0.094	0.022	0.559
	(0.13)	(0.40)	(0.20)
β_4	-0.070	0.076	0.116
	(0.13)	(0.40)	(0.19)
SER	98.83	111.79	96.12
R^2	0.22	0.00	0.26
F	5.19	0.01	6.54
μ	29.48	33.26	29.26
	(3.71)	(19.08)	(3.77)
λ	-0.003	0.711	-0.044
	(0.07)	(3.14)	(0.07)
SER	32.82	83.33	33.37
R^2	0.00	0.00	0.01
F	0.00	0.05	0.43

Note: For the equation (1), the lagged values of $\Delta YT(t)$ are used as instrumental variables. For the equation (2), the lagged values of $\Delta C(t)$ are used as instrumental variables. For the equation (3), the lagged values of $\Delta T(t)$ are used as instrumental variables. The standard error of coefficients is given in parentheses.

4.7 Summary and Conclusion

In this chapter, life cycle-permanent income hypothesis under rational expectations was tested in the nested model by investigating whether change in consumption is influenced by change in transitory income. In empirical estimation, the cycle component of the income series was interpreted as the transitory income and derived by applying the following four different detrending procedures:

1. linear detrending
2. differencing
3. detrending by state space model
4. detrending by spectral analysis

The test results from estimating the present model using calculated transitory income by the above different detrending procedures unanimously supported the implication of the theory that consumption follows a random walk with drift. The implication of the random walk model of consumption is that the optimal decisions of agents induce a stochastic trend in the consumption series.

The distinguishing features of the model used in this chapter are that the sensitivity of test results for different detrending procedures can be shown by estimating the model based on four different detrending procedures, and that the regression problem of Nelson and Kang (1981) and Granger (1986) can be avoided by using the first differenced series for the dependent and independent variables in the model.

Chapter V

ATHEORETICAL ANALYSIS OF AGGREGATE CONSUMPTION BEHAVIOR

5.1 Introduction

About the same time Hall (1978) published his seminal paper on the study of the life cycle-permanent income hypothesis under rational expectations, another atheoretical approach to explain the relationship between consumers' expenditure and disposable income was developed by a group of British econometricians, Davidson, Hendry, Srba, and Yeo (1978) (henceforth DHSY). A data-based approach[91] was applied to derive the consumption function of DHSY. The aggregate consumption function of DHSY is also known as the Error Correcting Model (ECM) since it is derived based on the assumption that consumers make plans which may not be achieved and they adjust the next period's plans to recoup a portion of the error between income and consumption. The traditional error correcting model of DHSY is validated by the recent paper of Granger and Engle (1987). Granger and Engle show that if a vector of variables is cointegrated,[92]

[91] The data-based approach to econometrics seeks to find the best model to describe the behavior of the variables involved, based on the concept of data generating process.

[92] For the definition of this term refer to section 5.3.

then there is a valid error correction representation of the data which is not liable to the spurious regression problem. Therefore, if the consumption series is cointegrated with the income series, then the error correcting model can be specified for the consumption series.

The purpose of this chapter is to establish the robustness of the model in chapter 4 by showing that the model encompasses the cointegrating and error correcting model of consumption. For the purpose, the organization of this chapter is as follows. The DHSY's error correcting model is discussed in section 2. In section 3, following Granger and Engle (1987), the cointegration between consumption and income in Canadian context is reviewed. In section 4, the relationship between the model in chapter 4 and the cointegrating and error correcting model for aggregate consumption behavior is discussed, and the present model is tested based on the specification of the cointegrating and error correcting model. Section 5 presents the summary and conclusion.

5.2 Error Correcting Model of Consumption

The error correcting model of DHSY is a study on the dynamic properties and lag structure of the relationship between non-durable consumption expenditure and disposable income using postwar UK quarterly data. The specification of an annual version of the error correcting model of DHSY can be shown in the following equation:

$$\Delta \ln C(t) = a_0 + a_1 \Delta \ln Y(t) - a_2[\ln C(t-1) - \ln Y(t-1)] + \upsilon(t) \qquad (5.1)$$

In the above model, the change in the natural logarithm of consumption $\Delta \ln C(t)$ is determined not only by the change in the natural logarithm of income $\Delta \ln Y(t)$, but also by the lagged discrepancy between consumption and income, which is a portion of the error between income and consumption. The above DHSY's error correcting model specification for consumption behavior is derived by imposing steady state equilibrium restrictions on the disequilibrium relationship between consumption and income as shown below.

The equilibrium relationship between consumption and income is

$$C^*(t) = K^*Y^*(t) \qquad (5.2)$$

where * represent equilibrium values.[93] Taking natural logarithms of both sides of the above equation, we obtain

$$\ln C^*(t) = \ln K^* + \ln Y^*(t) \qquad (5.3)$$

The disequilibrium relationship between consumption and income, which we normally observe in reality, is assumed to be represented in the following equation involving lagged values of consumption and income:

[93] For example, this equation may represent an underlying relationship between permanent consumption and permanent income.

$$\ln C(t) = \ln K + \beta_1 \ln Y(t) + \beta_2 \ln Y(t-1) + \gamma \ln C(t-1) \tag{5.4}$$

By setting that

$$\ln C(t)=\ln C(t-1)=\ln C^*(t)$$

and

$$\ln Y(t)=\ln Y(t-1)=\ln Y^*(t),$$

the long-run equilibrium along a steady state growth path of the above disequilibrium equation is obtained as follows:

$$\ln C^*(t) = \ln K/(1-\gamma) + [(\beta_1+\beta_2)/(1-\gamma)]\ln Y^*(t) \tag{5.5}$$

For the above equation to be consistent with the natural logarithm representation of equilibrium relationship between consumption and income, the following restrictions are imposed on the parameters:

$$K = K^*(1 - \gamma)$$
$$\gamma = 1 - \beta_1 - \beta_2$$

Substituting the above restrictions into the disequilibrium relationship equation, we have

$$\ln C(t) = \ln K^*(1 - \gamma) + \beta_1 \ln Y(t) + \beta_2 \ln Y(t-1) + (1 - \beta_1 - \beta_2)\ln C(t-1) \tag{5.6}$$

or

$$\Delta \ln C(t) = a_0 + a_1 \Delta \ln Y(t) - a_2[\ln C(t-1) - \ln Y(t-1)] \tag{5.7}$$

where $a_0 = \ln K^*(\beta_1 + \beta_2)$

$a_1 = \beta_1$

$a_2 = \beta_1 + \beta_2$

This error correcting model of DHSY relates change in consumption not merely to change in income, but also to disequilibrium between the levels of consumption and income in past periods. The premise of this kind of error correcting model approach to applied econometric modelling is that long-run relationships in the data can be incorporated into the model. This is a distinguishing feature compared with the influential Box-Jenkins approach (eg. ARIMA model) since the latter has the drawback that it results in a loss of valuable long-run information in the data.

Mizon and Richard (1985) have emphasized that a model should be evaluated not only in terms of the data coherency and the congruence with the underlying theory, but also the ability to encompass the findings of other researchers. Here, it is shown that the random walk model of consumption, which is the implication of life cycle-permanent income hypothesis under rational expectations, encompasses an error correcting model of consumption if the stochastic process of income is generated a specific way, as shown in the following equation:

$$\Delta \ln Y(t) = (\mu - a_0)/a_1 - (a_2/a_1)[\ln Y(t-1) - \ln C(t-1)] + (\lambda/a_1)\epsilon(t) \qquad (5.8)$$

where $\epsilon(t)$ is the innovation between time t-1 and t period. Given the above income process, the error correcting model of

$$\Delta \ln C(t) = a_0 + a_1 \ln\Delta\ln Y(t) - a_2[\ln C(t-1) - \ln Y(t-1)] + \upsilon(t) \quad (5.9)$$

will be observationally equivalent to the following random walk model of consumption

$$\Delta \ln C(t) = \mu + \lambda\epsilon(t) + \upsilon(t) \quad (5.10)$$

where $\upsilon(t)$ is the consumption disturbance. The above equation, in which the natural logarithm of consumption lnC(t) follows a random walk with drift, is an alternative specification of the theory derived by Hansen and Singleton (1983) under the assumptions of a constant relative risk aversion (CRRA) utility function and a lognormality for the conditional distribution of consumption. On this basis, Bean (1986) argued that the error correcting model of consumption should not necessarily be viewed as a mutually exclusive alternative to the random walk with drift model of consumption.

5.3 Cointegration between Consumption and Income

From the economic definition of equilibrium, there will be internal forces which tend to push the economy back toward equilibrium whenever it moves away from equilibrium. If there is an equilibrium relationship between consumption and income,[94] then the two variables should not diverge from each other by too great an extent, at least in the long-run. As argued by Granger (1986) and Engle and Granger (1987), such variables may drift apart in the short-run, for example, because of seasonal factors, but economic forces, such as market mechanism or government intervention, will bring them together again if they continue to be too far apart in the long-run. The above idea underlies building the cointegrating model. Engle and Granger (1987) found that consumption and income, short and long interest rates, and nominal GNP and M2 are cointegrated series, respectively. Therefore, the error correcting model of DHSY, which explains long-run relationship and short-run dynamic behavior between consumption and income, can be considered as an example of the application of the preceding idea. In fact, Engle and Granger (1987) clarified this point by proving that cointegrated series have an error correcting model representation and an error correcting model generates cointegrated series, conversely.

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[94] The permanent income hypothesis is one example of showing the equilibrium relationship between consumption and income.

The historical background of the development of the cointegrating model is as follows. As Granger (1966) observed, a large number of economic data has the typical spectral shape that power spectra have its maximum at zero frequency and decline sharply as frequency increases. From his observation of the typical spectral shape, it is possible to consider that there is a connection between or among the economic series. The implication of the 'typical spectral shape' of Granger (1966) is that most macro economic series have a unit root. The existence of unit roots in economic time series data has been well revealed by the analysis of Box-Jenkins modelling techniques and by the direct testing of Nelson and Plosser (1982). A formal test procedure for the existence of unit roots has also been developed. Dickey and Fuller (1979,1981) suggest a t-test for the existence of unit roots in autocorrelation, based on their own tabulated critical values. Sargan and Bhargava (1983) test the existence of unit roots based on the Durbin-Watson statistics. Phillips (1987) has also developed a test procedure based on the knowledge of the distribution of estimators. The results of these tests are that many macroeconomic time series have a unit root. The evidence of the existence of unit roots in time series data suggests differencing data in practice to remove nonstationarity caused by unit roots. The practice of using differenced data for regression analysis is especially useful to avoid the spurious regression problem of Granger and Newbold

(1974).[95] Since the procedure of differencing results in a loss of valuable long-run information in the data, the concept of cointegration has been suggested by Engle and Granger (1987) as one solution to the problem.

Consider a time series, Y(t), measured at equal intervals of time. This series Y(t) is called 'integrated of order zero', denoting I(0), if the series has a spectrum which is finite but non-zero at all frequency.[96] Some series may need to be differenced in order to achieve stationarity. If the series needs differencing d times to become I(0), then the series is called integrated of order d, denoting I(d). In this case, the bth differenced series of the data is I(d-b). Sometimes, we can achieve I(0) by integrating (summing) two series. Consider a pair of series Y(t) and X(t), each of which is I(1).[97] If there is a constant nonzero β such that

$$Y(t) - \beta X(t) \qquad (5.11)$$

is I(0), then Y(t) and X(t) are said to be 'co-integrated'. Based on their concept of the above integration and co-integration, Engle and Granger (1987) proved that there

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[95] Granger and Newbold showed that in the regression of a random walk series on an independent random walk series, the null hypothesis of no relation would be wrongly rejected at the 5 percent level by the traditional t test.

[96] This indicates that the series is stationary, implying that conditional mean, variance and autocorrelations are time-invariant.

[97] A series which can be represented by a random walk model is a good example.

always is the following error correcting form of a data generating mechanism for Y(t) and X(t):

$$\Delta Y(t) = \phi(L)[\Delta Y(t), \Delta X(t)] - \lambda_1[Y(t-1) - \beta X(t-1)] + \epsilon_1(t) \quad (5.12)$$

$$\Delta X(t) = \theta(L)[\Delta Y(t), \Delta X(t)] - \lambda_2[Y(t-1) - \beta X(t-1)] + \epsilon_2(t) \quad (5.13)$$

where $\phi(L)$ and $\theta(L)$ are a finite polynomial in the lag operator L. Engle and Granger (1987) suggest estimating the above model by the two-step estimation procedure. In the first step, the levels regression which shows the long-run relationship between Y(t) and X(t) is performed to obtain the estimator $\hat{\beta}$ by the Ordinary Least Squares (OLS). Then the residuals from this regression are entered into the above error correcting model, which describes short run dynamics, in place of the levels terms.

This two-step estimation procedure rests on the assumption that the series Y(t) and X(t) are cointegrated.[98] Therefore, it is important to test for cointegration before estimating a multivariate dynamic model. One test suggested by Engle and Granger (1987) is the Cointegrating Regression Durbin Watson (CRDW) test. This test investigates stationarity of the residuals from running the cointegrating regression by checking the Durbin-Watson statistic. The test rejects the null hypothesis of no cointegration if the

[98] This indicates that the relationship between the two series is in equilibrium in the long-run.

Durbin-Watson statistic of the cointegrating regression exceeds their tabulated critical value. Some other tests suggested by Engle and Granger are applying the Dickey-Fuller test to the residuals of the cointegrating regression. To test the existence of cointegration, the following Dickey-Fuller regression is estimated using the residuals u(t):

$$\Delta u(t) = -\phi u(t-1) + \sum_{i=1}^{k} b(i)\Delta u(t-i) + \epsilon(t) \qquad (5.14)$$

Engle and Granger (1987) tabulate the critical values for the Dickey-Fuller (DF) test statistics ξ_2 and the Augmented Dickey-Fuller (ADF) test statistics ξ_3, by calculating analogously to t-statistics for the coefficient ϕ in the above equation, with k set equal to zero for the DF test and to four for the ADF test.[99] The essence of the above test procedures is to investigate whether the residuals series u(t) of the cointegrated regression is I(0). If u(t) is I(1), then Y(t) and X(t) are not cointegrated since Y(t) is I(1) and X(t) is also I(1).

In this section, the concept of Engle and Granger's cointegration analyzed in the above is applied to the consumption series and the income series. The data used for

[99] Engle and Granger (1987) also suggest the Restricted VAR (RVAR), Augmented Restricted VAR (ARVAR), Unrestricted VAR (UVAR), and Augmented Unrestricted VAR (AUVAR) test procedure for testing cointegration. For the details of these test procedures see their paper p.264-270.

analysis is the Canadian quarterly real per capita personal disposable income and the real per capita consumption[100] for the sample period of 1961:I to 1987:II,[101] which is the same as the data used in the previous chapters.

First, the assumption that the income series and the consumption series are I(1) should be checked. The income series is already shown in section 3.3.2 to be I(1) by analyzing the autocorrelation function of the series and the Dickey-Fuller test results. The same technique is applied here to analyze the behavior of the consumption series.

The autocorrelations for the levels and the first differenced series of consumption are presented in table 5.1. The autocorrelation function (ACF) of C(t) shown in table 5.1 drops off slowly as lag length increases, indicating that the consumption series is nonstationary. The partial autocorrelation function (PACF) of C(t) in the table suggests an AR(1) model, since it drops to almost zero after lag one.[102] Furthermore, the simple and partial autocorrelations of the first differenced series of consumption $\Delta C(t)$ in table 5.2 are consistent with the assumption that the series is stationary. In fact, the shape of the spectral density function of the first

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[100] The consumption series is the sum of personal expenditure on nondurable goods and personal expenditure on services.

[101] The source of the data is "CANSIM University Base" data bank. See section 3.2.1 for the details of the data.

[102] See footnote 49 (p.72) in chapter 3.

TABLE 5.1

Sample Autocorrelations of Levels of Consumption C(t)

Number of Lags	Simple Autocorrelation	Partial Autocorrelation
1	0.97	0.97
2	0.95	0.00
3	0.92	-0.01
4	0.90	-0.03
5	0.87	-0.00
6	0.85	-0.01
7	0.82	-0.03
8	0.80	-0.01
9	0.77	0.01
10	0.74	-0.02
11	0.72	-0.02
12	0.69	-0.01
13	0.67	-0.00
14	0.64	-0.02
15	0.61	-0.02
16	0.59	-0.01
17	0.56	-0.01
18	0.54	-0.01
19	0.52	-0.00
20	0.49	-0.03
21	0.47	-0.04
22	0.44	-0.01
23	0.41	-0.03
24	0.39	-0.04

Note: The consumption series C(t) contains 106 observations.

TABLE 5.2

Sample Autocorrelations of $\Delta C(t)$

Number of Lags	Simple Autocorrelation	Partial Autocorrelation
1	-0.02	-0.02
2	-0.02	-0.02
3	0.24	0.24
4	0.10	0.11
5	-0.00	0.01
6	0.04	-0.01
7	0.10	0.06
8	-0.08	-0.09
9	0.05	0.05
10	0.18	0.15
11	0.03	0.08
12	-0.17	-0.20
13	0.10	-0.00
14	0.06	0.00
15	-0.07	0.01
16	-0.04	-0.05
17	0.10	0.08
18	-0.09	-0.07
19	-0.04	-0.01
20	0.15	0.06
21	-0.16	-0.13
22	-0.09	-0.04
23	-0.17	-0.25
24	-0.07	-0.10

Note: The first differences $\Delta C(t)$ contains 105 observations.

differenced series $\Delta C(t)$ shown in figure 5.1 is similar to that of the spectral density function for a white noise. Therefore, the above analysis of autocorrelations of the levels and first differences of the consumption series implies that C(t) is I(1).

To check more formally that the consumption series is I(1), the unit root test of Dickey-Fuller (1981) is applied. Following Dickey and Fuller, the levels and the first differences of the consumption series are assumed to be adequately represented by the following model:

$$X(t) = \beta_0 + \beta_1 t + \rho X(t-1) + \sum_{i=1}^{k} \alpha(i)\Delta X(t-i) + \epsilon(t) \tag{5.15}$$

where X(t) can be either C(t) or $\Delta C(t)$. Since only the standard error of autocorrelation of $\Delta C(t-3)$ exceeds the value of two,[103] the above equation with k=3 is considered to be sufficient for the purpose of testing the existence of a unit root. Table 5.3 reports the estimated results of the equation with k=3. The statistic Φ_3 shown in the table is calculated as one would calculate the F-statistic to test the null hypothesis that $(\beta_1,\rho)=(0,1)$. Since the critical value of the statistic Φ_3 at the 5 percent level is given as 6.49 in the Dickey and Fuller's table VI (1981, p.1063), we conclude that the statistic Φ_3 of 1.18 for C(t) does not

[103] This is known from the scatter diagram of autocorrelations (not shown here) printed by the SAS/ETS system.

Figure 5.1: Spectral Density of First Differences of Consumption

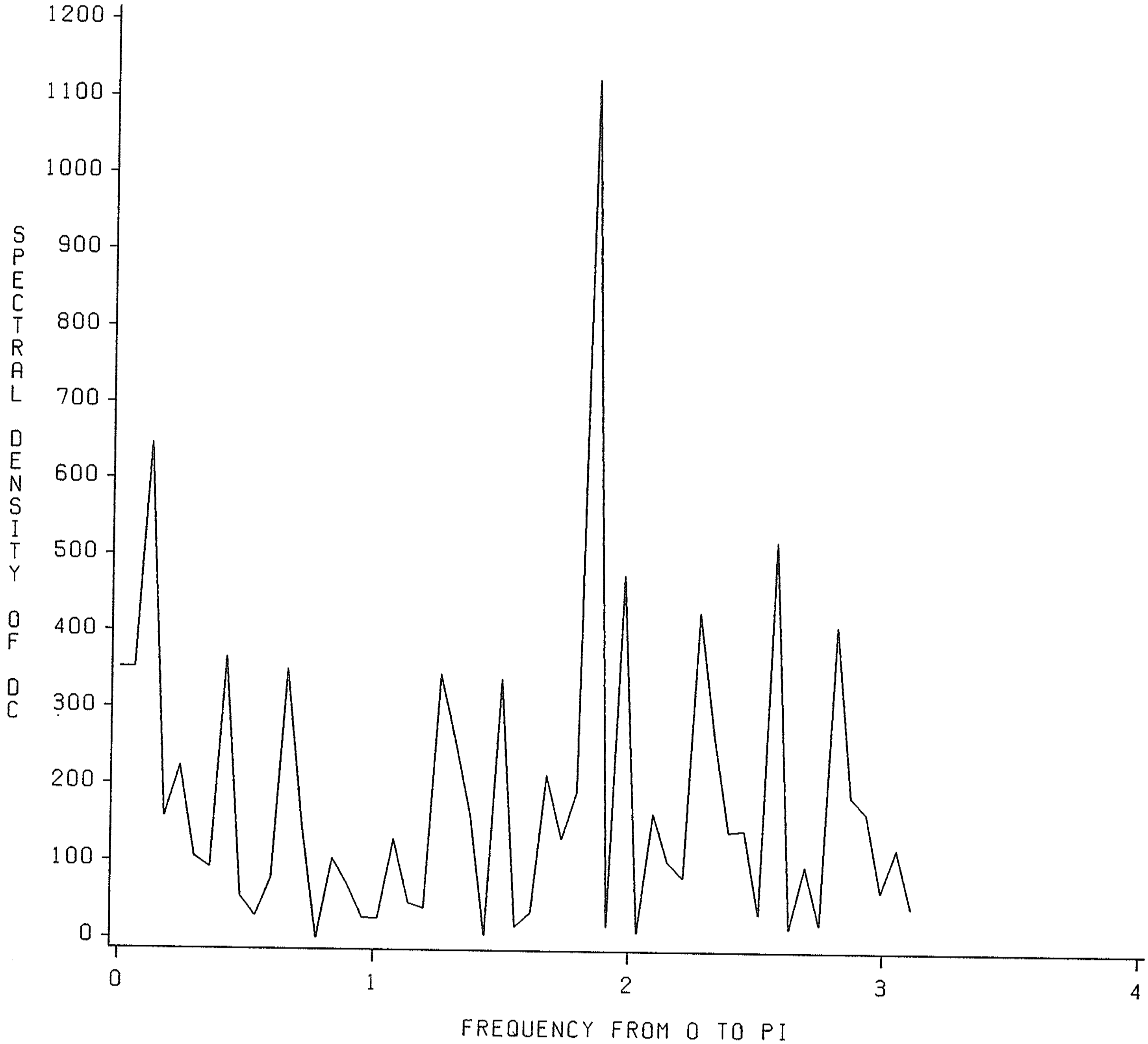

TABLE 5.3

Dickey-Fuller Test Results for Consumption Series

X(t):	C(t)	ΔC(t)
β_0	153.88	20.81
	(1.79)	(2.26)
β_1	1.11	-0.02
	(1.47)	(-0.16)
ρ	0.96	0.31
	(38.2)	(1.61)
α_1	0.01	-0.35
	(0.05)	(-2.00)
α_2	0.01	-0.35
	(0.15)	(-2.48)
α_3	0.26	-0.11
	(2.65)	(-1.08)
SER	33.49	33.69
Φ_3	1.18	6.54

Note: The t-ratios are given in parentheses below coefficients. The statistic Φ_3, calculated like the F-statistic, tests the null hypothesis $(\beta_1,\rho)=(0,1)$ against the alternative $(\beta_1,\rho)\neq(0,1)$.

reject the null hypothesis $(\beta_1,\rho)=(0,1)$ at the 5 percent significance level, whereas the statistic Φ_3 of 6.54 for ΔC(t) rejects the null hypothesis at the 5 percent level. The above Dickey-Fuller test results support the conclusion from the analysis of autocorrelations that the consumption series is nonstationary in levels but stationary in first differences, which means that C(t) is I(1).

Based on the findings that Y(t) and C(t) are I(1), the cointegrating regression of the consumption series C(t) on the income series Y(t) is performed and the following results are obtained:

$$C(t) = 1588.36 + 0.46\,Y(t) \tag{5.16}$$

$$SER=92.55 \quad DW=0.382$$

where the standard error of coefficients is shown in parentheses. According to the CRDW test, there is no evidence of the existence of cointegration since the test DW statistic of 0.382 is below the 5 percent critical value of 0.386, which is given in the Engle and Granger's table II (1987, p.269), and the null hypothesis of no cointegration is no rejected at the 5 percent significance level.

The reverse cointegrating regression of Y(t) on C(t) is also estimated and the results are as follows:

$$Y(t) = -3317.02 + 2.14\,C(t) \tag{5.17}$$

$$SER=198.73 \quad DW=0.383$$

where the standard error of coefficients is shown in parentheses. The DW statistic of 0.383 again does not reject the null hypothesis of no cointegration at the 5 percent level. Whichever way the cointegrating regression is run, the estimated results using the Canadian data show that there is no cointegration between consumption and income.

Next, for the DF and ADF tests, the Dickey-Fuller regression is run using the residuals from the cointegrating regression, and the Engle and Granger's ξ_2 and ξ_3-statistics are calculated for the cointegration test. The estimated

TABLE 5.4

Dickey-Fuller Regression for ΔRC and ΔRY

Δu(t):	ΔRC(t) (1)	ΔRC(t) (2)	ΔRY(t) (1)	ΔRY(t) (2)
ϕ	0.18 (2.84)	0.18 (2.52)	0.18 (2.86)	0.18 (2.54)
b_1		-0.17 (-1.51)		-0.17 (-1.54)
b_2		0.08 (0.67)		0.07 (0.67)
b_3		0.16 (1.41)		0.15 (1.40)
b_4		0.25 (2.40)		0.24 (2.39)
SER	55.96	54.09	120.39	116.38
DW	2.31	1.97	2.31	1.97

Note: The t-statistics are in parentheses. RC denotes the residuals from the cointegrating regression of C on Y and RY is the residuals from the cointegrating regression of Y on C. The model estimated for (1) is $\Delta u(t)=-\phi u(t-1)+\epsilon(t)$ and for (2) $\Delta u(t)=-\phi u(t-1)+b_1\Delta u(t-1)+b_2\Delta u(t-2)+b_3\Delta u(t-3)+b_4\Delta u(t-4)+\epsilon(t)$, in which u can be either RC or RY.

results are reported in table 5.4. The ξ_2-statistic for the DF test and ξ_3-statistic for the ADF test in the table are 2.84 and 2.52 for the cointegrating regression of C(t) on Y(t), and 2.86 and 2.54 for the cointegrating regression of

Y(t) on C(t). The critical value at the 5 percent level given in the Engle and Granger's table II (1987, p.269) are 3.37 for ξ_2-statistic, and 3.17 for ξ_3-statistic. Therefore, we conclude that both ξ_2 and ξ_3 statistics does not reject the null hypothesis of no cointegration at the 5 percent significance level.

From these test results we conclude that there is only negligible cointegration between the consumption series and the income series for the Canadian data.[104] Nevertheless, the error correcting model is estimated for the short-run dynamics of the system.

For the consumption series, the change in consumption is regressed on the error correction term from the cointegrating regression and one lagged change in income,[105] and the estimated result is shown in the first column of table 5.5. The second column of table 5.5 reports the estimated result of a general model in which change in consumption is specified to be related to the error correction term plus four lags of consumption and income changes. The third column of table 5.5 shows the estimated result of the model searched by applying the stepwise regression procedure to the second column model. The

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[104] Engle and Granger (1987) show that the null hypothesis of no cointegration between consumption and income is rejected at the 5 percent level for the U.S. quarterly data from 1947:I to 1981:II.

[105] This model is the same as the model specification of DHSY in section 5.2.

TABLE 5.5

Error Correcting Regression of Consumption

	(1)	(2)	(3)
Const.	26.78*	21.42*	21.54*
	(7.09)	(3.13)	(5.07)
RC(t-1)	0.03	0.02	
	(0.81)	(0.42)	
ΔY(t-1)	0.03	0.02	
	(0.94)	(0.57)	
ΔY(t-2)		0.02	
		(0.74)	
ΔY(t-3)		0.01	
		(0.42)	
ΔY(t-4)		-0.06	
		(-1.71)	
ΔC(t-1)		-0.06	
		(-0.50)	
ΔC(t-2)		-0.03	
		(-0.29)	
ΔC(t-3)		0.22	0.24*
		(1.92)	(2.51)
ΔC(t-4)		0.12	
		(1.05)	
SER	34.20	33.62	33.06
F	0.65	1.30	6.29

Note: The t-ratios are shown in parentheses. RC is the residuals from cointegrating regression of C(t) on Y(t). * denotes the coefficient which is significant at the 5 percent level.

estimated results of three different models shown in the table fail to find the relationship between consumption and income in the error correcting system context. Instead, it is found that three lagged value of change in consumption ΔC(t-3) has some influence on change in consumption.[106] The

[106] The interpretation of this result is not easy, but it is possible that the result is caused by some remaining

test result supports the implication of the life cycle-permanent income hypothesis that consumption follows a random walk with drift since the estimated results show that change in consumption is not related to either the error correcting term or the lagged values of change in income.[107]

For the income series, the same model that was specified for the consumption series is estimated. Table 5.6 reports the estimated results for the income series. The results show that change in income is related to the error correction term from the cointegrating regression and two lagged value of change in income $\Delta Y(t-2)$. However, as expected from the test results for cointegration between consumption and income, the estimated results of either the consumption series or the income series show no relationship between change in consumption and change in income.

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seasonal factors.

[107] The clear relationship between the error correcting model and the model of chapter 4 in testing the theory will be discussed in the next section.

TABLE 5.6

Error Correcting Regression of Income

	(1)	(2)	(3)
Const.	54.64*	40.91	43.30*
	(3.80)	(1.86)	(3.70)
RY(t-1)	-0.19*	-0.02	-0.20*
	(-3.35)	(-2.77)	(-3.69)
ΔC(t-1)	0.01	0.02	
	(0.04)	(0.06)	
ΔC(t-2)		0.18	
		(0.50)	
ΔC(t-3)		-0.22	
		(-0.60)	
ΔC(t-4)		-0.18	
		(-0.50)	
ΔY(t-1)		-0.12	
		(-1.10)	
ΔY(t-2)		0.19	0.21*
		(1.73)	(2.29)
ΔY(t-3)		0.14	
		(1.23)	
ΔY(t-4)		0.12	
		(1.14)	
SER	109.26	107.86	106.47
F	6.32	2.54	9.28

Note: The t-ratios are shown in parentheses. RY is the residuals from cointegrating regression of Y(t) on C(t). * denotes the coefficient which is significant at the 5 percent level.

5.4 Testing the Theory Based on ECM

In section 4.2 of chapter 4, the implication of the life cycle-permanent income hypothesis under rational expectations was tested in the following nested model:

$$\Delta C(t) = \mu + \lambda \Delta YT(t) + \nu(t) \qquad (5.18)$$

Since $\Delta YT(t)$ may not be orthogonal to $\nu(t)$, the Two Stage Least Squares (TSLS) method was applied and $\Delta YT(t)$ was estimated by instrumental variables in the first stage. The relationship between the model in chapter 4 and the error correcting model is that the model in chapter 4 would be the same as the error correcting model if the regressors in the error correcting model, the error correction term plus four lags of consumption and income changes, were considered as instrumental variables in the model.[108] The one lagged value of the residuals from the cointegrating regression is a good instrumental variable for the change in transitory income $\Delta YT(t)$ since the deviations from equilibrium will be strongly related with transitory income provided that the permanent income hypothesis holds.

In this section, the model in chapter 4 is estimated using transitory income, calculated by the four different detrending procedures discussed in chaper 4, and the instrumental variables, defined from the error correcting model of consumption in this chapter, i.e. the error correction term and four lags of income and consumption changes. Table 5.7 reports the estimated results. The coefficient of change in transitory income, λ, in the table is not significant at the 5 percent level. The values of R^2 are very low and F-statistics are insignificant at the 5 percent level in the second stage regression. These

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[108] This kind of interpretation was made by Campbell and Mankiw (1987) in the similar model as the present model.

TABLE 5.7

Test Results Based on the Specification of ECM

	(1)	(2)	(3)	(4)
dependent var: $\Delta C(t)$				
Const.	60.02	28.04	28.30	29.27
	(9.30)	(5.71)	(8.26)	(7.76)
λ	0.13	0.01	0.02	-0.04
	(1.71)	(0.08)	(0.54)	(-0.55)
SER	43.95	34.15	34.43	33.34
F_2	2.93	0.01	0.29	0.30
R_2^2	0.06	0.00	0.00	0.00
dependent var: $\Delta YT(t)$				
F_1	2.45	2.53	30.00	1.90
R_1^2	0.37	0.20	0.74	0.20

Note: The t-ratios are given in parentheses.

(1): the case of linear detrending
(2): the case of differencing detrending
(3): the case of detrending by state space model
(4): the case of detrending by spectral analysis

λ: the coefficient of $\Delta \hat{Y}T(t)$.
SER: SER for the second-stage regression
F_2: F-statistic for the second-stage regression
R_2^2: R^2 for the second-stage regression
F_1: F-statistic for the first-stage regression
R_1^2: R^2 for the first-stage regression

estimated results indicate that the regressor of change in transitory income $\Delta YT(t)$ does not explain the variations in the dependent variable $\Delta C(t)$ at all. Therefore, we conclude that the test results of all four cases in the table again support the theory, as we expected from the analysis of the error correcting model in section 5.3.

5.5 Summary and Conclusion

In this chapter the error correcting model of consumption, which is specified based on the concept of data generating process, was reviewed to show that the model to test the theory in chapter 4 encompasses the cointegrating and error correcting model of consumption function. With a specific process of income series, it was shown that the error correcting model of consumption is observationally equivalent to the random walk with drift model of consumption. Furthermore, the theory was tested based on the estimated results of the model in chapter 4 for which the regressors in error correcting model, i.e. the error correction term plus four lags of consumption and income changes, are used as instrumental variables in the model. The test results based on the cointegrating and error correcting model, using the same Canadian data as used in the previous chapters, supported the theory. This conclusion was expected since the cointegration test results by the CRDW, DF, and ADF tests for the consumption series and the income series of the Canadian data did not reject the null hypothesis of no cointegration. Therefore, from the analysis of the atheoretical model of consumption in this chapter, we conclude that the theory is supported for the Canadian data and that rational consumers let consumption follow a random walk with drift.

Chapter VI

SUMMARY AND CONCLUSION

The developments in recent research of the late 1970s and 1980s on consumption function with rational expectations have raised new questions that contradict the prediction of the original life cycle-permanent income hypothesis. Economists now want to examine two propositions with rational expectations: first, whether consumption behavior responds only to changes in permanent income; second, whether consumers make different consumption plans only in response to unanticipated changes in income. This study addresses the investigation of the propositions in the Canadian context in order to understand Canadian aggregate consumption behavior. The understanding of consumers' behavior from this study can be used in designing government policies, such as social security, fiscal, and monetary policy, which affect consumers' decision making on expenditures.

In chapter III, Hall's random walk model of consumption was tested to see whether the Canadian consumer follows the life cycle-permanent income hypothesis under rational expectations. If the coefficient of lagged variables in the random walk model were significant, the theory should be rejected because the current level of consumption is the level chosen by consumers so as to maximize expected lifetime utility given all available information. The theory was supported when actual Canadian data was used in Hall's test, and rejected when detrended Canadian data by linear detrending procedure was used in Flavin's test. The test results are the same as those for U.S. data. Following the arguments of Mankiw and Shapiro (1985) and Nelson (1987), Flavin's test results for detrended Canadian data were reappraised and we found that the rejection of the theory was attributed to the detrending procedure.

In chapter IV, the theory was further tested in the nested model where the random walk hypothesis and Keynesian consumption function are combined into a single model. The nested model was estimated based on all available detrending procedures and the test results showed that the theory was well supported by Canadian data. This conclusion is quite robust in the sense that it is insensitive to the different detrending procedures.

In chapter V, the theory was also tested by estimating the model of chapter 4 based on the specification of the error correcting model, and the test results again supported the theory. This conclusion on testing the theory is robust since the random walk model of consumption can encompass the cointegrating and error correcting model of consumption with some restrictions on income generating process.

Although the test results using aggregate time series data supported the theory, this conclusion has some limitations as discussed in introduction chapter. Therefore, further work on this subject can be done in the following ways. First, as shown in the beginning of this thesis, the random walk model of consumption is derived under specific assumptions about the consumers' utility function and the interest rates. The sensitivity of our conclusion on these assumptions is not discussed here and further study on this issue can be done.

Second, testing the theory by estimating the model using data from less developed countries might be useful to reinforce the conclusion. Considering that consumers in those countries are more likely liquidity-constrained because of such things as poor financial markets and low income levels, the comparison of the conclusion for Canadian data with that for less developed countries data would further test the theory.

Third, it may be more desirable to test the theory by tracing sample households' consumption behavior over a sufficient time period when the data is available. The theory can be tested by simulating the estimated model for different cohorts with different assumptions about government policies. For example, by analyzing the simulated effects that show how consumers respond to changes in income induced by temporary changes in tax and transfer policies, it is possible to observe whether consumers are following the theory and what proportion of and which category of consumers are liquidity-constrained or myopic. Testing the theory by this simulation method is desirable since it enables us to avoid the econometric difficulties involved in recent empirical work of testing the theory with liquidity-constrained consumers by estimating the model using aggregate time series data. However, this kind of research can not be done until the data is available.

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