Testing the Stochastic Implications of Permanent Income Hypothesis Using Canadian Provincial Data

by

Joseph P. DeJuan*, John J. Seater**, and Tony S. Wirjanto***

This Version: April 2008

Abstract

This paper utilizes relatively unexplored Canadian provincial-level data to investigate an old but still relevant question in macroeconomics as to whether consumption responds to income innovations in a manner consistent with the stochastic implications of the permanent income hypothesis (PIH). The empirical results obtained do not appear to be in accord with the PIH. Instead consumption's response to income innovations are found to be much weaker than the PIH predicts; in particular, the response displays an asymmetric pattern in the sense that it is much stronger for negative than positive income innovations. We interpret this evidence of asymmetry as being consistent with the presence of liquidity constraints in provincial households.

JEL Classification: E20, E21, R10

Keywords: Consumption, Permanent Income, Canadian Provinces

*University of Waterloo, Department of Economics, Waterloo, Ontario N2L-3G1 Canada, Tel. No. (519) 888-4567 ext. 33549. Email: jdejuan@uwaterloo.ca.
** North Carolina State University, Department of Economics, Raleigh, NC 27695 USA. Tel. No. (919) 513-2697. Email: john_seater@ncsu.edu
*** (Corresponding Author) University of Waterloo, Department of Economics, Waterloo, Ontario N2L-3G1 Canada. Tel. No. (519) 888-4567 ext. 35210. Email: twirjant@uwaterloo.ca

We thank, without implicating, two anonymous referees for their comments and suggestions.

1. Introduction

A well-known implication of Friedman's (1957) permanent-income hypothesis is that *news* about income should induce a revision in consumption exactly equal to the revision in permanent income. This implication has been extensively tested by studies that use time-series data at the country level, but the results have been mixed so far. For instance, Bilson (1980) finds support for the implication in post-war quarterly data for the US, UK, and Germany. By contrast, Flavin (1981) and Kotlikoff and Pakes (1984) report that aggregate US consumption responds much more strongly to income innovations than warranted by the PIH, and Weissenberger (1984) obtains similar results for seasonally unadjusted quarterly data for the UK and Germany.

In this paper, we apply the methods employed in DeJuan, Seater and Wirjanto (2004), who analyze U.S cross-state data, to time-series data from ten Canadian provinces with important extensions in the light of the results obtained. Canadian provincial-level data are still relatively unexplored in the study of consumption behavior in general, and the study of permanent-income hypothesis in particular, with an important exception of Ostergaard, Sorensen and Yosha (2002). Thus, it is interesting to examine whether the results obtained at the U. S. state-level data reported in DeJuan, Seater and Wirjanto (2004) apply to Canadian provinces as well.

The results from this paper can be summarized as follows. In sharp contrast to DeJuan, Seater and Wirjanto (2004), we find strong evidence against the stochastic implication of the PIH across Canadian provinces. The magnitude of the revision in consumption due to an income innovation is considerably smaller than the magnitude of the revision in permanent income due to the same innovation. Moreover consumption is found to be much more sensitive to a negative income innovation than a positive innovation. We provide some evidence that this asymmetry pattern are consistent with the presence of liquidity or borrowing constraints in Canadian provincial households.

2. Theoretical Framework

We begin with a very brief discussion of the PIH model for an individual household focusing only on the discussion that is directly relevant to our proposed approach. Then we proceed to derive the PIH implication for cross-sectional aggregate data that we test below. An infinitely-lived household *I* in period *t* chooses a path for consumption C_{it+j} to solve the following optimization problem:

$$MAX\ E_{it}\left[\sum_{\tau=0}^{\infty}\left(\frac{1}{1+\rho}\right)^{\tau}u(C_{i\tau+j})\right] \tag{1}$$

subject to the sequence of budget constraints:

$$W_{i\,t+1} = (1+r)\,W_{it} + Y_{it} - C_{it} \tag{2}$$

and the constraint that rules out the possibility of Ponzi game-type behavior:

$$\lim_{T\to\infty}\left[\left(\frac{1}{1+r}\right)^{T} W_{iT}\right] = 0 \tag{3}$$

In the foregoing expressions, E_{it} is the I-th household's conditional expectation $E(X_{t+\tau}|\mathrm{I}_{it})$ of any variable X based on the information set I_{it}, W is nonhuman wealth at the beginning of the period, r is the constant real interest rate, ρ is the constant rate of time preference, Y is labor income, and $u(.)$ is the intratemporal utility function.[1] Recursively substituting in equation (2) and taking expectations yields the infinite horizon budget constraint:

$$\sum_{\tau=0}^{\infty}\left(\frac{1}{1+r}\right)^{\tau} E_{it}\left[C_{i\,t+\tau}\right] = (1+r)\,W_{t} + \sum_{\tau=0}^{\infty}\left(\frac{1}{1+r}\right)^{\tau} E_{it}\left[Y_{i\,t+\tau}\right] \tag{4}$$

which, of course, equates the present values of consumption and expected income.

The solution to the above optimization problem yields the familiar first-order condition:

$$E_{it}\left[u'(C_{i\,t+1})\right] = \frac{1+\rho}{1+r}\,u'(C_{it}) \tag{5}$$

so that the optimal marginal utility of consumption is a super-martingale as long as $\rho \le r$. More importantly, this relation ensures that reallocating consumption across periods t and $t+1$ does not yield any improvements in expected intertemporal utility. For expository simplicity, we assume that $r = \rho$, which implies that planned consumption is constant, and that marginal utility is linear (i.e., utility is quadratic, at least as a local approximation near the optimal constant level of consumption).[2] We also assume that there are no taste shifting variables. Taste shifters, such as changes in household size, seem to be important in explaining household behavior (e.g., Attanasio and Browning, 1995), but it is not clear what changes might have occurred in Canada that would cause systematic deviations from the formulas we derive in this section. Under these conditions, equation (5) can be rewritten as:

---

[1]Note that equation (3) holds for every sample path, and not just on average.

[2]It is straightforward to generalize the model to allow for time-varying interest rates and risk aversion without certainty equivalence. Time-varying interest rates seems to complicate the mathematics but change nothing of a substantive nature. Also absence of certainty equivalence in general prevents an analytical solution for consumption. In specific cases where a solution for C is possible, again nothing important changes. Thus the simplifying assumptions of a constant interest rate and quadratic utility can be viewed as reasonable approximations.

$$E_{it}\left[C_{i\,t+\tau}\right] = C_{it} \qquad (6)$$

Substituting (6) into (4) yields the following "structural" formulation of the PIH:

$$C_{it} = Y_{it}^{p} \qquad (7)$$

where permanent income Y_{it}^{p} is given by

$$Y_{it}^{p} = r\,W_{it} + \frac{r}{1+r}\sum_{\tau=0}^{\infty}\left(\frac{1}{1+r}\right)^{\tau} E_{it}\left[Y_{i\,t+\tau}\right] \qquad (8)$$

Thus, according to this formulation of the model, consumption should equal permanent income, where permanent income is defined as a constant annuity stream of income from the household's lifetime wealth.

Instead of testing a stronger implication embedded in equation (7), we follow Flavin (1981) and consider a weaker implication in the first-difference form expressed as:

$$\Delta C_{it} = \Delta Y_{it}^{p} = \theta_{it} \qquad (9)$$

where the change in permanent income θ_{it} is equal to the revision in the expected present value of the income stream and the latter is given by

$$\theta_{it} \equiv \frac{r}{1+r}\sum_{\tau=0}^{\infty}\left(\frac{1}{1+r}\right)^{\tau}(E_{it} - E_{i\,t-1})\,Y_{i\,t+\tau} \qquad (10)$$

Equation (10) highlights a strong testable implication of the PIH; that is, the magnitude of the revision in consumption should equal exactly the magnitude of the revision in permanent income warranted by new information about the expected future path of income, $(E_{it} - E_{it-1})Y_{i\,t+\tau}$.

To make equation (10) operational, we need to specify a model for the stochastic income process, so that we can express the innovation in permanent income as a function of the innovation of observable variables. We follow earlier investigators (Bilson , 1980; Flavin, 1981; Deaton, 1992) and assume that income follows a linear stochastic process, for which there is a well-developed theory of estimation, inference, and prediction. Suppose that ΔY_{it} is a stationary process with an autoregressive moving-average (ARMA) representation:

$$A_i(L)\,\Delta Y_{it} = B_i(L)\,\varepsilon_{it} \qquad (11)$$

where $\Delta Y_{it} = Y_{it} - Y_{it-1}$, $A_i(L) = 1 - \Sigma\, a_{ij}L^j$, $B_i(L) = 1 - \Sigma\, b_{ij}L^j$, L is the lag operator, and ε_{it} is the innovation in or *news* about the household's current income. Using equation (11) to calculate the sequence of revisions in expected incomes, $(E_{it}-E_{it-1})Y_{i\,t+j}$, and substituting the result into equation (10), yields the formula for the change in permanent income:

$$\theta_{it}=\frac{1+\sum_{\tau=1}^{\infty}\frac{b_{i\tau}}{(1+r)^{\tau}}}{1-\sum_{\tau=1}^{\infty}\frac{a_{i\tau}}{(1+r)^{\tau}}}\cdot\varepsilon_{it}=\chi_i(r,b_i,a_i)\cdot\varepsilon_{it} \tag{12}$$

where a_i and b_i are the vectors of the AR and MA coefficients. The coefficient χ_i measures the size of the revision in permanent income associated with the realization of an innovation in current income ε_{it}. Conditional on the parameters of the ARMA representation of the income process and the value of r, the PIH implies that the *I*-th household's marginal propensity to consume out of an income innovation should be equal to χ_i.

Below we describe a test of this implication of the PIH. For each household, we can, in principle, estimate a two-equation system

$$A_i(L)\Delta Y_{it}=B_i(L)\varepsilon_{it} \tag{13}$$

and

$$\Delta C_{it}=\beta_i\varepsilon_{it}+\xi_{it} \tag{14}$$

where ξ_{it} is a zero-mean random error.[3] Then we can use the estimated values of $\{\beta_i,a_i,b_i\}_{i=1}^{I}$ to test the following restriction

$$\beta_i=\frac{1+\sum_{\tau=1}^{\infty}\frac{b_{i\tau}}{(1+r)^{\tau}}}{1-\sum_{\tau=1}^{\infty}\frac{a_{i\tau}}{(1+r)^{\tau}}}=\chi_i(r,b_i,a_i) \tag{15}$$

A likelihood-ratio (LR) test, which is asymptotically distributed as chi-squared with one degree of

[3]The presence of the error term in equation (14) may arise, for instance, from differences in the information sets used by agents and econometricians. Alternatively, the presence of this error term may be motivated by measurement error in consumption data, in which case it is serially correlated, and, in this case, it may follow a moving-average of order 1, MA(1), process under certain assumptions about the measurement error.

freedom, can be used to test the restriction in equation (15).[4] If the null hypothesis is not rejected at a specified level of significance, then it is taken to imply that the response of consumption to income innovations is consistent with the PIH.

The foregoing analysis applies to an individual household. If we assume that each group's aggregate choice can be characterized as that of a representative household, we can substitute group aggregate consumption and income for C_{it} and Y_{it} in the previous derivations and proceed as if we were using individual household data. In fact, we can proceed in the same way under weaker assumptions. To see this, suppose that we have a group H of households. Aggregate consumption C_t for H is

$$C_t \equiv \sum_{i=1}^{m} C_{it} \tag{16}$$

where m is the number of households in H. Using equations (7) and (8), we obtain

$$\begin{aligned} C_t &= \sum_{i=1}^{m} Y_{it}^{p} = \sum_{i=1}^{m} \left(r W_{it} + \frac{r}{(1+r)} \sum_{\tau=0}^{\infty} \frac{1}{(1+r)^{\tau}} E_{it}\left[Y_{i\,t+\tau}\right] \right) \\ &= r \sum_{i=1}^{m} W_{it} + \frac{r}{(1+r)} \sum_{j=0}^{\infty} \left(\frac{1}{(1+r)^{j}} \sum_{i=1}^{m} E_{it}\left[Y_{i\,t+j}\right] \right) \end{aligned} \tag{17}$$

In the last expression, we would like to pass the last summation sign through the expectations operator to leave us with a summation over household incomes, which equals aggregate income. In general, we cannot do that because the conditional expectations E_{it} depend on the index of summation, due to the fact that households may have different information sets. We therefore need to impose a restriction of some sort. We can assume, as does the representative-agent framework, that households have the same information sets: $I_i = I_j$ for all I and j. We then have $E_{it}(X) = E_{jt}(X) = E_t(X)$ for any variable X, allowing us to write

$$\begin{aligned} C_t &= r \sum_{i=1}^{m} W_{it} + \frac{r}{(1+r)} \sum_{j=0}^{\infty} \left(\frac{1}{(1+r)^{j}} E_t\left[\sum_{i=1}^{m} Y_{i\,t+j} \right] \right) \\ &= r W_t + \frac{r}{(1+r)} \sum_{j=0}^{\infty} \frac{1}{(1+r)^{j}} E_t\left[Y_{t+j}\right] \\ &= Y_t^{p} \end{aligned} \tag{18}$$

[4]The likelihood-ratio test statistic is defined as LR=-2[L(c)-L(u)], where L(c) is the log-likelihood value of the constrained model and L(u) is the log-likelihood value of the unconstrained model.

where Y_t and Y_t^p are aggregate income and aggregate permanent income, respectively. We thus have the result that aggregate consumption equals aggregate permanent income. We then can proceed to take first differences of equation (18) as in equation (9) and so on to arrive at the same testable implication. Note that the test requires that aggregate Y has an ARMA representation. However, Granger and Morris (1976) prove that a sum of ARMA processes is also an ARMA process, so aggregate income, being the sum of ARMA household-income processes, also must be an ARMA process.

It is important to point out that in deriving these aggregate results, we do not need to restrict household utility functions to be identical. Although we have used a quadratic approximation, we do not require that the quadratic parameters be the same across households. Thus household utility functions can be quite different with approximating quadratics that are correspondingly different. There are other sets of restrictions that can justify the representative agent framework, but the foregoing aggregate implication of the PIH does not require them, either.[5] Therefore the implication obtained applies to a broader class of models than the representative-agent framework.

3. Data and Econometric Issues

We propose to test the nonlinear restriction in equation (15) with Canadian provincial data on consumption and income. For simplicity each province will be treated as a household group H_i, and its aggregate consumption and income will be used to measure C_{it} and Y_{it}. The set of provincial parameter estimates of $\{\beta_i, a_i, b_i\}_{i=1}^{10}$ will be the data used for the test.

A useful feature of the data is that they pertain to a single country, thus avoiding potential problems that arise in cross-country comparisons. For example, Dawson, DeJuan, Seater and Stephenson (2001) test the same implication of the PIH that we examine here, but they do it by estimating the $\{\beta_i, \chi_i\}$ pairs for countries and then performing the test on the cross-country sample of pairs. In principle, the test is valid, but in practice it is unclear if cross-country differences in data quality, institutions, and so on vitiate the test. Our data set, being restricted to a single country, avoids any such problems.

Annual data on personal disposable income, expenditure on nondurables and services, population, and aggregate consumer price index for each of the ten Canadian provinces were collected from the *Provincial Economic Accounts* section of the CANSIM database maintained by *Statistics Canada*. The sample period covers the period 1961 to 1996, which is dictated by data consistency and data availability. Real per-capita expenditure on nondurables and services and real per-capita personal disposable income are used as measures of consumption (C) and income (Y), respectively.

---

[5]For example, no restriction is needed on the way in which changes in relative prices affect the wealth distribution.

There will always be some discrepancies between empirical tests and the theoretical relation they purport to test. Our paper is no exception in this regard. Therefore, before turning to the empirical analysis, it is important to keep in mind some caveats that may affect the estimates of β and χ, and hence the test for $\beta=\chi$. First, our discussion so far has assumed that consumers use only information contained in current and past values of income in order to predict future income. However, consumers may also use other information in predicting their future incomes (see, for example, West 1988, Quah 1990, Flavin 1993). In such case, the estimated income innovation, ε_i, is an errors-in-variable measure of the true income innovation. The use of ε_i as a regressor in equation (14), therefore, will yield a downward biased estimate of β. Second, the theoretically-appropriate consumption variable is per-capita private consumption, which excludes purchases of durables and includes the imputed services of the stock of consumer durables. In practice, reliable estimates of the latter series are not available and so, we use per-capita expenditure on nondurables and services as our measure of consumption. Of course, goods labeled as nondurables in the National Income Accounts might well be "durable" relative to the length of one time period. In the presence of strictly convex costs to adjusting durable stocks and the irreversible nature of some durable purchases, Bernanke (1985) and Abel (1990) among others, argued that the instantaneous response of consumption to an income innovation will be less than the amount predicted by the PIH, i.e., the estimate of β is likely to be biased downward. Third the theory requires ex ante real interest rates, which are unobservable and must be proxied. If the chosen proxy is too high (low) on average, then the estimate of χ will be biased downward (upward). Last but not the least, since at this time there is no data available to allow us to construct measures of labor income at the Canadian provincial level as envisaged in the theory, we follow the literature, in particular Ostergaard, C., B. E. Sorensen and O. Yosha (2002), and use personal disposable income as an imperfect measure for labor income.

4. Empirical Results

A preliminary step for the empirical estimation of the model is to examine the time series properties of C and Y for each province. To this end, we use the conventional Augmented Dickey-Fuller (ADF) test developed by Said and Dickey (1984), which tests the null hypothesis of a unit root against the alternative of trend stationarity. The results, presented in columns 2 and 6 of Table 1, show that the unit-root null hypothesis cannot be rejected, even at the ten percent level, for any of the series. It is widely known that the ADF test lacks power against near unit-root but stationary alternatives. To control for the possibility that our inability to reject a unit root simply reflects a lack of power, we also apply a test proposed by Kwiatowski, Phillips, Schmidt and Shin (1992, henceforth KPSS, that maintains stationarity as its null hypothesis. The KPSS test statistics, shown in columns 3 and 7 of Table 1, are large relative to their five percent critical value; so the null hypothesis of stationarity can be rejected for any series. For completeness, we have included in Table 1 the results of both unit root tests for the first differenced ΔC and ΔY series. As can be seen, the ADF tests reject the unit root hypothesis while the KPSS tests cannot reject the stationarity hypothesis at conventional significance levels. Thus, the results are consistent across the two unit root tests that C and Y are nonstationary in levels, but stationary after in first differences. In other words, the C and Y series are well-characterized as first-order integrated or I(1) processes. [6]

Having inferred that Y is $I(1)$, we now turn to the task of finding a suitable time series model for ΔY. To begin with, we estimate a second-order autoregressive, or AR(2), process for changes in the log of income

$$\Delta Y_{it} = \alpha_{0i} + \alpha_{1i}\,\Delta Y_{i,t-1} + \alpha_{2i}\Delta\, Y_{i,t-2} + \varepsilon_{it} \tag{19}$$

As shown in Table 2, the AR(2) coefficients are typically small, with a mean value of 0.024, and are all insignificantly different from zero at the 5 percent level. By contrast, the mean value of the AR(1) coefficients is 0.380, with the absolute value of the t-statistics averaging at 2.270 which is statistically significant at the 5 percent level.[7] From these results, it seems reasonable to conclude that a simple AR(1) process is appropriate for the province-level ΔY series.[8]

Next, we jointly estimate the two-equation system (13)-(14) both unconstrained and constrained by (15), reproduced as

$$\Delta Y_{it} = \alpha_{0i} + \alpha_{1i}\,\Delta Y_{i,t-1} + \varepsilon_{it} \tag{20}$$

and

$$\Delta C_{it} = \gamma_i + \beta_i \varepsilon_{it} + \xi_{it} \tag{21}$$

subject to the following nonlinear restriction

$$\beta_i = [1 - a_{1i}/(1+r)]^{-1} = \chi_i \tag{23}$$

using nonlinear least squares procedure. The estimation results are reported in columns 2 to 4 of Table 3. The point estimates of the marginal propensity to consume out of an income innovation, β, range in value from a low of 0.091 in Saskatchewan to a high of 0.615 in Newfoundland. The standard errors of β are small enough, so that the null hypothesis of β=0 can be easily rejected at the five percent level in each province. The fact that β is significantly different from zero implies

[6]Further pretests suggest that consumption and income for each province are not cointegrated. These results favor our strategy of working with the weaker implication of the PIH in first-difference form as in equation (9).

[7]It is interesting to note that, with the exception of Prince Edward Island and Saskatchewan, the AR(1) coefficient is positive, implying shocks to income are persistent.

[8]We also tried out the ARMA(1,1) process for ΔY series with no discernible change in the results.

that consumers revise their current consumption as a result of innovations to current income.

On the assumption that the annual real interest rate is three percent, the point estimates of χ are all significantly positive and range from 0.918 in Prince Edward Island to 2.051 in British Columbia.[9] These values imply that current income innovations contain information about future income that lead consumers to revise their estimated permanent income.

We come now to the main empirical question posed in this paper; namely, whether β is equal to χ. Comparing the estimates of β and χ in Table 3, it is apparent that β is systematically less than χ across provinces, indicating that consumption is much less sensitive to income innovations than warranted by the PIH. Indeed, the likelihood-ratio test rejects the null hypothesis that $\beta=\chi$ in favor of the alternative that $\beta<\chi$ at the five percent level for all provinces. These results provide strong evidence against the PIH.

Some previous empirical studies have used total consumption expenditures or retail sales as proxies for consumption whenever data on nondurable consumption are not readily available. Data on total expenditures and retail sales are available for the Canadian provinces, and so to assess the sensitivity of our results as well as for comparability with other studies, we re-estimated the model using these two alternative measures of consumption. The estimation results are reported in columns 5 to 10 of Table 3. Similar to nondurables and services, the $\beta=\chi$ null hypothesis can be rejected in favor of the $\beta<\chi$ alternative hypothesis in ten provinces for total expenditures, and in five out of ten provinces for total retail sales. All in all, a relatively robust empirical regularity has emerged across Canadian provinces that an income innovation leads to a revision in consumption that is less than the revision in permanent income.

The foregoing results show that consumption is insufficiently sensitive to *news* about income to be consistent with the PIH. We now examine whether myopia or liquidity constraints consumption behavior can explain the failure of the PIH across Canadian provinces. Following Altonji and Siow (1987) and Shea (1995), we exploit the fact that myopia and liquidity constraints have different testable implications for asymmetry in the response of consumption to income innovations.

Under myopia (or equivalently rule-of-thumb behavior), consumption tracks current income passively and so should be equally responsive to positive and negative innovations in income. Under liquidity constraints, on the other hand, consumption should be more responsive to negative income innovations than to positive innovations because consumers are constrained from borrowing but not from saving. To discuss further the logic behind this asymmetry, suppose that ΔY is positively autocorrelated such that a positive (negative) income innovation will be followed, on average, by a further positive (negative) innovation in the next period. Now if there is a positive income innovation, consumers would then want to increase their consumption by about

[9]None of the conclusions were substantially altered by modifying the real interest rate within the reasonable range of 1 percent and 6 percent.

the size of the increase in their permanent income, which by *more than* the size of the innovation due to its persistence. However, if consumers are unable to borrow and their current income is less than their permanent income, the increase in their consumption will be limited by the size of the innovation.

By contrast, if consumers are faced with a negative income innovation, they would want to decrease their consumption by about the size of the reduction in their permanent income, which is again more than the size of the innovation due to its persistence. Since consumers are not inhibited from decreasing their consumption, consumption should then react strongly to a negative income innovation. Thus, according to the liquidity-constraint hypothesis, consumption should respond asymmetrically to positive and negative innovations in income.

To distinguish between myopia and liquidity constrained behavior, we modify equation (21) to allow positive income innovations to have a different coefficient on changes in consumption than negative innovations:

$$\Delta C_i = \gamma_i + \beta_{1i}(POS_{it} * \varepsilon_{it}) + \beta_{2i}(NEG_{it} * \varepsilon_{it}) + \xi_{it} \tag{23}$$

where *POS* is a dummy variable for periods in which ε_{it} is positive, and *NEG* is a dummy variable for periods in which ε_{it} is negative (or zero). The discussion above suggests that under myopia, β_1 and β_2 are expected to be positive, significant, and not significantly different from each other. Under liquidity constraint, on the other hand, β_2 is expected to be significantly positive and significantly greater than β_1.

To implement this simple test, we jointly estimate equations (20) and (23) unconstrained for each province using iterative nonlinear least squares.[10] As presented in Table 4, the results indicate that in many provinces, the estimate of β_2 is significantly different from zero, while the estimate of β_1 is not quite significant. This evidence can be taken to imply that negative income innovation affects consumption more strongly than positive innovation, a finding which seems to be consistent with the liquidity constraint hypothesis.

In fairness, we should point out that due to the small number of observations available for which ε_{it} is positive and negative (about 15 observations each), the standard errors of β_1 and β_2 are often large. As a result, our tests may have low power to detect significant asymmetric effects of income innovation in the data. Below we will provide additional tests of asymmetric effects. Nonetheless, as shown in columns 4, 7 and 10, we can still formally reject the β_1=β_2 null hypothesis in favor of the β_1<β_2 alternative hypothesis for many provinces, particularly when using total expenditures or total retail sales are used to proxy the consumption variable.

[10]The use of ordinary least squares to estimate equations (19) and (22) jointly leads to qualitatively similar results and, thus, they are not reported here.

5. Sensitivity Analyses

An important caveat to the testing methodology carried out in this paper is that there are a number of joint hypotheses being tested and, therefore, rejection of a null hypothesis should be interpreted with caution. For this reason, we conduct a number of diagnostic tests. Specifically, we note that in the main two equation system (13) the implication of the PIH is that only innovations to income should help predict consumption. This implies that absent measurement error in the consumption data, the innovations should be serially uncorrelated and orthogonal to all t-1 dated information. This suggests that it is desirable to perform serial correlation and other diagnostic tests on the residuals of the estimated version of this equation. In particular, we perform individual significance tests on estimated autocorrelation coefficients of the residuals of equation (13) at first and second lags via t-statistic and joint significance tests of the estimated autocorrelation coefficients for the first six lags via Ljung-Box-Pierce statistic. In addition we also use the Shapiro-Wilk W statistic to the test for the normality of the residuals. The results are reported in Table 5. From the table, it is apparent that for the majority of the provinces and irrespective of the proxy used for consumption the individual and joint autocorrelation tests as well as the normality test are not significant the conventional level of significance. Most of the significant statistics in the table can be readily attributed to a single outlier residuals.

In the previous section, we made the assumption that the ex ante real interest rate is 3%. While this is a reasonable value and also we find that the results are unaffected by varying this rate within the range between 1% and 6%, it is useful to use the results obtained in the previous section to derive the implied real interest rate that equates β and χ. The results are presented in Table 6. For all provinces and regardless of the proxy used for consumption, we find that the implied values of real interest rate that equates β and χ are much too low and we attribute these results to the excess smoothness of consumption.

Lastly, in our previous study in DeJuan, Seater, and Wirjanto (2004), using U.S. state-level data, we obtain evidence in support of the PIH . In the light of this, we examine whether the results in the previous section can be overturned to be in support of the PIH, if we follow Ostergaard Sorensen, Yosha (2002) and use provincial-specific shocks as opposed to overall regional shocks. The results are reported in Table 7. As shown in the table, the null hypothesis that $\beta=\chi$ is rejected for majority of the provinces based on province-specific shocks as suggested by Ostergaard Sorensen, Yosha, (2002).

Given the results reported from the sensitivity analyses, we conclude that there is evidence of asymmetric effects of income innovations. We interpret the test results as follows. Across the Canadian provinces, individuals appear to adjust their consumption more quickly in response to negative income innovations, but when income innovations are positive they seem to only adjust their consumption at a much slower rate. We are tempted to conclude that this behavior is consistent with the presence of significant liquidity constraints in Canadian provinces. However, there is one concern with the above liquidity-constraint interpretation that should be addressed first; that is, risk-averse individuals whose utility functions have positive third derivatives exhibit "cautious" behavior, tending to save more of any income shock than would be implied by the quadratic utility function that we use. Depending on the shape of the utility function, it may be that large changes in permanent income elicit consumption responses of different magnitudes when those changes are positive than when they are negative, thus producing the asymmetry we observe even in the absence of liquidity constraints. For infinitesimal changes in permanent income, the changes in consumption are the same, but that might not be true for discrete changes. The characteristics of the Canadian provincial data suggest, however, that this issue is of little practical concern. The ratio of the change in permanent income to the level of current income is, on average, is small enough to be treated as infinitesimal.[11]

5. Concluding Remarks

We have examined the adjustment of consumption to income innovations using aggregate time-series data from the ten Canadian provinces over the period 1961-1996. In particular, we tested whether the size of the revision in consumption (β) due to an income innovation is equal to the size of the revision in permanent income (χ) due to the same income innovation, as the rational expectations version of the permanent income hypothesis (PIH) predicts.

Our investigation leads to the following conclusions. First, for the Canadian provincial data, the estimates of β and χ are significantly positive for each province, implying that innovations in current income contain new information about the expected future path of income that lead consumers to revise both their consumption and permanent income.

Second, the data strongly reject the $\beta=\chi$ hypothesis for each province. In fact, there is evidence that $\beta<\chi$, which means that the response of consumption to fluctuations in income is much less than the value implied by the PIH. These results are robust to using alternative measures of consumption. They also contrast strongly with the results obtained by DeJuan, Seater and Wirjanto (2004) for states in the US, which supported the PIH implication.

Third, we find that consumption is more sensitive to negative income innovations than to positive innovations. This evidence of asymmetry is suggestive of the presence of liquidity constrained consumers in Canadian provinces. In view of this, it is worthwhile, as an avenue for future research, to examine specifically which provinces have more binding liquidity constraints and what are the causes of liquidity constraints in these provincial economies.

There is caveat to the finding of an asymmetric response of consumption to income shocks reported in this paper. Clearly, our interpretation of the results is not unique and represents one of several possibilities suggested in the literature. We could extend the discussion of the results by carrying out simulation studies within the PIH setting and/or some alternative models to assess if the magnitude of the asymmetry reported in this paper is consistent with the extended PIH or more so with other models. For example, it is interesting to examine what proportion of liquidity constrained consumers is needed to generate the observed asymmetry. Also, it is worthwhile to

[11]From equation (12), the change in permanent income is estimated as $\hat{\theta}_{it} = \hat{\chi}_i \cdot \hat{\varepsilon}_{it}$.

document if the asymmetry pattern reported in this paper is a general feature by using data for a sample of countries (which to the best of our knowledge has not been done in the literature). This would enable us to check if the asymmetry is more pronounced in countries/regions where a higher fraction of consumers maybe subject to liquidity constraints, which could support our earlier explanation for the asymmetry. We leave this for future study.

References

Abel, A. (1990), "Consumption and Investment." In *Handbook of Monetary Economics*, Vol.2, edited by Benjamin M. Friedman and Frank H. Hahn, 726-78. Amsterdam: North-Holland Publishing Co.

Altonji, J., and A. Siow (1987), "Testing the Response of Consumption to Income Changes with (noisy) Panel Data," *Quarterly Journal of Economics*, 102, 293-328.

Andrews, D.W.K. (1993), "Tests for Parameter Instability and Structural Change with Unknown Change Point," *Econometrica*, 61, 821-856.

Attanasio, O., and Browning, M. (1995). "Consumption Over the Life Cycle and Over the Business Cycle," *American Economic Review*, 85, 1118-1137.

Blanchard, O., and Fischer, S. *Lectures on Macroeconomics*, MIT Press: Cambridge, MA, 1989.

Bilson, J. (1980), "The Rational Expectations Approach to the Consumption Function: A Multi-Country Study," *European Economic Review,* 13, 273-99.

Bernanke, B. (1985), "Adjustment Costs, Durables, and Aggregate Consumption," *Journal of Monetary Economics,* 15, 41-68.

Deaton, A. (1992), *Understanding Consumption*, Oxford University Press.

Dawson, J., J. DeJuan, J., J. Seater,. and E. F. Stephenson (2001), "Economic Information versus Quality Variation in Cross-Country Data," *Canadian Journal of Economics,* 34, 988-1009.

DeJuan, J., J. J. Seater, and T. S. Wirjanto (2004) "A Direct Test of the Permanent Income Hypothesis with an Application to the US States," *Journal of Money, Credit, and Banking*, 36, 1091-1103.

Flavin, M. (1981), "The Adjustment of Consumption to Changing Expectations about Future Income," *Journal of Political Economy,* 89, 974-1009.

Flavin, M. (1993), "The Excess Smoothness of Consumption: Identification and Interpretation," *Review of Economic Studies,* 60, 651-666.

Granger, C. W. J, and M. J. Morris (1976), "Time Series Modelling and Interpretation," *Journal of the Royal Statistical Society A*, 139, 246-257.

Kotlikoff, L. and A. Pakes (1984), "Looking for the News in the Noise - Additional Stochastic Implications of Optimal Consumption Choice," National Bureau of Economic Research Working Paper 1492.

Ostergaard, C., B. E. Sorensen and O. Yosha (2002), "Consumption and Aggregate Constraints: Evidence from the U.S. States and Canadian Provinces," Journal of Political Economy, 110, 634-645.

Quah, D. (1990), "Permanent and Transitory Movements in Labor Income: An Explanation for "Excess Smoothness" in Consumption," *Journal of Political Economy,* 98, 449-75.

Shea, J. (1995), "Myopia, Liquidity Constraints, and Aggregate Consumption: A Simple Test," *Journal of Money, Credit, and Banking*, 27(3), 798-805.

Weissenberger, E. (1986), "Consumption Innovations and Income Innovations: Evidence from UK and Germany," *The Review of Economics and Statistics,* 78, 1-8.

West, K. (1989), "The Insensitivity of Consumption to News About Income," *Journal of Monetary Economics,* 21, 17-34.

Table 1: Pre-test Results

	C		ΔC		Y		ΔY	
Canadian Province	ADF (lag)	KPSS	ADF (lag)	KPSS	ADF (lag)	KPSS	ADF (lag)	KPSS
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Alberta	0.180 (0)	0.179*	-4.315* (0)	0.117	-0.066 (0)	0.178*	-4.357* (0)	0.101
British Columbia	-1.000 (0)	0.207*	-6.274* (0)	0.061	-0.897 (1)	0.177*	-4.183* (0)	0.125
Manitoba	-0.192 (0)	0.206*	-5.012* (0)	0.083	-0.928 (0)	0.185*	-6.626* (0)	0.057
New Brunswick	-0.642 (0)	0.208*	-5.165* (0)	0.055	0.863 (0)	0.190*	-4.732* (0)	0.110
Newfoundland	1.026 (1)	0.208*	-3.402**(2)	0.063	0.896 (0)	0.207*	-4.207* (0)	0.105
Nova Scotia	0.271 (0)	0.205*	-5.477* (0)	0.092	1.213 (0)	0.184*	-4.834* (0)	0.115
Ontario	-0.086 (0)	0.185*	-4.242* (0)	0.065	0.155 (1)	0.210*	-4.068* (1)	0.080
Prince Edward Island	-1.036 (0)	0.191*	-5.203* (0)	0.064	-0.670 (0)	0.209*	-7.077* (0)	0.105
Quebec	-0.093 (0)	0.200*	-4.900* (0)	0.058	0.376 (0)	0.211*	-3.963* (0)	0.103
Saskatchewan	-0.821 (1)	0.152*	-3.927* (0)	0.112	-2.563 (0)	0.189*	-6.846* (0)	0.047

Notes: C is real per capita expenditure on nondurable goods and services. Y is real per capita personal disposable income. Δ denotes the first-difference operator. ADF(lag) is the Augmented Dickey and Fuller *t*-statistics, using the lag length selection procedure advocated by Ng and Perron (1995). The initial number of AR lags is set equal to 4, and the 5% critical value is used to determine significance. The finite-sample critical values developed by MacKinnon (1991) are used to determine statistical significance of the ADF test statistic. KPSS is the Kwiatkowski-Phillips-Schmidt-Shin (1992) test statistic. The critical values in Kwiatkowski et al. are used to determine statistical significance of the KPSS test statistic. Here, * and ** indicate significance at the 5 and 10% levels, respectively.

Table 2: **Estimates of the AR(1) and AR(2) Parameters for Real Per Capita Personal Disposable Income**

Canadian Province (1)	$\alpha_{i,1}$ (2)	$t(\alpha_{i,1})$ (3)	$\alpha_{i,2}$ (4)	$t(\alpha_{i,2})$ (5)
Alberta	0.463*	2.582	-0.169	0.939
British Columbia	0.762*	4.246	-0.280	1.543
Manitoba	0.093	0.521	-0.012	0.071
New Brunswick	0.484*	2.701	0.232	1.250
Newfoundland	0.419*	2.382	0.350**	1.876
Nova Scotia	0.394*	2.144	0.137	0.717
Ontario	0.791*	4.220	-0.101	0.533
Prince Edward Island	-0.027	0.150	0.139	0.760
Quebec	0.556*	3.010	0.103	0.555
Saskatchewan	-0.132	0.743	-0.156	1.057
Average	0.380*	2.270	0.024	0.930

Notes: $\alpha_{i,1}$ is the AR(1) coefficient, $\alpha_{i,2}$ is the AR(2) coefficient, $t(\alpha_{i,1})$ is the absolute value of the t-statistic of the AR(1) coefficient, and $t(\alpha_{i,2})$ is the absolute value of the t-statistic of the AR(2) coefficient. Here, * and ** indicate significance at the 5 and 10% levels, respectively.

Table 3: Constrained Nonlinear Least Squares Estimates Using Overall Province Shocks

Canadian Province	Nondur & Services			Total Consumption			Total Retail Sales		
	β	χ	LR	β	χ	LR	β	χ	LR
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Alberta	0.359*	1.405*	0.001	0.529*	1.351*	0.005	0.835*	1.353*	0.144
	(0.095)	(0.257)		(0.104)	(0.215)		(0.180)	(0.223)	
British Columbia	0.380*	2.051*	0.001	0.757*	1.964*	0.001	1.138*	2.110*	0.066
	(0.102)	(0.502)		(0.121)	(0.372)		(0.240)	(0.487)	
Manitoba	0.282*	1.004*	0.002	0.356*	0.986*	0.009	0.519*	0.948*	0.137
	(0.068)	(0.129)		(0.087)	(0.125)		(0.158)	(0.124)	
New Brunswick	0.281*	1.988*	0.001	0.393*	1.874*	0.001	0.611*	1.881*	0.020
	(0.146)	(0.540)		(0.173)	(0.473)		(0.280)	(0.479)	
Newfoundland	0.615*	1.572*	0.003	0.654*	1.552*	0.007	0.812*	1.476*	0.134
	(0.108)	(0.277)		(0.127)	(0.284)		(0.245)	(0.301)	
Nova Scotia	0.420*	1.596*	0.001	0.555*	1.498*	0.005	0.693*	1.569*	0.077
	(0.115)	(0.341)		(0.135)	(0.291)		(0.273)	(0.357)	
Ontario	0.560*	2.044*	0.001	0.866*	1.820*	0.007	1.252*	1.923*	0.217
	(0.128)	(0.437)		(0.158)	(0.324)		(0.309)	(0.402)	
Prince Edward Island	0.321*	0.918*	0.016	0.358*	0.910*	0.028	0.350*	0.911*	0.059
	(0.094)	(0.124)		(0.102)	(0.120)		(0.165)	(0.133)	
Quebec	0.450*	1.764*	0.001	0.745*	1.608*	0.011	1.185*	1.768*	0.259
	(0.122)	(0.375)		(0.144)	(0.279)		(0.281)	(0.359)	
Saskatchewan	0.091*	0.970*	0.001	0.174*	0.959*	0.001	0.349*	0.921*	0.025
	(0.041)	(0.124)		(0.055)	(0.114)		(0.119)	(0.107)	

Notes: Standard errors are in parentheses. β is the marginal propensity to consume out of an income innovation. Here χ is the implied revision in permanent income due to an income innovation. LR denotes *p*-values of the Likelihood Ratio statistic under the H_o: $\beta=\chi$. Here, * and ** indicate significance at the 5 and 10% levels, respectively.

Table 4: Unconstrained Nonlinear Least Squares Estimates

	Nondurables and Services			Total Expenditures			Total Retail Sales		
Canadian Province	β_1	β_2	Wald $\beta_1 = \beta_2$	β_1	β_2	Wald $\beta_1 = \beta_2$	β_1	β_2	Wald $\beta_1 = \beta_2$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Alberta	0.241	0.492*	0.49	0.287	0.795*	1.69	0.271	1.457*	3.22
	(0.201)	(0.206)	[0.482]	(0.221)	(0.225)	[0.194]	(0.379)	(0.384)	[0.073]
British Columbia	0.108	0.604*	2.61	0.311	1.139*	5.48	-0.029	2.333*	13.05
	(0.196)	(0.177)	[0.100]	(0.225)	(0.209)	[0.019]	(0.386)	(0.429)	[0.000]
Manitoba	0.177	0.413*	1.25	0.275	0.455*	0.43	0.189	0.900*	2.09
	(0.117)	(0.136)	[0.264]	(0.152)	(0.176)	[0.513]	(0.280)	(0.310)	[0.148]
New Brunswick	-0.144	0.654*	2.51	-0.467	1.147*	8.48	-0.837	1.953*	10.18
	(0.290)	(0.302)	[0.113]	(0.323)	(0.348)	[0.004]	(0.516)	(0.549)	[0.001]
Newfoundland	0.572*	0.648*	0.03	0.415	0.827*	0.67	0.730	0.877	0.02
	(0.256)	(0.223)	[0.857]	(0.309)	(0.263)	[0.414]	(0.591)	(0.501)	[0.880]
Nova Scotia	0.192	0.684*	2.17	0.147	1.037*	5.19	-0.343	2.256*	10.53
	(0.192)	(0.216)	[0.141]	(0.217)	(0.262)	[0.023]	(0.398)	(0.585)	[0.001]
Ontario	0.520*	0.597*	0.04	0.721*	1.005*	0.36	0.531	1.948*	2.47
	(0.237)	(0.233)	[0.844]	(0.289)	(0.285)	[0.550]	(0.545)	(0.552)	[0.116]
Prince Edward Island	0.507*	-0.048	2.06	0.523*	0.023	1.41	0.147	0.757	0.74
	(0.168)	(0.271)	[0.151]	(0.182)	(0.295)	[0.235]	(0.295)	(0.497)	[0.389]
Quebec	0.249	0.669*	1.09	0.605*	0.908*	0.40	0.614	2.080*	2.21
	(0.225)	(0.251)	[0.297]	(0.266)	(0.297)	[0.527]	(0.468)	(0.685)	[0.137]
Saskatchewan	0.154*	0.016	1.00	0.252*	0.083	0.80	0.384	0.310	0.03
	(0.076)	(0.086)	[0.318]	(0.104)	(0.116)	[0.371]	(0.225)	(0.255)	[0.857]

Notes: Standard errors are shown in parentheses. β_1 denotes the estimated coefficient for ($POS_{it}*\varepsilon_{it}$). β_2 denotes the estimated coefficient for ($NEG_{it}*\varepsilon_{it}$). Wald reports the *p*-value of the Wald statistics for testing the hypothesis $\beta_1 = \beta_2$. Here, * and ** indicate significance at the 5 and 10% levels, respectively.

Table 5: Residuals Diagnostic Tests

	Nondur & Services				Total Consumption				Total Retail Sales				Disposable Income			
Provinces	AR(1)	AR(2)	Q(6)	Normal	AR(1)	AR(2)	Q(6)	Normal	AR(1)	AR(2)	Q(6)	Normal	AR(1)	AR(2)	Q(6)	Normal
Alberta	0.386*	0.161	7.712	0.940**	0.242	0.057	9.670	0.960	0.203	0.113	11.650**	0.940**	0.154	-0.179	4.854	0.950
British Columbia	0.052	0.275	4.899	0.930*	-0.090	0.103	4.160	0.970	0.143	0.010	7.850	0.960	0.211	-0.276	8.242	0.960
Manitoba	0.072	-0.054	5.188	0.980	0.121	-0.027	5.040	0.970	0.195	0.172	14.390*	0.980	0.089	-0.059	4.741	0.980
New Brunswick	0.275	0.123	5.519	0.970	0.378*	-0.015	6.910	0.950	0.161	-0.153	10.400	0.940**	-0.012	0.159	3.285	0.960
Newfoundland	0.301	0.439*	11.757**	0.980	0.381*	0.219	8.040	0.950	0.254	-0.076	9.310	0.970	0.082	0.362	6.315	0.950
Nova Scotia	0.112	-0.032	3.677	0.960	0.188	0.029	4.090	0.960	0.188	-0.042	8.970	0.940**	0.011	0.021	5.178	0.940**
Ontario	0.205	0.013	8.959	0.970	0.131	0.054	10.350	0.940	0.179	0.137	17.600*	0.920*	0.252	-0.106	6.677	0.980
Prince Edward Island	0.084	0.106	2.421	0.850*	0.355	-0.071	5.770	0.910*	0.060	-0.147	3.110	0.920*	0.070	0.130	5.308	0.910*
Quebec	-0.013	0.023	5.312	0.970	-0.008	0.236	11.36**	0.970	0.188	0.174	20.190*	0.960	0.130	0.098	3.928	0.990
Saskatchewan	0.377*	0.325	10.845**	0.950	0.237	0.182	9.090	0.970	0.204	0.153	10.860**	0.970	-0.100	0.005	7.171	0.980

Notes: AR(1) is the first-order serial correlation; AR(2) is the second-order serial correlation; Q(6) is the Ljung-Box statistic which test the joint significance of the first six autocorrelation coefficients. Normal presents the value of the Shapiro-Wilk W statistics which is a normality test for the residuals. Here, * denotes significance at the 5% level, and ** denotes significance at the 10% level.

Table 6: Implied Real Interest Rate that Equates β and χ

	Nondur & Services	Total Consumption	Retail Sales
Canadian Province	r	r	r
Alberta	-1.166	-1.300	-2.364
British Columbia	-1.323	-2.571	3.457
Manitoba	-1.002	-0.992	-0.939
New Brunswick	-1.200	-1.312	-1.757
Newfoundland	-1.598	-1.691	-2.439
Nova Scotia	-1.279	-1.426	-1.842
Ontario	-1.668	-4.011	1.453
Prince Edward Island	-0.956	-0.943	-0.946
Quebec	-1.365	-2.139	1.862
Saskatchewan	-0.997	-0.991	-0.953

Table 7: Constrained Nonlinear Least Squares Estimates Using Province Specific Shocks

Canadian Province	Nondur & Services			Total Consumption			Total Retail Sales		
	β	χ	LR	β	χ	LR	β	χ	LR
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Alberta	0.396*	1.050*	0.012	0.486*	1.022*	0.039	0.697*	0.985*	0.331
	(0.099)	(0.153)		(0.099)	(0.135)		(0.158)	(0.131)	
British Columbia	0.301*	1.364*	0.001	0.714*	1.203*	0.096	1.203*	1.069*	0.724
	(0.133)	(0.257)		(0.136)	(0.162)		(0.259)	(0.140)	
Manitoba	0.172*	0.729*	0.006	0.189*	0.730*	0.008	0.268	0.720*	0.089
	(0.064)	(0.074)		(0.066)	(0.073)		(0.166)	(0.077)	
New Brunswick	0.147	1.065*	0.002	0.200	1.017*	0.013	0.546	1.002*	0.310
	(0.182)	(0.170)		(0.195)	(0.154)		(0.327)	(0.146)	
Newfoundland	0.197	0.892*	0.005	0.277*	0.868*	0.018	0.644*	0.744*	0.777
	(0.128)	(0.122)		(0.120)	(0.111)		(0.240)	(0.082)	
Nova Scotia	0.225	0.942*	0.006	0.225**	0.907*	0.009	0.388	0.830*	0.296
	(0.145)	(0.135)		(0.132)	(0.124)		(0.293)	(0.107)	
Ontario	0.431*	1.236*	0.004	0.465*	1.232*	0.006	0.447**	1.342*	0.022
	(0.097)	(0.196)		(0.105)	(0.194)		(0.223)	(0.274)	
Prince Edward Island	0.269*	0.730*	0.045	0.295*	0.728*	0.058	0.365*	0.722*	0.152
	(0.102)	(0.076)		(0.098)	(0.074)		(0.134)	(0.074)	
Quebec	0.063	0.866*	0.002	0.242**	0.875*	0.012	0.529*	0.936*	0.219
	(0.154)	(0.123)		(0.137)	(0.121)		(0.229)	(0.135)	
Saskatchewan	0.078*	0.881*	0.001	0.135*	0.875*	0.001	0.262*	0.846*	0.014
	(0.034)	(0.102)		(0.042)	(0.095)		(0.096)	(0.092)	

Notes: Standard errors are in parentheses. β is the marginal propensity to consume out of an income innovation. Here χ is the implied revision in permanent income due to an income innovation. LR denotes *p*-values of the Likelihood Ratio statistic under the H_o: $\beta=\chi$. Here * and ** indicate significance at the 5 and 10% levels, respectively.