Unit Root Tests of Canadian Poverty Measures

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Abstract

This note examines the non-stationarity property of a most widely used Canadian poverty measure, low income cut-off, for Canada and for each of its ten provinces using various unit root tests which started gaining popularity since the early 1980s. Most test results indicate that the Canadian poverty rates for the period of 1980 to 2003 are non-stationary. Therefore it is quite reasonable and appropriate to model the Canadian poverty rates as an I(1) process in the empirical studies on poverty issues in Canada.

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1. Introduction

Canada has been, in recent years, one of the fastest growing economies among the OECD countries and it is also one of the few OECD countries with a fiscal surplus at the federal level. But its record on the social front especially its record on poverty (and inequality) has not been without critics. Some critics argue that the growing global interface especially with U.S. and better economic performance has not "trickle down' to the less affluent while others point out the fact that the increase in poverty in Canada has been less pronounced than that in U.S. See, for example, Hanratty and Blank (1992), Maxwell (1996), Morrissette (1997), Gaston and Refler (1997), Beaulieu (2000), Osberg (2000), Zyblock and Lin (2000) and Picot and Hou (2003), among others.

Most studies on trends of poverty in Canada and policy implications have been so far conducted using conventional regression techniques and results are quite diverse depending on different model specifications and variables used in regressions. One problem that has not gained much attention in these studies is that the stationarity properties of poverty data (and data of other time series variables in regressions) need to be verified prior to the use of conventional regressions. The stationarity property is crucial in regression analysis because in case that the poverty data is non-stationary the use of conventional regression techniques may not be appropriate and results may be quite misleading.

The purpose of this study is, therefore, to examine whether the Canadian poverty data are stationary. To this end, various unit root tests, which started gaining popularity in the early 1980s, are used to examine the annual time series data of the most widely used poverty measure, low income cut-off (LICO), available for the years 1980-2003 for Canada and for each of its ten provinces (Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland, Nova Scotia, Ontario, Prince Edward Island, Quebec, and Saskatchewan). Since some social safety programs currently differ among the ten Canadian provinces, the results of this study may also provide useful hints on the design and reform of these programs.

This note is organized as follows: Section 2 provides a brief description of the unit root tests employed in this study; Section 3 discusses the poverty data for Canada and for each of its ten provinces; Section 4 presents the results of the unit root tests; and Section 5 summarizes this study.

2. The Unit Root Tests

We first test for the unit roots of the poverty rates for Canada and for each of the ten Canadian provinces individually using three different tests, namely the ADF test (Dickey and Fuller, 1979, 1981), the PP test (Phillips and Perron, 1988), and the DF-GLS test (Elliot, Rothenberg, and Stock, 1996). The ADF and PP tests for testing the null hypothesis of a unit root have been widely used in empirical work. The DF-GLS test has the advantage of having more power than the ADF and PP tests in the sense that it is more likely to reject the null hypothesis of a unit root against a stationary alternative when the alternative is true. In all three tests, models with and without a time trend are used. Although we believe that one lag is appropriate when annual time series data are used, nevertheless the search for the optimal lag length is conducted over four lags in the case of the ADF test and the DF-GLS test. Using three different unit root tests allows us to test the robustness of the results to the choice of the unit root test and disaggregating the data by provinces allows us to discern any significant differences among provinces.

There are several events in Canada during the period of 1980-2003 that may have caused a structural break in the poverty measures, such as the 1989 Canada-U.S. Free Trade Agreement (CUSFTA), the introduction of GST in 1991, the 1994 North American Free Trade Agreement, the cutbacks in social programs started in 1994 at the federal level as part of fiscal prudence etc.. Perron (1989) shows that if there is a structural break, the power to reject a unit root hypothesis decreases when the stationary alternative is true and the structural break is ignored. Therefore failure to find significant evidence of stationarity from the conventional unit root tests may reflect misspecification of the deterministic trend. To investigate whether or not there is a structural break, the Zivot-Andrews unit root test (Zivot and Andrews 1992), which is extended from Perron test (1989), is performed in this study using three models:

<u>Model A</u> (a shift in the mean of the process):

$$\Delta w_t = \mu + \alpha w_{t-1} + \beta t + \theta DU_t + \sum_{i=1}^{p} \eta_i \Delta w_{t-1} + e_t \qquad (1)$$

<u>Model B</u> (a shift in the rate of growth of the process, i.e., the slope):

$$\Delta w_t = \mu + \alpha w_{t-1} + \beta t + \gamma DT_t + \sum_{i=1}^{p} \eta_i \Delta w_{t-1} + e_t \qquad (2)$$

<u>Model C</u> (a shift in both the mean and the rate of growth of the process):

$$\Delta w_t = \mu + \alpha w_{t-1} + \beta t + \theta DU_t + \gamma DT_t + \sum_{i=1}^{p} \eta_i \Delta w_{t-1} + e_t \qquad (3)$$

where w_t, DU_t, DT_t, e_t denote, respectively, the time serious variable under the investigation (LICO in this study), the indicator dummy variable for a mean shift occurring at the break time (TB), the corresponding trend shift dummy variable, the error term, and Δ is the first-difference operator. For DU_t and DT_t, we have

$$\mathrm{DU}_t = \begin{cases} 1 & \text{if } t > \mathrm{TB} \\ 0 & \text{Otherwise} \end{cases} \quad \text{and} \quad \mathrm{DT}_t = \begin{cases} t - \mathrm{TB} & \text{if } t > \mathrm{TB} \\ 0 & \text{Otherwise} \end{cases}$$

To implement the sequential trend break model, some regions must be chosen such that the end points of the sample are not included. The reason is that in the presence of the end points, the asymptotic distribution of the statistics diverges to infinity. Zivot and Andrews (1992) suggest that the 'trimming region' be specified as (0.15T, 0.85T). The break points are selected recursively by choosing the value of TB for which the ADF t-statistic (the absolute value of the t-statistic for α) is maximized. Since their testing methodology is not conditional on prior selection of breakpoint (all points are considered potential candidates), their critical values are larger than those of Perron (1989) and hence it is difficult to reject the null hypothesis of the unit root. The null hypothesis in Equations (1) to (3) is that $\alpha = 0$ which implies that there is a unit root in w_t. The alternative hypothesis is that $\alpha < 0$, which implies that w_t is a trend stationary process with a once only breakpoint occurring at an unknown time.

It has been well known that the conventional unit root tests lack power in distinguishing the unit root null from stationary alternative in small samples. Researchers have tried to exploit the panel dimension of the data as one way of increasing the power of unit root tests. In recent years, a number of methodological developments by Levin and Lin (1993), Im, Pesaran and Shin (1997), Maddala and Wu (1997), and Sarno and Taylor (1998), have provided foundations for the application of panel tests to a wide variety of economic variables. The main advantage of panel unit root tests is that they can be used even with a small number of observations using the panel dimension.

The general model of N series and T time periods that encompass all panel unit root tests is

$$\Delta w_{it} = \alpha_i + \beta_i w_{it-1} + \sum_{j=1}^{k_i} \gamma_{ij} \Delta w_{it-j} + u_{it} \ , \quad i = 1,2,...N \tag{4}$$

where w_{it} is the poverty rate for province *i* at time *t*,, u_{it} is the error term, and k_i is the optimal leg length for series w_{it}. Levin and Lin (1993) provide the statistical foundation for panel unit root tests. The null hypothesis under the Levin and Lin (LL) test is $\beta_i = 0$ for all *i* against the alternative $\beta_i < 0$ for all *i*. In their specification, they allow the lagged differences to correct for serial correlation of the error terms. But they do not address the problem of contemporaneous cross-correlation of the errors and also restricted all panel members to have identical orders of integration. This limitation becomes all the more important in panels with mixed orders of integration. Although the null hypothesis that all series have a unit root is correctly rejected, the alternative of 'all stationary' is also false in these mixed panels.

Recognizing this problem, Im, Pesaran and Shin (1997), Maddala and Wu (1997), Somo and Taylor (1998) present second generation panel unit root tests that allow the auto regressive co-efficient to differ across the panel under alternative hypothesis. Under the Im, Pesaran and Shin (IPS) test, the null hypothesis is $\beta_i = 0$ for all *i* against the alternative $\beta_i < 0$ for some *i*. The IPS test is constructed as a simple average of the t statistics on all β_i generated from N single-equation ADF tests, so it allows different autoregressive co-efficient as well as heterogeneity of lag structures in the N individual series. Maddala and Wu (1997) use single-equation OLS estimation similar to IPS test except that the p-values corresponding to the individual t-statistics on all β_i are used to construct the (Fisher) test statistic. Sarno and Taylor (1998) propose a test that is a multivariate ADF test and also allows the autoregressive coefficient across panel members to be different.

In this study, the panel unit root tests developed by Levin and Lin (LL) and by Im, Pesaran, and Shin (IPS) are performed to test for the panel unit root of the poverty rates in all ten Canadian provinces. The results can also provide evidence on whether there is a convergence of poverty rates among these provinces.

3. The poverty data

Canada does not have an official definition of poverty. In the literature on poverty, a number of concepts have been used, such as low income cut-off (LICO), low income measure (LIM), and market based measure of poverty (MBM).

In Canada, most of the discussion on poverty is so far based on LICO measure compiled by Statistics Canada since the early1970s. To compute these cut-offs, Statistics Canada conducts a detailed survey of the expenditure patterns of Canadian families every four years. It then calculates the average percentage of pre-tax income that Canadian families spend on food, shelter, and clothing. The LICOs are set where families spend 20 percentage points more of their income than this average. The low-income lines are then calculated for communities and for families of various sizes within those communities and updated annually using the data obtained from the Consumer Price Index surveys. As a poverty measure, it is a relative measure and is based on the concept that people in poverty live in compromised circumstances - defined as spending a disproportionate amount of their total gross income on food, clothing, and shelter.

Another measure introduced in the late 1980s by Statistics Canada is LIM. The LIM is defined as 50% median income, adjusted for family size[1] and composition using an equivalence scale. It takes all of the after-tax incomes and finds the median income, so anyone who makes less than half of that median income is considered to be poor.

In 1997, Federal/Provincial/Territorial Ministers Responsible for Social Services asked Statistics Canada to work on developing the MBM to complement LICO and LIM and to measure those who are substantially worse off than the average. The MBM, only available since 2000, is based on a basket of goods and services. The "basket" includes five types of expenditures for a reference family of two adults and two children: expenditures on food, clothing, shelter, and other household needs (e.g., school supplies, personal care products, a telephone, etc.). The cost of purchasing this basket of goods and services has been determined for 48 different geographical areas in the 10 provinces, and takes into account the fact that living costs vary depending on where people live.

The present study uses national and provincial data on annual “low income cut-offs before tax and percentage of persons in low income” from 1980 to 2003, collected from Table 2020802 in CANSIM II - the Canadian Socio-economic and Information Management database compiled by Statistics Canada. Although some have been

[1] The scale in question uses a weight of 1 for the first family member and 0.4 for the second family member regardless of age. The third and subsequent family members are assigned a weight of 0.4 if they are aged 16 or over.

questioning about the effectiveness and appropriateness of using this poverty measure[2], it happens to be the longest currently available and most reliable time-consistent data on the poverty measures for Canada and for its ten provinces.

The LICOs for Canada and for most of its provinces are between 10% and 27% during the period from 1980 to 2003. Among all provinces, Prince Edward Island has a lowest LICO (14.12%) on average. The average LICOs for Manitoba, Newfoundland, and Quebec are 2.5-4% higher than the national average (17.3%), indicating these three provinces have the most serious poverty problem in Canada.

4. Test results.

Table 1 summarizes the results of the ADF test. For the poverty rates modeled as "constant without a time trend", the results indicate that the poverty rates for New Foundland and Nova Scotia are stationary, i.e., they are integrated of order 0; and the poverty rates for Canada and for all other provinces are non-stationary, i.e., they have a unit root or they are integrated of order 1. When the ADF test incorporates both a constant and a time trend, the results show that the poverty rates for British Columbia and Nova Scotia are stationary; the poverty rate for Canada is integrated of order 2 or higher; and the poverty rates for all other provinces are non-stationary.

The results of the PP test, summarized in Table 2, indicate that the null hypothesis of a unit root cannot be rejected at all conventional significance levels for all poverty rates, except that for New Foundland, when they are modeled as "constant without a time trend". For series modeled as "constant with a time trend", the null hypothesis of a unit root is rejected only for Canada. However, the results show while the series for New Foundland is stationary, i.e., integrated of order 0, the series for Canada is integrated of order 2 or higher.

The results of the DF-GLS test are reported in Table 3. It can be seen that, when the poverty rates are modeled as "constant without a time trend", the null hypothesis of a unit root is rejected for most poverty series except those for New Brunswick, Quebec, and Saskatchewan, indicating that the poverty rates for only these three provinces are non-stationary. However, when the poverty series are modeled as "constant with a time trend", the null hypothesis of a unit root is only rejected for British Columbia, New Foundland, and Nova Scotia, indicating that most poverty rates, except these three, are non-stationary.

Table 4 presents a summary of the unit root test results in Tables 1 to 3. Two points are apparent from the table. First, the tests are sensitive to the choice of unit root tests and the inclusion of a drift (constant) or a time trend, especially in the case of the

[2] For example, Sarlo (2001) has criticized LICO as a good poverty measure by arguing that LICO is a 'relative' measure in the sense that it rises with increases in average spending, so this "relativism" means that LICO is really measuring inequality and not poverty. Sarlo also argues that the LICO measure has no relation to the actual costs that people must face in buying the necessities and no relation to the regional differentials in costs that really matter.

ADF and DF-GLS tests. Second, the results for the provinces of New Brunswick, Quebec, and Saskatchewan are the most consistent in the sense that all the three unit root tests show that the series of poverty rates in these three provinces are non-stationary, i.e., they have a unit root. Overall, the ADF, PP, and DF-GLS test results suggest modeling the poverty rates for Canada and for most provinces as $I(1)$ series is quite reasonable.

Table 5 presents the results of the Zivot-Andrews test for models A, B and C for all poverty rates. The test results are not perfectly consistent but they do not seem to reject the null hypothesis of a unit root in all cases. A plausible reason for the inconsistent results of Zivot-Andrews test is the low frequency of the data and the fact that reforms in the Canadian economy have been gradual and distributed over a wider time frame. Given the divergent test results yielded by Zivot-Andrews unit root test, we are more inclined to go with the results of the conventional unit root tests reported in Table 1, 2, and 3.

As mentioned earlier, the conventional unit root tests lack power in distinguishing the unit root null from stationary alternative in small samples. To complement the conventional tests, the LL and IPS panel unit root tests are performed in this study to further examine the Canadian poverty rates and results of these tests are reported in Table 6. It is shown in the table that both tests provide same results. For all series modeled as "constant without a time trend", both tests reject the null hypothesis of a unit root in panel data, indicating that all series are stationary. For all series modeled as "constant with a time trend", both tests confirm the existence of a unit root in the panel data. However, the LL test result suggests that all series be non-stationary whereas the IPS test result does not exclude a possibility that some series may be stationary. The panel unit root test results are quite consistent with the results obtained from those individual unit root tests, especially with the results from the DF-GLS test. The non-stationarity property of the panel data, as modeled as "constant with a time trend", implies that there is no convergence in poverty rates among ten Canadian provinces during this period. This result also implies that social safety and assistance programs designed and adopted in each province need not to be identical cross the country.

5. Conclusions

In this paper, we have investigated whether the poverty rates for Canada and for each of its provinces are non-stationary, or, equivalently, have a unit root. The investigation is conducted using different unit root tests. The conclusion is that modeling the poverty rates for Canada and for most provinces as $I(1)$ series is quite reasonable. One important implication from this study is that it must be with great cautiousness to use the conventional regression analysis to conduct the empirical work on Canadian poverty and to interpret the regression results. Although the results obtained in this study may be regarded as preliminary while we await the availability of even longer and better time series data on the poverty rates for Canada. Nevertheless these results should also be viewed as an important step in addressing such an important topic, which has important public policy implications.

Table 1. Results of the Augmented Dickey-Fuller (ADF) Unit Root Test

	Constant without trend				Constant with trend			
	Levels		1st difference		Levels		1st difference	
Canada	-2.60	[1]	-2.96***	[0]	-2.41	[1]	-3.00	[0]
Alberta	-2.01	[0]	-4.67*	[0]	-1.83	[0]	-5.08*	[0]
British Columbia	-2.48	[0]	-4.14*	[4]	-4.70*	[3]	-4.09**	[4]
Manitoba	-1.89	[0]	-3.82*	[0]	-1.88	[0]	-4.57*	[1]
New Brunswick	-1.32	[0]	-4.28*	[0]	-2.33	[0]	-4.14**	[0]
New Foundland	-2.74***	[0]	-5.55*	[0]	-3.01	[0]	-5.38*	[0]
Nova Scotia	-3.61**	[2]	-2.56	[1]	-4.11**	[3]	-2.39	[1]
Ontario	-2.19	[1]	-3.40**	[0]	-2.10	[1]	-3.34***	[0]
Prince Edward Island	-2.30	[0]	-6.21*	[0]	-2.44	[0]	-6.14*	[0]
Quebec	-1.43	[0]	-4.66*	[0]	-1.27	[0]	-4.86*	[0]
Saskatchewan	-0.96	[1]	-7.21*	[0]	-0.18	[4]	-4.31**	[3]

Note: The optimal lag length, presented in brackets, for the unit root tests were based on the SIC criterion. *, **, and *** indicate significance at 1%, 5%, and 10% levels respectively.

Table 2. Results of the Phillips-Perron (PP) Unit Root Test

	Constant without trend		Constant with trend	
	Levels	1st difference	Levels	1st difference
Canada	-1.89	-2.95***	-1.62	-3.02
Alberta	-2.03	-4.66*	-1.82	-5.10*
British Columbia	-2.51	-4.19*	-2.55	-4.15**
Manitoba	-2.12	-3.81*	-2.06	-3.86**
New Brunswick	-1.44	-4.34*	-2.56	-4.16**
New Foundland	-2.74***	-5.55*	-3.01	-5.38*
Nova Scotia	-1.84	-3.50**	-1.83	-3.40***
Ontario	-1.83	-3.40**	-1.81	-3.34***
Prince Edward Island	-2.13	-6.46*	-2.33	-6.54*
Quebec	-1.50	-4.66*	-1.29	-4.86*
Saskatchewan	-2.40	-6.88*	-2.75	-7.86*

Note: *, **, and *** indicate significance at 1%, 5%, and 10% levels respectively.

Table 3. Results of the DF-GLS Unit Root Test

	Constant without trend				Constant with trend			
	Levels		1st difference		Levels		1st difference	
Canada	-2.49**	[1]	-3.02*	[0]	-2.59	[1]	-3.14***	[0]
Alberta	-1.81***	[0]	-4.63*	[0]	-1.88	[0]	-5.00*	[0]
British Columbia	-1.72***	[0]	-4.20*	[4]	-4.85*	[3]	-4.31*	[0]
Manitoba	-1.73***	[0]	-3.63*	[0]	-1.96	[0]	-4.57*	[1]
New Brunswick	-1.36	[0]	-3.85*	[0]	-2.33	[0]	-4.19*	[0]
New Foundland	-2.20**	[0]	-3.58*	[0]	-2.99***	[0]	-4.76*	[0]
Nova Scotia	-3.80*	[2]	-2.32**	[1]	-3.59**	[2]	-2.36	[1]
Ontario	-2.21**	[1]	-3.43*	[0]	-2.25	[1]	-3.49**	[0]
Prince Edward Island	-2.18**	[0]	-5.55*	[0]	-2.54	[0]	-6.01*	[0]
Quebec	-1.49	[0]	-4.77*	[0]	-1.53	[0]	-5.10*	[0]
Saskatchewan	-0.94	[1]	-2.17**	[1]	-1.37	[1]	-3.29**	[3]

Note: The optimal lag length, presented in brackets, for the unit root tests were based on the SIC criterion. *, **, and *** indicate significance at 1%, 5%, and 10% levels respectively.

Table 4. Summary of the results of the unit root tests

	ADF		**PP**		**DF-GLS**	
	Constant without trend	Constant with trend	Constant without trend	Constant with trend	Constant without trend	Constant with trend
Canada	**I(1)**	I(>1)	**I(1)**	I(>1)	I(0)	**I(1)**
Alberta	**I(1)**	**I(1)**	**I(1)**	**I(1)**	I(0)	**I(1)**
British Columbia	**I(1)**	I(0)	**I(1)**	**I(1)**	I(0)	I(0)
Manitoba	**I(1)**	**I(1)**	**I(1)**	**I(1)**	I(0)	**I(1)**
New Brunswick	**I(1)**	**I(1)**	**I(1)**	**I(1)**	**I(1)**	**I(1)**
Newfoundland	I(0)	**I(1)**	I(0)	**I(1)**	I(0)	I(0)
Nova Scotia	I(0)	I(0)	**I(1)**	**I(1)**	I(0)	I(0)
Ontario	**I(1)**	**I(1)**	**I(1)**	**I(1)**	I(0)	**I(1)**
Prince Edward Island	**I(1)**	**I(1)**	**I(1)**	**I(1)**	I(0)	**I(1)**
Quebec	**I(1)**	**I(1)**	**I(1)**	**I(1)**	**I(1)**	**I(1)**
Saskatchewan	**I(1)**	**I(1)**	**I(1)**	**I(1)**	**I(1)**	**I(1)**

Note: I(0), I(1), and I(>1) denote, respectively, that the series is stationary, that the series has a unit root, and that the series is integrated of order 2 or higher.

Table 5. Results of the Zivot-Andrews Unit Root Tests

	Model A A shift in the mean		Model B A shift in the rate of growth		Model C A shift in both the mean and the rate of growth	
	Levels	1st differences	Levels	1st difference	Levels	1st difference
	Break point t value	Break point t value	Break point t value	Break point t value	Break point t value	Break point t value
Canada	1992	1990	1997	1994	1995	1990
	-2.71	-4.80**	-2.55	-2.98	-3.41	-4.43
Alberta	1999	1990	1997	1986	1996	1999
	-4.31	-3.61	-5.03*	-3.45	-4.82	-3.96
British Columbia	1988	1990	1990	1985	1992	1990
	3.57	-2.83	-3.44	-2.70	-3.66	-4.44
Manitoba	1991	1990	1998	1992	1996	1990
	-2.81	-5.70*	-3.46	-4.26	-3.16	-5.49**
New Brunswick	1988	1990	1986	1994	1988	1990
	-4.02	-6.90*	-4.10	-5.59*	-3.94	-5.34**
New Foundland	1988	1990	1989	1996	1992	1990
	-3.21	-4.61	-3.43	-3.13	-3.53	-5.22**
Nova Scotia	1994	1998	1998	1985	1994	1998
	-4.55	-4.58	-3.85	-3.69	-3.85	-4.01
Ontario	1993	1997	1985	1993	1995	1997
	-3.23	-4.07	-2.75	-3.24	-3.21	-3.60
Prince Edward Island	1995	2000	1988	1998	1986	1996
	-4.34	-3.67	-2.08	-4.09	-2.38	-5.34**
Quebec	1993	1990	1998	1994	1996	1990
	-2.05	-4.55	-2.52	-2.76	-2.71	-4.70
Saskatoon	1991	1990	1996	1986	1991	1989
	-4.79	-2.69	-3.99	-2.62	-4.56	-2.79

Note: The table presents the potential break points (years) which correspond to the largest (in absolute value) test statistic in all tests. The computed t test statistics for variables in level and in first difference are presented below the break points in the table. *, **, and *** indicate significance at 1%, 5%, and 10% levels respectively.

Table 6. Results of the Panel Unit Root Tests (LL and IPS)

	Constant without trend		Constant with trend	
	Levels	1st difference	Levels	1st difference
The LL Test	-2.0428**	-10.749*	-0.9155	-6.1717*
	(0.0205)	(0.0000)	(0.1800)	(0.0000)
The IPS Test	-2.2606**	-10.653*	-0.9941	-7.9501*
	(0.0119)	(0.0000)	(0.1601)	(0.0000)

Note: The optimal leg length selection is based on SIC criteria. The p-values of the test statistic are presented in parentheses. *, **, and *** indicate significance at 1%, 5%, and 10% levels respectively.

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