Preliminary Draft

Provincial Convergence of Consumer Prices in Canada

Tarek Harchaoui and Faouzi Tarkhani

Prices Division
Statistics Canada

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Abstract: This paper investigates the dynamics of consumer prices indices for Canadian provinces using panel econometric methods. The results suggest that over the 1980-2007 period, the persistence of deviations in response to shocks, measured by the estimated adjusted half-life, is low, at about three quarters for the CPI All-items. There is, however, a great deal of variation across commodities classes and time periods. While the estimated rate of convergence in Canada is comparatively faster than the rates for similar studies reported for other countries, it is also a relatively faster during the post-inflation targeting period than earlier and much more rapid for goods than for services.

1. Introduction

This paper, which is complementary to a growing literature on price dynamics within a single-currency area, asks the following four set of questions: Do absolute or relative prices across Canadian provinces revert to a shared common trend after a shock? How fast do they converge after that shock? Do these conclusions various across commodities and do they depend on the nature of the monetary policy regime established by monetary authorities?

This research has two main motivations: First, the existence of large systematic price divergence despite a common currency and no implicit or explicit restrictions on factor mobility may, therefore, indicate market segmentation, and its eradication is a challenge to policymakers in terms of regional real earnings and the allocation of resources. Second, in the post-Bretton Woods era, research in the international Purchasing Power Parity (PPP) literature has had difficulty finding evidence for PPP. In the face of these somewhat negative conclusions, there has been an increasing interest in studying PPP in an intra rather than an international context. Typically, there is much more trade in goods and labour and capital between states and cities within a country than between countries; the many barriers and distortions to trade are usually much smaller inside a country. Thus we might expect PPP to have a better chance of holding in an intranational context, and with a faster convergence to the PPP equilibrium.

To answer our questions, we apply recent advances in panel time-series econometrics that have been used to study inflation dynamics, growth in real output and levels of real exchange rates across countries (for example, Culver & Papell (1997) for inflation dynamics, Oh (1996), Papell (1997) and Wu (1996) for real exchange rates). We will also compare our results to those obtained by Cecchetti et al. (2002) for the U.S., Chaudhuri and Sheen (2004) for Australia and some European countries like Spain (Carrion-I-Silvestre et al. 2004), Italy (Busetti et al. 2006).

Econometric analysis of PPP typically involves conducting unit root tests for the real exchange rate. If the real exchange rate is a mean reverting process, there exists a tendency for the real exchange rate to return (however, slowly) to its equilibrium parity path. However with a unit root in the real exchange rate, there is no tendency for the real exchange rate to return to its equilibrium path, thus violating the theory of PPP even in the long run.

Common sense suggests that due to a single currency, near-free factor movements and policies adopted by the central authority, prices in different regions in Canada would share a common trend, and,

accordingly, quickly revert to that trend following a local shock to the price level. At the same time, it is also plausible that due to its large size, different agro-climatic and economic conditions and federal structure of governance, prices would also be affected by local shocks.

To summarize our main results, we find consumer price index convergence across Canadian provinces to be fairly widespread and surprisingly transitory. Average annual inflation rates measured over 5-year intervals can differ by as much as 6.0 percentage points. While differentials of this size may not seem large by current international standards, the real interest rate differentials they create within a common currency zone could have a substantial impact on resource allocations.

With regard to the degree of persistence of deviations from PPP after a shock, our empirical estimates showed a surprisingly modest half-life of about 3 quarters, which is lower than similar estimates for Australia, a country with similar structures (an average of 7 quarters). The persistence of deviations in response to shocks varies significantly across commodity classes, with very slow convergence in the case of shelter, alcohol and tobacco, reflecting both the non tradable nature of these commodities and the presence of provincial regulations. In contrast, clothing, food, household furnishing and transportation, which are considered are mostly tradable goods, show a rapid rate of convergence, thereby explaining the exceptional rapid mean reversion of consumer prices. As regards the various sub-periods, the post inflation-targeting period had relatively faster convergence in prices.

2. Data and Descriptive Statistics

Our primary dataset consists of a panel of seasonally adjusted quarterly observations of provincial Consumer Price Index (CPI) for the eight major classes— Food, alcoholic beverages and tobacco products, Health and personal care, Household operations, furnishings and equipment, Recreation, education and reading, Shelter and Transportation—over the period January 1980 to March 2007. The data are publicly available from CANSIM II – the online database of Statistics Canada. As data for full panel are not available for the territories, we have excluded them from our analysis.

We begin with a very preliminary and coarse examination of these data. The results in Table 1 are based on annualized CPI rates calculated for seven non-overlapping five-year periods, beginning in 1980, computed for each of the 10 provinces. We report the highest and lowest average annual consumer prices for each ten-year interval, as well as the differential. For example, from 1980 to 1985, British Columbia's (BC)

inflation of 14.1 percent per year on average was the highest in the sample, while Alberta (AB) average annual inflation of 2.6 percent was the lowest. The differential was 11.5 percentage points per year on average.

Table 1. Selected provincial Inflation Rates

	Province	**Maximum**	**Province**	**Minimum**	**Differential**
1980-1985	BC	14.1	AB	2.6	11.5
1986-1991	PEI	7.5	PEI	2.1	5.4
1992-1997	BC	3.5	QC	-1.3	4.8
1998-2003	AB	4.4	PEI	-0.4	4.8
2004-2007	AB	5.0	AB	1.4	3.5
Average		**6.9**		**0.9**	**6.0**
1980-1991	BC	14.1	PEI	2.1	12.0
1992-2007	AB	5.0	QC	-1.3	6.2
Average		**9.5**		**0.4**	**9.1**

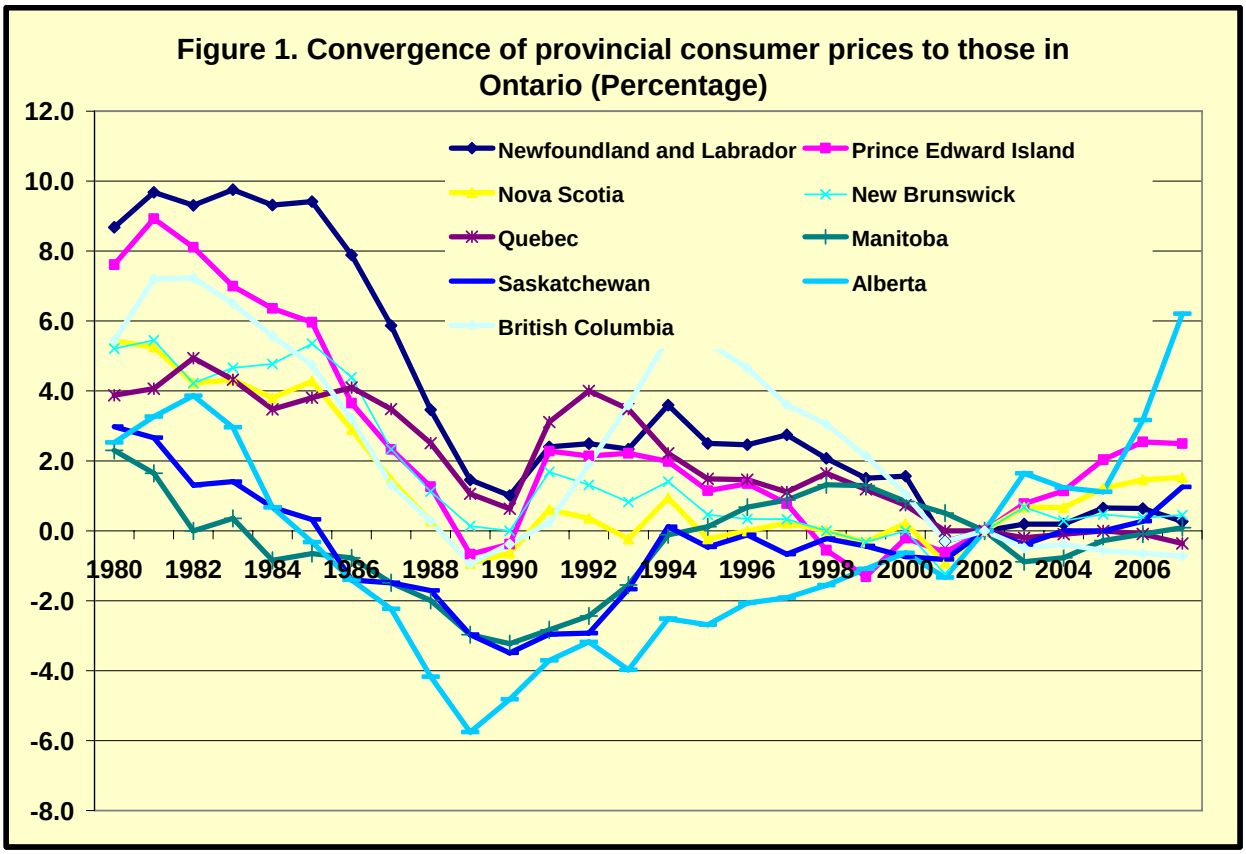
As one might expect, these differentials become larger when we lengthen the horizon from five to one decade. We draw several conclusions from these results.

First, significant inflation differentials of more than ten percentage point per year do not persist over ten-year periods. But even this very crude look at the data suggests that these differences reverse themselves, as British Columbia's relatively more moderate inflation from 1992 to 1997 is preceded by relatively high inflation from 1980 to 1985. These reversals suggest that the differentials die out, but on a quenquennial time scale.

Second, on average the difference between the province with the highest and the lowest inflation is 6.0 percentage points, with relatively huge variations from the 1980s to the 2000s. This is the first indication that there may have been a significant change in the dynamics of adjustment over the twenty five plus years of the sample. Increasing the time span from five to ten years, and looking at two non-overlapping intervals, the average differential increases by 50% to close to 10 percentage points annually, again suggesting a rapid adjustment.

Next, we plot the data to give a graphical impression of the convergence in relative prices. To do this, we need some sort of base. To foreshadow the more detailed work in the next section, we compute the log of the CPI of each province relative to that of Ontario. Figure 1 displays the deviations from this mean of the log CPI in every province.

The impression one gets from the figure is that deviations from PPP between Canadian provinces are not as persistent as those observed between nations. Deviations from parity are common and appear to occur in cycles lasting on the order of ten years. Generally though, the data suggest the presence of cycles around a downward trend, as the log of the provincial shows a tendency to revert to the mean represented by Ontario.



This preliminary examination of the data suggests that the Canadian inter-provincial real exchange rates exhibit significant movements that do not seem to persist for many years. We now proceed with a detailed examination of their time-series properties.

3. Econometric Analysis

Set up

Our interest in this paper concerns the persistence of shocks to economic time series.

According to PPP, since the (bilateral) nominal exchange rate (E_t) is the relative price of two currencies (the price of the foreign country's currency in terms of the home country's currency), in equilibrium it should reflect their relative purchasing powers. So, if P_t is the price level in the home country and P_t^* is the price level in the foreign country, then PPP requires:

$$E_t = \frac{P_t}{P_t^*} \tag{1}$$

Thus, the logarithm of the real exchange rate, defined as $y_t = \ln\left(\frac{E_t P_t^*}{P_t}\right)$, should be constant if PPP holds at every point in time. A weaker version of the PPP, which is followed in this paper, requires only that (1) holds in the long run.

The empirical evidence on PPP is mixed. Although casual evidence suggests that the two series, E_t and $\frac{P_t}{P_t^*}$, tend to revert towards each other over time, there are long-drawn-out periods in which the nominal exchange rate deviates from its PPP level. How persistent are these deviations? The half-life measure is a measure of persistence of PPP deviations. To motivate this measure, suppose that the deviations of the logarithm of the real exchange rate y_t from its long run value y_0, which is constant under PPP, follow an autoregressive process of order one:

$$y_t - y_0 = \rho(y_{t-1} - y_0) + \varepsilon_t$$

where ε_t is a white-noise. Then, at horizon h, the percentage deviation from equilibrium is ρ^h. The half-life deviation from PPP is defined as the smallest value of h such that $\xi(y_{t+h} - y_0 | y_{t-s} - y_0, s \le 0) \le \frac{1}{2}(y_t - y_0)$, where ξ is the expectation operator. That is:

$$\rho^h = \frac{1}{2} \quad \Rightarrow \quad h(\rho) = \frac{\ln(1/2)}{\ln(\rho)} \tag{2}$$

The half-life $h(\rho)$, commonly employed as a measure of the speed at which convergence to PPP occurs, is the time require for a divergence from PPP to dissipate by one half.

In the case of an $AR(p)$ process $Y_t = \mu + \rho_1 Y_{t-1} + \rho_2 Y_{t-2} + ... + \rho_p Y_{t-p} + e_t$, any $p+1th$ order difference equation can be written as a 1st order $p+1th$ vector difference equation of the form $\hat{\lambda}_t = F\hat{\lambda}_{t-1} + \xi_t$, where

$\lambda_t = \{Y_t, Y_{t-1}, ..., Y_{t-p-1}\}'$ and matrix F and ξ_t are defined accordingly (see below). Then $E\lambda_t = F^h\lambda_1$. Setting $\lambda_0 = 0$ and then allowing $Y_1 = e_1/2$, we can determine the value of the exact half-life, $h(\rho_1)$, that makes $EY_h = e_1/2$ [1], with

$$F \equiv \begin{bmatrix} \rho_1 & \rho_2 & \rho_3 & \cdots & \rho_{p-1} & \rho_p \\ 1 & 0 & 0 & \cdots & 0 & 0 \\ 0 & 1 & 0 & \cdots & 0 & 0 \\ \vdots & \vdots & \vdots & \cdots & \vdots & \vdots \\ 0 & 0 & 0 & \cdots & 1 & 0 \end{bmatrix}.$$

Due to the non linearity nature of $h(\rho)$, small variations in ρ in the region near unity lead to disproportionately large variations in the half-life (for example, $h(0.93) = 9.56$, $h(0.95) = 13.5$, $h(0.97) = 22.8$). Thus, if the estimator of ρ is biased, failure to adjust for the bias can produce substantively misleading estimates of the half-life.

Unit root tests

Our objective is to ascertain whether the real exchange rates between Canadian provinces contain a unit root, with the alternative hypothesis being that they converge to a steady state in the long run. If the unit root hypothesis cannot be rejected, we will conclude that PPP is rejected by the data. In this event, the real exchange rate of different provinces will tend to diverge over time, with increasing variance.

We begin with an analysis of univariate unit root results, and in the next section we report the results from panel unit root tests. The univariate unit root tests provide time series information about the stationarity properties of the individual series in relation to some (arbitrary) numeraire price. The panel unit root tests are more powerful because they utilise the cross-sectional interdependence information for provinces in the panel data.

Univariate unit root tests

We perform augmented Dickey–Fuller (ADF) unit root tests to serve as a benchmark for the subsequent analysis. We estimate the following equation

[1] For an AR(p) model, the percentage deviation from equilibrium is the first element of the matrix.

$$\Delta S_t = \alpha + \beta S_{t-1} + \sum_{j=1}^{k} \gamma_j \Delta S_{t-j} + \varepsilon_t \,, \qquad (3)$$

where S_t is the series in question. In this univariate context, the construction of S_t requires a numeraire province, which we choose as Ontario – the largest province, which means that we are testing whether a province's CPI does not diverge stochastically over time from Ontario's CPI. We define $S_t = \ell n\left(\frac{P_{jit}}{P_{jot}}\right)$, where P_{jit} refers to the price index of good j in province i at time t, and P_{jot} is that in Ontario. The γ_js are the lag coefficients in the process characterizing S_t; $\beta \equiv \rho - 1$ and $\rho \equiv \sum_{j=1}^{k} \gamma_j$. The approximate half-life of a chock to S_t, is computed as mentioned earlier as $\frac{\ell n(0.5)}{\ell n(\rho)}$.

To select the lag length k, we follow the recursive procedure suggested by Campbell and Perron (1991) and Hall (1994). Since we only have 110 observations through time, we start with $k = k\max = 8$ and use the 10 per cent asymptotic normal distribution to assess the significance of the last lag. If the last lag is significant, then we choose $k = k\max$. If not, we decrease k by 1 and repeat the procedure until the last lag becomes significant. We did not include a trend term in (3) because we assume its inclusion is inconsistent with our alternate hypothesis of PPP between provinces.

The results of the ADF 'studentised t' tests for the all-items CPIs as well as the disaggregated ones by major classes are outlined in Table 2. The null hypothesis of a unit root is rejected in favour of the alternative if β is significantly different from zero. In most cases, we reject the unit root null.

The univariate regressions also yield measures of persistence in relative price movements, which are computable from the estimated autoregressive parameters. Since these least squares estimates are known to be downward biased as the autoregressive parameter approaches 1, we adjust them using Kendall's (1954) formula.

Once we have obtained the adjusted values by the two methods, we are then able to analyse their implied persistence measures. We calculate three measures of the half-life: (i) the unadjusted measure. (ii) the approximate one simply based on the Kendall-adjusted ρ and (iii) the exact one based on all the estimated parameters of the AR process with only a first order Kendall adjustment.

Table 2. Results from Individual Unit Root (ADF) Tests Q1/1980 - Q2/2007
(Seasonally Adjusted Quarterly Data)

	NFLD-L	PEI	NS	NB	QC	MAN	SASK	AB	BC
All items	-3.286	-3.764	-4.052	-3.952	-3.084	-4.116	-3.844	-3.194	-2.777
Clothing and footwear	-4.981	-5.397	-4.811	-5.601	-4.622	-5.505	-4.255	-5.320	-5.440
Food	-3.735	-3.921	-3.569	-4.487	-4.180	-4.107	-3.986	-3.635	-3.715
Alcoholic beverages and tobacco products	-3.193	-4.335	-4.405	-3.625	-2.935	-3.891	-4.440	-4.775	-3.005
Health and personal care	-3.287	-4.851	-4.883	-4.957	-4.685	-3.759	-4.291	-3.744	-3.203
Household operations, furnishings and equipment	-5.610	-4.147	-4.535	-6.063	-4.587	-4.544	-4.606	-4.749	-3.952
Recreation, education and reading	-4.109	-3.809	-3.132	-2.874	-1.938	-3.178	-3.002	-3.454	-2.796
Shelter	-2.960	-3.388	-3.076	-2.908	-3.422	-2.855	-2.533	-3.299	-2.642
Transportation	-4.928	-4.956	-5.166	-4.257	-4.293	-5.245	-4.039	-5.748	-4.587

Note: For 110 observations, the critical values at the 1 per cent, 5 per cent and 10 per cent levels of significance are -2.599, -1.950 and -1.611.

Based on the point estimates with the Kendall, we compute both the approximate and exact half-life measures along with their 95 per cent confidence intervals. The 95 per cent confidence intervals are calculated using a parametric bootstrap.

Table 3 reports the half-life results for the CPI-All items and a sample of the CPI major classes—food, clothing and shelter. For the provincial CPIs, the three measures of half-life give similar results, with exception for British Columbia, where the approximate estimate is twice the exact measure.

With the exception for British Columbia, the exact half-life measure is similar at about three quarters across the other Canadian provinces for the CPI-All items. The results for the three selected major classes—clothing, food and shelter—suggest that the half-life for convergence to PPP is the highest for shelter and the lowest for clothing and footwear. As for overall CPI, in the case of shelter, exact half-life measure is the highest in British Columbia, with 12 quarters, whereas in the other provinces, half-lives are between 3 and 5 quarters.

In general, our half-life estimates across are somewhat small, and for all goods and services categories, we accept non stationarity. Hence, in the next section, we will increase the power of these unit root tests, by allowing for cross-sectional variation, and using therefore panel methods.

Panel unit root tests

The tendency of univariate tests to accept nonstationarity even when it is untrue can arise in part because of the short time span of the data. To increase the power of the unit root tests, an increasingly popular approach is to allow for cross-sectional variation using panel methods. We explore this by employing two separate procedures, one by Levin and Lin (1993) – henceforth LL and the other by Im *et al.* (1997) – henceforth IPS and estimate the following equation

$$\Delta S_{it} = \alpha_i + \beta S_{it-1} + \theta_t + \sum_{j=1}^{k_i} \gamma_{ij} \Delta S_{it-j} + \varepsilon_{it} \qquad (4)$$

where i is an index for the province. We do not include a trend, as the inclusion of the trend is not consistent with the PPP hypothesis, particularly in a provincial context. In (4), we have allowed the intercepts to differ across provinces, and also common time effects (θ_t). The common time effects, known as aggregate shocks in the panel data literature, take into consideration the possible impact of national macroeconomic shocks that induce cross-sectional dependence in the provincial real exchange rates. We incorporate these effects by subtracting the cross-sectional mean of the real exchange rate in each period and performing the tests based on the transformed data. This is equivalent to including time dummies in our regression (4).

Table 3 Half-lives for Selected Individual Unit Roots: 1980:1-2007:2

Province	All items			Clothing and footwear			Food			Shelter		
	Before Adjustment	Approx-Kendall	Exact-Kendall	Before Adjustment	Approx-Kendall	Exact-Kendall	Before Adjustment	Approx-Kendall	Exact-Kendall	Before Adjustment	Approx-Kendall	Exact-Kendall
NFLD-L	2.1	2.5	3	1.1	1.2	2	2.4	2.9	3	3.5	4.3	5
PEI	2.5	3.0	3	1.9	2.2	2	2.4	2.9	3	2.5	2.9	3
NS	1.7	1.9	3	1.7	1.9	2	1.8	2.1	3	3	3.6	4
NB	1.7	2.0	3	0.8	0.8	3	0.9	1.0	3	3.7	4.7	5
QC	1.5	1.6	3	0.9	1.0	2	1.0	1.1	3	2.6	3.1	3
MB	3.1	3.8	3	2.2	2.5	1	2.3	2.7	3	4.1	5.5	5
SASK	2.5	2.9	3	1.9	2.1	3	2.2	2.5	3	7.4	12.7	4
AB	2.4	2.9	4	1.3	1.4	3	1.2	1.3	3	3.1	3.8	4
BC	7.0	11.7	6	2.9	3.5	1	2.4	2.8	3	7.6	13.2	12

Notes: Lag length is selected using Campbell and Perron (1991) procedure. The first column present half-life numbers before adjustment on ρ. The approximate half-life numbers represent the usual AR(1) approximation as discussed in the paper. The exact half-life numbers are based on all estimated parameters in the AR(p) model. The adjusted bias less estimator proposed by Kendall (1954) has been used in the AR(1) and in the first coefficient of the AR(p).

While it is necessary to have a numeraire province in the individual unit root tests, this is not the case with the panel estimates in the presence of the common time effects. The inclusion of different fixed intercept effects (α_i) takes account of unobserved heterogeneity across cities, such as varying sales taxes or levels of per capita income. Both of the test procedures (LL and IPS) we employ are formulated with the null hypothesis that each series contains a unit root. The two tests differ in their treatment of β_i in the alternative hypothesis. Formally the null and the alternative hypothesis under the two tests can be expressed as

$$H_0: \quad \beta_i = \beta = 0$$
$$H_1^{LL}: \quad \beta_i = \beta < 0$$
$$H_1^{IPS}: \quad \beta_i < 0 \quad \textit{for some } i$$

Thus the IPS test allows heterogeneity across cross section units, that is, provinces in our case. Bowman (1998) and Maddala and Wu (1997) provide evidence that the IPS test has more power than LL.[2]20 However, the LL procedure provides us with a panel estimator of ρ (where β = ρ − 1), which the IPS procedure does not. The critical values of the test statistics as derived by LL and IPS do not take into account the dependency across individual cities in the error term.

The inclusion of time dummies solves the problem asymptotically only. To control for the residual dependence across cities in our finite sample, we follow Cechetti *et al.* (2002) and calculate the critical values of the LL[3] and IPS[4] tests

[2] We prefer the IPS test as it allows for cross-sectional heterogeneity

[3] To compute the LL test: (i) subtract the cross-sectional means from the logs of the data series to remove the common time effects, (ii) regress the change in each province de-meaned real exchange rate on a constant and ki lags of itself (ki being determined by the Campbell and Perron (1991) procedure), and keep the estimated residuals, ε_{it}, (iii) repeat step (ii) except use the one period lagged real exchange rate as the dependent variable and keep the estimated residuals, η_{it-1}, (iv) regress ε_{it} on η_{it-1} with no constant and use the estimated standard error of this regression to normalise ε_{it} and, η_{it-1}, (v) with these normalised values, run a panel OLS regression with no constant. The LL statistic is the t-statistic of the estimated slope coefficient. The finite sample critical value of this panel *t* statistic is obtained from parametric bootstrapping.

[4] To compute the IPS test: (i) remove the cross-sectional mean from the logs of the data, (ii) conduct ADF regressions for each province of the changes in its de-meaned real exchange rate on a constant, ki of its own lags (ki being determined by the Campbell and Perron (1991) procedure) and the lagged level of the exchange rate. Obtain the studentised *t* statistics, t_i on the lagged level coefficient in each regression, and (iii) compute the group *t* statistic as the simple average of these province t_i values. The finite sample critical value of this statistic is obtained from parametric bootstrapping.

using parametric bootstrapping[5] with 5 000 replications using the estimated variance-covariance matrix from our data.

In practice, panel data estimation of the half-life to convergence are potentially subject to two sources of bias addressed individually in the literature. The first potential source of bias is the downward small-sample estimation bias. This bias was discussed in the univariate context by Marriott and Pope (1954) and Kendall (1954) and in the dynamic panel context by Nickell (1981). We henceforth refer to the bias in the panel data context as "Nickell bias." The second source bias is Time Aggregation Bias, which an is an upward bias that results because price indices used to form real exchange rates are not constructed from point-in-time sampled commodity prices. Instead, statistical agencies, such as Statistics Canada, report period averages of commodity and service prices. The consequences of this time aggregation of the data were first discussed by Working (1960). Taylor (2001) extends Working's analysis to the study of PPP and shows that time aggregation leads to an upward bias in the estimated half-life.

In this paper, we use the least squares dummy variables estimator proposed by Choi et al. (2006) to deal with these sources of bias to arrive at a final and unbiased estimate of the half-life.

4. Empirical Results

Panel Unit Root Results for Provincial All-items CPIs

In the section, we present the LL and IPS panel unit root tests for the CPI-all items and its major classes. This empirical analysis controls for aggregate shocks by subtracting the cross-sectional means, and hence, we are not required to have a numeraire province.

Table 4 reports the results from LL and the IPS tests along with the P-values using the parametric bootstrap procedures for the provincial CPIs. We have estimated the full sample and two sub-samples reflecting the pre- and post

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[5] To compute the parametric bootstrap: (i) model each log exchange rate as a univariate unit root process, estimating a simple autoregression in first differences, the number of lags, k_i, being determined by the Campbell and Perron (1991) procedure. Retain the parameter estimates and residuals from each regression, (ii) to account for intercity dependence, estimate the joint error variance-covariance matrix $\sum$, from the set of residual series, (iii) make a random draw of T + 100 (= 210 in our case) observations from a multivariate normal distribution with mean 0, and variance-covariance as the estimated $\sum$; (iv) using these, and the estimated parameters from (i), generate pseudo-data for each exchange rate, and then drop the first 100 observations; (v) do the LL or IPS test on this data, and retain the LL *t* statistic or the IPS group *t* statistic; (vi) replicate (iii) and (iv) 5 000 times, and find the proportion of the *t* or group *t*-test statistics with the pseudo-data that are higher in absolute value than those with the actual data. These are the parametric bootstrapped *P*-values presented in our tables.

monetary policy targeting regime (before and after 1991). The adjusted ρ along with the half-life measure are also reported in Table 4.

Table 4. Results from Panel Unit Root Tests for Province CPI

A. Levin and Lin (LL)					
	Test Statistic	***p-value***	ρ	***adjusted*** ρ	***adjusted half-life***
Q1/1980 - Q2/2007	-8.372	0.000	0.766	0.777	2.748
Q1/1980 - Q1/1992	-8.107	0.000	0.728	0.739	2.289
Q2/1992 - Q2/2007	-11.531	0.000	0.656	0.666	1.706
B. Im, Pesaran and Shin (IPS)					
	Test Statistic	***p-value***	ρ	***adjusted*** ρ	***adjusted half-life***
Q1/1980 - Q2/2007	-2.908	0.000	0.698	0.723	2.136
Q1/1980 - Q1/1992	-2.611	0.000	0.69	0.755	2.465
Q2/1992 - Q2/2007	-4.037	0.000	0.56	0.596	1.341

For the full sample and both sub-samples, we are able to reject the null hypothesis of unit root using both the LL and the IPS test (at 1 per cent). For the IPS model, estimates of ρ are hypothesised to differ across provinces and hence the bias adjustment is done based on the average of the estimated ρ across provinces. For the full-sample period, we find that the half-life measure to convergence is 2.7 quarters using the LL and 2.1 quarters using IPS test.

The half-life estimates show a clear pattern. For the first half of the sample, the value stands at 2.3 quarters for the LL procedures and 2.5 for the IPS procedures. The estimated ρ decreases substantially in the second half, with correspondingly lower half-life estimates (1.7 and 1.3 quarters for the LL and IPS procedures respectively). Hence, during the period when Bank of Canada has adopted a monetary policy for controlling inflation, the half-life to convergence takes less than two quarters. In the following section, we test whether this is still the case with disaggregated data.

Panel Unit Root Results for Disaggregated CPIs

As mentioned in the introduction, an explanation for the empirical failure of the PPP hypothesis in an international context is that there are non-traded goods in the construction of the CPI. The provincial CPIs might also be viewed as having components that are traded and non-traded between the provinces.

Table 5 reports the results from the LL and the IPS (1997) tests, P-values, estimated bias adjusted ρ, and the half-life measure, for goods and services categories.

Generally, we might consider the idea that goods and services can be placed anywhere in the tradability spectrum between traded and non-traded. The greater the preponderance towards the non-traded end, the less likely is PPP to hold, and the longer the expected half-life of the adjustment process. We might expect that the portion of non traded items is higher within the services categories than with goods categories (i.e. shelter services).

For the full-sample period and for goods category, we find that the half-life measure to convergence is 1.9 quarters using the LL and 1.6 quarters using IPS test. This is significantly lower than for services, where the half-life measure to convergence is 5.6 and 4.5 quarters using the LL and IPS tests, respectively.

For the full sample, and both sub-samples, half-life measure for goods is less than two quarters using both LL and IPS tests, a sharp contrast to services where the half-life measure is around four quarters. Both goods and services generally report a half-life measure lower in the post 1991 period than before.

Panel Unit Root Results across CPI Major Classes

In this section we examine the importance of tradability in the provincial CPIs by analysing major classes of the CPIs – alcohol and tobacco, clothing and footwear, communications, food, health, shelter, household furnishings and transport—for the full-sample and sub-samples periods.

Several observations can be drawn from Table 6. First, for the full sample and both sub-samples, both the LL and IPS tests allow us to reject the null hypothesis of a unit root. Second, clothing and footwear, transportation, household operations, furnishings and equipment and food are major classes that report the shortest half-lives to convergence—less than two quarters. This contrasts markedly with shelter and alcoholic beverages and tobacco products which report estimates of half-lives higher than three quarters. From these results, we may conclude that those with relatively fast convergence, namely clothing, food, transport and household operations are likely to be the more tradable goods.

In order to examine the sensitivity of our results in terms of disaggregated CPIs, we also analyse the components of the provincial CPIs for both sub-sample periods. We can make several inferences based on these results. First, for both sub-samples, and all type of disaggregated CPIs, we are able to reject the unit root null hypothesis. Second, with the exception for transportation, the half-life measures are lower in the second sub-sample than in the first one, suggesting that shocks have become more persistent after 1991 perhaps largely due to gasoline prices.

Table 5. Panel Unit Root Tests Results for Disaggregated CPIs

	A. Levin and Lin (LL)					***B. Im, Pesaran and Shin (IPS)***				
	Test Statistic	***p-value***	ρ	***adjusted*** ρ	***adjusted half-life***	***Test Statistic***	***p-value***	ρ	***adjusted*** ρ	***adjusted half-life***
Goods										
Q1/1980 - Q2/2007	-8.742	0.000	0.690	0.700	1.946	-2.989	0.000	0.626	0.649	1.604
Q1/1980 - Q1/1992	-9.421	0.000	0.619	0.629	1.494	-3.006	0.000	0.589	0.647	1.593
Q2/1992 - Q2/2007	-12.044	0.000	0.605	0.615	1.425	-4.036	0.000	0.553	0.589	1.311
Services										
Q1/1980 - Q2/2007	-6.982	0.000	0.872	0.884	5.644	-2.53	0.000	0.829	0.859	4.547
Q1/1980 - Q1/1992	-8.668	0.000	0.811	0.823	3.549	-2.87	0.000	0.774	0.844	4.078
Q2/1992 - Q2/2007	-7.641	0.000	0.814	0.826	3.617	-2.524	0.000	0.783	0.829	3.688

Table 6. Panel Unit Root Tests Results for Disaggregated CPIs

		A. Levin and Lin (LL)					B. Im, Pesaran and Shin (IPS)				
		Test Statistic	***p-value***	ρ	***adjusted*** ρ	***adjusted half-life***	***Test Statistic***	***p-value***	ρ	***adjusted*** ρ	***adjusted half-life***
Clothing and footwear	*Q1/1980 – Q2/2007*	-9.806	0.000	0.585	0.595	1.334	-3.255	0.000	0.544	0.565	1.216
	Q1/1980 – Q1/1992	-6.623	0.000	0.732	0.743	2.331	-2.117	0.000	0.697	0.762	2.548
	Q2/1992 – Q2/2007	-9.715	0.000	0.522	0.531	1.096	-3.185	0.000	0.466	0.499	0.997
Food	*Q1/1980 – Q2/2007*	-9.004	0.000	0.688	0.698	1.931	-2.996	0.000	0.646	0.670	1.731
	Q1/1980 – Q1/1992	-8.002	0.000	0.693	0.703	1.970	-2.506	0.000	0.658	0.721	2.119
	Q2/1992 – Q2/2007	-9.919	0.000	0.647	0.657	1.651	-3.266	0.000	0.599	0.638	1.543
Alcoholic beverages and tobacco products	*Q1/1980 – Q2/2007*	-8.892	0.000	0.785	0.796	3.043	-2.995	0.000	0.729	0.756	2.475
	Q1/1980 – Q1/1992	-7.485	0.000	0.729	0.740	2.299	-2.583	0.000	0.664	0.727	2.173
	Q2/1992 – Q2/2007	-7.629	0.000	0.795	0.806	3.221	-2.481	0.000	0.762	0.807	3.227
Health and personal care	*Q1/1980 – Q2/2007*	-9.709	0.000	0.676	0.686	1.841	-3.317	0.000	0.619	0.642	1.565
	Q1/1980 – Q1/1992	-8.776	0.000	0.642	0.652	1.621	-2.814	0.000	0.604	0.663	1.687
	Q2/1992 – Q2/2007	-11.505	0.000	0.585	0.595	1.334	-3.701	0.000	0.555	0.591	1.319
Household operations, furnishings and equipment	*Q1/1980 – Q2/2007*	-10.110	0.000	0.657	0.667	1.713	-3.327	0.000	0.625	0.649	1.604
	Q1/1980 – Q1/1992	-7.674	0.000	0.641	0.651	1.615	-2.782	0.000	0.496	0.548	1.151
	Q2/1992 – Q2/2007	-9.291	0.000	0.641	0.651	1.615	-3.117	0.000	0.58	0.617	1.437
Recreation, education and reading	*Q1/1980 – Q2/2007*	-10.205	0.000	0.751	0.762	2.549	-3.323	0.000	0.717	0.743	2.331
	Q1/1980 – Q1/1992	-6.788	0.000	0.780	0.791	2.960	-2.386	0.000	0.688	0.753	2.442
	Q2/1992 – Q2/2007	-8.908	0.000	0.762	0.773	2.692	-3.158	0.000	0.65	0.691	1.875
Shelter	*Q1/1980 – Q2/2007*	-7.365	0.000	0.802	0.813	3.357	-2.607	0.000	0.741	0.768	2.623
	Q1/1980 – Q1/1992	-9.583	0.000	0.793	0.804	3.184	-3.065	0.000	0.743	0.811	3.304
	Q2/1992 – Q2/2007	-12.621	0.000	0.581	0.591	1.316	-4.082	0.000	0.556	0.592	1.324
Transportation	*Q1/1980 – Q2/2007*	-11.169	0.000	0.604	0.614	1.420	-3.537	0.000	0.556	0.577	1.262
	Q1/1980 – Q1/1992	-10.377	0.000	0.581	0.591	1.316	-3.462	0.000	0.48	0.531	1.094
	Q2/1992 – Q2/2007	-10.674	0.000	0.648	0.658	1.657	-3.501	0.000	0.588	0.626	1.481

Panel Unit Root Results for the Shelter Sub-Categories

In this section we analyse components within the shelter category – rented accommodation and owned accommodation.

Table 7. Panel Unit Root Tests Results for Shelter Price Indexes

Q1/1980 - Q2/2007 (Seasonally Adjusted Quarterly Data)					
A. Levin and Lin					
	Test Statistic	***p-value***	ρ	***adjusted*** ρ	***adjusted half-life***
Shelter					
Q1/1980 - Q2/2007	-7.365	0.000	0.802	0.813	3.357
Q1/1980 - Q1/1992	-9.583	0.000	0.793	0.804	3.184
Q2/1992 - Q2/2007	-12.621	0.000	0.581	0.591	1.316
Rented accommodation					
Q1/1980 - Q2/2007	-7.942	0.000	0.918	0.931	9.766
Q1/1980 - Q1/1992	-7.528	0.000	0.889	0.902	6.703
Q2/1992 - Q2/2007	-6.003	0.000	0.903	0.916	7.907
Owned accommodation					
Q1/1980 - Q2/2007	-5.765	0.000	0.892	0.905	6.930
Q1/1980 - Q1/1992	-8.114	0.000	0.827	0.839	3.942
Q2/1992 - Q2/2007	-5.946	0.000	0.875	0.887	5.807
B. Im, Pesaran and Shin					
	Test Statistic	***p-value***	ρ	***adjusted*** ρ	***adjusted half-life***
Shelter					
Q1/1980 - Q2/2007	-2.607	0.000	0.741	0.768	2.623
Q1/1980 - Q1/1992	-3.065	0.000	0.743	0.811	3.304
Q2/1992 - Q2/2007	-4.082	0.000	0.556	0.592	1.324
Rented accommodation					
Q1/1980 - Q2/2007	-2.958	0.000	0.866	0.897	6.348
Q1/1980 - Q1/1992	-2.648	0.000	0.825	0.899	6.483
Q2/1992 - Q2/2007	-2.043	0.000	0.859	0.909	7.229
Owned accommodation					
Q1/1980 - Q2/2007	-2.025	0.000	0.861	0.891	5.981
Q1/1980 - Q1/1992	-2.726	0.000	0.783	0.854	4.381
Q2/1992 - Q2/2007	-1.86	0.000	0.850	0.899	6.482

Several observations can be drawn from Table 7. First, for the full sample and both sub-samples, both the LL and the IPS tests are able to reject the null hypothesis of a unit root. Second, for both rented and owned accommodations the half-lives to convergence takes twice more quarters compared to that of shelter. In fact, rented accommodation half-life measure is 9.8 by the LL procedure and 6.3 quarters using the IPS procedure, whereas owned

accommodation half-lives to convergence takes 6.9 quarters by the LL procedure and 6.0 quarters using the IPS procedure. Second, unlike shelter, the half-lives to convergence takes less quarters during the post 1991 period, than during the prior 1991 period. This true using both LL procedure and IPS procedure.

In general, rented accommodation half-lives to convergence is slower than that of owned accommodation. This can be explained by the provincial rent regulation that could affect the rent price estimates across provinces, and hence its slower convergence pace.

5. Conclusion

This paper examined convergence of CPIs across Canadian provinces, using recent advances in panel unit root econometrics. More specifically, it asks the following questions: Is intranational real exchange rates in Canada are non-stationary, in which case PPP would not hold? Is the deviation from PPP that results from a shock persistent? Are there any variations across commodities and monetary regimes?

With regard to the first question, we find univariate evidence that the real exchange rates for the provincial CPIs between any two provinces are stationary. The same results hold for disaggregated data.

Using more powerful panel estimates provide substantial evidence in support of intranational PPP for provincial CPIs. That is, we reject a panel unit root, over the whole sample. We also examine the evidence of PPP using disaggregated data to highlight the importance of the tradability of goods in yielding our evidence of PPP for province CPIs. For all item categories, we are able to reject non-stationarity, thus supporting intranational PPP.

Having established stationarity for provincial CPIs and for its components, we now tackle the second question.

With regard to the CPI components, the results suggest a much faster pace of convergence for tradable goods such as clothing, food, transportation, household operations, compared to services such as shelter. Within both goods and services, commodities such as alcoholic and tobacco products and rent report the highest half-lives to convergence, a reflection of important provincial regulations in these two areas. Generally though, convergence appears to be faster during the monetary target regime.

Even though, our result can not compared to tests on city, it is important to know that in contrast to the surprisingly long persistence with a half-life of 8.9 or 8.1 years (using the Levin and Lin (1993) and IPS (1997) tests) for city CPIs found for US cities over the 1918-1995 period (but with annual data) by Cechetti et al.

(2002), similar study on half-life for Australian city CPIs over 1972-1999 period by Chaudhuri and Sheen (2004) found between five and 10 quarters with the two tests. And they conducted the analysis by converting their quarterly data to annual data, they found half-life measure between 2 and 4 years.

References

Campbell, J.Y. and Perron, P. (1991), 'Pitfalls and Opportunities: What Macroeconomists Should Know About Unit Roots', NBER Macroeconomics Annual. MIT Press, Cambridge and Oxford; 141–201.

Chaudhuri, K. and Sheen, J. (2004), 'Purchasing Power Parity Across States and Goods Within Australia', The Economic Record, Vol. 80, No. 250, 314-29.

Cecchetti, S., Mark, N. and Sonora, R. (2002), 'Price Index Convergence Among United States Cities', International Economic Review, 43, 1081–99.

Culver, S. and Papell, D. (1997), 'Is there a Unit Root in the Inflation Rate? Evidence from Sequential Break and Panel Data Models', Journal of Applied Econometrics, 12, 435–44.

Hall, A. (1994), 'Testing for a Unit Root in Time Series with Pretest Data-Based Model Selection', Journal of Business and Economic Statistics, 12, 461–70.

Im, K.S., Pesaran, H.M. and Shin, Y. (1997), 'Testing for Unit Roots in Heterogeneous Panels'. Manuscript. Department of Applied Economics, University of Cambridge, Cambridge.

Kendall, M.G. (1954), 'Note on Bias in the Estimation of Autocorrelation', Biometrika, 51, 403–4.

Levin, A. and Lin, C.-F. (1993), 'Unit Root Tests in Panel Data: Asymptotic and Finite Sample Properties'. Discussion Paper No. 92–23. University of California, San Diego.

Nickell, S.J. (1981), 'Biases in Dynamic Models with Fixed Effects', Econometrica, 49, 1417–26.

Oh, K.-Y. (1996), 'Purchasing Power Parity and Unit Root Test using Panel Data', Journal of International Money and Finance, 15, 405–18.

Papell, D. (1997), 'Searching for Stationarity: Purchasing Power Parity under the Current Float', Journal of International Economics, 43, 313–32.

Taylor, A. (2001) 'Potential Pitfalls for the PurchasingPower-Parity Puzzle? Sampling and Specification Biases in Mean-Reversion Tests of the Law of One Price', Econometrica, 69, 473–98.

Wei, S.J. and Parsley, D. (1995), 'Purchasing Power Dis-Parity During the Floating Rate Period: Exchange Rate Volatility, Trade Barriers and Other Culprits', Harvard University, Cambridge, MA.

Wu, Y. (1996), 'Are Real Exchange Rates Nonstationary: Evidence from a Panel-Data Test', Journal of Money, Credit and Banking, 28, 54–63.

Zhou, S. (1997), 'Purchasing Power Parity in High-Inflation Countries: a Cointegration Analysis of Integrated Variables with Trend Breaks', Southern Economic Journal, 64, 450–67.