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Food price convergence in Canada: A nonparametric nonlinear cointegration analysis

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Abstract

Canada has paid great efforts to reduce interprovincial trade barriers in order to establish an integrated local economy. In order to assess the cross-border movements of goods across provinces and territories, this paper examines the price index convergence of food products within Canada from 1997 to 2016. Since the cointegrating relationship between food product prices may not be exact or linear, we adopt the rank tests for analysis which do not require prior knowledge and specification of the linear or nonlinear functional form. Our results validate the price convergence of all food products under study within Canada and show that government initiatives are effective. Furthermore, a subset of the cointegration relationships exhibits nonlinear long-run price co-movements.

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1. Introduction

The Law of One Price (LOP) states that the same good should sell for the same price in all countries, once prices are converted to a common currency. This law, undoubtedly, is an important concept that lays theoretical foundations in modern international economics. However, its underlying assumptions are not realistic and may not be consistent with the observed facts. LOP is enticed by visions of an imaginary world that has assumed neither transaction costs nor trade restrictions (Miljkovic, 1999; Pippenger and Phillips, 2008). Although empirical studies are abundant, whether the LOP holds is a controversial issue.

We suggest studying the LOP using Canadian data. Canada is one of the best countries to study this because it is geographically vast. It is the second largest country in the world in terms of land area. It spans from the Atlantic Ocean to the Pacific Ocean and the Arctic ocean. It consists of ten provinces and three territories.[1] Although Canada has a well-established Trans-Canada highway system that connects the entire country, interprovincial trade barriers are a long existing problem. Historically, different local governments may have various restrictions on internal trade within Canada. There has been a struggle to reduce interprovincial trade barriers. One important step forward is the Agreement on Internal Trade (AIT) that came into effect in 1995. The AIT is an agreement between the federal, provincial and territorial governments, and it is aimed at minimizing and removing, wherever possible, interprovincial barriers. The intended outcomes are to achieve free movements of people, goods, services, and investments within Canada, and to establish an open, efficient and integrated domestic economy.[2]

The on-going economic integration amounts to convergence of prices, which would then enforce the LOP (Lindenblatt and Feuerstein, 2015). The first paper to address intra-national LOP is Parsley and Wei (1996), which shows that convergence rates for tradable categories within the US are faster than those found in cross-country data. Using the intra-country data within Canada, most empirical works show overwhelming support for price convergences. Ceglowski (2003) studied the LOP using Statistics Canada's Average Retail Price Survey (1976 February to 1993 February) of forty-five consumer goods across twenty-five Canadian cities. The results favor strong evidence of intercity price convergence. Dayanandan and Ralhan (2005) studied CPI convergence at aggregate and nine commodity groups from September 1978 to March 2001 across ten Canadian provinces and fifteen cities. The empirical results reveal the presence of price convergence and LOP within Canada. Woo et al. (2014) examined the convergence of CPI between seventeen pairs of cities in Canada during the period from December 1984 to May 2010. The evidence indicates the existence of price convergence across Canadian cities.

In this paper, we choose to examine provincial food prices in Canada. The food industry is an important sector in the country because food products, as the basic necessities of life, are purchased and consumed daily. Table 1 shows that the percentages of after-tax income per household spent on food range from about 13% to 17% in Canadian provinces during 2013-16. Moreover, homogeneity and tradability are important for studying the LOP (Baldwin and Yan, 2004). Hence, instead of looking at the CPI from the aggregate category of food, which may be made up of heterogeneous kinds of food products, we study the convergence of CPI series on a set of individual food products. When each food product is highly homogenous as well as

[1] While Canada is indeed a large country, the vast majority of the population are concentrated near the Canadian-US border and 86.277% live within the provinces of Ontario (38.258%), Quebec (23.226%), Alberta (11.570%) and British Columbia (13.223%) in Year 2016 (Statistics Canada. https://www12.statcan.gc.ca/census-recensement/2016/dp-pd/hlt-fst/pd-pl/Table.cfm).

[2] The details of the AIT are available from https://www.cfta-alec.ca.

highly tradable, food prices are relevant for studying the LOP (Tasić, 2007).[3]

Table 1: Percentages of median after-tax income per household spent on food (2017 constant dollars), Canada and Provinces

	2013	2014	2015	2016
Canada	14.937	14.586	15.396	15.406
Provinces:				
Alberta	13.480	12.232	14.210	13.903
British Columbia	15.072	15.210	16.609	16.174
Manitoba	13.629	15.405	15.179	14.635
New Brunswick	14.589	15.868	16.025	14.754
Newfoundland and Labrador	15.053	15.520	15.690	16.143
Nova Scotia	14.610	15.413	15.658	16.291
Ontario	14.183	14.029	14.431	14.751
Prince Edward Island	14.018	14.407	14.475	14.967
Quebec	16.490	16.111	16.695	17.023
Saskatchewan	12.979	14.744	14.468	14.910

Source: Statistics Canada. Table 11-10-0125-01 Detailed food spending, Canada, regions and provinces. Table 11-10-0190-01 Median after-tax income, Canada and provinces, 2013 to 2017. Table 18-10-0005-01 Consumer Price Index, annual average, not seasonally adjusted

Cointegration tests for price convergence have been undertaken on relevant market and competition analysis in the literature (Boshoff, 2011). Evidence of product price cointegration reveals the existence of long-run co-movements of prices which indicates price convergence and the LOP in the same relevant market. The cointegrating relationship may be in a nonlinear functional form based on different theoretical backgrounds (e.g., Baumol et al., 1964; Shum et al., 2018; Woo and Lee, 2018). There is however no single theory for any precision in the functional form. While parametric linear and nonlinear cointegration tests require the functional form to be exact for estimation, they would suffer from a misspecification problem if the wrong parametric models are identified, and therefore may not be appropriate for our study on the LOP analysis. On the other hand, the nonparametric rank tests proposed by Breitung (2001) have advantages over their parametric counterparts since they do not require such prior knowledge and precise specification of the linear or nonlinear functional form. Therefore, it would be more appropriate to use the nonparametric rank tests for non-linear cointegration as our methodology to study long-run price convergence and the LOP on a set of food items.

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[3] Moreover, when price indices of food products are used instead of aggregate CPI data, our study would not be affected by the negative impact of non-traded goods on price convergence (Dutton and Strauss, 1997).

The remainder of this article is organized as follows. Section 2 discusses the methodology, followed by data description and presentation of empirical results in Section 3. Finally, Section 4 concludes.

2. Methodology

For testing the nonlinear cointegration of Breitung (2001), two steps are involved. The first step is to test the null hypothesis of no cointegration against the alternative hypothesis of cointegration of either the linear or nonlinear form. This is the rank test for cointegration. If cointegration is supported in the first step, the second step is to test the null hypothesis of linear cointegration against the alternative hypothesis of nonlinear cointegration. This is the rank test for neglected nonlinearity, which is a score statistic used to examine whether cointegration is linear or nonlinear. Nonlinear cointegration means that the long-run equilibrium relationship between the variables is of non-linear form.

Consider the general nonlinear functional relationship between two variables y_t and x_t given by:

$$g(y_t) = f(x_t) + u_t \tag{1}$$

where $g(y_t)$ and $f(x_t)$ are both I(1) series, for t = 1,…, T. The functions $g(y_t)$ and $f(x_t)$ are monotonically increasing but their exact forms are usually unknown in practice. If u_t is I(0), then a nonlinear cointegration relationship is said to exist between y_t and x_t. While the sequence of ranks is invariant to a monotonic transformation of the original data, the rank transformation enables us to move away from the specific functional forms of the cointegration relationship. The rank test statistics are then constructed by replacing unknown $g(y_t)$ and $f(x_t)$ with the ranked series, which are defined as $R_T[g(y_t)] = R_T(y_t)$ and $R_T[f(x_t)] = R_T(x_t)$, for $R_T(w_t)$ = Rank of [w_t among w_1 ,…, w_T] where $w = \{y, x\}$.

Breitung (2001) proposes two rank test statistics for cointegration based on distance measures between the sequences of ranked series:

$$\kappa^* = \frac{\sup\limits_{1<t<T} |d_t|}{T\hat{\sigma}_{\Delta d}} \tag{2}$$

$$\psi^* = \frac{\sum_{t=1}^{T} d_t^2}{T^3 \hat{\sigma}_{\Delta d}^2} \tag{3}$$

where $d_t = R_T(y_t) - R_T(x_t)$ Note that $\hat{\sigma}_{\Delta d}^2 = T^{-2}\sum_{t=1}^{T}(d_t - d_{t-1})^2$ is used to adjust for possible correlation between the series of interest in the cases where $g(y_t)$ and $f(x_t)$ are correlated.

The above rank tests (2) and (3) are applicable for functions $g(y_t)$ and $f(x_t)$ that are known to be monotonically increasing. When it is not certain whether these functions are monotonically increasing or decreasing, it is useful to apply a two-sided test constructed by Breitung (2001) using the least squares residual $\tilde{u}_t^R$ which is obtained from a regression of $R_T(y_t)$ on $R_T(x_t)$:

$$\Phi = T^{-3}\hat{\sigma}_{\Delta\tilde{u}}^2 \sum_{t=1}^{T}(\tilde{u}_t^R)^2 \tag{4}$$

$\tilde{u}_t^R = R_T(y_t) - b_T R_T(x_t)$, where b_T is the least squares estimate. $\hat{\sigma}_{\Delta\tilde{u}}^2 = T^{-2}\sum_{t=1}^{T}(\tilde{u}_t^R - \tilde{u}_{t-1}^R)^2$ is used to account for a possible correlation among the series.

The sequences of the ranked series evolve similarly under cointegration; otherwise, they will diverge. Hence, the null hypothesis of no (nonlinear) cointegration between y_t and x_t is rejected if the above test statistics are smaller than their respective critical values.

When the rank test for cointegration indicates a stable long-run relationship, we then test whether the cointegrating relationship is nonlinear. Under the null hypothesis of linear cointegration, the following dynamic OLS regression of y_t on x_t is employed by Stock and Watson (1993) to adjust for serially correlated errors and endogenous regressors:

$$y_t = \gamma_0 + \sum_{j=1}^{p} \alpha_j y_{t-j} + \gamma_1 x_t + \sum_{j=-q}^{q} \pi_j \Delta x_{t-j} + u_t \tag{5}$$

Breitung (2001) suggests a rank test for neglected nonlinearity, which is a score statistic obtained as TR^2 for the regression of the estimated residuals $\tilde{u}_t$ on the regressors of (5) and $R_T(x_t)$ given by:

$$\tilde{u}_t = a_0 + \sum_{j=1}^{p} a_j y_{t-j} + b_1 x_t + \sum_{j=-q}^{q} c_j \Delta x_{t-j} + \theta R_T(x_t) + \varepsilon_t \tag{6}$$

where R^2 is the coefficient of determination of regression (6), p and q are the finite lag orders. The null hypothesis of linear cointegration (i.e. $\theta = 0$) is rejected in favour of nonlinear cointegration if TR^2 exceeds the χ^2 critical value with one degree of freedom.

3. Data and empirical findings

All the data are collected from the CANSIM Dataset, Statistics Canada. We employ monthly price indices of eleven food products (Bakery products; Butter; Cereal products; Cheese; Dairy products and eggs; Fish, Seafood and other marine products; Fresh or frozen meat; Fresh or frozen poultry; Fresh vegetables; Preserved vegetables and vegetable preparations; Processed meat) sold in ten provinces (Alberta, British Columbia, Manitoba, New Brunswick, Newfoundland and Labrador, Nova Scotia, Ontario, Prince Edward Island, Quebec, Saskatchewan) and two territories (Northwest Territories and Yukon) for analysis.[4] The sample period of the data runs from 1997:01 to 2016:12, with 240 observations in total. These price indices are seasonally adjusted using the X12 method.

Before undertaking the cointegration tests, the existence of a unit root in the price index series is first verified. For the unit root and cointegration tests, all the price data are transformed into natural logarithms. The Augmented Dickey-Fuller (ADF) unit root test is implemented in the ADF regression. We find that the null of a unit root for the price indices in level cannot be rejected, but the null can be rejected for the price indices in first difference. Consequently, all data series are integrated of order one.[5]

After the unit root test, the next step is to detect the existence of cointegration. Ontario, the largest province in Canada in terms of population and GDP, is selected as a base region. The study is then undertaken in the bivariate models of the price index of a food product in one area

[4] The CPI data are not available for Nunavut, which was separated officially from the Northwest Territories on April 1, 1999, via the Nunavut Act (S.C. 1993, c. 28) (https://laws-lois.justice.gc.ca/eng/acts/N-28.6/page-1.html) and the Nunavut Land Claims Agreement Act (S.C. 1993, c. 29) (https://laws-lois.justice.gc.ca/eng/acts/N-28.7/).

[5] The results of the ADF tests are not reported but are available upon request.

(y_t) and the price index in Ontario of the same food product (x_t).[6] In Table 2, we report the results of the rank tests for cointegration, together with the parametric Engle-Granger (1987) cointegration z-test statistics for comparison, which are the Dickey-Fuller type of tests.[7] Empirical findings show that the parametric z-test statistics cannot reject the null hypothesis of non-cointegration in most cases. Nevertheless, the null of non-cointegration, i.e. u_t is I(0) in equation (1), can be rejected by the rank tests for almost all cases with the results based on the p-values. The results are consistent with the simulation experiments in Breitung (2001) that the nonparametric rank tests possibly outperform the parametric Dickey-Fuller type of tests under linear and nonlinear cointegration processes. Hence, the findings indicate absolutely strong evidence of provincial food price convergence in Canada and conclude that the food products in Canada satisfy the LOP.

Then, we proceed to the score tests that can identify whether the cointegrating relationship is nonlinear. The score statistics shown in Table 3 reject the null hypothesis of linear cointegration in favor of nonlinear cointegrating relationship as shown in equation (1), for the majority of cases in the food markets of 'Cereal products', 'Cheese', 'Fish, seafood and other marine products', 'Fresh or frozen meat', 'Fresh or frozen poultry' and 'Processed meat'. This indicates strong evidence of nonlinear long-run price co-movements of these food products within Canada. Moreover, the results of the rejection of the score statistics signify some evidence of nonlinear food price convergence in the food categories of 'Butter', 'Dairy products and eggs' and 'Preserved vegetables and vegetable preparations'. Weak evidence of nonlinearity is also found in 'Bakery products' and 'Fresh vegetables'. Empirically, the existence of transportation costs and measurement errors in data (Taylor, 1988), asymmetric adjustment dynamics (Woo et al., 2014), nonlinear demand functions (Maskin and Tirole, 1988), dynamic strategic behaviors (Petrosjan, 2005) and so on, may lead to the rejection of a linear cointegration relationship between food prices.

4. Conclusion

This article explores the price convergence and LOP of food products within Canada using nonparametric cointegration rank tests over the period 1997–2016. The results confirm the achievements of efforts promoting free movements of products and removing provincial barriers to trade as validated by the evidence of price convergence and the LOP of food within Canada. These efforts started from the AIT in 1995 and after that, the Trade, Investment, and Labour Mobility Agreement (TILMA) coming in effect in 2006 and the Canadian Free Trade Agreement (CFTA) entering into force in 2017 have further reduced provincial barriers to trade and promote domestic trade. Also, we find evidence of nonlinear cointegration relationships in some food markets which may be caused by transaction costs, asymmetric adjustments and dynamic strategic behaviors and so on. Possible future research could include cointegration tests with pre-determined and endogenously determined breaks. It potentially can help examine the effectiveness of the AIT policy and study the convergence patterns before and after the AIT policy.

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[6] We have selected British Columbia as the base region to check for nonlinear cointegration. The results (unreported) are qualitatively equivalent to those reported in Table 2 below.

[7] The results of the Engle-Granger (1987) cointegration τ-test and z-test statistics are qualitatively the same. To save space, we do not to report the results of the τ-test, but they are available upon request.

Table 2: Linear and nonlinear cointegration tests

	Bakery products				Butter				Cereal products				Cheese				Dairy products and eggs				Fish, Seafood and other marine products			
	z	**κ***	**Ψ***	**Φ**	**z**	**κ***	**Ψ***	**Φ**	**z**	**κ***	**Ψ***	**Φ**	**z**	**κ***	**Ψ***	**Φ**	**z**	**κ***	**Ψ***	**Φ**	**z**	**κ***	**Ψ***	**Φ**
AB	0.14	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.95	0.02	0.00	0.00	0.60	0.02	0.04	0.04
BC	0.46	0.00	0.00	0.00	0.01	0.06	0.00	0.00	0.13	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.86	0.02	0.00	0.00	0.76	0.02	0.02	0.02
MB	0.27	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.58	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.86	0.00	0.00	0.00	0.19	0.00	0.00	0.00
NB	0.37	0.00	0.00	0.00	0.77	0.00	0.00	0.00	0.41	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.97	0.12	0.01	0.01	0.44	0.00	0.00	0.00
NL	0.28	0.00	0.00	0.00	0.33	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.65	0.00	0.00	0.00	0.81	0.09	0.02	0.02
NT	0.28	0.00	0.00	0.00	0.05	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.54	0.00	0.00	0.00	0.57	0.02	0.03	0.02
NS	0.61	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.50	0.00	0.00	0.00	0.27	0.00	0.00	0.00	0.81	0.06	0.00	0.00	0.64	0.00	0.00	0.00
PE	0.75	0.02	0.00	0.00	0.32	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.26	0.01	0.00	0.00	0.94	0.11	0.01	0.01	0.29	0.01	0.00	0.00
QC	0.51	0.00	0.00	0.00	0.61	0.00	0.00	0.00	0.88	0.00	0.00	0.00	0.74	0.00	0.00	0.00	0.19	0.00	0.00	0.00	0.30	0.09	0.05	0.04
SK	0.16	0.00	0.00	0.00	0.53	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.97	0.00	0.00	0.00	0.81	0.09	0.09	0.08
YT	0.62	0.00	0.00	0.00	0.16	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.93	0.00	0.00	0.00	0.70	0.01	0.03	0.02

Table 2: Linear and nonlinear cointegration tests

	Fresh or frozen meat				Fresh or frozen poultry				Fresh vegetables				Preserved vegetables and vegetable preparations				Processed meat			
	z	**κ***	**Ψ***	**Φ**	**z**	**κ***	**Ψ***	**Φ**	**z**	**κ***	**Ψ***	**Φ**	**z**	**κ***	**Ψ***	**Φ**	**z**	**κ***	**Ψ***	**Φ**
AB	0.02	0.01	0.00	0.00	0.57	0.00	0.00	0.00	0.55	0.02	0.00	0.00	0.75	0.00	0.00	0.00	0.58	0.00	0.00	0.00
BC	0.27	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.51	0.03	0.00	0.00	0.24	0.00	0.00	0.00
MB	0.11	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.62	0.00	0.00	0.00	0.49	0.00	0.00	0.00	0.80	0.00	0.00	0.00
NB	0.40	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.92	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.07	0.00	0.00	0.00
NL	0.12	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.03	0.00	0.00	0.00
NT	0.82	0.02	0.01	0.01	0.34	0.00	0.00	0.00	0.71	0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.02	0.00	0.00	0.00
NS	0.06	0.02	0.00	0.00	0.34	0.00	0.00	0.00	0.70	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.15	0.00	0.00	0.00
PE	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.61	0.01	0.00	0.00	0.15	0.00	0.00	0.00	0.71	0.00	0.00	0.00
QC	0.11	0.00	0.00	0.00	0.73	0.00	0.00	0.00	0.32	0.00	0.00	0.00	0.52	0.00	0.00	0.00	0.81	0.00	0.00	0.00
SK	0.68	0.05	0.00	0.00	0.56	0.00	0.00	0.00	0.23	0.03	0.01	0.01	0.37	0.00	0.00	0.00	0.48	0.00	0.00	0.00
YT	0.80	0.07	0.05	0.04	0.03	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.73	0.00	0.00	0.00	0.13	0.00	0.00	0.00

Notes:

AB stands for Alberta, BC for British Columbia, MB for Manitoba, NB for New Brunswick, NL for Newfoundland and Labrador, NT for Northwest Territories, NS for Nova Scotia, PE for Prince Edward Island, QC for Quebec, SK for Saskatchewan and YT for Yukon.

z stands for the Engle-Granger (1987) z-test statistic, κ*, Ψ* and Φ are the rank test statistics for cointegration.

The figures are p-values.

The p-values of the z-test statistic were obtained from MacKinnon (1996) where the number of I(1) variables in the cointegrating regression (N) is two.

The p-values of the rank test statistics were calculated by Monte Carlo simulations based on 50,000 replications for a sample size of 240.

Table 3: Score test of nonlinearity

	Bakery products	Butter	Cereal products	Cheese	Dairy products and eggs	Fish, Seafood and other marine products	Fresh or frozen meat	Fresh or frozen poultry	Fresh vegetables	Preserved vegetables and vegetable preparations	Processed meat
AB	0.22	0.08	0.00	0.00	0.12	0.02	0.13	0.01	0.40	0.39	0.00
BC	0.04	0.60	0.03	0.34	0.37	0.00	0.03	0.69	0.96	0.02	0.00
MB	0.20	0.83	0.00	0.09	0.05	0.00	0.54	0.12	0.12	0.73	0.00
NB	0.97	0.31	0.00	0.08	0.18	0.00	0.02	0.00	0.04	0.01	0.05
NL	0.99	0.08	0.05	0.03	0.18	0.05	0.00	0.00	0.32	0.27	0.02
NT	0.00	0.32	0.96	0.01	0.04	0.03	0.03	0.04	0.15	0.01	0.48
NS	0.59	0.29	0.00	0.91	0.04	0.02	0.04	0.00	0.06	0.16	0.01
PE	0.73	0.07	0.40	0.00	0.09	0.11	0.02	0.61	0.17	0.32	0.00
QC	0.13	0.06	0.60	0.07.	0.66	0.00	0.07	0.00	0.07	0.38	0.01
SK	0.30	0.08	0.06	0.66	0.25	0.00	0.96	0..02	0.99	0.00	0.00
YT	0.92	0.59	0.00	0.46	0.09	0.00	0.00	0.63	0.54	0.00	0.00

Note:
The figures are the p-values of the score statistic.

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