Review of Income and Wealth
Series 50, Number 1, March 2004

THE LAW OF ONE PRICE: A CANADA/U.S. EXPLORATION

BY JOHN R. BALDWIN

AND

BEILING YAN

Statistics Canada

The paper examines whether arbitrage tends to equalize commodity prices for internationally traded homogenous products. It also investigates whether the increasing integration of North American markets has reduced price differences over time, and tests the validity of the so-called Law of One Price. We find that price differences for homogenous tradables between Canada and the U.S. are smaller than those for differentiated tradables and non-tradables, and are statistically insignificant over the period 1985 to 1999. We find no support for the notion that the increasing integration of North American markets due to trade liberalization has reduced price differences between Canada and the United States. Instead, the shifts in the price differences (expressed in the same currency) generally reflected fluctuations in the exchange rate. Canadian prices adapt with a lag to U.S. price changes that are brought about by changes in the exchange rate.

1. INTRODUCTION

It is argued that in a perfectly integrated, competitive market, an internationally traded identical product should sell for the same common-currency price in each country, thereby obeying the so-called "Law of One Price" (LOP). The LOP underpins many theoretical models in international economics and has practical implications for statistical agencies. If the hypothesis is valid, it would be a justified and cost-efficient practice to use the exchange rate to convert and compare inter-country real output—for example, to use U.S. prices adjusted for the exchange rate in the Canadian statistical price system. To the extent that the LOP does not hold, such practice leads to incorrect price estimates.

The importance of the LOP has motivated an extensive empirical literature testing the hypothesis.[1] The results are mixed and inconclusive. Part of the explanation may lie in the data used. The majority of the studies have used aggregate price indexes. Using aggregate price indexes has its limitations. And some products, such as services, are not generally traded in the way goods are, so their prices are likely to disobey the LOP.

In order to gain a deeper understanding of inter-country price differences, a number of studies (Isard, 1977; Giovannini, 1988; Engels, 1993; Rogers and Jenkins,

Note: We thank Professors Mike Burns, Eshan Choudhri and Larry Schembri for comments on the earlier draft of the paper, seminar participants at the 2002 conference in Sweden of the International Association for Research in Income and Wealth, at Statistics Canada, and at the Bank of Canada, and to two referees for helpful suggestions.

Correspondence to: Micro-Economic Analysis Division, Statistics Canada, Ottawa, Ontario, Canada K1A 0T6 (baldjuh@statcan.ca).

[1]See survey articles by Froot and Rogoff (1995) and Rogoff (1996).

1995) have examined the prices for individual commodities, and found substantial price differences even for goods that are highly traded.[2] This is not surprising, however, since many tradable products are highly differentiated and heterogeneous in nature. In the case of differentiated products, differences in productivity, cost, and market power are likely to result in price differences across countries. In a recent summary of the literature, Caves *et al*. (2002, p. 380) review the expected difference in prices for homogenous "auction goods" as opposed to heterogeneous "customer goods," a distinction that Bordo and Choudhri (1977) demonstrated empirically, was related to differences in international price behaviour.

If the LOP is to be a valid hypothesis anywhere, we might expect it to hold for homogenous products that are traded internationally. And if trade tends to equalize prices through commodity arbitrage, we might also expect that price differences decrease over time with the increasing integration of markets.

This paper makes use of a dataset that underlies the PPP (Purchasing Power Parity) program at Statistics Canada to ask two questions: whether commodity arbitrage has equalized Canada/U.S. prices for internationally traded products; and whether the increasing integration of Canada/U.S. markets has reduced price differences over time. The dataset used in the paper is particularly useful for the purposes of this paper. It contains Canada/U.S. prices for more than 160 categories of goods and services for each of the five benchmark years (1985, 1990, 1993, 1996, and 1999). The commodities in the dataset range from tradables to nontradables and in the tradable class, they include both homogenous and non-homogenous commodities.

Canada and the U.S. share many similarities in terms of income levels, economic structure, climate and tastes, and the commodities present in both markets are broadly similar. The commodities have been carefully chosen to provide accurate PPPs for international comparisons. The time period covered in the database coincides with the introduction of the Free Trade Agreement (FTA) in 1989 and the North American Free Trade Agreement (NAFTA) in 1994. This provides an excellent opportunity to investigate the questions of interest for two countries whose economies are closely integrated, who have substantially reduced trade barriers, and where commodities in both markets closely resemble one another.

In carrying out the investigation, we utilize several approaches. First, we develop a grouping scheme that classifies categories of goods and services into three groups: homogenous tradables, differentiated tradables and nontradables. Second, we utilize non-parametric tests to examine whether the law of one price holds on average. Third, we use dissimilarity indices to measure the extent of dispersion of prices within each commodity group.

The remainder of the paper is organized as follows. Section 2 describes the data and the grouping scheme. Section 3 conducts non-parametric tests for

[2]Isard (1977) find large price differences for a broad group of manufactured goods, such as apparel, industrial chemicals, electrical industrial equipment, and glass products. Giovannini (1988) further finds substantial price differences between the United States and Japan, even among primary commodities such as nuts, bolts, and screws. Rogers and Jenkins (1995) find that price differences do not disappear over a long period of time for more than five-sixths of the 54 commodities from the U.S. and Canada; most of them are tradable goods, such as frozen vegetables, lettuce, tomatoes, flour, and several others. Heston *et al*. (1995), however, do find some evidence that tradable prices are more uniform across countries than nontradable ones.

differences in median price relatives. Section 4 provides dissimilarity indices. Section 5 concludes.

2. Data

The data come from Statistics Canada's bilateral Canada/U.S. Purchasing Power Parity Program, a part of the Eurostat/OECD/UN International Comparison Program. The price and expenditure data in the bilateral study were collected at the same time as the data used in the multilateral studies, but the specifications of items to be priced are more precisely matched.

The data contain relative Canada/U.S. prices for more than 160 categories of goods and services (basic heading) that together comprise total GDP.[3] They are available for each of the five benchmark years (1985, 1990, 1993, 1996 and 1999). To make categories more comparable, we concentrate on goods and services in the business sector and exclude government expenditures, medical and health care, and other "adjustment" entries used for PPP purposes. This results in a set of 168 categories of goods and services for the first four years, and 165 for 1999.[4]

Goods and services are classified into three groups: homogenous tradables, differentiated tradables and non-tradables. In general, products that are not easily traded across borders (such as construction, services and utilities) are classified as non-tradables. Products that can flow relatively freely across borders are classified as tradables. Within tradables, those that are more standardized (such as food products like flour) are grouped together as homogenous tradables, and those that are relatively more heterogeneous in nature (such as machinery and equipment) are defined as differentiated tradables.[5]

The grouping scheme is created using a two-step procedure. In the first instance, we sort commodities into tradables and non-tradables based on professional judgment and trade data. In the second case, we also use professional judgment to divide tradables into homogenous and non-homogenous; but we then modify this initial allocation using discriminant analysis that utilizes exogenous information on the amount of intra-industry trade, advertising intensity, and product variety, all of which are postulated to be associated with product differentiation.

Intra-industry trade occurs when commodities are simultaneously both imported and exported. It is intimately associated with the notion of product differentiation (Grubel and Lloyd, 1975). The Grubel–Lloyd intra-industry trade index was used as an indicator of the extent of product differentiation in the discriminant analysis. The index is constructed using Canadian input-output tables.

Product differentiation is also related to the intensity of advertisement. We postulate that when the proportion of expenses on advertisement increase, product

[3]Underlying these categories are detailed prices for more than 2000 items. These individual item price ratios are averaged to calculate the relative prices for basic headings (categories of goods of services). For example, under the basic heading "rice," there are eight specifications of different types of rice. These basic headings are groups of similar, well-defined commodities constituting the most detailed level of commodity classification in the PPP program.

[4]The classification system is slightly different between the first four years and 1999.

[5]See Globerman and Storer (2003).

differentiation is generally higher. Data on the intensity of advertisement is constructed using Canadian input-output tables, available at industry level and spread to the commodity level using the commodity structure of the input/output tables.

Differentiated markets are also likely to contain a variety of products. We make use of the number of items specified within each category of goods and service to capture this aspect of product differentiation.

3. Non-parametric Tests

A non-parametric sign test is used to ask whether the median Canada/U.S. price relative differs significantly from one and whether there are any significant changes in the median price relative over time. An advantage of the non-parametric test, as compared to the *t*-test, is that it does not require a normal distribution of the observations. We also used a *t*-test and examined whether the observations were normally distributed. We found that once several obvious outliers were removed, the relative prices in general were distributed normally and the *t*-tests produced similar results to the sign tests. For the sake of brevity, we report only the non-parametric tests here.

Price differentials are examined using the ratio of prices in the two countries, where prices are expressed in the same currency (in this case, the U.S. dollar). Let E be the exchange rate measured in U.S. dollars per Canadian dollar, and p_n^i be the price level of commodity n in country i, where $i = 1, 2$ for Canada and the U.S., respectively. The price differential p_n, also called the comparative price level (CPL), is defined as the common-currency price ratio, e.g. $p_n = (p_n^1 E)/(p_n^2)$. The CPL measures the degree to which one country's price level is above or below another's.

For example, for a kilo of rice costing 2.49 ($U.S.) in the U.S. and 2.99 ($Can) in Canada, and an exchange rate of 0.7 $U.S. per $CAN, the CPL is 0.84 ((2.99 × 0.7)/2.49), implying a price level in Canada 16 percent lower than in the United States. If the Canadian price were 3.52 ($Can), then the CPL would be 1.0 ((3.52 × 0.7)/2.49). In this latter case, there would be no price difference between the two countries, thus fulfilling the LOP.

3.1. *Comparative Price Levels by Product Group*

The median comparative price level for each of the three product groups over the five benchmark years is shown in Table 1 (all tables are presented with the

TABLE 1

Median Comparative Price Level (CPL) by Product Group (U.S. = 1.0)

Group	No. of Observations	Comparative Price Level	Price Difference in %	Sign Text
Tradable	600	1.03	3%	***
Homogenous tradable	344	1.02	2%	
Differentiated tradable	256	1.04	4%	***
Non-tradable	235	0.92	–8%	***

Note: Three asterisks (***) indicate that the null hypothesis of CPL = 1 is statistically rejected at 1 percent level or better.

United States as the reference country). For products that can flow relatively freely across borders, prices were on average 3 percent more expensive in Canada than in the U.S. For products that are not easily traded across borders, such as services, prices were on average 8 percent cheaper in Canada. The latter likely reflects the fact that services are labor intensive to produce, and Canadian wages are less than American wages.

The price differences for both tradables and nontradables are statistically significant at the 1 percent confidence level. However, for highly standardized homogenous tradables, prices were only 2 percent more expensive in Canada than in the U.S., and the difference is statistically insignificant. This is consistent with the argument that competitive pressures tend to equalize prices for identical products.

3.2. *Changes in Comparative Price Levels over Time*

If trade tends to equalize prices for identical tradable products, one might expect that, with the reduction of trade barriers between Canada and the U.S., prices for homogenous tradables in Canada should have converged to U.S. levels. We, however, find little support for this trade effect. It is true that price differences for homogenous tradables decreased from a median CPL of 1.13 in 1990 to 1.07 in 1993 and 1.01 in 1996 and the price differences for the years 1993 and 1996 became statistically insignificant (Table 2 and Figure 1). Since this trend coincides with a period of increasing integration between the two markets, this at first glance suggests that trade liberalization that took place in the early 1990s had the hypothesized effect.

There are two facts that shed doubt on this conclusion. First, price differences for homogenous tradables actually widened during the period from 1985 to 1990, even though tariffs were continuing to fall during this period. Second, by 1999, the CPL had widened again and become statistically significant. This is contrary

TABLE 2

MEDIAN COMPARATIVE PRICE LEVEL BY PRODUCT GROUP OVER TIME (U.S. = 1.0)

		1985	1990	1993	1996	1999
Tradables	Comparative price level	0.98	1.14	1.09	1.02	0.95
	Price difference in %	–2%	14%	9%	2%	–5%
	Sign test		***	***	*	
Homogenous tradables	Comparative price level	0.98	1.13	1.07	1.01	0.88
	Price difference in %	–2%	13%	7%	1%	–12%
	Sign test		***			*
Differentiated tradables	Comparative price level	0.98	1.15	1.11	1.03	1.005
	Price difference in %	–2%	15%	11%	3%	0.5%
	Sign test		***	***	**	
Non-tradables	Comparative price level	0.83	1.01	0.98	0.89	0.82
	Price difference in %	–17%	1%	–2%	–11%	–18%
	Sign text	***			***	***
All Products	Median	0.95	1.10	1.04	0.99	0.93
	Price differences in %	–5%	10%	4%	–1%	–7%
	Sign test	***	***	***		***
Exchange rate (US$/CAN$)		0.73	0.86	0.78	0.73	0.67

Note: One, two and three asterisks (*, **, ***) indicate that the null hypothesis of CPL = 1 is statistically rejected at 10 percent, 5 percent and 1 percent level respectively.

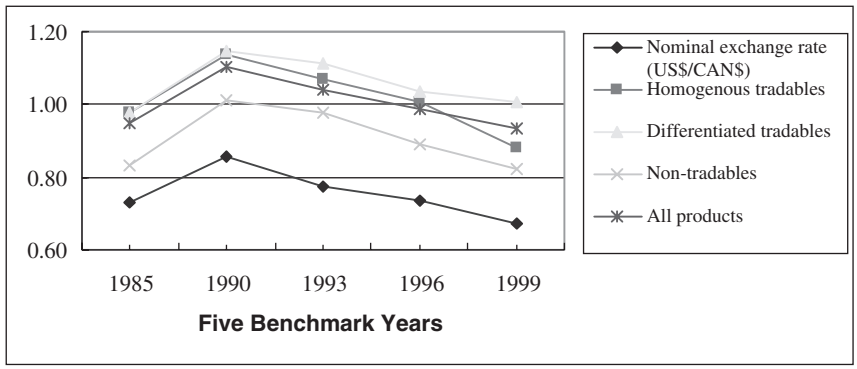

Figure 1. Median Comparative Price Level by Group (U.S. = 1.0)

to what one would have expected if trade liberalization had been the predominant factor driving price movements. Second, the shifts in the price differences for differentiated tradables and nontradables share the same time pattern as those for homogenous tradables. This again suggests that trade cannot be the main factor that drives the movements of price differences for all product groups. If it was this factor, we would have expected a greater convergence for tradables than nontradables (see Globerman and Storer, 2003).

The comparative price levels follow closely with the movements in the exchange rate (Figure 1). The correlations between the changes of the median CPL and the exchange rate are 0.96, 0.95 and 0.95 for homogenous tradables, differentiated tradables and nontradables respectively.

There are a number of reasons why the CPL may respond to changes in the exchange rate. For one thing, the prices of commodities reflect both the cost of the manufactured good and the retailing/wholesaling margin. The retailing and wholesaling component of the final price is not subject to the same degree of arbitrage as the price of manufacturing products. Therefore, Canadian market prices may not respond immediately to fluctuations in the exchange rate. In addition, prices may be sticky in the short-run. They may not react fully to fluctuations in the exchange rate, but rather adjust with a lag. In these cases, movements in the comparative price levels will be correlated with fluctuations in the exchange rate. In a world where there is no reaction of the Canadian price to the exchange rate, the correlation between changes in the exchange rate and the CPL would be one. In a world where arbitrage equated the two prices quickly, a change in the exchange rate would be accompanied by no change in the CPL and the correlation between changes in the exchange rate and the CPL would be zero.

The exchange rate between Canada and the U.S. has undergone several long-term movements during the past twenty years (Figure 2). The Canadian dollar depreciated in relation to the U.S. dollar from 1980 to 1986, followed by an appreciation from 1986 to 1991. Since 1991, the Canadian dollar declined steadily from 87 U.S. cents in 1991 to only 64 U.S. cents in 2002.

The fluctuation of the exchange rate is reflected in the movement of the comparative price level of the two countries. For example, when the Canadian dollar

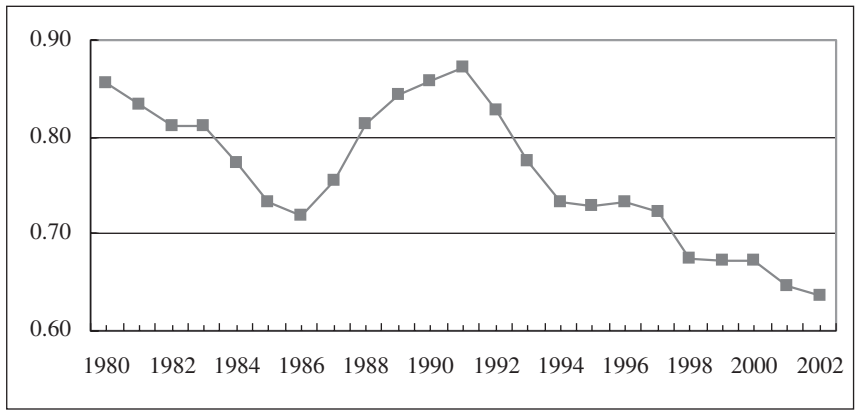

Figure 2. The Exchange Rate (US$/CAN$)

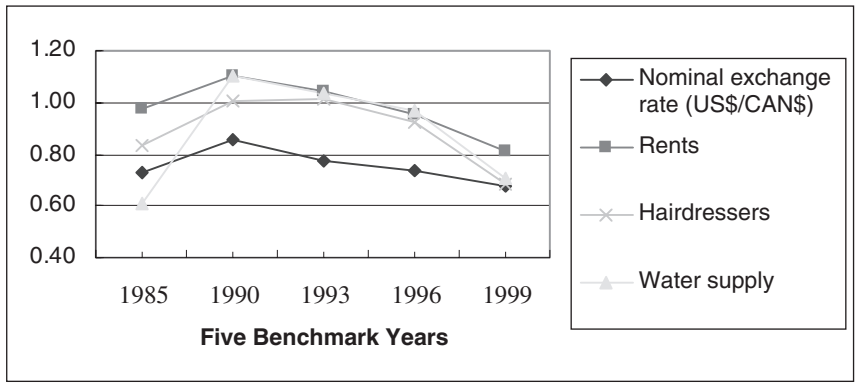

Figure 3. Comparative Price Level (U.S = 1.0)

appreciated in the late 1980s, the median price in Canada for all products used in the study increased from being 5 percent less expensive than in the U.S. in 1985 to 10 percent more expensive in 1990. With the depreciation of Canadian dollar after 1991, the purchasing power of Canadian consumers has improved. By 1999, the overall median price in Canada was 7 percent lower than its U.S. counterpart. This difference was 12 percent for homogenous tradables, 0.5 percent for differentiated tradables and 18 percent for nontradables (Table 2 and Figure 1).

The correlation between changes in the comparative price level and changes in the exchange rate varies across individual items. For example, movements in the CPL for hairdressers, rents and water supply largely reflect changes in the exchange rate, with a correlation of 0.81, 0.93 and 0.97 respectively (Figure 3). These items are nontradables. Canadian prices (expressed in Canadian dollars) do not respond to changes in the exchange rate and therefore the CPL almost completely reflects movements in the exchange rate.

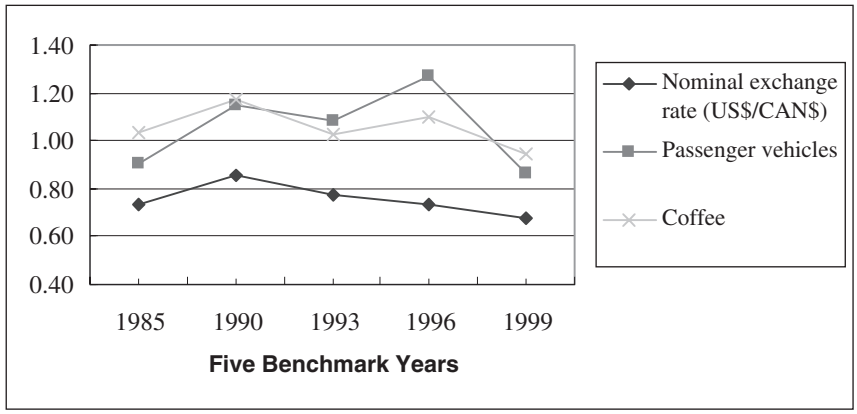

Figure 4. Comparative Price Level (U.S = 1.0)

Changes in the CPL for items such as coffee and passenger vehicles partly reflect exchange-rate fluctuations (Figure 4). For example, in 1985 it cost 9 percent less to buy a passenger vehicle in Canada than in the U.S. By 1990, however, it had become 15 percent more expensive in Canada, following a period when the Canadian dollar appreciated. By 1999, after the steady depreciation in the Canadian dollar, it had become 14 percent less expensive. The correlation between exchange-rate changes and changes in the CPL are 0.80 and 0.70 for coffee and passenger vehicles respectively. They are less than for the three non-tradable examples, but still high.

It should be noted that changes in the CPL, for both homogenous and non-homogenous tradables, did not move by as much as the exchange rate. The size of the movement that occurs in the CPL as exchange rates fluctuate might be taken as a measure of the degree to which price discrimination developed in the two markets. The greater the movement in the CPL, the greater is the differential that develops between U.S. and Canadian prices (expressed in the same currency). It is therefore noteworthy that the differential widened more in the homogenous rather than the differentiated sectors by 1999. If we associated the former with "auction" goods and the latter with "customer" goods, we might have expected the opposite to have occurred.

4. Dissimilarity Index

The previous analysis examines only median price differences for product groups as a whole. To take into account the price behavior of individual products within each product group, we utilize a dissimilarity index developed by Diewert (2002).

Diewert (2002) proposes a set of dissimilarity indexes based on an axiomatic approach. The indexes are designed to determine which pair of countries has the most similar price or quantity structures, which then serves an essential input into the spatial chaining method currently being explored in international comparisons

TABLE 3

DISSIMILARITY INDEX

	1985	1990	1993	1996	1999	All Years
Tradables	0.08	0.18	0.11	0.07	0.07	0.10
Homogenous tradables	0.11	0.29	0.16	0.09	0.12	0.15
Differentiated tradables	0.06	0.09	0.07	0.05	0.04	0.06
Non-tradables	0.36	0.05	0.06	0.08	0.18	0.13

of prices and quantities. The index approach is used here to determine whether price dissimilarities are less for tradable products and whether they decrease over time.[6]

The weighted dissimilarity index D is given by:

$$D \equiv \sum_{n=1}^{N} (1/2)(s_n^1 + s_n^2)\left[\{p_n - 1\}^2 + \{(1/p_n) - 1\}^2\right] \tag{1}$$

where weight s_n^i is the expenditure share of commodity n in country i, and p_n is the comparative price level. Intuitively one may interpret the dissimilarity index as a measure of dispersion. Note that $\{p_n - 1\}$ and $\{(1/p_n) - 1\}$ measure the extent of deviation from the LOP of one, and D is thus a type of weighted average of the variance. If all prices (expressed in the same currency) within a group are the same in the two countries, the dissimilarity index would be zero. The higher the dissimilarity index, the higher the variation from the LOP across all commodities in a group.

A priori, one might expect a smaller dissimilarity index for tradables than for nontradables. Table 3 indicates that over the five benchmark years, the dissimilarity index, calculated after removing some obvious outliers, is slightly lower for tradables than for nontradables.

If trade tends to equalize prices for identical tradable goods, one might expect that the dissimilarity index for homogenous tradables would decrease over time. We again do not find strong support for this trade effect. The dissimilarity index does not have a downward trend, rather, its fluctuations reflect movements in the absolute value of the median price differences (CPL).

It should be noted that the dissimilar index is not stable over time for homogenous tradables and nontradables. Its fluctuation is correlated with the median price level differences (CPL). This implies that the phenomenon being measured is a function of the exchange rate and may not just reflect the characteristics inherent to these categories of products. The substantial differences in response within these categories may also be due to varying degrees of competition within each of these markets.

5. CONCLUSIONS

The expectation that, in an integrated, competitive market, commodity arbitrage tends to equalize prices for internationally traded identical products is supported by our data. Price differentials between Canada and the U.S. for homogenous tradables were on average small and statistically insignificant.

[6]Heston, Summers, Aten, and Nuxoll (1995) and Heston, Summers, and Aten (2001) have proposed and used a similarity index in examining price structures across countries.

There were, however, subsets of products with significant differences. Over the period under study, Canadian consumers on average paid 4 percent more for highly differentiated tradable products, but 8 percent less for products that are not easily traded across borders, such as services. Given the size of the service sector, lower prices for services in Canada plays an important role in determining its standard of living compared with the U.S.

Our expectation that trade and the increasing integration of North American markets would remove price differences over time is, however, not supported by the data. A possible explanation is that the price used here is the final product price, which includes a nontradable component. Thus the final product price may not fully respond to arbitrage through trade.

We find that shifts in the comparative price levels of the two countries generally reflected fluctuations in the exchange rate. Canadian prices, especially for tradable goods, may reflect U.S. prices in the long run, but over the periods under study, they do not react fully to fluctuations in the exchange rate. There is a lag in the adaptation of Canadian prices to U.S. prices when expressed in similar currencies. Interestingly, there is evidence to suggest that the variance of price differential also reacts to changes in the exchange rate—suggesting that there is considerable heterogeneity in the responses of prices to changes in exchange rates.

References

Bordo, Michael D. and Ehsan Choudhri, "The Behaviour of the Prices of Traded and Nontraded Goods: the Canadian Case 1962–1974," Carleton University Discussion Paper 77–101, 1977.

Caves, Richard E., Jeffrey A. Frankel, and Ronald W. Jones, *World Trade and Payments: an Introduction*, Addison-Wesley, MA, 2002.

Diewert, Erwin, "Similarity and Dissimilarity Indexes: An Axiomatic Approach," Discussion Paper No. 02–10, Department of Economics, University of British Columbia, 2002. URL: http://www.econ.ubc.ca/discpapers/dp0210.pdf.

Engels, C., "Is Real Exchange Rate Variability Caused by Relative Price Changes? An Empirical Investigation," *Journal of Monetary Economics*, 32, 35–50, 1993.

Froot, Kenneth A. and Kenneth Rogoff, "Perspectives on PPP and Long-Run Real Exchange Rates," in Gene M. Gross and Kenneth Rogoff (eds), *Handbook of International Economics*, 3, North Holland, Amsterdam, 1995.

Giovannini, Alberto, "Exchange Rates and Traded Goods Prices," *Journal of International Economics*, 24, 45–68, 1988.

Globerman, Steven and Paul Storer, "Canada-U.S Economic Integration Following CUSTA and NAFTA," paper presented for a conference at the Kelley School of Business at Indiana University, April 11–12, 2003. URL: http://www.cbe.wwu.edu/cib/faculty%20research/globermanstorer.pdf.

Grubel, Herbert G. and Peter J. Lloyd, *Intra-Industry Trade: The Theory and Measurement of International Trade in Differentiated Products*, Wiley, New York, 1975.

Heston, Alan, Robert Summers, Bettina Aten, and Daniel A. Nuxoll, "New Kinds of Comparisons of the Prices of Tradable and Nontradables," Centre for International Comparisons at the University of Pennsylvanian, June, 1995. URL: http://pwt.econ.upenn.edu/papers/prices.pdf.

Heston, Alan, Robert Summers, and Bettina Aten, "Price Structures, the Quality Factor, and Chaining," *Statistical Journal of the United Nations*, ECE 18, 77–101, 2001.

Isard, Peter, "How Far Can We Push the 'Law of One Price'?" *American Economic Review*, 67(5), 942–8, 1977.

Rogers, John H. and Michael Jenkins, "Haircuts or Hysteresis? Sources of Movements in Real Exchange Rates," *Journal of International Economics*, 38, 339–60, 1995.

Rogoff, Kenneth, "The Purchasing Power Parity Puzzle," *Journal of Economic Literature*, 34, 647–68, 1996.