John Kuszczak
Memorial Lecture

Canada's Exchange Rate: New Evidence, a Simple Model, and Policy Implications

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Introduction

Canada and the United States are two large economies sharing the North American continent, but separated by an exchange rate. Should monetary policy stabilize the Can$/US$ exchange rate? Or does the movement in the exchange rate reflect optimal adjustment to shocks to the Canadian and US economies?

This paper proceeds to explore the question by:

- Examining the evolution of the "border effect" as measured by goods-price deviations between Canada and the United States. Following the methods of Engel and Rogers (1996) and Engel, Rogers, and Wang (2004), we construct a measure of the degree of integration of the US and Canadian economies. We show how this border measure has evolved since 1990. The apparent barriers actually rise steadily from around 1994 and peak around 2001, before falling dramatically in the past few years.
- Reviewing the evidence on the determination of the Canadian real exchange rate. Amano and van Norden (1995) and Chen and Rogoff

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(2003) estimate models that show that the Canadian dollar strengthens as the price of commodities rises. Both papers present a model that explains this relationship by relating export prices of commodities to changes in the price of non-traded to traded goods.

- Accounting for the movements in the Can$/US$ real exchange rate. We find that movements in the relative price of non-traded goods do not appear to explain much of the real exchange rate movement over the past 15 years. But we do find that the real exchange rate tracks nominal exchange rate movements very closely. This behaviour is consistent with the hypothesis that consumer goods are sticky in local currencies (Canadian dollars in Canada, and US dollars in the United States). This finding can also explain the seemingly anomalous behaviour of the border effect.
- Constructing an alternative model that might account for the behaviour of commodity prices and the Canadian dollar. In this model, the short-run impact of an increase in commodity prices works like a transfer from the United States to Canada. In a simple version of the model of Devereux and Engel (2004), we find that such a transfer leads to a nominal and real appreciation of the Canadian dollar.
- Examining policy implications of such a model. A number of distortions in the economies inhabit this model. There is nominal price stickiness, and there is market incompleteness, so that it is not possible to ensure against fluctuations in commodity prices. We find that optimal co-operative monetary policy smoothes exchange rate fluctuations relative to the exchange rate behaviour that would emerge if monetary policy took a neutral stance.

The evidence and the model presented in this paper are simple. They are certainly not definitive enough that the policy implications should be taken literally. The objective, rather, is to suggest an alternative paradigm for Canada's "commodity currency." The arguments of this paper at best suggest a role for further empirical and theoretical investigation.

1 Border Effects

If two markets for consumer goods are well integrated, prices should not differ greatly across the pair of markets. If formal trade barriers, transportation costs, exclusivity of distribution networks, etc., are low, we might say the markets are well integrated. Engel and Rogers (1996) (referred to as ER hereinafter) assessed the integration of Canadian and American markets for goods by examining prices across a number of cities in the two countries. They found that the markets were, surprisingly, not very well integrated.

They also discovered that the border between the United States and Canada acted as a much larger barrier than physical distance between cities. Pairs of cities that lie across the US-Canada border showed much less harmony in prices than city pairs within each country, even if the within-country pairs were in very distant markets. In other words, there was a large border effect.

Engel, Rogers, and Wang (2004) re-examine the border effect using a new source of data. The data are from the Economist Intelligence Unit (EIU), and they measure the prices of 97 consumer goods in 12 US cities and 4 Canadian cities. The data are annual, from 1990 to 2004. EIU collects the data to compare cost of living for cities throughout the world. The data are for a wide variety of products. Seventy-six of the prices are for goods: 41 food items, 8 clothing items, 6 consumer durables, and 21 other products. Typical items are tomatoes, ground beef, six-year aged Scotch whiskey, women's cardigan sweater, two-slice electric toaster, and Aspirin (100 tablets). The remaining 21 items are services, such as men's haircut (including tip) and one hour's babysitting. Table 1 lists the products that we use in this study.[1]

There are three key differences between these data and those used by ER:

(i) The goods and services in these data are very narrowly defined. ER use fairly broad categories, such as "food at home" and "men's clothing."

(ii) The data are not collected by a government statistical agency. The EIU data are not nearly as well documented as official consumer price data collected in the United States and Canada. One might suspect that the prices in this study are not as representative as those in the official data. Also, the array of goods and services is not as comprehensive as those in the official data.

(iii) These data are actual prices. The official data used by ER are price indexes. Price-level comparisons are not possible with index data. ER attempt to measure price deviations by looking at changes in the price index in one city compared with another. If the prices are equal, then the price changes should also be equal. But there are obvious drawbacks to this approach as a means of determining how large the deviations from price equality are.

The empirical exercises undertaken here are very similar to those in Engel, Rogers, and Wang (2004). The chief difference is that Engel, Rogers, and Wang estimate a constant border effect using panel methods for the entire 1990–2002 data span. Here, we allow the border effect to vary from year to

1. In a typical year, the EIU reports prices on many more products. We use 97 items, because price data for all of them are available for each city for every year. The EIU reports data for various types of outlets in some instances. In all cases, we use the low-price outlet.

Table 1
List of cities and goods

US cities	Boston, Chicago, Cleveland, Detroit, Houston, Los Angeles, Miami, New York, Pittsburgh, San Francisco, Seattle, Washington, DC	
Canadian cities	Calgary, Montréal, Toronto, Vancouver	
Goods (type of retail outlet)		
White bread (1 kg)	Drinking chocolate (500 g)	Women's dress, ready to wear, daytime
Butter (500 g)	Coca-Cola (1 L)	Women's shoes, town
Margarine (500g)	Tonic water (200 ml)	Women's cardigan sweater
White rice (1 kg)	Mineral water (1 L)	Women's tights, panty hose
Spaghetti (1 kg)	Wine, common table (750 ml)	Child's shoes, sportswear
Flour, white (1 kg)	Beer, local brand (1 L)	Hourly rate for domestic cleaning help
Sugar, white (1 kg)	Beer, top-quality (330 ml)	Babysitter's rate per hour
Cheese, imported (500 g)	Scotch whiskey, six years old (700 ml)	Compact disc album
Cornflakes (375 g)	Soap (100 g)	Television, colour (66 cm)
Milk, pasteurized (1 L)	Laundry detergent (3 L)	Kodak colour film (36 exposures)
Olive oil (1 L)	Toilet tissue (two rolls)	Cost of developing 36 colour pictures
Peanut or corn oil (1 L)	Dishwashing liquid (750 ml)	Daily local newspaper
Potatoes (2 kg)	Batteries (two, size D/LR20)	Paperback novel (at bookstore)
Tomatoes (1 kg)	Frying pan (Teflon or good equivalent)	Three-course dinner at top restaurant for four people
Oranges (1 kg)	Electric toaster (for two slices)	Four best seats at cinema
Apples (1 kg)	Laundry (one shirt)	Low-priced car (900–1299 cc)
Lemons (1 kg)	Dry cleaning, man's suit	Family car (1800–2499 cc)
Bananas (1 kg)	Dry cleaning, woman's dress	Deluxe car (2500 cc upwards)
Lettuce (one)	Dry cleaning, trousers	Cost of a tune-up (but no major repairs)
Peas, canned (250 g)	Aspirin (100 tablets)	Hilton-type hotel, single room, one night including breakfast
Peaches, canned (500 g)	Razor blades (five pieces)	Moderate hotel, single room, one night including breakfast
Sliced pineapples, canned (500 g)	Toothpaste with fluoride (120 g)	One drink at bar of first-class hotel
Beef: steak, entrecôte (1 kg)	Facial tissues (box of 100)	Two-course meal for two people

(cont'd)

Table 1
List of cities and goods (cont’d)

Beef: stewing, shoulder (1 kg)	Hand lotion (125 ml)	Simple meal for one person
Beef: roast (1 kg)	Lipstick (deluxe type)	Regular unleaded petrol (1 L)
Beef: ground or minced (1 kg)	Man’s haircut (tip included)	Taxi: initial meter charge
Pork: chops (1 kg)	Woman’s cut and blow-dry (tip included)	Taxi rate per additional kilometre
Pork: loin (1 kg)	Cigarettes, Marlboro (pack of 20)	Taxi: airport to city centre
Ham: whole (1 kg)	Cigarettes, local brand (pack of 20)	International foreign daily newspaper
Chicken: fresh (1 kg)	Electricity, monthly bill for family of four	International weekly news magazine
Instant coffee (125 g)	Men’s business suit, two-piece, med. weight	One good seat at cinema
Ground coffee (500 g)	Men’s business shirt, white	
Tea bags (25 bags)	Socks, wool mixture	

year (extending the data to 2004) and trace the evolution of the border barrier.

We measure integration by estimating an equation that explains the absolute value of the log price difference of good i between locations j and k: $|p_{i,j} - p_{i,k}|$, where $p_{i,j}$ refers to the log of the price expressed in US dollars of good i in city j. All prices are expressed in US dollars so that we can compare them across all cities.[2]

Following the literature that estimates the gravity model of trade, we use the log of the distance between locations j and k, $dist_{jk}$ as an explanatory variable. ER present a simple model of how distance might also help explain deviations from the law of one price. While ER discuss a few possible reasons why distance might influence prices, the most plausible focuses on distribution costs. Distribution costs are a large component of the final consumer price,[3] and are more likely to be similar for neighbouring locations. Distribution tends to be labour-intensive, and labour markets may be more tightly integrated if they are nearer geographically.

We also use the absolute value difference in the log of the population between cities j and k, pop_{jk}, as an explanatory variable, because larger cities tend to have higher prices. For the United States, the data refer to Metropolitan (MSA) Population Data. For Canada, the data are described as "Total Population, Census Div/Metro Areas."[4]

A dummy variable, $bord_{jk}$, which takes on the value of one if cities j and k lie on opposite sides of the national border between the United States and Canada, is meant to capture the degree of integration between US and Canadian markets. The coefficient on this variable measures the absolute average log price difference between US and Canadian cities that is not explained by distance or city size (or one of the dummy variables described below).

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2. This means that the Canadian-dollar price of goods sold in Canadian cities is converted into US-dollar values by multiplying by the US dollar per Canadian dollar exchange rate. The EIU survey reports prices in US-dollar terms, converted using "the market exchange rate on the date of the survey."
3. Burstein, Neves, and Rebelo (2003) find that distribution costs account for up to 40 per cent of the cost of consumer goods.
4. The US data are from the Census Bureau, and the Canada data from Statistics Canada. The US data were downloaded from: <http://recenter.tamu.edu/Data/popm>, and the Canadian data from Haver in the CANSIMR database (Canadian regional economic indicators).

We also include a dummy variable for each city, $citdum_j$, that takes on the value of one if one of the cities in the city pair is city *j*. This variable captures idiosyncratic aspects of the price of a given city.

We estimate this regression for each of the 15 years in our sample:

$$|p_{i,j} - p_{i,k}| = \beta_1 dist_{jk} + \beta_2 pop_{jk} + \beta_3 bord_{jk} + \sum_{h=1}^{N} \alpha_h citdum_h + u_{i,jk}. \quad (1)$$

This equation was estimated for all the goods and services together and then separately for the goods and the services.

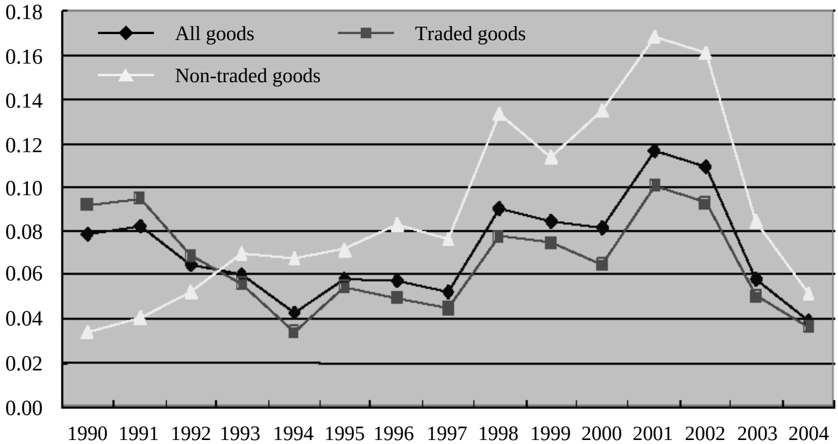
In contrast to the findings of Engel, Rogers, and Wang (2004), the estimated coefficients on the distance variable are rarely statistically different from zero. The distance coefficient takes on the correct sign in 14 of the 15 years, but is statistically significant (in a one-sided test at the 5 per cent level) in only 4 of the years. The population variable fares better. It takes on the expected sign in 14 of the 15 years, and was statistically significant (again in a one-sided test at the 5 per cent level) in 9 of the years. Compared with Engel et al. (2004), the lack of statistical significance in these regressions is probably attributable to the lower power of the tests when the regressions are run year by year as opposed to as a panel regression.

But we do find that the border coefficient is of the right sign and easily statistically significant (at the 5 per cent level) in all years. Figure 1 plots the estimated border coefficients. In the graph, we refer to goods as "traded goods" and to services as "non-traded goods" on the grounds that the physical goods in our sample are easily transportable across borders, while the services are not. The numbers on the vertical axis can be interpreted as the average log price deviation imposed by the border effect.

For all goods and services, and for the subset of traded goods, the border coefficient falls initially in the early 1990s from around 0.08 (or, roughly 8 percentage points) to 0.04 for traded goods (and slightly higher for all goods). But then, in the period from 1994 to 2001, the border coefficient for traded goods rises back to around 0.10. Finally, between 2001 and 2004, the coefficient falls back to about its 1994 level of 0.04. The border effect for non-traded goods shows a nearly monotonic increase from 1990 to 2001, rising from around 0.03 to 0.17. But then between 2001 and 2004, it falls sharply to approximately 0.05.

What accounts for these fluctuations in the border effect? Did the US and Canadian economies really become less integrated during much of the

Figure 1
Estimated "border coefficients" (1990–2004)



1990s? And why has there been a sudden apparent increase in integration since 2001? We return to these questions in section 3.

2 The Canadian Dollar and the Commodity Terms of Trade

Here, we review empirical evidence gathered by Amano and van Norden (1995) and Chen and Rogoff (2003) that links the value of the Canadian dollar to the export price of non-energy commodities. Both papers find evidence that as the price of commodities increases, the value of the Canadian dollar strengthens (in real terms).

The studies take slightly different approaches, but reach essentially the same conclusion. Amano and van Norden (1995) use monthly data on commodity prices from 1973Q1 to 1992Q2 to estimate an error-correction model that relates Canada's real CPI exchange rate relative to the United States to commodity prices and oil prices. In this dynamic model, they find that an increase in commodity prices leads to a real appreciation (while, surprisingly, the effect of oil prices on the real Canadian dollar is in the opposite direction).

Chen and Rogoff (2003) revisit this relationship, using quarterly data from 1980QI to 2000QI. They find a statistically significant relationship between the Can$/US$ real exchange rate and the non-energy commodity price index for some (but not all) of their statistical specifications.[5] They note that the relationship between the commodity terms of trade and the real exchange rate seems to be tighter for Canada relative to its large, non-US, trading partners.

What explains the relationship of the commodity terms of trade with the real exchange rate? Both papers offer similar explanations. It is helpful to quote directly from Chen and Rogoff (2003, 149):

> First, consider the following extension of the flexible-price Balassa-Samuelson model. Let Home be a small economy whose agents consume three goods—non-traded goods, exports, and imports—but produce only the first two. Assume that labour is perfectly mobile across industries, and that physical capital can be freely imported from abroad at real interest rate *r*, measured in importables. The production function for exportables is $y_x = A_x f(k_x)$, where *y* and *k* are output and capital per unit labour, respectively, and $y_N = A_N f(k_N)$ is the analogous function for non-traded goods production. Let p_x be the world price of exportables, which is given exogenously to the small country, and p_N be the Home price of non-traded goods, both measured in terms of importables. Then, assuming that labour mobility leads to a common wage across the two Home industries, one can derive the approximate relation:
>
> $$\hat{p}_N = \left(\frac{\mu_{LN}}{\mu_{LX}}\right)(\hat{A}_x + \hat{p}_x) - \hat{A}_N$$
>
> where a "hat" above a variable represents a logarithmic derivative, and μ_{LN} and μ_{LX} are labour's income share in the non-traded and export goods sectors, respectively. Thus, the effect of a rise in the relative price of exportables is the same as a rise in traded goods productivity in the standard Balassa-Samuelson model. The impact on the real exchange rate depends, of course, on the utility function. Assume a simple logarithmic (unit-elastic) utility function: $U = C_N^{\alpha} C_1^{\beta} C^{(1-\alpha-\beta)}{}_X$. Normalizing the price of importables to one, the consumption-based consumer price index is then given by $p_N^{\alpha} p^{(1-\alpha-\beta)}{}_X$. Therefore, as $\hat{p}_N$ moves proportionately in response to $\hat{p}_X$,

5. They also examine the statistical relationship for other "commodity currencies"—of Australia and New Zealand. For these countries, they find that the link between commodity prices and exchange rates is more robust to statistical specification than for Canada.

> the effect of an export price shock on the utility-based real CPI is then given by $\hat{p}_X^{(1-\beta)}$. Assuming that importables account for 25% of consumption, the elasticity of the CPI with respect to a unit change in the price of exportables would be 0.75, which is broadly consistent with our estimated coefficients. (If $\mu_{LN} > \mu_{LX}$—it is standard to assume that non-traded goods production is more labour intensive—one would get a larger effect.)

Here, we do not challenge the empirical work linking the value of the real Canadian dollar to commodity prices, but we offer evidence that the mechanism linking the two does not work through the relative price of non-traded goods. We argue that the evidence on Canadian prices and the exchange rate is consistent with a view that the Canadian CPI, expressed in units of Canadian dollars and denoted *P*, and the US CPI, expressed in US dollars and denoted P^*, are sticky in their local currencies. That is, Canadian consumer prices are set in Canadian dollars and adjust sluggishly, and US consumer prices are set in US dollars and also adjust slowly. The implication is that the real Canadian exchange rate, given by SP^*/P, where *S* is the Canadian dollar per US dollar exchange rate, is tightly linked to the nominal exchange rate *S*. Call this model the LCP (local currency pricing) model.

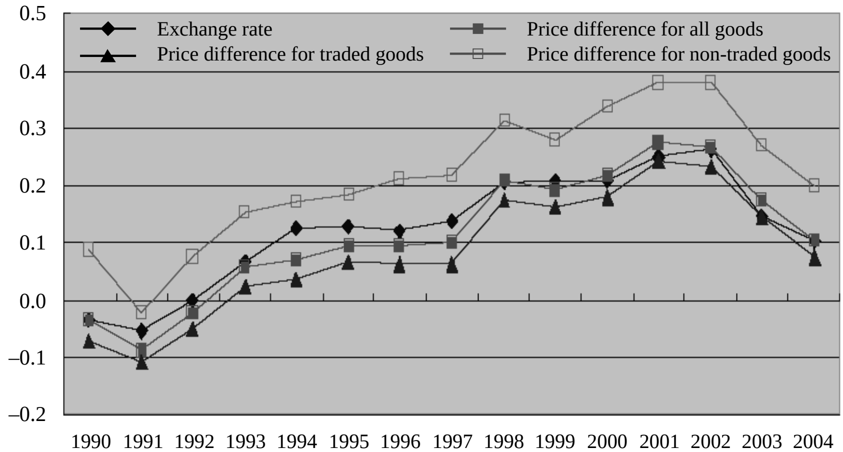
Section 3 presents evidence supporting this view and evidence against the model in which the Canadian real exchange rate is driven by the relative price of non-traded goods. Section 4 presents an alternative model of how an increase in commodity prices might lead to a real appreciation that is consistent with the data.

3 Evidence on Canada's Real Exchange Rate

Figure 2 plots a measure of Canada's real exchange rate based on the price data from the EIU, annually from 1990 to 2004. The line is denoted "price difference for all goods." This line is calculated by taking $p_{i,USk} - p_{i,CAj}$, the log of the price of good *i* in US city *k* relative to log of the price of good *i* in Canadian city *j*, with both expressed in a common currency. We first average this price difference for each good *i* across all Canadian/US city pairs and across all goods.

An increase in this price indicates that US consumer prices are rising relative to Canadian consumer prices. That is, an increase reflects a real depreciation of the Canadian dollar. Figure 2 shows that sometime between 1992 and 1993, average prices became higher in the United States than in Canada (the average price difference exceeds zero). That price differential

Figure 2
Relative prices and exchange rates for Canada and the United States



rose until it peaked in 2001 at nearly a 30 per cent difference. Between 2001 and 2004, the average price differential fell to around 10 per cent.

Figure 2 also plots *s*, the log of *S*, the Canadian dollar per US dollar exchange rate. For graphical purposes, the 1990 value of *s* was set equal to the 1990 value of the relative price. The plot indicates remarkably close movement between the real and nominal exchange rates. In log levels, the correlation coefficient is 0.979, and in first differences it is 0.882.

That evidence alone strongly supports the view that Canadian consumer prices are set in Canadian dollars, and US consumer prices are set in US dollars. But it is not definitive. In fact, the close correlation of real and nominal exchange rates is perfectly consistent with a world in which there is complete nominal price flexibility and where real exchange rates are linked to the relative price of non-traded goods.

To see this, following Chen and Rogoff's exposition of the classical model, let the nominal price index in Canada be given by $P_N^{\alpha} P_T^{1-\alpha}$, where P_N is the nominal price of non-traded goods, and P_T is the nominal price of traded goods. Following the model of Chen and Rogoff, P_T is an index of imported and exported traded goods:

$$P_T = P_I^{\frac{\beta}{1-\alpha}} P_X^{\frac{1-\alpha-\beta}{1-\alpha}},$$

where again the upper-case *P*s refer to nominal prices.

Assume that foreign consumers have a price index with identical weights. Use lower-case letters to represent prices. (To avoid confusion, I specify here that this notation is at odds with the notation of Chen and Rogoff above. In their model, lower-case *p*s represented the level of prices of goods relative to the numeraire good. Here, lower-case *p*s are the logs of the nominal prices.)

We can write the log of the real exchange rate as:

$$q = s + p^* - p = \alpha(s + p_T^* - p_T) + (1 - \alpha)(s + p_N^* - p_N). \tag{2}$$

If we now use the usual assumption of the classical model (implicit in Chen and Rogoff's description) that the law of one price holds up to a constant, so that $s + p_T^* - p_T = k$, where k is some constant, we obtain:

$$q = s + p^* - p = \alpha k + (1 - \alpha)(s + p_N^* - p_N), \tag{3}$$

or

$$q = s + p^* - p = k - (1 - \alpha)[p_N - p_N^* - (p_T - p_T^*)]. \tag{4}$$

Equation (3) shows us directly that the real exchange rate should be related to the relative price of non-traded to traded goods in the home relative to the foreign country (Canada relative to the United States).

Equation (3) is expressed all in terms of real prices. The classical model can be consistent with a wide variety of behaviour of nominal prices. For example, if Canadian and US policy-makers kept inflation (in local currencies) equal in the two countries, then $p^* - p$ would be constant. In that case, from equation (3), the log of the nominal exchange rate, s, would equal the log of the real exchange rate, q, up to an additive constant. So, the fact that nominal and real exchange rates co-move can be consistent with the classical model in which real exchange rates reflect movements in the relative prices of non-traded goods.

But there are two other implications of the classical model that are directly contradicted by the data. The first is that $s + p_T^* - p_T = k$, i.e., the assumption that the law of one price holds for traded goods (up to a constant). Figure 2 also plots the "price difference for traded goods." It is calculated the same way as the "price difference for all goods," but averages only across prices of traded goods. That is, it is a measure of $s + p_T^* - p_T$.

It is easy to see from Figure 2 that $s + p_T^* - p_T$ is not constant. In fact, it tracks $q = s + p^* - p$ very closely. The correlation of these two series in levels is 0.999. In first differences, the correlation is 0.992. As one might expect, given these correlations, we also find that $s + p_T^* - p_T$ is highly correlated with the nominal exchange rate, s. The correlation in levels is 0.978, and in differences is 0.883.

This behaviour is completely consistent with a sticky-price LCP model in which the Canadian price of traded consumer goods, p_T, is rigid and preset in Canadian dollars, while the US price of consumer goods, p_T^*, is set in US dollars and adjusts sluggishly.

Figure 2 also graphs the "price difference for non-traded goods," a measure of $s + p_N^* - p_N$ constructed analogously to the measures of $s + p_T^* - p_T$ and $q = s + p^* - p$. From the graphs, it is easy to see that $s + p_N^* - p_N$ is also highly correlated with s, $s + p^* - p$, and $s + p_T^* - p_T$. In levels, those correlations are 0.970, 0.993, and 0.987, respectively. In differences, the respective correlations are 0.816, 0.947, and 0.901.

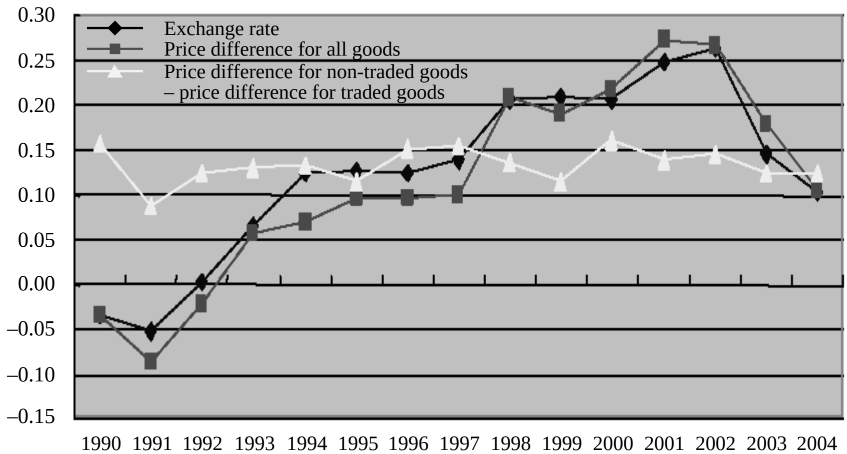
That behaviour is again consistent with local-currency price stickiness of p_N and p_N^*. If all consumer prices are sticky in consumers' currencies, then $s + p_N^* - p_N$, $s + p_T^* - p_T$, and $s + p^* - p$ will all follow s quite closely, as indeed they do in Figure 2.

Note, however, that the close correlation of $s + p_N^* - p_N$ with s or with $s + p^* - p$ is also consistent with the classical model, as equation (2) makes apparent. What the classical model cannot account for are the movements of $s + p_T^* - p_T$: its correlation with s, $s + p^* - p$, and $s + p_N^* - p_N$. But the LCP model is consistent with all of the prices plotted in Figure 2.

The second major implication of the classical model that is inconsistent with the data can be seen in Figure 3. This figure shows "price difference for non-traded goods – price difference for traded goods." This is a measure of $p_N - p_N^* - (p_T - p_T^*)$. Equation (3) of the classical model says that this relative price should be perfectly correlated with the real exchange rate, $q = s + p^* - p$. There is support for the classical model, but the correlations are quite low: 0.340 in levels and 0.218 in differences. In fact, as is evident from Figure 3, $p_N - p_N^* - (p_T - p_T^*)$ is negatively serially correlated at the annual frequency, while $s + p^* - p$ is positively serially correlated and quite persistent.

Equation (3) not only implies that $p_N - p_N^* - (p_T - p_T^*)$ is perfectly correlated with q, but it also implies that $p_N - p_N^* - (p_T - p_T^*)$ is much more volatile than q. The variance of q should be only $(1 - \alpha)^2$ times the variance of $p_N - p_N^* - (p_T - p_T^*)$, where $1 - \alpha$ is the weight of non-traded goods in the price index. Clearly, the relative variances go the other way. (The standard deviation of $p_N - p_N^* - (p_T - p_T^*)$ is only about one-fifth the standard deviation of q!)

Figure 3
Relative prices and exchange rates for Canada-US



On the other hand, the low correlation of $p_N - p_N^* - (p_T - p_T^*)$ with $q = s + p^* - p$ is exactly the prediction of the LCP model, as is the low volatility of $p_N - p_N^* - (p_T - p_T^*)$ compared to q.

If we adopt the LCP model, we are now also able to understand the border puzzle raised in section 1 of this paper. Why did the measured border effect rise throughout most of the 1990s, but then drop from 2001 to 2004? The answer is not in changing trade barriers. The answer is in local currency pricing. While some sort of barriers are needed to explain why consumers do not arbitrage price differences across locations, it is not time variation in those barriers that accounts for time variation in the border coefficient (as seen in Figure 1). Instead, the movements of the border coefficient seem to be mostly related to movements in the exchange rate. As Figure 2 shows, consumer prices in the United States rose relative to those in Canada as the nominal exchange rate rose. It was not until the US dollar began to depreciate that the price gap narrowed and the border coefficients fell. That is, by consumer price measures, the US dollar was overvalued and became increasingly overvalued relative to the Canadian dollar through the 1990s. Since 2001, the US dollar has depreciated and become less overvalued.

Many recent papers[6] have argued that the failures of the law of one price—the deviations of $s + p_T^* - p_T$ from zero—can be explained by distribution

6. Among them prominently are Burstein, Neves, and Rebelo (2003) and Burstein, Eichenbaum, and Rebelo (2004).

costs of traded consumer goods. The argument revives the classical model by explaining that the measured (log) of the price of traded goods, p_T, is actually a weighted average of the true price of traded goods as measured at the dock, p_D, and the price of non-traded goods and services used to bring the traded goods to the consumer:

$$p_T = \psi p_D + (1 - \psi) p_N . \tag{5}$$

We can then substitute this expression (and its counterpart for the foreign country) into $s + p_T^* - p_T$, and amend equation (1) to write:

$$q = \alpha\psi(s + p_D^* - p_D) + (1 - \alpha\psi)(s + p_N^* - p_N) .$$

Now, according to this "revised classical" (RC) model, the law of one price holds for traded goods at the dock, so $s + p_D^* - p_D = k$, where k is some constant. So we have

$$q = \alpha\psi k + (1 - \alpha\psi)(s + p_N^* - p_N) . \tag{6}$$

At first blush, the RC model seems compatible with our data. On the one hand, we are unable to measure $s + p_D^* - p_D$, because we have only data on consumer prices and not data on true traded goods prices at the dock. So we cannot verify or disprove the assumption that the law of one price holds, $s + p_D^* - p_D = k$.

By analogy to the derivations above, we might rewrite equation (4), under the assumption that $s + p_D^* - p_D = k$, to obtain:

$$q = s + p^* - p = k - (1 - \alpha\psi)[p_N - p_N^* - (p_D - p_D^*)] . \tag{7}$$

But this also does not give us an equation we can verify or refute, again because we do not observe $p_D - p_D^*$.

It would seem that the only equation of the RC model we can examine empirically is equation (5), which implies that $s + p_N^* - p_N$ is highly correlated with $s + p^* - p$. But we have already noted that correlation is high. To be sure, that high correlation is also consistent with the LCP model, and also with the original version of the classical model (see equation (2)) that was refuted by other evidence.

But there is evidence that we can use. Even though p_T is not a perfect measure of the price of traded goods at the dock, p_D, it does contain information about traded prices at the dock. We can exploit the fact that consumer traded goods are intensive in the actual traded good compared with consumer non-traded goods. That is, the share of the true traded goods,

γ, in the price of consumer traded goods is greater than the share of true traded goods in consumer non-traded goods, which is zero.

So, equation (4) can be written as:

$$p_N - p_D = \frac{p_N - p_T}{\psi}.$$

Substituting into equation (6), the RC model implies:

$$q = s + p^* - p = k - \left(\frac{1 - \alpha\psi}{\psi}\right)[p_T - p_T^*]. \tag{8}$$

Equation (7) gives us a relationship between the real exchange rate and sub-indexes of prices we can observe. It is exactly like equation (3) in implying that $p_N - p_N^* - (p_T - p_T^*)$ should be perfectly correlated with the real exchange rate, $q = s + p^* - p$. But this was the empirical implication that Figure 2 refutes.

Equation (3) also had the implication that the variance of $p_N - p_N^* - (p_T - p_T^*)$ had to be greater than the variance of $q = s + p^* - p$. That is not true of equation (7). $p_N - p_N^* - (p_T - p_T^*)$ can have a smaller variance if $1 - \psi > \alpha\psi$. What is the meaning of this condition? $1 - \psi$ is the weight of p_N, the non-traded distribution services, in the price of the traded consumer good, p_T. $\alpha\psi$ is the weight of the price of traded consumer goods at the dock, p_D, in the overall consumer price index, p. That condition could plausibly be met, but recall that in our data the standard deviation of $p_N - p_N^* - (p_T - p_T^*)$ is only one fifth the standard deviation of $s + p^* - p$. For the RC model to account for this, we would need

$$\psi = \frac{1}{\alpha + 5}.$$

For this to be possible, the weight of p_D in p_T would have to be less than one fifth.

Put another way, equation (4) implies that the standard deviation of $s + p_T^* - p_T$ must equal $1 - \psi$ times the standard deviation in $s + p_N^* - p_N$, if the classical model is correct and $s + p_D^* - p_D$ equals zero.[7] In our data, $s.d.(s + p_T^* - p_T) = 0.107$ and $s.d.(s + p_N^* - p_N) = 0.115$. For these statistics to be consistent with the classical model, we would need

7. I thank Mick Devereux for pointing this out to me.

$\psi = 0.073$. That is, the actual traded content of traded goods would have to be very small—only 7 per cent of the total value of the traded consumer good.

So the evidence works against even the RC model of the real exchange rate. A simpler explanation of these data is the LCP model. But what replaces the classical model to explain the relationship between the price of commodities and the real exchange rate? Section 4 sketches a very simple LCP model, based on the work of Devereux and Engel (2004). It incorporates local-currency price stickiness for consumer goods, but potentially can explain the behaviour of commodity currencies.

4 A Simple Model

Here, we outline a very simple model based on Devereux and Engel (2004). (This work is referred to as DE hereinafter.) The model cannot masquerade as a realistic description of the Canadian economy. It is not dynamic and does not allow for any asset trade. It is a two-country model, and so it does not account for the determination of commodity prices in a world economy in which Canada and the United States are a part. Because the model is static, it is not amenable to examining the role of price adjustment. The model does not even account for the different sizes of the US and Canadian economies. But the model may contain the seed of the economics that links commodity prices to the real exchange rate in Canada.

Commodity prices are determined in the global economy, and not just by the supplies and demands of the US and Canadian economies. Our approach assumes that the United States and Canada are small in the markets for commodities—that they are price-takers.

We are concerned about the short-run effects of commodity price changes on exchange rates. The "short run" is the period during which certain nominal prices have not fully adjusted. The model presented here is one in which prices of consumer goods are sticky and set in the currency of the consumer. That is, it is an LCP model, and is thus consistent with the data reported in section 3.

The model treats all consumer goods as non-traded. Final consumer goods are assembled from traded intermediate goods. Consumer goods in each country require locally produced tradable intermediate goods and imported intermediate goods. We assume that the law of one price holds for the traded intermediate goods. We assume that intermediate goods prices are flexible and can adjust to shocks.

Commodities are separate sectors of the economies, and are modelled very simply. In the short run, supply and demand for commodities are highly inelastic. When the price of a commodity increases, in the short run the economic effect is principally an increase in wealth for the exporter and a decrease in wealth for an importer. This leads us to capture the role of commodity price fluctuations in the short run as a simple transfer. When commodity prices rise, there is a transfer from the United States to Canada. That is, there is a decrease in wealth for the importer of commodities (the United States) and an increase in wealth for the exporter (Canada). Given the confines of a two-country model, we are forced to assume that Canada's gain is exactly equal to the US loss.

Our model is essentially the same as that of DE, except for the following differences:

- DE focus on the effects of real shocks to labour supply. In our model, the only source of shocks is to commodity prices, i.e., to the transfer.
- DE mainly examine models in which asset markets are complete. We will assume, to the contrary, that there is no asset trade. Given that the transfer is the only source of shocks, what we mean is that there is no insurance market for these transfers. That is the only missing asset market. If it were in place, asset markets would be complete.
- DE allow some prices to be flexible and some to be fixed, both for consumer prices and for intermediate prices. In DE, some consumer prices are fixed in consumers' currencies and some are flexible. Some intermediate goods prices are fixed in producers' currencies, and some are flexible. Here, we look only at the version of the model in which all consumer prices are set in local currencies and all intermediate prices are flexible.
- We slightly simplify household preferences, having leisure enter the utility function quasi-linearly.
- In assessing monetary policy rules, we do not consider how a change in the rule would affect the ex ante preset nominal prices, as DE do. This consideration might be important if we were considering the welfare implications of various policies, but is not very important in considering the implications of policies for exchange rate smoothing.

Otherwise, the model is identical to that of DE, and their paper contains a fuller exposition of the model than the brief outline contained here.

Household *i* in the home country has preferences given by:

$$U(i) = \frac{1}{1-\rho} C(i)^{1-\rho} - L(i), \text{ with } \rho > 0. \tag{9}$$

C represents aggregate consumption. It is a constant-elasticity-of-substitution aggregate over a continuum of home-produced final commodities with an elasticity of substitution of $\theta > 1$. L represents labour services that each household uses to produce an intermediate good. Foreign households have identical preferences, but theirs are defined over consumption of final goods sold in the foreign country and foreign labour.

Each household in the home country produces an intermediate good according to the production function $Y_H(i) = L(i)$. Each variety of the final consumption good in the home country is produced using domestic and foreign intermediate good aggregates. For instance, the final good variety j is produced using the home and foreign intermediate good aggregates, respectively $Y_H(j)$ and $Y_F(j)$, with the production function:

$$Y(j) = \left(\left(\frac{1}{2}\right)^{\frac{1}{\gamma}} Y_H(j)^{\gamma - 1/\gamma} + \left(\frac{1}{2}\right)^{\frac{1}{\gamma}} Y_F(j)^{\gamma - 1/\gamma}\right)^{\gamma/\gamma - 1}, \tag{10}$$

where γ is the elasticity of substitution between the home and foreign intermediate goods aggregates. The home intermediate aggregate $Y_H(j)$ is defined over a continuum of home-produced intermediate goods, with elasticity of substitution ϕ:

$$Y_H(j) = \left[\int_0^1 Y_H(i, j)^{\frac{\phi - 1}{\phi}} di\right]^{\frac{\phi}{\phi - 1}}, \text{ with } \phi > 1,$$

and $Y_F(j)$ is defined analogously. Home households consume all of each home final good variety $Y(j)$.

As noted above, we assume that all consumer prices are set in the consumer currency. Producers of final goods will alter production levels to meet demand. We set the price of consumer goods in each country equal to one.

We eliminate any sources of inefficiency that are due to monopoly pricing wedges in the intermediate goods sectors. To avoid these, we assume that firms receive a per-unit subsidy on production to ensure that price would equal marginal cost. The subsidy is financed by lump-sum profit taxes on the producers.

For household/intermediate-goods producers, the first-order condition for the trade-off between consumption and leisure is:

$$P_H = C^{\rho}. \tag{11}$$

This extremely simple equation requires some explanation. Each household i sells its intermediate good at the price $P_H(i)$ (denominated in the home currency). Given that all households are identical, $P_H(i)$ is the same across all households and equal to the aggregate price of home-produced intermediate goods, P_H, in equilibrium. Since we assume that the nominal price of consumer goods is set equal to one, P_H also equals the price of intermediate goods relative to consumption goods. Households set the marginal rate of substitution between consumption and leisure equal to this relative price. Given that the marginal disutility of work equals unity, the marginal rate of substitution equals C^{ρ}, and so we have equation (10).

The decisions of foreign households are analogous to those of home households, so we have their first-order condition given by:

$$P_F^* = C^{*\rho}. \tag{12}$$

Here, P_F^* is the foreign-currency price of foreign-produced intermediate goods.

Demand for labour is a derived demand coming from producers of final goods in each country. Their demand for intermediate goods from each country depends on the level of consumption of the final good in each country, and the relative price of foreign to home intermediate producers, SP_F^*/P_H. We can derive the demand for home labour as:

$$L = \frac{1}{2}P_H^{-\gamma}\left(\frac{1}{2}P_H^{1-\gamma} + \frac{1}{2}(SP_F^*)^{1-\gamma}\right)^{\frac{\gamma}{1-\gamma}}(C + C^*). \tag{13}$$

Note that the demand for home labour coming from foreign final-goods producers (and hence the demand for exports of home intermediate producers) is given by:

$$\frac{1}{2}P_H^{-\gamma}\left(\frac{1}{2}P_H^{1-\gamma} + \frac{1}{2}(SP_F^*)^{1-\gamma}\right)^{\frac{\gamma}{1-\gamma}}C^*.$$

We can also derive demand for foreign labour:

$$L^* = \frac{1}{2}(SP_F^*)^{-\gamma}\left(\frac{1}{2}P_H^{1-\gamma} + \frac{1}{2}(SP_F^*)^{1-\gamma}\right)^{\frac{\gamma}{1-\gamma}}(C + C^*). \tag{14}$$

The balance-of-payments equilibrium condition is that the sum of transfers from the foreign country to the home country plus exports of the home country equals imports of the home country:

$$\tau + \frac{1}{2}P_H^{1-\gamma}\left(\frac{1}{2}P_H^{1-\gamma} + \frac{1}{2}(SP_F^*)^{1-\gamma}\right)^{\frac{\gamma}{1-\gamma}}C^*$$

$$= \frac{1}{2}(SP_F^*)^{1-\gamma}\left(\frac{1}{2}P_H^{1-\gamma} + \frac{1}{2}(SP_F^*)^{1-\gamma}\right)^{\frac{\gamma}{1-\gamma}}C. \quad (15)$$

τ is a monetary transfer, denominated here in the home-country currency. It is assumed to be a random variable. The units of equation (14) are home currency.

Finally, we follow DE in assuming that the instrument of monetary policy makers in each country is nominal consumption. This could be thought of as the equivalent in the static context as control over nominal interest rates. That is, the gross nominal interest rate is equal to the expected marginal utility of a unit of currency today relative to the marginal utility of a unit of currency next period. In the static model, we take expected future values as given. And given that all consumer prices are assumed to be fixed and equal to one in our simple model, the marginal utility of a dollar today is determined by the level of consumption today. So we are assuming that C and C^* are instruments of monetary policy makers.

When monetary policy is passive, so that C and C^* are not responsive to τ shocks, from equations (10), (11), and (14), the effect of a change in the transfer on exchange rates is immediately apparent. Equations (10) and (11) indicate that with no change in C and C^*, P_H and P_F^* will not change with movements in τ. Therefore, equation (14) tells us how movements in τ affect the exchange rate.

When the home country receives a transfer (τ is positive), it is able to increase the (domestic currency) value of its imports. For a small increase in τ, starting from τ equal to zero, there will be a drop in *S*—an appreciation of the home currency—when the elasticity of demand for intermediate goods is greater than one. Specifically, we have

$$\left.\frac{ds}{d\tau}\right|_{\tau=0} = \frac{2}{1-\gamma}P_F^{*1-\gamma}S^{-\gamma}\left(\frac{1}{2}P_H^{1-\gamma} + \frac{1}{2}(SP_F^*)^{1-\gamma}\right)^{\frac{-\gamma}{1-\gamma}}C^{-1}.$$

This derivative is less than zero when γ is greater than one.

In short, a positive commodity price shock works like a wealth transfer to the commodity exporter. Ultimately, it will increase the value of its imports. When the elasticity of demand for imports is sufficiently high, this requires an appreciation of the currency.

5 Policy Implications

What role might policy play in this setting? There are two sources of inefficiencies in this model. The first is that there is no market to hedge the risk of commodity price changes. Suppose that there was a perfect insurance market for these shocks. This would mean that no transfers take place. Equation (14) would be altered because τ would drop out. In that case, there would be no shocks to the system. Even though nominal consumer prices are sticky, that would have no meaning, because there would be no shocks that would cause optimal prices to deviate from preset levels.

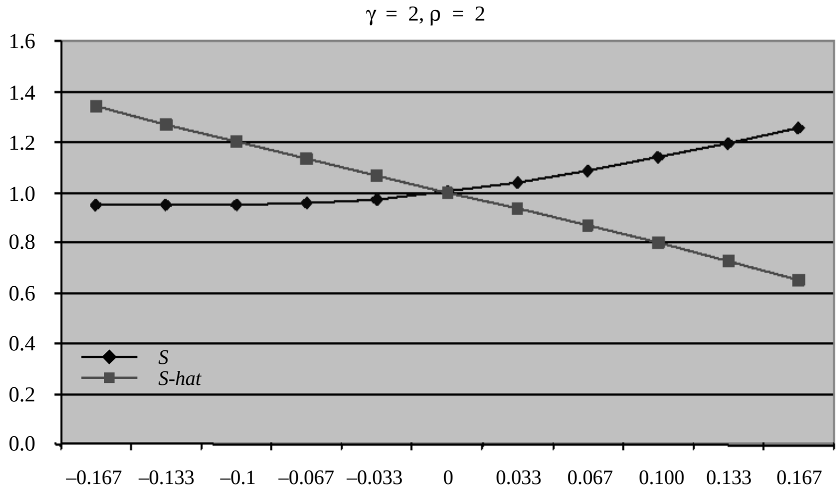
But asset markets are not complete, so the allocations that arise in the presence of the transfer shocks are suboptimal. In fact, when monetary policy is passive, C and C^* can be set at their optimal levels independent of the shock. But employment levels will not be optimal. As we have seen, a positive transfer leads to an appreciation of the domestic currency. This translates into a decline in the relative price of foreign intermediate goods, SP_F^*/P_H, since equations (10) and (11) tell us that P_H and P_F^* will not change with movements in τ when C and C^* do not change. That, in turn, implies that foreign employment will rise and home employment will fall. But when optimal insurance for commodity price shocks is in place, employment would not respond to those shocks.

A second source of inefficiency is the price stickiness of the final consumer goods. As DE emphasize, when final consumer prices are sticky in consumers' currencies, any change in the nominal exchange rate will lead to a change in the price of consumer goods in the home country relative to the foreign country. This is potentially inefficient. An efficient allocation would be obtained only when the relative price change reflects some underlying change in the resource cost of producing the goods.

In this simple model, the resource cost of producing home and foreign consumption goods is identical. Identical production functions combine home and foreign intermediates to produce the consumption good in each country. Therefore, any movement in the consumption real exchange rate is inefficient.

Both of the sources of inefficient allocation point towards exchange rate movements as the transmitter of the distortion. Here, we ask what an optimal, co-operative monetary policy would imply for exchange rate

Figure 4
Exchange rate under optimal and passive monetary policy



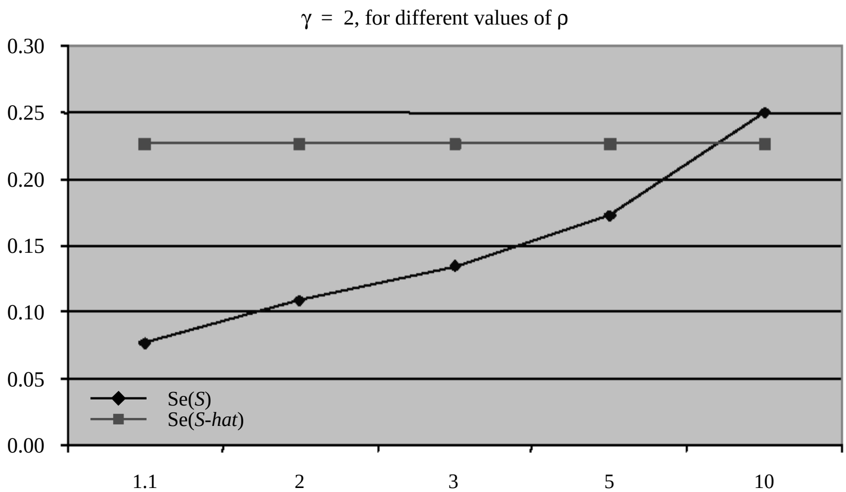
movements. Specifically, we consider monetary policy under commitment, in which policy-makers can precommit to changing C and C^* in response to τ shocks. We solve the model numerically.

Figure 4 plots the exchange rate that would result under optimal policy choices for values of τ. The horizontal axis plots the values of τ equal to zero and $\pm$ 0.033, 0.067, 0.100, 0.133, and 0.167. In this case, we set $\rho = 2$ and $\gamma = 2$. The line labelled "*S*" plots the exchange rate under optimal co-operative policy, while the line labelled "*S-hat*" plots the exchange rate under passive policy.

It is clear from this graph that optimal monetary policy tends to stabilize the exchange rate relative to the passive case. Optimal monetary policy tends to reduce the real exchange rate distortion that occurs when nominal exchange rates fluctuate.

Figure 4 shows that optimal policy pushes the exchange rate in the opposite direction from under passive policy. For example, when there are positive realizations of τ, we find that S rises, in contrast to exchange rate behaviour under passive policy. Optimal policy interventions push C up and C^* down in this case. In turn, from equations (10) and (11), there is an increase in P_H and a decline in P_F^*. The relative price of the foreign intermediate good, SP_F^*/P_H, falls as under passive policy, in spite of the increase in S that occurs under active policy. But the decline in the relative price is less than that which occurs under passive monetary policy. So, optimal policy also

Figure 5
Exchange rate volatility under optimal and passive monetary policy



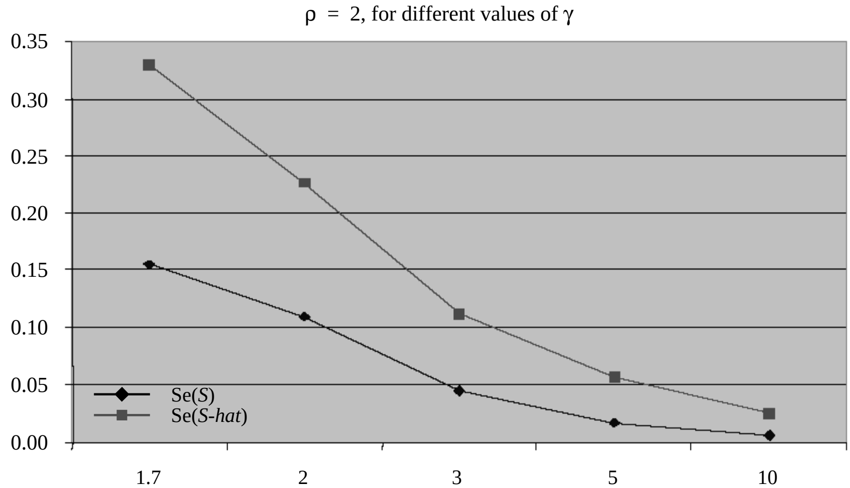
reduces the distortion to employment induced by changes in the relative price of intermediate goods.

Figure 5 plots the standard deviation of the exchange rate (using the distribution of τ values mentioned above) for optimal policy and passive policy as the coefficient of relative risk aversion, ρ, changes. In all cases, we set $\gamma = 2$. The line labelled "Se(*S*)" plots the standard deviation of *S* under optimal policy, while the one labelled "Se*(S-hat*)" plots the standard deviation under passive policy. Except for one case—when ρ is at the very high value of 10—we find that optimal policy stabilizes the nominal exchange rate.

Figure 6 is similar to Figure 5, only we vary the elasticity of substitution between home and foreign intermediate goods, γ, while keeping $\rho = 2$. Here, in all cases, monetary policy stabilizes nominal exchange rates.

The fact that optimal monetary policy under commitment would tend to smooth exchange rate changes lies in contrast to the implications of the classical model. In the classical model, the real exchange rate changes represent optimal movements in the relative prices of non-traded goods. Monetary policy has no role in such a model. But, Chen and Rogoff (2003) argue that there may, in fact, be a role for monetary policy to achieve the optimal relative price adjustments when there is some nominal price stickiness. They ask (2003, 149–50),

Figure 6
Exchange rate volatility under optimal and passive monetary policy



> What if the price of non-traded goods is sticky? Assuming that export prices are flexible with complete pass-through, a simple model of optimal monetary policy would require the exchange rate to accommodate the requisite rise in the relative price of non-traded goods. This implies that the exchange rate should adjust one-for-one with changes in the world price of exportables.

So there is a contrast between the implications for monetary policy of the model presented here and the model of Chen and Rogoff. Our model implies that the exchange rate effects of commodity price changes should be smoothed by monetary policy.

Conclusion

The model presented here is far too simplified to give a definitive answer to how monetary policy in Canada should respond to commodity price shocks. As we have noted, a more realistic model would be dynamic; it would (i) allow for nominal price adjustment; (ii) introduce realistic asset-market assumptions; (iii) explicitly model the commodity market; (iv) allow for the differences in size of Canada and the United States; and (v) allow more general functional forms for preferences and technology.

In addition, we have not considered optimal policy from the perspective of a single country. We have noted only the features of optimal co-operative monetary policy in our model. But that does little to pinpoint the optimal choices for the Bank of Canada, which does not actively co-operate with the Federal Reserve in setting interest rates.

What the model does capture is the fact that real exchange rate movements in the short run—and it is the short run that matters for monetary policy—look more like those that occur under local currency pricing. There is another channel through which a positive commodity shock could lead to a real appreciation in the context of an LCP model.[8] It may be that the nominal exchange rate behaviour of the Canadian dollar is linked to the policy reaction of the Bank of Canada. A positive commodity price increase is expansionary for the Canadian economy. It may be that the Bank of Canada has consistently reacted to this expansion by raising interest rates, and that action, in turn, leads to the appreciation of the Canadian dollar.

It does not appear that the movements in the relative prices of non-traded to traded goods account for much of the real Can$/US$ exchange rate movement, at least in the short run. The actual transmission mechanism from commodity prices to real exchange rates matters for monetary policies. Further investigation is needed to understand the link.

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8. Mick Devereux pointed this out to me.

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General Discussion*

Robert Lafrance asked if the presumed exchange rate misalignments in the paper were simply reflecting deviations from purchasing-power-parity (PPP) calculations. He wondered whether nominal exchange rate volatility had major welfare implications, given that Canada-US PPP estimates exhibited only moderate volatility over time. Charles Engel responded that as national prices were not reflecting actual cost differences, this indicated important economic inefficiencies. Nicholas Rowe argued that the data could be reconciled with a simpler model that introduced differentiated transportation costs for goods (low) and services (high) across the border. Engel replied that this merited further thought, but that such a model would still require some form of price stickiness. John Murray wondered if this approach had been tried to explain cross-border price differences with other country pairs. Engel replied no, but that it might be interesting, since the Canadian-US dollar exchange rate was not volatile when compared with other major currencies. Pierre Duguay questioned the role of monetary policy in the model, in particular, in controlling a real variable (i.e., consumption). What monetary policy can actually control is a nominal variable, such as prices. Engel answered that in his highly simplified model, monetary policy ultimately affects real wages and that his static model has no price dynamics.

* Prepared by Robert Lafrance.