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COMMENTARY

NO. 502

Understanding the Volatility of the Canadian Exchange Rate

Bank of Canada monetary policy allows for a volatile Canada/US nominal exchange rate rather than a volatile inflation rate relative to our peers. We examine the historical determinants of the Canadian-US dollar nominal exchange rate and whether they can be used in real-time forecasting.

Martin Eichenbaum, Benjamin K. Johannsen
and Sergio Rebelo

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The Study In Brief

In this *Commentary*, we document the nature of the Bank of Canada's current monetary policy regime by focusing on the following questions: what are the historical determinants of the Canadian–US dollar nominal exchange rate, and can they be used in real-time forecasting applications?

We find that the current real exchange rate is more useful than commodity prices for forecasting changes in the nominal exchange rate. In fact, short-run forecasts based on the real exchange rate are as good as random-walk forecasts according to which the future exchange rate is expected to be the same as today's. Strikingly, medium- and long-run forecasts based on the real exchange rate are superior to random-walk forecasts. We argue that these findings reflect the fact Bank of Canada and the U.S. Federal Reserve System follow similar inflation-targeting regimes and neither actively manages exchange rates.

A fundamental question is whether Canadian policymakers are satisfied with the current inflation-targeting regime. A cost of the current regime is that it allows for very volatile nominal and real exchange rates. A benefit is that consumers and firms can avoid many of the changes in prices and wages that would be required if the nominal exchange rate did not adjust in a flexible manner. In this *Commentary*, we take no stand on the merits of the current regime. Instead, we highlight the tradeoffs that policymakers face. Evaluating the costs and benefits of those tradeoffs should play an important role in the process leading to the Bank of Canada's next five-year agreement with the government.

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Open economies depend on the health and wealth of their trading partners. The Canadian economy is particularly open and, because of its reliance on commodity exports, particularly vulnerable to shocks from abroad.

How should monetary policy be conducted under these circumstances? One option is to allow for a volatile nominal exchange rate (Canadian dollars per unit of foreign currency). Another option is to allow for sharp changes in Canada's inflation rate relative to those of its major trading partners. Historically, policymakers have chosen the first option. A potential cost of this choice is that Canada's real exchange rate – the relative cost of a typical bundle of consumer goods in Canada and its major trading partners – is highly volatile. A benefit of this choice is that it minimizes the need for firms to change nominal prices in response to shocks to the Canadian economy. As the Bank of Canada enters its next five-year contract with the Canadian government, it is useful to put these costs and benefits into sharp focus so that the merits of allowing for a volatile nominal exchange rate can be widely discussed and debated.

In this *Commentary*, we do not address whether the current monetary policy regime is the correct one. Instead, we document the nature of the current regime by focusing on the following questions: what are the historical determinants of the Canadian–US dollar nominal exchange rate, and can they be used in real-time forecasting applications? There are two stock responses to these questions. The first is that we are on a fool's errand: even if we understood why the exchange rate had moved in the past, we would not be able to forecast future changes in the exchange rate. The second response is that the answer is obvious: it is all about commodity prices. When they go up, the Canadian dollar appreciates; when they go down, the Canadian dollar depreciates. That is certainly a view often expressed in the popular press.[1]

Both of these stock answers are incorrect. Building on results in Eichenbaum, Johannsen, and Rebelo (2017), we show that the real exchange rate can be used to forecast changes in the nominal exchange rate. Forecasters know that it is hard to improve upon or even do as well as a forecast of no change in the nominal exchange rate. Such a forecast is referred to as a "random-walk forecast."[2] Remarkably, for time horizons longer than three years, forecasts based on the real exchange rate do

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1 Various researchers have documented a relationship between commodity prices and the Canadian exchange rate. See, for example, Berg, Guerin, and Imura (2016); and Ferraro, Rogoff, and Rossi (2015).

2 Rossi (2013) documents just how difficult it is to do as well as or better than a simple random-walk forecast for a large sample of countries. Cheung et al. (2017) examine the ability of a host of economic models to forecast nominal exchange rates. They also find that, relative to random-walk forecasts, relative-purchasing-power-parity-based forecasts outperform other economic models.

much better than random-walk forecasts.[3] This result reflects two basic statistical facts. First, the real exchange rate is negatively correlated with future changes in the nominal exchange rate – that is, when Canadian consumer goods are expensive relative to US consumer goods, the Canadian dollar tends to depreciate. Second, the negative correlation grows stronger with the length of the time horizon. These statistical regularities are useful for forecasting Canada's nominal exchange rate.

What about commodity prices? There is in fact a strong positive *contemporaneous* correlation between real (inflation-adjusted) commodity prices and changes in the nominal exchange rate. In this sense, the view in the popular press is correct: high commodity prices *are* associated with a strong Canadian dollar. But a contemporaneous correlation is not useful for forecasting purposes; for that, one would have to be able to predict the value of *future* commodity prices. In fact, commodity prices are mean-reverting – that is, when they are unusually high today, they will tend to fall in the future. So, unusually high real commodity prices should be associated with a future *depreciation* of the Canadian dollar. Indeed, that is what we see in the data: high real commodity prices are negatively correlated with changes in the value of the Canadian dollar. However, the underlying correlations are not sufficiently strong to make commodity prices as useful as the real exchange rate for forecasting the value of the dollar.

Our results about the usefulness of the real exchange rate for predicting the nominal exchange rate reflect the similarities between Canadian and US monetary policy.[4] In particular, the Bank of Canada and the Federal Reserve have similar inflation objectives, and neither actively manages exchange rates. As a consequence, the Canadian economy responds to major shocks through gradual changes in the nominal exchange rate, rather than through changes in relative inflation rates. The similarity between the inflation objectives of the Bank of Canada and the Federal Reserve prevents wide swings in the two countries' relative inflation rates. So, when Canada's consumption basket is relatively expensive, its nominal exchange rate tends to depreciate by enough to move the real exchange rate back to its long-run level. That gradual adjustment process can be exploited to predict nominal exchange rates at medium and long horizons.

The previous argument requires policymakers to respond actively to inflation. If, for example, the Bank of Canada had a money-growth-rate rule that did not respond to economic developments, policymakers could, under plausible assumptions, achieve an average rate of inflation of 2 percent over long periods of time. But such a rule would allow for sharp and persistent deviations in Canadian and US inflation rates. Under these circumstances, the real exchange rate would be much less useful for forecasting future nominal exchange rates.

In summary, both commodity prices and the real exchange rate are correlated with the value of the Canadian dollar. But the real exchange rate is more useful for forecasting changes in the nominal exchange rate. We conclude the *Commentary* by offering a brief discussion of the implications of our empirical results for Canadian monetary policy.

3 This result is remarkable because Meese and Rogoff (1983) showed that it is difficult to predict exchange rates better than the random-walk forecast.

4 Eichenbaum, Johannsen, and Rebelo (2017) make this argument for a broad set of countries whose monetary policies are reasonably well characterized by a Taylor rule.

The Historical Behavior of Canada's Nominal and Real Exchange Rates

After adopting a fixed exchange rate regime in 1962, Canada moved to a floating exchange rate regime in 1970. The United States abandoned the convertibility of the US dollar into gold on August 15, 1971. In March 1973, six members of the European Community formally decided to float their currencies against the US dollar. This decision marked the end of the Bretton Woods fixed-exchange-rate regime and the beginning of the modern floating-exchange-rate era.

The dark blue line in the top panel of Figure 1 depicts the behavior of Canada's nominal exchange rate in the post–Bretton Woods era, March 1973 to September 2017. The data correspond to the average monthly price of the Canadian dollar in US currency. So a rise in the exchange rate corresponds to an appreciation of the Canadian dollar. The light gold line in the top panel shows the behaviour of Canada's real exchange rate, measured as the ratio of the value of the Canadian consumer price index (CPI) in US dollars divided by the US CPI.[5] A rise in the real exchange rate means that consumer goods have become relatively more expensive in Canada than in the United States.

A number of features of Figure 1 are worth noting. First, there is no obvious trend in either the nominal or the real exchange rate.[6] Second, the values of the two exchange rates are virtually the same at the beginning and end of the sample period, meaning that the ratio of the Canadian CPI to the US CPI changed little over the 45 years. Consistent with this observation, the average inflation rate in both Canada and the United States over the period was 3.9 percent.[7] Third, movements in the nominal and real exchange rate have a remarkably high correlation of 0.97. So differentials in inflation account for only a small fraction of the movements in the real exchange rate. Consistent with this observation, Canadian and US inflation rates also have a very high correlation of 0.89.[8]

In the bottom panel of Figure 1, the dark blue line again shows the nominal exchange rate over time. The light gold line in that panel is an index of real commodity prices weighted by their contribution to Canadian commodity exports.[9] This index provides an inflation-corrected measure of the average US dollar price of all commodities that Canada sells to the rest of the world. Two features of the figure are worth noting. First, there is no obvious trend in the index of real commodity prices. Second, the nominal exchange rate and the real index of commodity prices are positively correlated, although less so than the nominal and real exchange rates.

5 We normalized the Canadian and US CPIs to have the same value in March 1973.

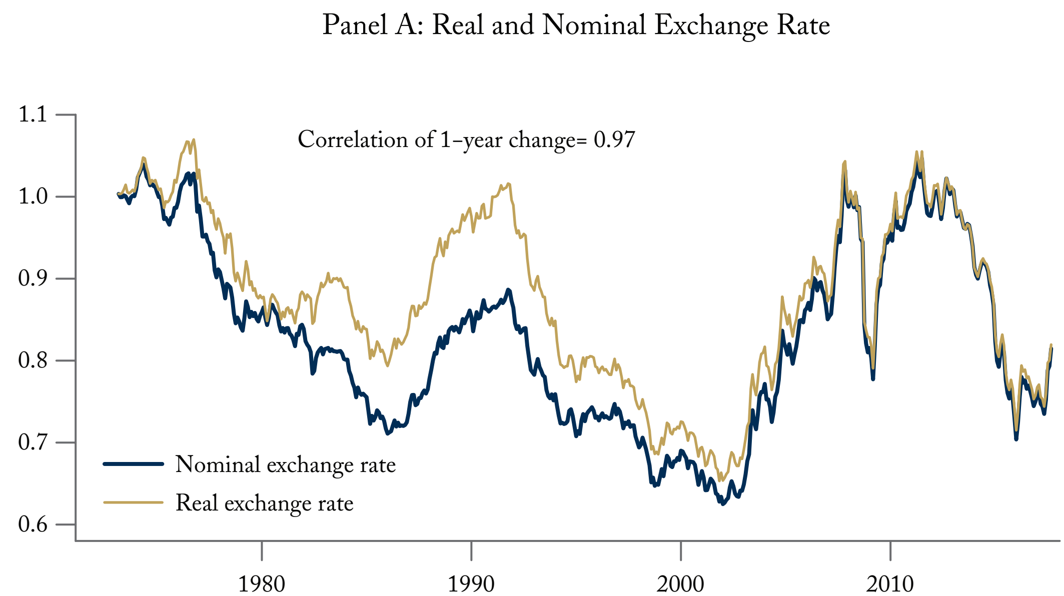
6 Johnson (1993) concludes that the real exchange rate is plausibly stationary over long periods.

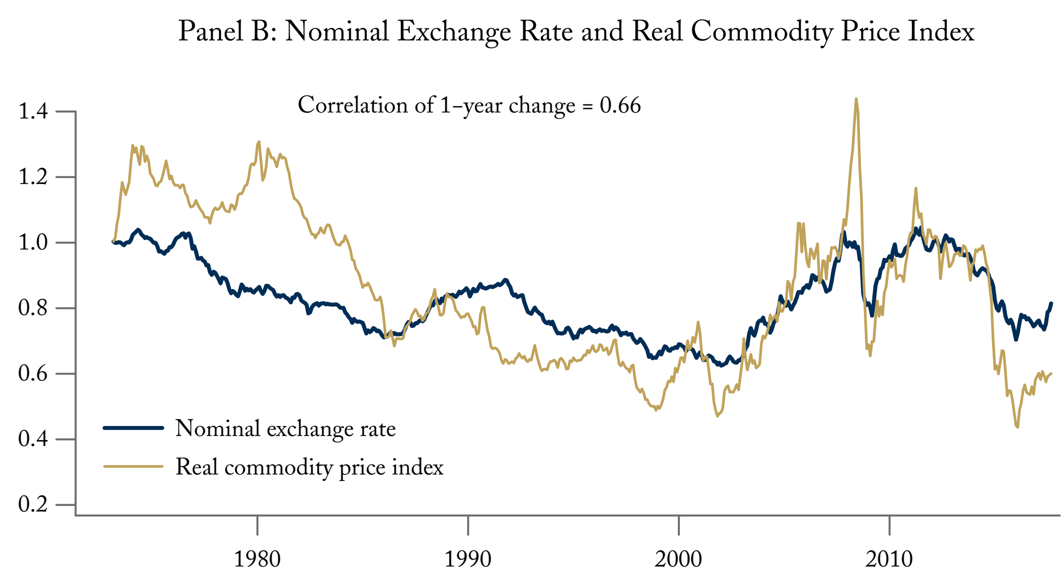
7 From March 1973 to December 1990, the average inflation rate in Canada and the United States was 7.0 percent and 6.3 percent, respectively. From January 1991 to September 2017, the corresponding rates were 1.8 percent and 2.3 percent, respectively.

8 This correlation was computed for a twelve-month moving average of inflation rates. Over the sample periods of March 1973 to December 1990 and January 1991 to September 2017, the correlation is 0.81 and 0.62, respectively.

9 The commodity price index is from the Bank of Canada, "Commodity Price Index," available online at http://www.bankofcanada.ca/rates/price-indexes/bcpi/. The Bank describes the index as "a chain Fisher price index of the spot or transaction prices in US dollars of 26 commodities produced in Canada and sold in world markets." We adjusted the index for inflation by dividing by the US CPI.

Figure 1: CAD/USD Exchange Rates and Commodity Prices, Canada, 1973–2017





Sources: Bank of Canada; International Monetary Fund, *International Financial Statistics*; and authors' calculations.

The Key Determinants of the Nominal Exchange Rate

We now turn to the key question: are there variables correlated with the nominal exchange rate that are also useful for real-time forecasting? The first candidate is the real exchange rate. This choice is motivated by the idea that the cost of consumer goods in Canada and in the United States, when measured in the same currency, should converge over time to some long-run average level. Absent non-tradable goods, the cost of consumer goods in the two countries should be the same. In the presence of non-traded goods, the overall cost of living could be different in the two countries. But since Canada and the United States have had roughly the same long-term growth rate, the ratio of the price of non-tradable goods in the two countries should be stable in the long run. So, whether non-tradable goods are important or not, the real exchange should be mean-reverting.

The previous considerations imply that, if the real exchange rate is initially high relative to its long-run average value, future changes in the nominal exchange rate should be *negative*. This is exactly the pattern that we see in the data. The left-hand panels of Figure 2 show that the real exchange rate is negatively correlated with changes in the real exchange rate at the one-, five- and ten-year time horizons. Notice that the negative correlation is stronger the longer is the horizon.

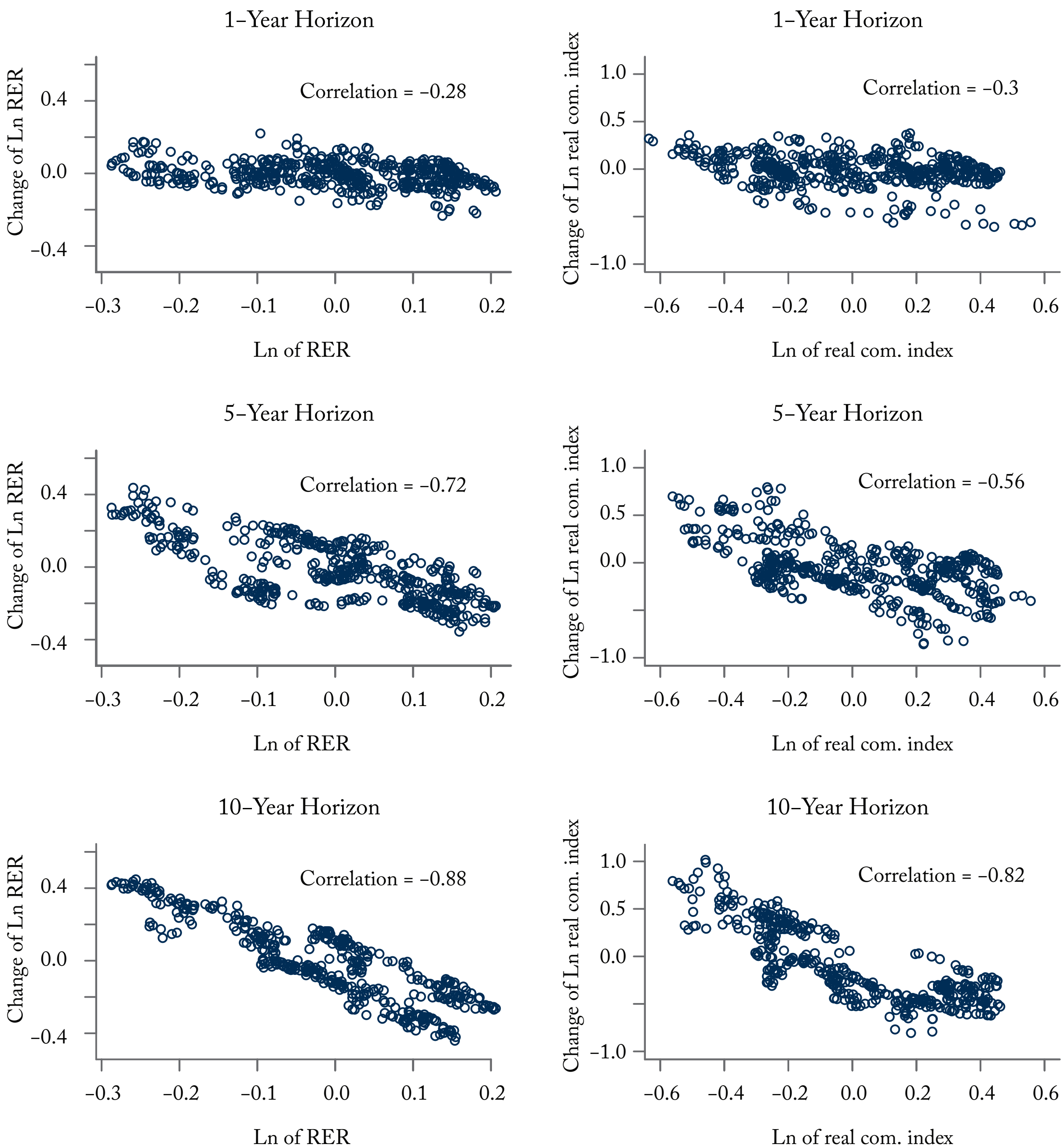
By definition, a rise in the real exchange rate must be associated with either a depreciation of the Canadian dollar or lower inflation in Canada than in the United States. To the extent that the first mechanism is operative, an unusually high real exchange rate will signal, in general, a future depreciation of the nominal exchange rate. This pattern is borne out by the data. The left-hand panels of Figure 3 display scatter diagrams of the level of the real exchange rate and the future change in the nominal exchange rate at one-, five- and ten-year time horizons. The first row of Table 1 reports the correlations between the current level of the real exchange rate and future changes in the nominal exchange rate at different time horizons. Two features are important to note. First, the correlation is negative even at the one-year horizon. Second, the negative correlation grows stronger the longer is the horizon. At the ten-year horizon, the correlation is an extraordinary: 0.96.[10] Table 1 also reports the correlation between the current level of the real exchange rate and future relative inflation rates between Canada and the United States at various time horizons. As Eichenbaum, Johannsen, and Rebelo (2017) report, this correlation is statistically insignificant at every horizon.[11] Figure 3 and Table 1 provide strong support for the view that Canada's real exchange rate is an important determinant of future changes in the nominal exchange rate.

Our results imply that the real exchange rate adjusts overwhelmingly through changes in the nominal exchange rate, not through differential inflation rates. Put another way, when consumer goods are relatively more expensive in Canada than in the United States, the nominal exchange rate eventually depreciates by enough to move the real exchange rate back to its long-run level. For intuition, it is useful to consider what would happen if inflation in Canada and the United States did not respond to shocks. In that case, the real exchange rate could move back to its long-run level only via changes in the nominal exchange rate. So long as monetary policy limits movements in inflation, the bulk of the convergence of the real exchange rate will happen through movements in the nominal exchange rate.

10 These results are robust to the sample period selected.

11 Using an early sample, Longworth, Boothe, and Clinton (1983) find that the real exchange rate is useful for explaining movements in the nominal exchange rate at time horizons up to one year.

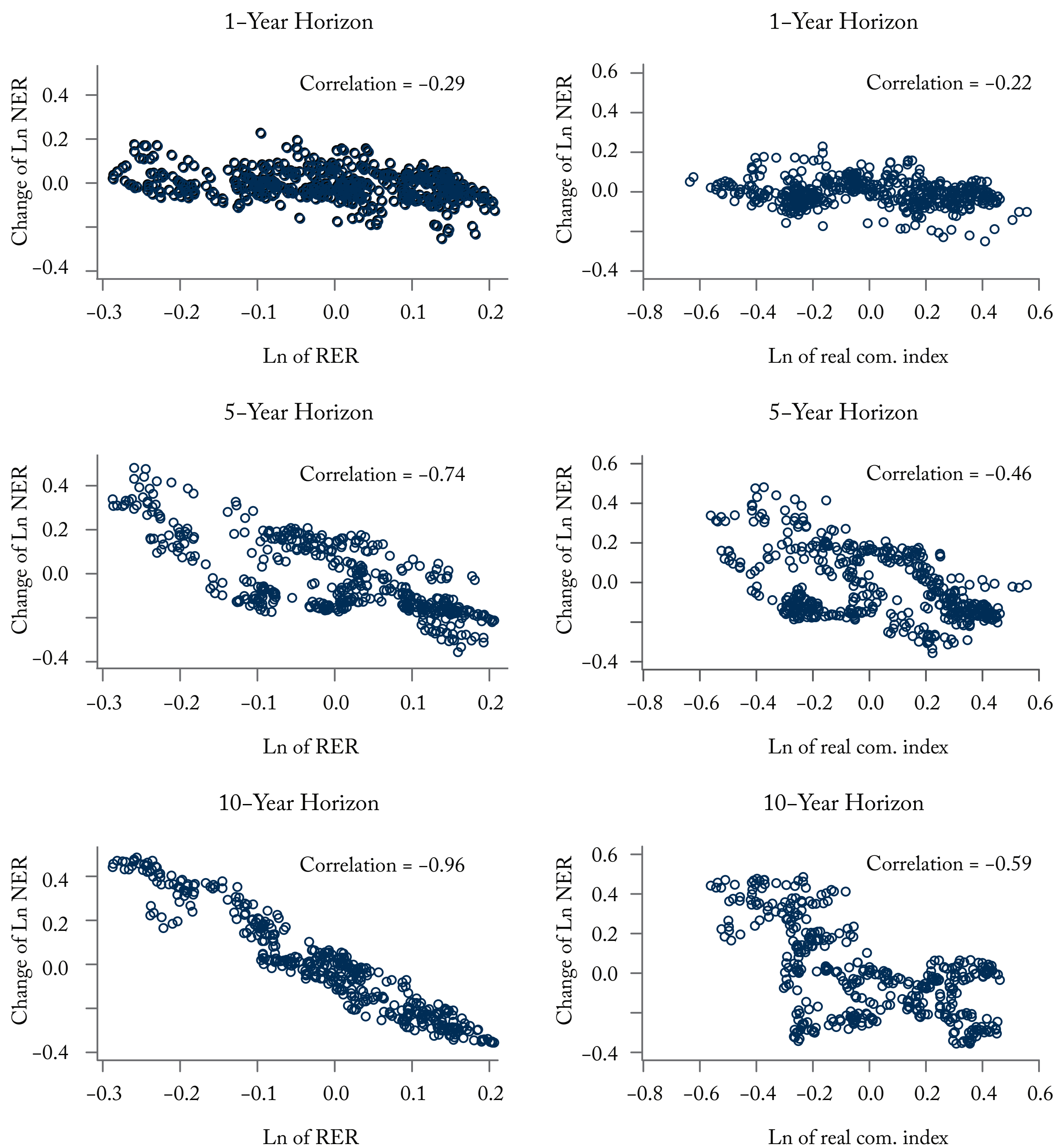
Figure 2: Values of the Real Exchange Rate and the Real Commodity Price Index, Canada, over One-, Five- and Ten-Year Time Horizons



Note: Ln is natural logarithm; RER is real exchange rate.

Sources: Bank of Canada; International Monetary Fund, *International Financial Statistics*; and authors' calculations.

Figure 3: The Real Exchange Rate, the Real Commodity Price Index and Changes in the Nominal Exchange Rate, Canada, over One-, Five- and Ten-Year Time Horizons



Note: Ln is natural logarithm; RER is real exchange rate.

Sources: Bank of Canada; International Monetary Fund, *International Financial Statistics*; and authors' calculations.

Table 1: Correlation of the Real Exchange Rate with the Future Nominal Exchange Rate and Relative Inflation Rate, Various Time Horizons

	Horizon in years				
	1	**3**	**5**	**7**	**10**
Change in Ln nominal exchange rate	-0.29	-0.57	-0.74	-0.83	-0.96
	(0.11)	(0.13)	(0.10)	(0.05)	(0.01)
Change in Ln relative prices	0.09	0.11	0.14	0.24	0.40
	(0.11)	(0.14)	(0.17)	(0.22)	(0.25)

Note: Numbers in parentheses are Newey-West (1987) standard errors computed using a number of lags equal to one year more than the horizon of the log-change in the nominal exchange rate or the relative prices.

Sources: Bank of Canada; International Monetary Fund, *International Financial Statistics*; and authors' calculations.

Canada is not unique in this pattern of adjustment: Eichenbaum, Johannsen, and Rebelo (2017) show that it holds for a large group of countries that share similar monetary policies. They also show that the results are not unique to the bilateral exchange rate with the United States, but also hold for Canada's exchange rate with Australia, Norway, Sweden and Switzerland.[12]

Now consider the potential role of Canadian commodity prices in real-time forecasting of the nominal exchange rate. As noted, the idea that commodity prices are an important determinant of that rate certainly holds sway in the popular press.[13] One simple rationale for this view is that a rise in the real price of commodities that Canada exports increases the demand for the Canadian dollar, which leads to an appreciation of the dollar. This view is consistent with the fact that the correlation between annual changes in the nominal exchange rate and real commodity prices is 0.66. So, increases in commodity prices are associated with contemporaneous appreciations of the Canadian dollar.

Recall from Figure 1 that real commodity prices do not exhibit any obvious long-term trend; so, like the real exchange rate, they revert to their long-run average. Figure 2 illustrates this pattern: a high current real value of commodity prices is associated with negative future changes in the real value of commodity prices. The strength of this negative correlation increases with the time horizon. Future declines in commodity prices signal falls in future demand for the Canadian dollar and a future depreciation of the nominal exchange rate.

The right-hand panels of Figure 2 document the co-movement of current and future changes in real commodity prices. The right-hand panels of Figure 3 show the co-movement of the current real commodity price index and future changes in the nominal exchange rate at the one-, five- and ten-year time horizons. Three features are important to note. First, in both figures, the correlations are

12 Cheung, Lai, and Bergman (2004) provide corroborating evidence for this view using a different statistical methodology.
13 See, for example, Kirby, Hutchins, and Gillis (2016). See also Bogart (2016); Sharp (2017); and Shriber (n.d.).

negative even at the one-year horizon. Second, these negative correlations grow stronger with the horizon. Third, at every horizon, the correlation between the current real commodity price index and future changes in the nominal exchange rate is weaker than the correlation between the current real exchange rate and future changes in the nominal exchange rate.

We conclude that there is substantial evidence that real commodity prices play an important role in determining the bilateral exchange rate between Canada and the United States. But the evidence regarding their importance for future movements of the nominal exchange rate is somewhat weaker than the corresponding evidence for the real exchange rate.

The Real Test: Forecasting the Nominal Exchange Rate in Real Time

As we have seen, the real exchange rate and real commodity prices are strongly negatively correlated with future changes in the nominal exchange rate. The statistical significance of these correlations does not necessarily imply that these variables are useful in real-time forecasting. That is because, in real time, forecasters do not have the full sample of data to use in estimating the statistical relationship between the real exchange rate, real commodity prices and changes in the nominal exchange rate.

To investigate the usefulness of the real exchange rate and commodity prices in real-time forecasting, we proceeded as follows. Using data from the early part of our sample (through 1990), we regressed future changes in the nominal exchange rate on the current real exchange rate. Then, as we added data points to our sample, we reran the regression and updated our estimates of the relationship between changes in the nominal exchange rate and the current real exchange rate. Given that update, we generated new forecasts for the nominal exchange rate. We repeated the process using data on real commodity prices instead of the real exchange rate.[14]

We measured the accuracy of our forecasts using a standard measure referred to as the "root mean squared prediction error" (RMSPE). This measure involves a weighted average of the forecasting errors where disproportionately more weight is given to large forecast errors. The key question is whether forecasts based on the real exchange rate outperform those based on the real commodity price index.

The dark blue line in Figure 4 displays the ratio of the RMSPE of forecasts based on the real commodity price index to the RMSPE of forecasts based on the real exchange rate. A value greater than 1 indicates that forecasts based on the real exchange rate are more accurate than forecasts based on the real commodity price index. Notice that forecasts based on the real exchange rate are roughly 5 percent more accurate than those based on the real commodity price index at the one-year horizon and 15 percent more accurate at the two-year horizon. The relative accuracy of forecasts based on the real exchange rate is even more pronounced at longer time horizons. For example, at the ten-year horizon, forecasts based on the real commodity price index are three times less accurate than forecasts based on the real exchange rate. These results establish the usefulness of the real exchange

14 Amano and van Norden (1993) discuss out-of-sample forecasting of the real exchange rate using energy prices and non-energy commodity prices; the performance of this equation is discussed by Bailliu and King (2005). We considered versions of our forecasting equation that use the energy and non-energy components of the Bank of Canada's commodity price index. Forecasts based on these measures do not outperform forecasts based on the real exchange rate.

rate relative to real commodity prices in forecasting the nominal exchange rate.[15]

A natural question is whether we should use both the real exchange rate and the commodity price index to forecast changes in the nominal exchange rate. The key tradeoff is as follows. On the one hand, adding a new variable to the forecasting equation introduces new information into the analysis. On the other hand, we must estimate how the new variable enters into the forecasting equation. In small samples, one could easily end up using coefficients that are very far from their true values. It is well known that the errors associated with the second consideration can easily lead to worse forecasts than those associated with ignoring the new variable.

To investigate this issue, we included both the real exchange rate and the commodity price index in our forecasting equation. The light gold line in Figure 4 displays the ratio of the RMSPE error of the forecasts obtained with the two variables to those based only on the real exchange rate. Notice that the gold line lies uniformly above 1. We infer that small-sample considerations dominate the new-information considerations.

Recall from Figures 2 and 3 that, compared to the real commodity price index, the real exchange rate has a tighter relationship with changes in its own future value and changes in the future value of the nominal exchange. Small-sample considerations imply that a forecaster will want to focus on either the real exchange rate or the real commodity price index. The evidence from Figures 2 and 3 provides a rationale for focusing on the real exchange rate, rather than on real commodity prices, when forecasting the nominal exchange rate.[16]

A Tougher Standard

The most demanding benchmark for measuring the accuracy of exchange rate forecasts is the no-change forecast.[17] This is the forecast associated with modelling the nominal exchange rate as a random walk with no drift. The so-called random-walk-without-drift model assumes that, at each point in time, the series merely takes a random step away from its last recorded position, with steps whose mean value is zero. Here, we show that our simple forecasts based on the real exchange rate are as accurate as no-change (or random-walk) forecasts at short time horizons and substantially more accurate at medium- and long-run horizons.[18]

The dark blue line in Figure 5 displays the ratio of the RMSPE of forecasts based on the real exchange rate to that of forecasts based on the random walk. A value greater than 1 indicates that forecasts based on the real exchange rate are more accurate than the random-walk forecasts. Two features of Figure 5 are worth noting. First, the forecasts based on the real exchange rate and random walk have essentially the same RMSPE at time horizons up to four years. For longer horizons, forecasts based on the real exchange rate are more accurate than random-walk forecasts, with the

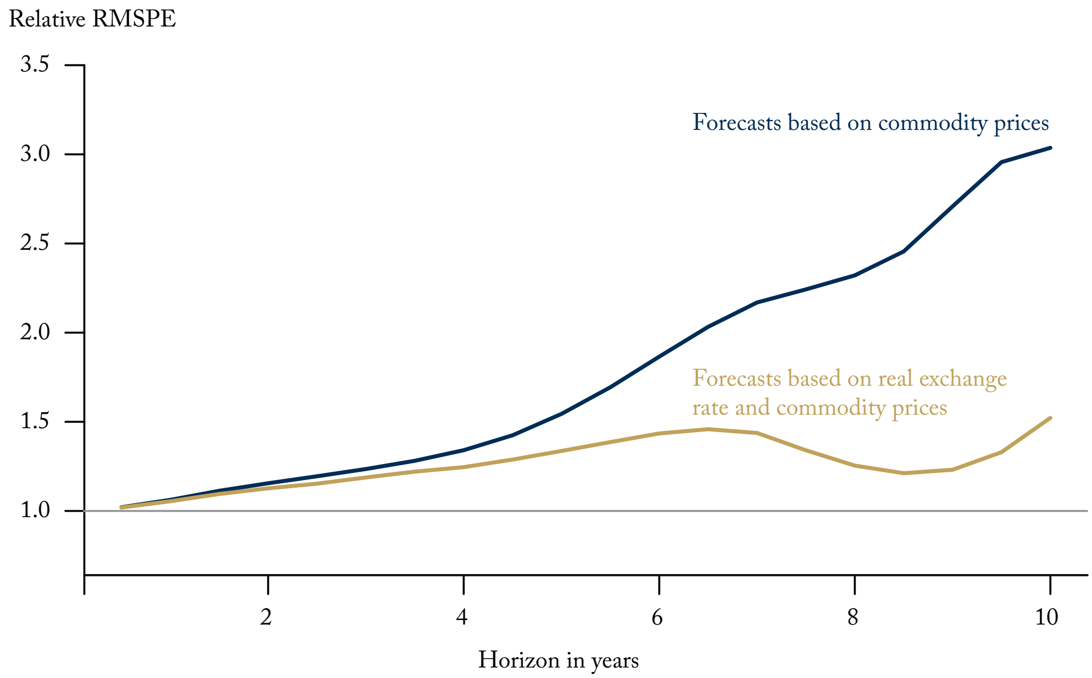
15 We re-did our out-of-sample forecasting analysis for data starting in 1983 – 10 years after our starting date for our benchmark results – and found similar results.

16 We re did our analysis using oil prices instead of commodity prices, and found that commodity prices are substantially more valuable than oil prices in helping to predict the nominal exchange rate, in the sense that using oil prices produces larger out-of-sample RMSPEs.

17 See Rossi (2013) for further discussion of the good performance of the no-change forecast relative to many models.

18 We obtained similar results when we used the core CPI rather than the headline CPI, where core CPI excludes food and energy prices but headline CPI does not.

Figure 4: Relative Root Mean Squared Prediction Error (RMSPE) of the Real Exchange Rate and Real Commodity Price Index Forecasting Equations



Sources: Bank of Canada; International Monetary Fund, *International Financial Statistics*; and authors' calculations.

relative accuracy rising dramatically with the length of the forecasting horizon.[19] At the six- and eight-year horizons, forecasts based on the real exchange rate are 25 percent and 70 percent, respectively, more accurate than random-walk forecasts. At the ten-year horizon, random-walk forecasts are 2.7 times less accurate than forecasts based on the real exchange rate.[20] Once again, the lesson is clear: for medium- and long-term forecasting, pay attention the real exchange rate.[21]

Conclusion and Policy Implications

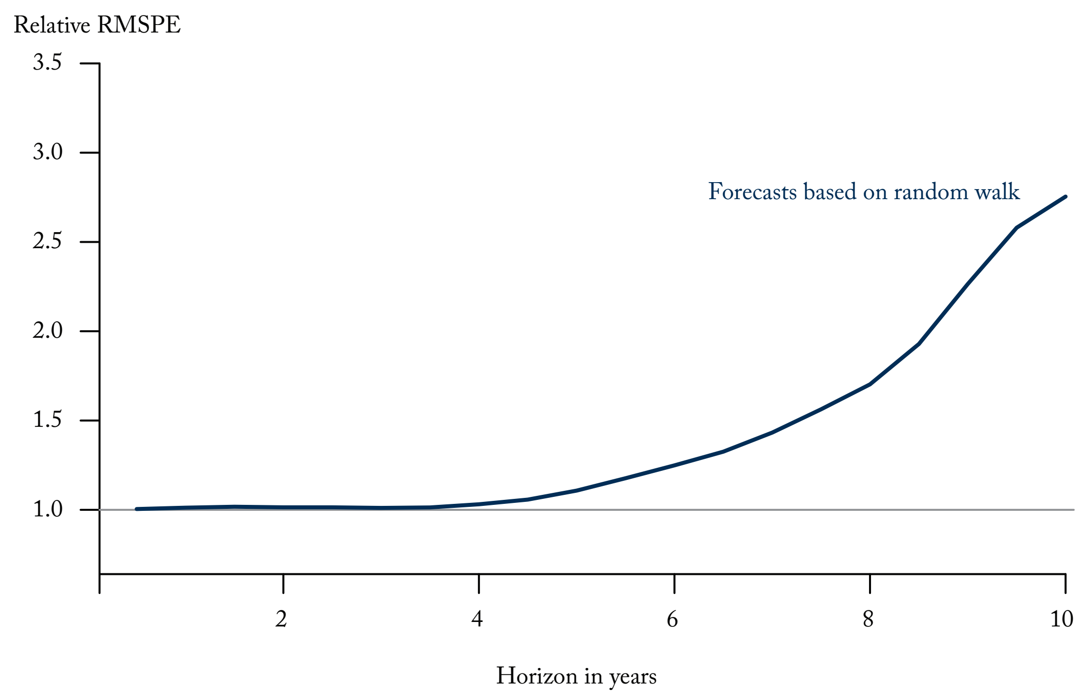
The current real exchange rate is more useful than commodity prices for forecasting changes

19 Nelson (1995) first reported results indicating that long-horizon forecasts could beat random-walk forecasts.

20 Using trade-weighted exchange rates for Canada, we found similar results at long time horizons. The similarity between results using Canada–US bilateral exchange rates and trade-weighted exchange rates potentially reflects the relatively large amount of trade between the two countries.

21 One might think that professional forecasters could improve upon the simple random-walk forecast. There is a large literature that shows that this is not the case. See, for example, Ince and Moldotsova (2017), who look at this question using data for many countries, including Canada

Figure 5: Relative Root Mean Squared Prediction Error (RMSPE) of the Real Exchange Rate and Random-Walk Predictions



Sources: Bank of Canada; International Monetary Fund, *International Financial Statistics*; and authors' calculations.

in the nominal exchange rate. In fact, short-run forecasts based on the real exchange rate are as good as random-walk forecasts. More important, medium- and long-run forecasts based on the real exchange rate are superior to random-walk forecasts. These findings reflect two facts. First, Canada's real exchange rate with the United States is mean-reverting – that is, when the real exchange rate is high, it tends to fall to its long-run average. Second, the current real exchange rate displays a tight negative correlation with future values of the Canadian dollar relative to the US dollar.

We suspect that the explanation for the first fact is that the shocks driving the real exchange rate are not permanent in nature. A non-exhaustive list of such shocks includes movements in commodity prices, changes in government spending and temporary shocks to the US economy. The explanation for the second fact is that Canadian and US monetary policies are similar in their broad contours in that both countries use a short-term interest rate to control inflation and do not explicitly manage the exchange rate. As a result, there have not been persistent changes in the relative price levels of the two countries. As Eichenbaum, Johannsen, and Rebelo (2017) stress, under these circumstances the only way for the real exchange rate to adjust in response to shocks is via current and future movements in the nominal exchange rate.

A fundamental question is whether policymakers are satisfied with the current policy regime. A cost of the current regime is that it allows for very volatile nominal and real exchange rates. A benefit is that consumers and firms can mostly avoid the type of potentially costly changes in prices and wages that would be required if the nominal exchange rate did not adjust in a flexible manner. In this *Commentary*, we have taken no stand on the merits of the current regime; instead, we have aimed to help clarify the tradeoffs that policymakers face. Evaluating the costs and benefits of those tradeoffs should play an important role in the process leading to the Bank of Canada's next five-year agreement with the government.

APPENDIX: OUT-OF-SAMPLE FORECASTING

To construct out-of-sample forecasts, we used data from March 1973 through the period in which we made the forecast to estimate the following regression equation:

$$\ln\left(\frac{NER_{t+j}}{NER_t}\right) = \beta_{t,0} + \beta_{t,1}\ln\left(RER_t\right),$$

where t indicates the period in which we made the forecast, *j* is the horizon of the forecast of the nominal exchange rate (NER) and ln is the natural logarithm of the data. With estimates of $\beta_{(t,0)}$ and $\beta_{(t,1)}$, we were able to produce a forecast for the change in the NER using the current value of the real exchange rate (RER). We denote this forecast $f^{RER}_{t,t+j}$.

We computed the root mean squared prediction error in the following way. For each date *t* on which we made a forecast, we computed the forecast error, which is given by

$$\log\left(\frac{NER_{t+j}}{NER_t}\right) - f^{RER}_{t,t+j}.$$

We raised the forecast error to the power 2, so that positive and negative forecast errors were treated symmetrically and large forecast errors more-heavily penalized. We then averaged these squared forecast errors over the sample in which we made predictions, and took the square root of the average for comparison across models:

$$\left[average\left(\left[\log\left(\frac{NER_{t+j}}{NER_t}\right) - f^{RER}_{t,t+j}\right]^2\right)\right]^{1/2}.$$

We then constructed these root-mean-squared-prediction errors for different horizons, *j*.

To construct out-of-sample forecast errors using the commodity price index, we estimated the regression equation

$$\log\left(\frac{NER_{t+j}}{NER_t}\right) = \beta_{t,0} + \beta_{t,1}\log\left(COM_t\right),$$

where COM_t is the real commodity price index. We then constructed forecasts and forecast errors in a way analogous to that of the RER. To construct out-of-sample forecast errors using the RER and the commodity price index, we estimated the regression equation

$$\log\left(\frac{NER_{t+j}}{NER_t}\right) = \beta_{t,0} + \beta_{t,1}\log\left(RER_t\right) + \beta_{t,2}\log\left(COM_t\right)$$

and then constructed forecasts and forecast errors in a way analogous to that of the other cases. To construct out-of-sample prediction errors using the random-walk forecast, we computed the forecast error as

$$\log\left(\frac{NER_{t+j}}{NER_t}\right),$$

since the random walk implies a no-change forecast. Note that this is equivalent to setting $\beta_{(t,0)} = \beta_{(t,1)} = \beta_{(t,2)} = 0$ in the other specifications.

To compare out-of-sample forecasting performance and horizon j, we took the ratio of the RMSPE from the different models to the RMSPE of the model that uses only the RER. A ratio larger than 1 indicates that the average squared prediction error is larger than in the model that uses only the RER, meaning that the model using only the RER performs better at that time horizon.

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