Session 2:
The Role of the Exchange Rate in Adjustment and Integration

Shocks Affecting Canada and the United States and the Flexible Exchange Rate's Contribution to Macroeconomic Adjustment

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Introduction

Several recent studies have used structural vector-autoregression (VAR) models to analyze the determination of the Canada-U.S. exchange rate. Clarida and Galí (1994), for example, use a model of the Mundell-Fleming-Dornbusch type to identify supply shocks, real demand shocks, and monetary shocks in a VAR formulation including the real production differential, the real exchange rate, and the consumer price differential. The authors find that real demand shocks explain the bulk of the variation in the Canada-U.S. exchange rate for all time horizons.

In an examination of whether Canada and the United States constitute an optimal currency area,[1] Dupasquier, Lalonde, and St-Amant (1997) use VAR models including real production, inflation rates, and interest rates (in levels rather than in differences) to identify real and monetary supply and

1. Bayoumi and Eichengreen (1993); Racette, Raynauld, and Lalonde (1993); DeSerres and Lalonde (1994); and Lalonde and St-Amant (1995) also use structural VARs to determine whether North America constitutes an optimal currency area.

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demand shocks. Like Clarida and Galí, they find that real demand shocks account for most of the variation in the Canada-U.S. exchange rate. They further conclude that exchange rate flexibility promotes macroeconomic adjustment.[2] This conclusion follows from the fact that the reaction functions they estimate imply that real exchange rate adjustments to various shocks are primarily transmitted over changes in nominal exchange rates rather than over changes in the relative price levels of two countries. In a fixed exchange rate regime, this realignment must occur over price-differential adjustments, creating disequilibrium in both labour and goods and services markets, assuming the standard macroeconomic framework with price rigidity.[3]

Another group of researchers emphasize commodity prices (energy and non-energy) as explanatory factors in the evolution of the real Canada-U.S. exchange rate. In particular, Amano and van Norden (1993) conclude that one can explain variations in this rate using a model with a cointegrating relationship between the exchange rate and commodity prices. McCallum (1999) and Djoudad and Tessier (2000) arrive at the same conclusion using somewhat different models. Murray, Zelmer, and Antia (2000) argue that these results support flexible exchange rate regimes, since they reflect the influence of fundamental factors rather than speculative bubbles.

These studies raise at least two questions. First, what type of shock dominates when commodities are added to the factors identified by Clarida and Galí? Second, can we always conclude, as do Dupasquier, Lalonde, and St-Amant, that the nominal exchange rate's reaction facilitates macroeconomic adjustment to shocks with asymmetric effects on Canada and the United States when commodity prices are included in the estimated models?

To answer these questions, we incorporate the variables used by Amano and van Norden into the structural VAR model of Clarida and Galí. Contrary to our expectations, our tests show little empirical support over the sample period for the cointegrating relationship identified by Amano and

2. Rose (1995) evaluates the contribution of the exchange rate to macroeconomic adjustment on the basis of models, using panel data from several countries. He concludes that there is no empirical evidence to support the claim that flexible exchange rates promote this adjustment. Osakwe and Schembri (1999) compare estimates of the conditional variance in Mexican real GDP under the historical regime of a managed float and under a hypothetical flexible exchange rate regime approximated by an adjusted parallel market rate. They conclude that fluctuations in real GDP would have been reduced had Mexico's exchange rate floated since the 1970s.

3. It is possible that in a fixed exchange rate regime or in a monetary union, agents adjust their behaviour so that prices become less rigid. However, we are not aware of any study having concluded that adopting a fixed exchange rate or joining a monetary union has, in fact, engendered any significant changes along these lines.

van Norden. Nonetheless, we consider two scenarios—with and without cointegration—for two reasons. First, the capacity of the tests to distinguish between the presence and absence of cointegration is uncertain. Second, several authors have concluded that the assumption of a cointegrating relationship is valid. Our reference model excludes cointegration between the variables, but the inclusion of the broader information set makes it more compatible with tests for cointegration. Our alternative scenario uses the approach proposed by King et al. (1991) to model a cointegrating relationship between commodity prices and the real exchange rate.

Our models allow us to re-examine the relative contribution of various shocks in explaining variations in the real Canada-U.S. exchange rate. Moreover, we are able to evaluate the robustness of the results obtained by Dupasquier, Lalonde, and St-Amant, that flexible exchange rates promote macroeconomic adjustment.[4]

In addition, our models enable us to address several other questions. For example, they allow us to estimate the relative contribution of nominal shocks to variations in the real exchange rate. Since the models also include the real Canada-U.S. GDP differential, we are able to isolate its determinants as well.

In section 1 of this paper, we describe the approaches recommended by Clarida and Galí and Amano and van Norden. In section 2, we define and analyze our data. We explain our methodological approach in section 3 and our results in section 4. The final section concludes and suggests directions for further research.

1 Clarida and Galí's Approach and the Bank of Canada's Exchange Rate Determination Model

1.1 Clarida and Galí

To identify different types of shocks, Clarida and Galí (1994) use a theoretical two-country model of the Mundell-Fleming-Dornbusch type to construct a VAR specification with the following variables: the real GDP differential, the real exchange rate computed using consumer price indexes (CPIs), and CPI differentials. They demonstrate that the theoretical model can be arranged to show that, in long-term equilibrium, only supply shocks have an impact on the relative real GDP levels of the two countries, and that only real supply and demand shocks affect the level of the real exchange

4. Our work can also be considered as a response to Raynauld's (1997) comments on the paper by Dupasquier, Lalonde, and St-Amant. Raynauld emphasized that it would be of interest to explicitly account for commodity prices in the estimation of these models.

rate. These predictions of the theoretical model ensure identification of VAR models estimated for various country pairs.

For each country pair considered, the models thus constructed present the first difference of the real GDP differential, the real exchange rate, and the CPI differential as responding to three types of structural shocks: supply shocks, ε^s; real demand shocks, ε^d; and monetary shocks, ε^m. Wold's decomposition theorem allows us to write the structural model in the following form (the constant has been omitted for simplification):

$$x_t = A_0\varepsilon_t + A_1\varepsilon_{t-1} + \ldots = \sum_{i=0}^{\infty} A_i\varepsilon_{t-i} = A(L)\varepsilon_t, \tag{1}$$

where $\varepsilon_t = \begin{bmatrix} \varepsilon_t^s \\ \varepsilon_t^d \\ \varepsilon_t^m \end{bmatrix}$ and $x_t = \begin{bmatrix} \Delta y \\ \Delta rer \\ \Delta p \end{bmatrix}$.

y represents the differential of real GDP in logs, rer the real exchange rate, and p the differential of the price level in logs. To simplify, the variance of the structural shocks is normalized to $E(\varepsilon_t\varepsilon_t') = I$, the identity matrix.

The following autoregressive vector is estimated for each pair of countries considered:

$$x_t = \Pi_1 x_{t-1} + \ldots + \Pi_q x_{t-q} + e_t, \tag{2}$$

where e_t is an estimated vector of residuals, q is the number of lags, and $E(e_t e_t') = \Sigma$. This process is then inverted to yield the following moving-average representation:

$$x_t = e_t + C_1 e_{t-1} + \ldots = \sum_{i=0}^{\infty} C_i e_{t-i} = C(L)e_t. \tag{3}$$

The residuals of the reduced form are related to those of the structural model by:

$$e_t = A_0\varepsilon_t. \tag{4}$$

Equations (1), (3), and (4) can be solved to show that the matrix of long-term effects of the reduced form, $C(1)$, is related to the matrix of long-term effects of the structural form, $A(1)$, as follows:

$$A(1) = C(1)A_0. \tag{5}$$

To complete identification of the system, Clarida and Galí impose three restrictions on the matrix $A(1)$, reflecting the predictions of their theoretical model, yielding:

$$A(1) = \begin{bmatrix} a_{11} & 0 & 0 \\ a_{21} & a_{22} & 0 \\ a_{31} & a_{32} & a_{33} \end{bmatrix}. \tag{6}$$

The first, second, and third columns of the matrix $A(1)$ represent the impact of supply shocks, demand shocks, and monetary shocks, respectively, on the real GDP differential (first row), the real exchange rate (second row), and the price-level differential (third row). The zeros in the first row indicate that real demand shocks and monetary shocks do not have a long-term impact on the GDP differential. The zero in the second row of $A(1)$ indicates that monetary shocks do not have a long-term impact on the real exchange rate.

The following predictions also follow from Clarida and Galí's theoretical model, when prices are assumed rigid in the short term but flexible in the long term.

- In the short and long term, the currency of a country affected by a positive supply shock depreciates in real terms.[5] In the short term, it depreciates in real terms subsequent to a monetary shock, and it appreciates in the short and long term in response to a positive real demand shock.
- The CPI of a country affected by a positive real demand or monetary shock progressively rises relative to that of the other country, but it declines subsequent to a positive supply shock.
- A supply shock, a real demand shock, or a monetary shock in a given country induces a short-term increase in production relative to the other country.

The empirical results obtained by Clarida and Galí correspond to their theoretical expectations. In the case of Canada and the United States, one of their conclusions is that variations in the exchange rate are dominated by

5. Conversely, the Balassa (1964) and Samuelson (1964) model predicts that, under certain assumptions, a positive supply shock will result in a currency appreciation.

real demand shocks.[6] They also find that supply shocks account for the largest share of the variance in the real GDP differential between the two countries. We re-evaluate these conclusions using richer models.

1.2 A model of exchange rate determination used by the Bank of Canada

Some economists at the Bank of Canada use a model of exchange rate determination derived from the work of Amano and van Norden (1993). This model is written:

$$\Delta \ln(rer)_t = \alpha(\ln(rer)_{t-1} - \beta_0 - \beta_c c_{t-1} - \beta_o o_{t-1}) + \Upsilon r_{t-1} + \varepsilon_t, \qquad (7)$$

where the variables o and c, respectively, represent the price of energy and the price of non-energy commodities expressed in U.S. dollars and are deflated using the implicit GDP index for the United States. The variables in parentheses constitute a cointegrating relationship.[7] Actions of Canadian and U.S. monetary authorities are incorporated via r, the short-term Canada-U.S. interest rate differential.

Equation (7), which explains the principal fluctuations in the Canada-U.S. exchange rate, remained stable throughout the 1990s.[8] McCallum (1999) and Djoudad and Tessier (2000) include further variables in the models of Canada-U.S. exchange rate determination they estimate. However, at the centre of their models, we also find a long-term relationship between the real exchange rate, the price of energy, and the price of non-energy commodities.

2 The Data

2.1 Definitions and sources

We simultaneously incorporate the variables retained by Clarida and Galí and those in the exchange rate determination model represented by equation (7). We consider the following series:

- the Canada-U.S. real GDP differential in logs, y_t.
- the Canada-U.S. real CPI differential in logs, p_t.

6. The U.K.-U.S. country pair is the only other one for which they find this dominance of real demand shocks. Rogers (1999) re-evaluates that conclusion for the U.K.-U.S. pair using models that incorporate more variables. His approach is very different from the one we use here (accounting for neither commodity prices nor cointegrating relationships).
7. The cointegrating relationship doesn't hold when no distinction is made between the price of energy and that of non-energy commodities.
8. A recent evaluation can be found in Djoudad and Tessier (2000).

- the real exchange rate computed using the two countries' CPIs, rer_t. An increase in this series implies that fewer Canadian dollars are required to buy one U.S. dollar.
- the short-term interest rate differential, which we measure as the gap between the Canadian overnight rate and the federal funds rate, r_t.
- price indexes for non-energy commodities, c_t, and for energy, o_t. These series are expressed in U.S. dollars and deflated using the implicit GDP index for the United States.

The real Canadian GDP, the Canadian implicit GDP index, the federal funds rate, and commodity price indexes were provided by Statistics Canada. OECD data yielded the CPIs for the two countries. The implicit GDP deflator and real GDP for the United States were obtained from Data Research Incorporated (DRI). The overnight-rate series were from the Bank of Canada. The nominal exchange rate data were provided by the International Monetary Fund.

Our data are quarterly and cover the period subsequent to the collapse of the Bretton Woods system: from the first quarter of 1973 until the fourth quarter of 1999.

The above-mentioned series are reproduced in levels in Appendix 1.

2.2 Unit-root tests

Table A2.1 (Appendix 2) contains the results of several tests for a unit root applied to various series. These tests clearly indicate that the price of energy, the CPI differential, and the real exchange rate are non-stationary.[9] Most tests indicate that the price of non-energy commodities and the real GDP differential are non-stationary, but that the interest rate differential is stationary. We incorporate the corresponding assumptions into our model. Clarida and Galí and the exchange rate determination model of the Bank of Canada make the same assumptions.

2.3 Tests for cointegration

Johansen's (1991) tests for cointegration applied to the system $\{c, o, y, e, p, \Sigma r\}$ are presented in Table 1. We include the interest rate differentials (Σr) cumulatively rather than in levels, because this variable is stationary in levels. Note, however, that this variable is not significant in the

9. Some authors have concluded that the real exchange rate is stationary when considered over a very long time period. However, Engel (1996) shows that this result does not hold when certain biases in the tests are accounted for.

Table 1
Tests for cointegration

	λ-max test			Trace test		
H_0	Stat.	Corrected stat.[a]	90% critical value	Stat.	Corrected stat.	90% critical value
$p = 0$	45.90	29.04	37.45	141.34	89.42	97.18
$p \leq 1$	33.99	21.51	31.66	95.45	60.38	71.86
$p \leq 2$	25.07	15.86	25.56	61.45	38.88	49.65
$p \leq 3$	14.53	9.19	19.77	36.39	23.02	32.00
$p \leq 4$	12.12	7.67	13.75	21.86	13.83	17.85
$p \leq 5$	9.73	6.16	7.53	9.73	6.16	7.53

a. Here we have applied a small-sample correction by replacing *T* with *T–nm*, where *T* is the number of observations, *n* the number of variables, and *m* the number of lags. For more information, see Reinsel and Ahn (1988).

postulated cointegrating vector and thus only comes into play in levels (as opposed to cumulatively) in the estimated models. Moreover, omitting this variable does not change the results of the tests for cointegration on a qualitative level.

The number of lags, five, was determined by applying a likelihood-ratio test to an approach in which the generality of the model was progressively reduced. The critical values of the tests for cointegration were obtained from Osterwald-Lenum (1992).

We cannot reject the presence of two cointegrating vectors on the basis of the uncorrected λ-max test. Nonetheless, we conclude that all the variables are stationary on the basis of the uncorrected trace test. We reject this scenario, since it is incompatible with the results of our unit-root tests. Tests corrected to account for small-sample bias, on the other hand, allow us to reject any cointegration.[10] Since these tests are designed to be most reliable with small samples, results supporting cointegration are weak. Since the strength of these tests remains unknown, we also consider a scenario with

10. We performed a variety of robustness tests. For example, we tested for cointegration using models containing one or two more or fewer lags, and on time series beginning a little earlier or a little later than the sample period of the reference scenario. In the majority of cases, we were unable to reject the assumption of non-cointegration on the basis of corrected tests. We repeated these tests using only the variables included in equation (7). Again, in the vast majority of scenarios, we were not able to reject the assumption of non-cointegration. Consequently, this result does not seem to depend on the fact that our model incorporated more variables than that of Amano and van Norden (1993).

cointegration. Considering the results of our tests for cointegration, however, we make the case of no cointegration our reference scenario.

A rolling-regression-type stability test applied to the cointegrating vectors identified using the uncorrected λ-max reveals that the first vector is unstable. We cannot reject the null hypothesis that the coefficients of the following variables in the retained cointegrating vector are zero: price differential, real GDP differential, and cumulative interest rate differential (type-one risk = 0.1124). The restricted vector can thus be expressed as follows when we normalize the cointegrating relationship on the exchange rate:

$$rer_t = 0.403 - 0.057 o_t + 0.385 c_t . \qquad (8)$$

Consequently, it is with some difficulty that we identify the cointegrating vector included in the exchange rate equation used by the Bank of Canada.[11] This is the vector we integrate into the model for the scenario with cointegration.[12]

3 Our Methodology

3.1 Model with commodity prices but without cointegration

The VAR model includes the price of energy, the price of non-energy commodities, the real GDP differential, the real exchange rate, the CPI differential, and the interest rate differential. Thus, we assume a structural model responsive to six types of shocks: energy-price shocks, ε^o; non-energy commodity-price shocks, ε^c; supply shocks, ε^s; real demand shocks, ε^d; monetary shocks, ε^m; and transitory shocks, ε^t (shocks having no permanent impact on any of the variables except the cumulative interest rate). These shocks, the first difference of the variables considered in the estimated stationary VAR, and the postulated matrix $A(1)$, can be written as follows:

11. The coefficients generated by that vector have the same sign and are of the same order of magnitude as those obtained from models with fewer variables.

12. Nonetheless, we believe that in future work it would be worthwhile to undertake a more detailed examination of the other cointegrating vector.

$$\varepsilon_t = \begin{bmatrix} \varepsilon_t^o \\ \varepsilon_t^c \\ \varepsilon_t^s \\ \varepsilon_t^d \\ \varepsilon_t^m \\ \varepsilon_t^t \end{bmatrix}, \; x_t = \begin{bmatrix} \Delta o \\ \Delta c \\ \Delta y \\ \Delta rer \\ \Delta p \\ \Delta r \end{bmatrix}, \; A(1) = \begin{bmatrix} a_{11} & 0 & 0 & 0 & 0 & 0 \\ a_{21} & a_{22} & 0 & 0 & 0 & 0 \\ a_{31} & a_{32} & a_{33} & 0 & 0 & 0 \\ a_{41} & a_{42} & a_{43} & a_{44} & 0 & 0 \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} & 0 \\ a_{61} & a_{62} & a_{63} & a_{64} & a_{65} & a_{66} \end{bmatrix}.$$

It is worth noting that, as in Clarida and Galí, the identification restrictions pertain to the levels of the variables. We assume, therefore, that no shock, except a shock to the energy price, can have an impact on the energy price in the long term (the five zeros in the first row of $A(1)$). We further assume that, in the long run, shocks to the price of energy are the only ones to affect the price of non-energy commodities. We justify this ordering of o relative to c by the fact that energy is an important input into the production of many commodities, and may thus affect their long-term price. Nonetheless, we test the sensitivity of our results with respect to this assumption. The ordering of the other variables corresponds to that used by Clarida and Galí.

We also identify a transitory shock (sixth column) as one whose long-term impact is nil on all of the variables except the cumulative interest rate (sixth row). This could be a demand shock that differs from other demand shocks in that it has no long-term effect on either the real exchange rate or on the price differential. It could also be a shock reflecting the intrinsic volatility (not connected to fundamental factors) of the affected series.

3.2 Expanding the Clarida-Galí model to include a cointegrating vector

The variables we deal with here are the same as those presented in section 3.1. However, we now incorporate the following cointegrating relationship:

$$e_t = \beta + \beta_c c_t + \beta_o o_t . \tag{9}$$

We use the methodology described by King et al. (1991), which consists of combining the prior identification restrictions with the empirical cointegration restrictions to identify reduced-form equations. The procedure is presented in Appendix 3.

Since we have one cointegrating relationship and five non-stationary variables, four permanent shocks must be identified. The permanent components of the model and the reaction functions are identified by imposing a structure on the matrix of long-term multipliers. The specific structure of this matrix is as follows:

$$A = \tilde{A}\Pi = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ \beta_c & \beta_o & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \pi_{11} & 0 & 0 & 0 \\ \pi_{21} & \pi_{22} & 0 & 0 \\ \pi_{31} & \pi_{32} & \pi_{33} & 0 \\ \pi_{41} & \pi_{42} & \pi_{43} & \pi_{44} \end{bmatrix} = \begin{bmatrix} \pi_{11} & 0 & 0 & 0 \\ \pi_{21} & \pi_{22} & 0 & 0 \\ \pi_{31} & \pi_{32} & \pi_{33} & 0 \\ \omega_{41} & \omega_{41} & 0 & 0 \\ \pi_{41} & \pi_{42} & \pi_{43} & \pi_{44} \end{bmatrix}.$$

The first, second, third, fourth, and fifth rows of the matrix A represent the long-term impact of shocks on o, c, y, e, and p, respectively. No shock has a long-term effect on the interest rate differential, r, since it is stationary. Various shocks may, however, have a short-term impact on this variable.

The first, second, third, and fourth columns of A represent the long-term impact on the variables of energy-price shocks, non-energy commodity-price shocks, supply shocks, and demand shocks, respectively. As in the case of models that do not incorporate cointegration, but do include commodity prices, we assume that the other shocks have no long-term impact on the price of energy (three zeros in the first row of Π) and that only the price of energy can have a long-term effect on the price of non-energy commodities (two zeros in the second row).

As in Clarida and Galí, supply shocks differ from demand shocks in that only the former result in a long-term change in production (the zero in the third row). In the long run, demand shocks only affect the price differential (three zeros in the fourth column).

We further observe that the estimated cointegrating relationship (as reflected in the matrix A) implies that only shocks to the prices of energy and of non-energy commodities can have a long-term effect on the real exchange rate. Thus, we cannot distinguish real from nominal demand shocks, unlike in the scenario without cointegration, since the cointegrating vector prevents us from identifying demand shocks having a long-term impact on the real exchange rate. What we are left with, therefore, is a combination of these two types of shock.

In addition to shocks having a permanent effect on the variables, we have two transitory shocks whose impact we sum since they are indistinguishable from an economics perspective.[13] As in the case of the transitory shock we

13. It is, however, possible to distinguish between them from an econometric perspective, since one has a long-term impact on the cumulative interest rates and the other does not.

saw in section 3.1, we may be dealing with demand shocks with a purely transitory impact on all variables, or with shocks reflecting the intrinsic volatility of the series.

4 Results

To facilitate the comparison of our results with those of Clarida and Galí, we begin by updating their estimates. In the second step, we present detailed results for the model with commodity prices and without the cointegrating relationship. We consider this our reference model, since it is more compatible with the tests for cointegration. Next, we present the results of the model including a cointegrating relationship between commodity prices and the real exchange rate. Finally, we provide some robustness tests.

Our principal results are presented with 90 per cent confidence intervals, which we compute using a bootstrap-type resampling method of 1,000 draws. All figures show the percentage change in the series (0.10 = 10 per cent). The horizontal axis represents the number of quarters.

4.1 Update of Clarida and Galí

Clarida and Galí's sample, which also uses quarterly data, is considerably shorter than our own, since it ends in the first quarter of 1992 and begins at the same time as ours. Nevertheless, we obtain results that are virtually identical to theirs. In particular, the reaction functions correspond to the theoretical expectations described in section 2.1. We do not present these reaction functions, but they are available on request.

One important result obtained by Clarida and Galí (and by Dupasquier, Lalonde, and St-Amant 1997), is that variation in the Canada-U.S. exchange rate is explained primarily by real demand shocks. Moreover, the authors find that supply shocks explain a large share of the variance in the GDP differential between the two countries. We obtain the same result from our update of their estimates (also available on request).

The results for supply shocks, real demand shocks, and monetary shocks, presented in section 4.2, are very similar to those generated by the Clarida and Galí model.

4.2 The model with commodity prices and without cointegration

In this section, we incorporate commodity prices into the Clarida and Galí model. What is the expected response of the variables to positive price shocks on commodities? Given that such shocks imply an improvement in Canada's terms of trade (Canada being a net exporter of commodities), they also indicate an improvement in Canadians' relative wealth. Consumption and production are thus both expected to increase relative to the United States (a net importer of commodities). Moreover, the real exchange rate should appreciate since Canada will subsequently be able to attain a desired level of foreign indebtedness by reducing the volume of net exports.[14]

4.2.1 Reaction functions

The figures in Appendix 4 reveal the response of the real GDP differential and of the interest rate differential to the various shocks. Energy and commodity price shocks cause increases in these values by about 8 per cent and 4 per cent, respectively.

As anticipated, shocks to the prices of non-energy commodities and energy have a positive impact on Canada's relative real GDP. However, this effect is weak and not statistically significant. The response of production to the other shocks is very similar to that found by Clarida and Galí. Thus, shocks to supply, real demand, and money drive up relative production in Canada. However, of these three types of shocks, only the supply shock has a long-term impact on the real GDP differential (by construction).

The reaction of the interest rate differential to the various shocks we have identified is weak and not significant. The only exception is the case of the transitory shocks, which drive up the interest rate. These shocks also tend to result in a slight increase in production and prices in the short term. We suspect that these are positive demand shocks to which monetary authorities respond by tightening the money supply to neutralize their impact on the price level.

Here, we are particularly interested in the effect of the various shocks on the real exchange rate, on the nominal exchange rate (which we compute from the response of the price differential and the real exchange rate to various shocks), and on the price differential. As mentioned, these reactions allow us to determine whether the flexibility of the Canada-U.S. exchange rate has facilitated the adjustment of the real exchange rate to shocks. The figures in Appendix 5 illustrate these reaction functions. The reaction functions for the three variables are placed together on one page, while those for price and exchange rate differentials occupy two pages.

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14. Macklem (1992, 1993) obtains these results in the framework of a dynamic general-equilibrium model of an economy producing three types of goods and with overlapping generations. The long-term implications for production and the exchange rate are ambiguous in this setting, however, because of the movement of factors between the sectors.

Clearly, the reaction functions for the real exchange rate and prices are as expected. Thus, subsequent to a positive supply shock, the real exchange rate depreciates and prices fall in Canada relative to the United States.[15] The opposite result obtains in the case of a shock to real demand and to the price of non-energy commodities. A monetary shock produces a real depreciation in the short term only, but a nominal depreciation in both the short and the long term (though these responses are not statistically significant).

A shock to the price of energy induces a depreciation of the real exchange rate. This result may seem surprising, but it corresponds precisely to the findings of Amano and van Norden and others. However, we observe that this reaction is not statistically significant.

We further observe that, in all cases, adjustment of the nominal exchange rate facilitates the adjustment of the real exchange rate. For example, after a supply shock, the real exchange rate depreciates (as predicted by Clarida and Galí's theoretical model). This real depreciation is almost entirely explained by a nominal depreciation. In the case of a shock to real demand, the real exchange rate appreciates, and again most of this adjustment occurs over the nominal exchange rate. In most cases, the reaction of the real exchange rate cannot be distinguished statistically from that of the nominal exchange rate. Usually, except in the case of a real demand shock and a monetary shock, the reaction of the CPI differential is not statistically different from zero.

These results indicate that, to the extent that prices remain rigid in the short term, adopting a fixed exchange rate will create disequilibrium in markets for labour and production, since under those conditions the real exchange rate's adjustment can only occur over relative prices and not over the nominal exchange rate.

4.2.2 Variance decompositions

Tables 2 and 3 present the contribution of various shocks to the variance of the real exchange rate and production, respectively. Referring to Clarida and Galí's work, we see that adding commodity prices does little to change the results pertaining to the variance of the exchange rate, which remain strongly affected by shocks to real demand. Shocks to commodity prices contribute minimally to explaining this variance in the model omitting the cointegrating vector.

15. This result contradicts the predictions of Balassa (1964) and Samuelson (1964).

Table 2
Variance decomposition of the real exchange rate—
Model with cointegration[a]

Horizon	Energy shocks	Commodity shocks	Supply shocks	Real demand shocks	Monetary shocks	Transitory shocks
1 quarter	0 (12)	1 (9)	12 (9)	74 (19)	9 (12)	2 (11)
4 quarters	0 (14)	1 (10)	23 (13)	74 (19)	1 (5)	0 (8)
8 quarters	0 (17)	2 (13)	18 (13)	77 (22)	0 (3)	0 (6)
20 quarters	2 (20)	4 (14)	18 (14)	77 (23)	0 (1)	0 (1)
Long term	2 (21)	3 (14)	18 (14)	77 (24)	0 (1)	0 (2)

a. Simulated standard deviations in parenthesis.

Table 3
Variance decomposition of the real GDP differential—
Model without cointegration[a]

Horizon	Energy shocks	Commodity shocks	Supply shocks	Real demand shocks	Monetary shocks	Transitory shocks
1 quarter	2 (10)	1 (7)	53 (21)	24 (16)	0 (7)	19 (18)
4 quarters	18 (17)	1 (9)	57 (21)	20 (15)	0 (5)	4 (11)
8 quarters	13 (17)	8 (13)	77 (21)	2 (8)	0 (3)	0 (6)
20 quarters	8 (20)	6 (15)	86 (23)	0 (1)	0 (2)	0 (2)
Long term	10 (22)	6 (15)	84 (24)	0 (1)	0 (2)	0 (2)

a. Simulated standard deviations in parenthesis.

As in Clarida and Galí, it is essentially real demand shocks that explain the variance of the real exchange rate. This result would argue in favour of a flexible exchange rate. Indeed, one benefit of a fixed exchange rate is to eliminate the impact of monetary policy shocks as a source of asymmetric shocks. The fact that monetary shocks contribute little to the variance of the real exchange rate suggests that only small gains can be expected in this area.

Conversely, again as in Clarida and Galí, supply shocks explain the bulk of the variation in the real GDP differential in the medium and long term. They are also very significant in the short term, where real demand shocks likewise play a major role. In Clarida and Galí, the domination of supply shocks in the long term is attributable to the identification restrictions. This is not the case here, since nothing keeps the prices of non-energy commodities or of energy from playing a significant role in the determination of this variable in the long term.

4.3 Incorporating a cointegrating vector

We will describe the implications of incorporating a vector of cointegration between commodity prices and the real exchange rate, according to the methodology laid out in section 3.2. Recall that the results of our tests for cointegration led us to attribute less significance to this case.

Most of the reaction functions (available on request) relating the interest rate and the real GDP differential to the various shocks resemble those obtained from the model without cointegration. Reactions to demand shocks here differ from the reactions to real or nominal demand shocks presented in section 4.2. However, there are problems comparing demand shocks between the two models (see section 3.2).

Appendix 6 presents the reactions of the real and nominal exchange rates and of the price differential to the various shocks. The directions of the reaction functions are again similar to those observed in the case without cointegration. Once again, we find that adjustments in the real exchange rate are essentially transmitted over adjustments in the nominal exchange rate. Thus, this result is not sensitive to the presence or absence of the cointegrating vector.

Tables A7.1 and A7.2 (Appendix 7) present the contribution of the various shocks to the variance of the real exchange rate and production, respectively. These results are quite different from those we found in the case without cointegration. In particular, the impact of commodity prices on the variance of the real exchange rate increases considerably in the long term. This is attributable to the fact that we have imposed a cointegrating relationship. The cointegrating vector actually implies that only commodity prices explain the long-term evolution of the real exchange rate. More precisely, the price of non-energy commodities is the key variable for explaining the long-term exchange rate. Nevertheless, it is important to bear in mind that demand shocks and transitory shocks are very persistent. Indeed, after 20 quarters, shocks to the price of non-energy commodities account for only 13 per cent of the variance of the real exchange rate.

The variance decomposition of the GDP differential is also modified by incorporating the cointegrating relationship. The share of GDP's variance explained by supply shocks diminishes, being superseded by shocks to commodity prices in the long term and, in the short and medium term, by transitory shocks.

The great persistence of the impact of transitory shocks may indicate problems with the cointegrating relationship we impose. Indeed, a spurious cointegrating relationship implies a non-stationary, or very persistent, transitory component.

4.4 Sensitivity tests for the results

We performed the following sensitivity tests:

- We verified that the principal results are insensitive to a small increase or decrease in the number of lags.
- We confirmed that reversing the order of the price of energy and the price of non-energy commodities in the models has little impact on the results.
- We verified that the results of the reference model are not sensitive to use of the three-month interest rate differential rather than the overnight rate differential.
- Faust and Leeper (1997) demonstrate the necessity of postulating that the parameter space considered in the context of models with long-term identification restrictions be finite. We assume here that the moving-average representation of the various models is truncated at a finite horizon. We also verify that the results are not sensitive to an increase in the truncation horizon of the moving-average representation of the models.

Conclusions

Our principal conclusions are as follows.

- Exchange rate flexibility facilitates macroeconomic adjustment by accelerating the realignment of the real exchange rate. Relative price movements contribute little to exchange rate adjustment. This result confirms the advantages of a flexible exchange rate, since in a fixed exchange rate regime changes to the real exchange rate would need to occur entirely over price-level changes. In the presence of nominal short-term rigidities, this would create disequilibrium in the markets for labour and for the production of goods and services. This result confirms that obtained by Dupasquier, Lalonde, and St-Amant (1997) using a model without commodity prices. This result is also not sensitive to the addition of a cointegrating relationship into the model.
- Contrary to expectations, our results do not bear out the existence of a cointegrating relationship between the exchange rate and commodity prices. Therefore, we emphasize the results obtained with the omission of this relationship.
- Incorporating commodity prices into our model does little to challenge Clarida and Galí's conclusion that real demand shocks account for the bulk of the variation in the exchange rate over all time horizons. Furthermore, it does not contradict their result that supply shocks are the primary factor in variations in the Canada-U.S. GDP differential for all time

horizons. However, specifying a cointegrating relationship between commodity prices and the real exchange rate implies that, in the very long term, it is the price of non-energy commodities that determines the variation in the real exchange rate.

- The reference model allows us to estimate the relative contribution of monetary shocks to the explanation of the variance of the real exchange rate. This share is minimal (as in Clarida and Galí, among others), providing a further argument in favour of a flexible exchange rate. While a fixed exchange rate eliminates monetary shocks as a source of asymmetric shocks, we estimate this benefit to be negligible.

Clearly, the scope of our results' applicability to the choice of an exchange rate policy for Canada is limited, since we only consider the issue from the perspective of macroeconomic adjustment. To arrive at more general conclusions, one would also need to address the exchange rate regime's impact on factors such as transactions costs, investment, and trade. Political considerations must also play a role.[16]

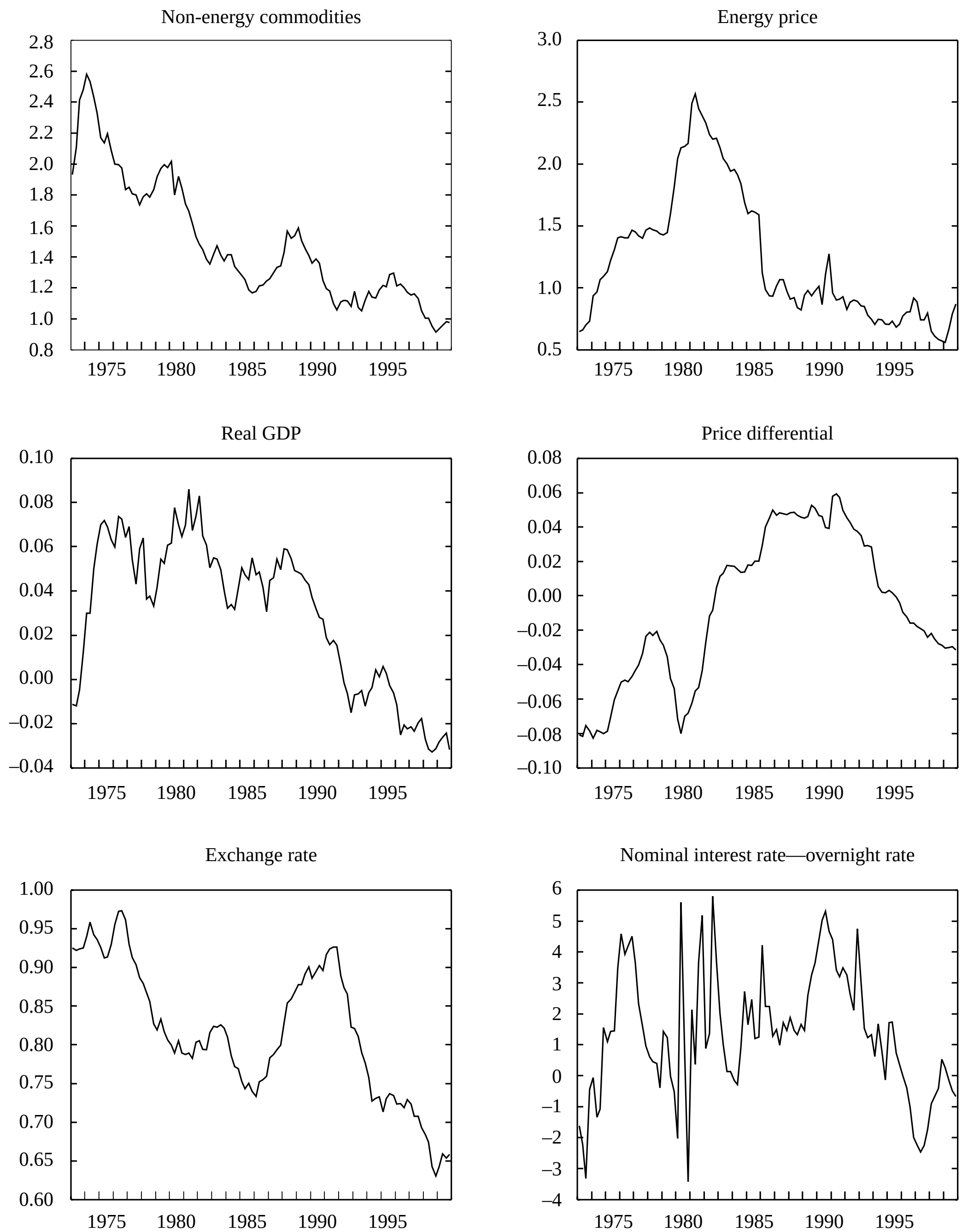
Several topics for further research are indicated.

- Our results reveal that real demand shocks explain a significant share of the variation in the Canada-U.S. exchange rate. It would be of interest to better understand the precise nature of these shocks. We could, for example, examine the extent to which they reflect fiscal shocks.
- Several of our conclusions depend on whether or not there is a cointegrating relationship between the exchange rate and commodity prices. Our tests reveal that support for the existence of this relationship is not very robust. It would be worthwhile to examine this question in greater detail.

16. Lafrance and St-Amant (1999) present a survey of the recent literature on optimal currency zones.

Appendix 1
Graphs of the Series

Variables of the model



Appendix 2
Augmented Dickey-Fuller (ADF)

Table A2.1
Unit-root tests

Series[a]	Augmented Dickey-Fuller (ADF) Detrended	Augmented Dickey-Fuller (ADF) With trend	Phillips-Perron (PP) Detrended	Phillips-Perron (PP) With trend	Schmidt-Phillips (SP) —
CPI differential	–1,986	–0,877	–1,731	–1,550	–0,122
Real GDP differential	–1,088	–3,819*	–1,334	–3,781*	4,561
Real exchange rate	–1,706	–2,317	–0,716	–2,514	–0,067
Interest rate differential	–2,168	–2,424	–4,699*	–4,854*	47,842*
Energy prices	–1,203	–3,317	–1,543	–3,174	1,494
Non-energy commodity prices	–1,941	–4,294*	–0,871	–4,205*	1,633

a. The number of lags used for the ADF test is chosen using the method suggested by Ng and Perron (1995). The 5 per cent critical value for the ADF and PP tests without trend is –2.89, and that for the tests corresponding with trend is –3.45. Cases in which the unit root is rejected are indicated with an asterisk (*). The critical value for the SP test is 18.1. The unit root is rejected for all first-difference series.

Appendix 3
The King et al. Methodology

After estimating a cointegrated VAR model, or vector-error-correction model, it is possible, as in the case of the structural VAR approach, to represent the stationary economic variables as functions of lagged error terms:

$$x_t = e_t + C_1 e_{t-1} + \ldots = \sum_{i=1}^{\infty} C_i e_{t-1} = C(L)e_t, \tag{A3.1}$$

where e_t is a $(n \times 1)$ reduced-form vector of innovations.

We wish to identify the following structural model:

$$x_t = \Gamma_0 \eta_t + \Gamma_1 \eta_{t-1} + \ldots = \sum_{i=0}^{\infty} \Gamma_i \eta_{t-i} = \Gamma(L)\eta_t, \tag{A3.2}$$

where the structural shocks, η_t, are unknown and Γ_j is an unknown $(n \times n)$ matrix, the typical element of which, τ_{kl}, measures the impact of the l-th structural shock on the k-th variable after i periods.

The first identification constraint stipulates that the matrix $var(\eta_t) = \Sigma_\eta$ be block diagonal, with the two blocks corresponding to the partition $\eta_t = (\eta_t^{p'}, \eta_t^{t'})'$, where η_t^p is the $(k \times 1)$ vector of the model's permanent shocks, and η_t^t is the $[n(n-k) \times 1]$ vector of shocks having a transitory impact on all the variables in the model.

The other identification restrictions are:

$$\Gamma(1) = [\tilde{A}\Pi \; 0], \tag{A3.3}$$

where $\tilde{A}$ is a known $(n \times k)$ matrix of full rank whose columns are orthogonal to the cointegrating vectors, such that $\beta'\tilde{A} = 0$. Π is a $(k \times k)$ lower-triangular matrix with ones in the diagonal, and 0 is an $n \times (n-k)$ matrix of zeros. The matrix Π serves to establish the long-term ordering of the variables. In this, its role is similar to that of the matrix $A(1)$ represented by equations (5) and (6).

Equations (A3.1) and (A3.2) are linked as follows:

$$\Gamma_0 \eta_t = e_t, \tag{A3.4}$$

$$C(L) = \Gamma(L)\Gamma_0^{-1}, \tag{A3.5}$$

$$\text{and } C(1) = \Gamma(1)\Gamma_0^{-1}. \tag{A3.6}$$

Let D be a $(k \times n)$ matrix that solves $C(1) = \tilde{A}D$. Since $C(1)e_t = \Gamma(1)\eta_t = \tilde{A}\Pi\eta_t^p$, we can write:

$$\tilde{A}De_t = \tilde{A}\Pi\eta_t^p \tag{A3.7}$$

$$\text{and } D\Sigma_e D' = \Pi\Sigma_{\eta'}\Pi'. \tag{A3.8}$$

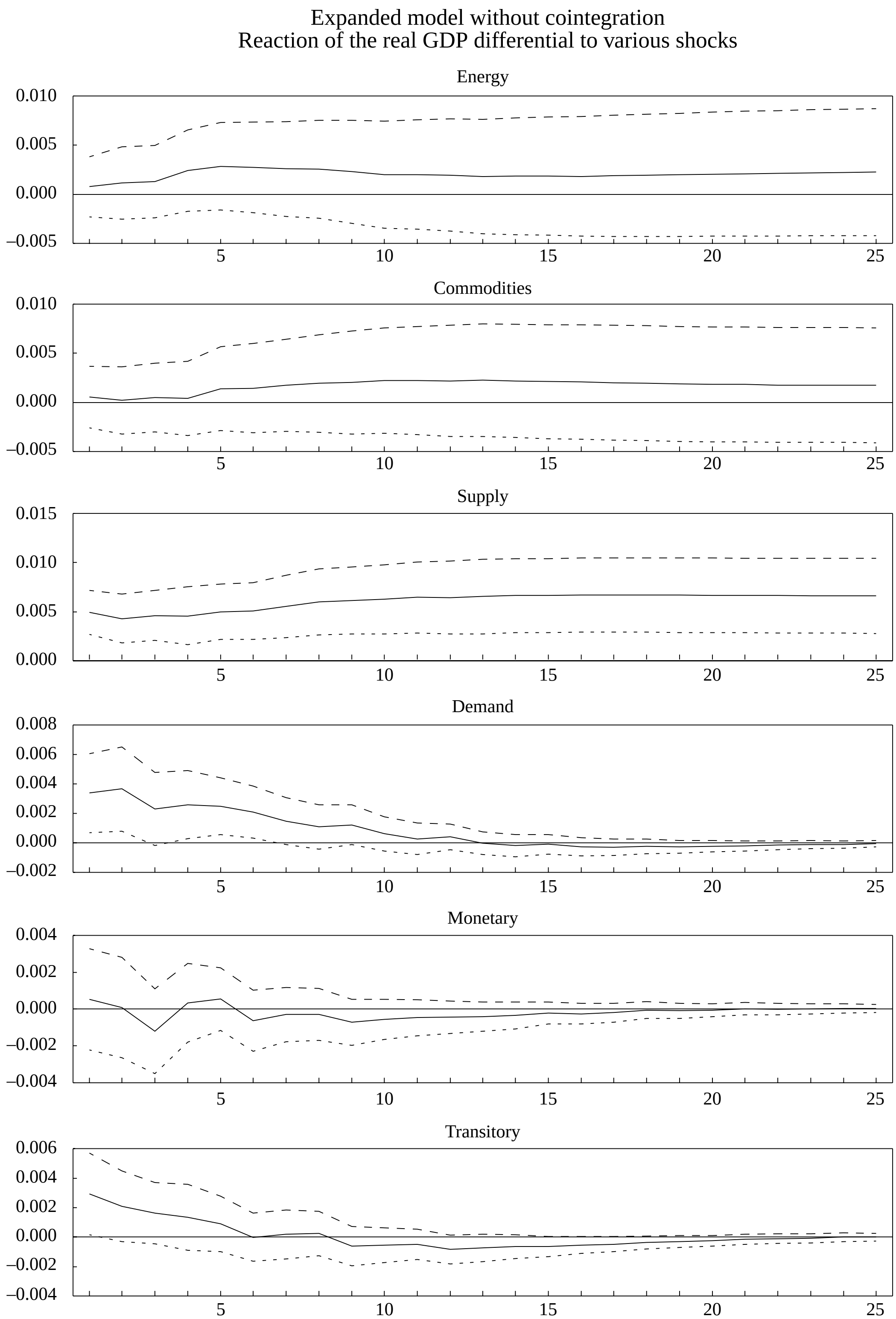
Let $\overline{\Pi} = chol(D\Sigma_e D') = \Pi\Sigma_{\eta'}^{1/2}$. Since Π is triangular, and $\Sigma_{\eta'}$ is diagonal, we obtain a unique solution for Π and $\Sigma_{\eta'}$. From equation (A3.5), we can thus identify the permanent shocks as:

$$\eta_t^p = \Pi^{-1}De_t = Ge_t.$$

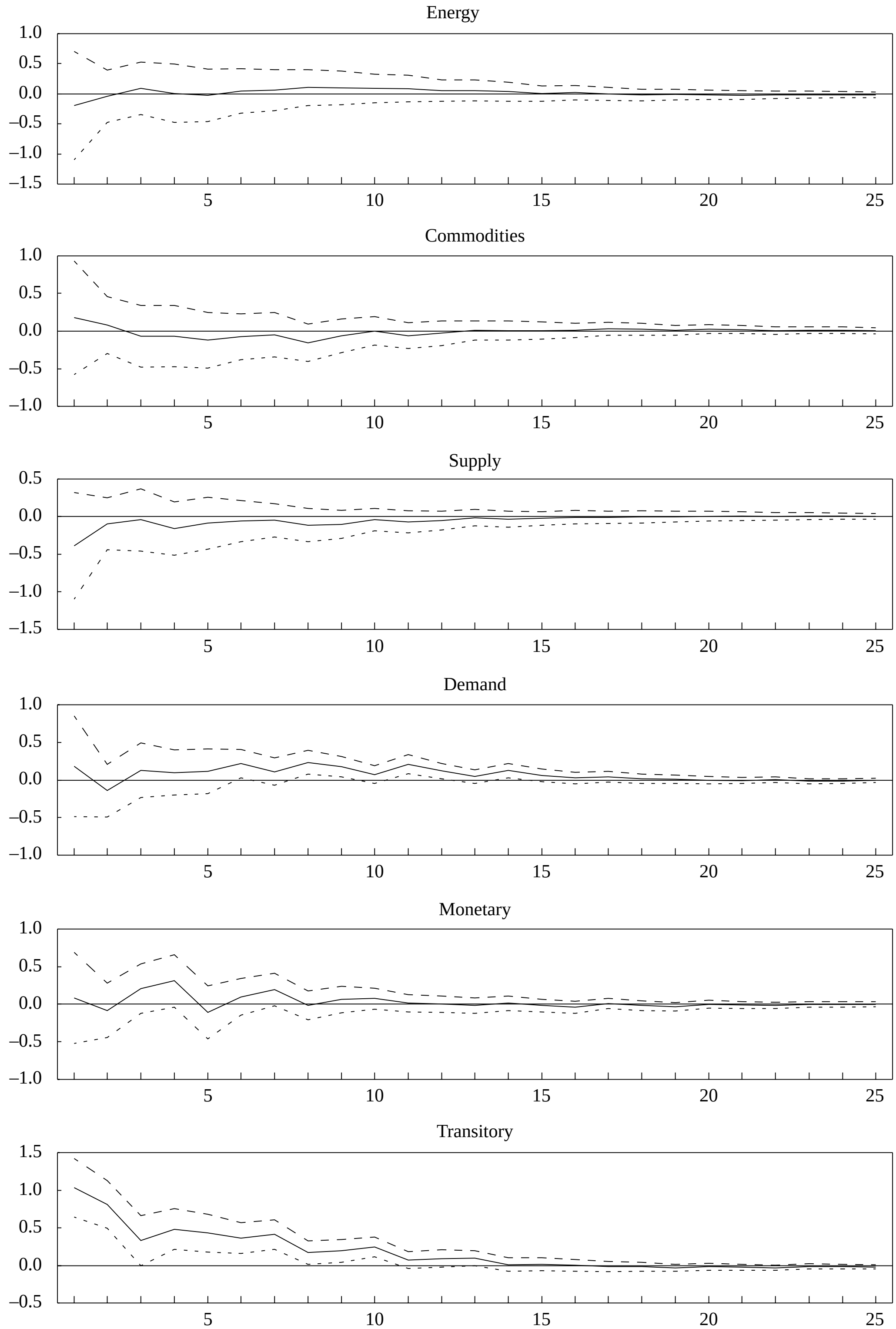
We can easily show (see King et al.) that the matrix Π also allows us to identify the dynamic multipliers for η_t^p using the relationship:

$$\Gamma(L) = C(L)\Sigma_e G'\Sigma_{\eta^p}^{-1}.$$

Appendix 4
Reaction Functions for the Real GDP Differential and the Interest Rate Differential—Expanded Model Without Cointegration

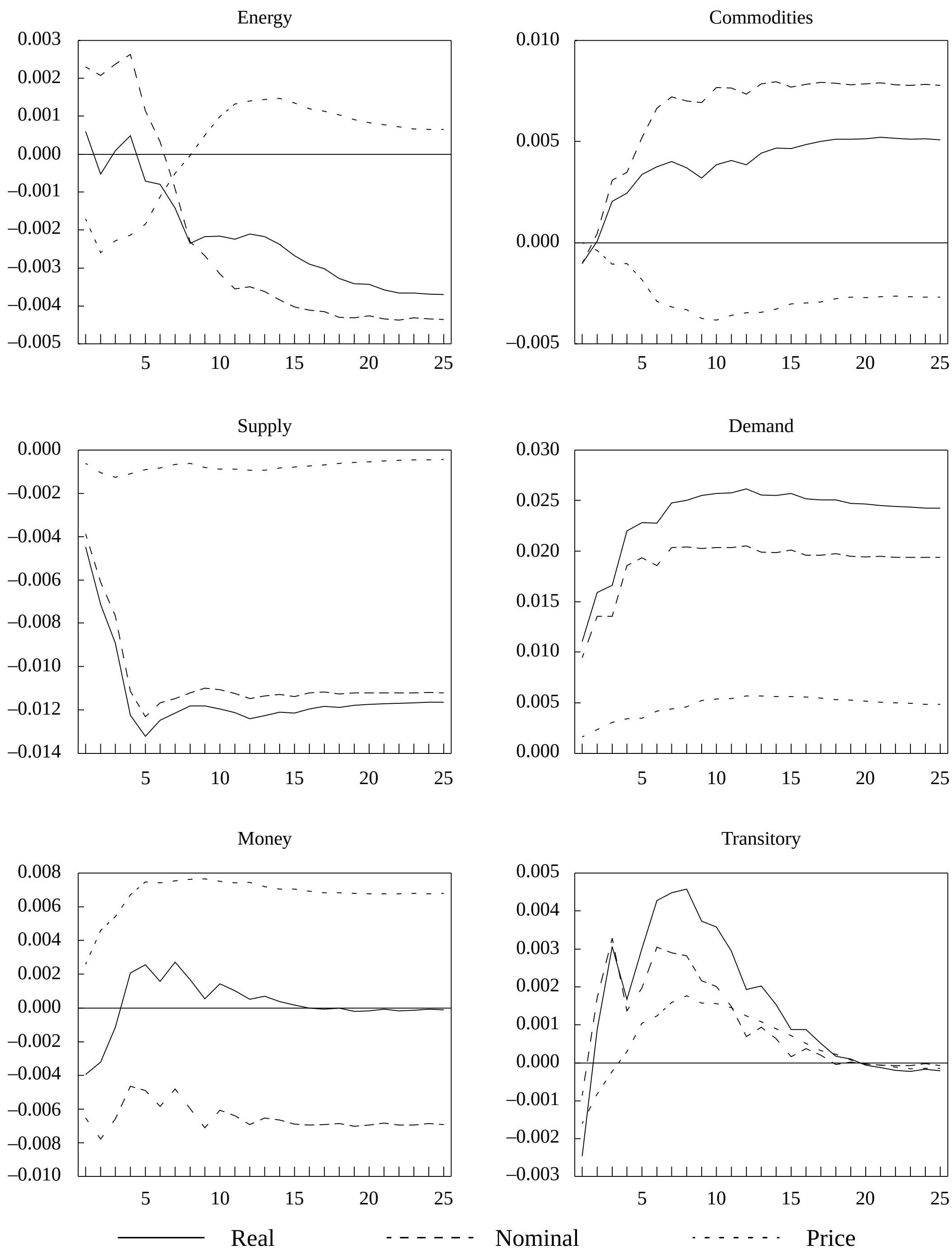


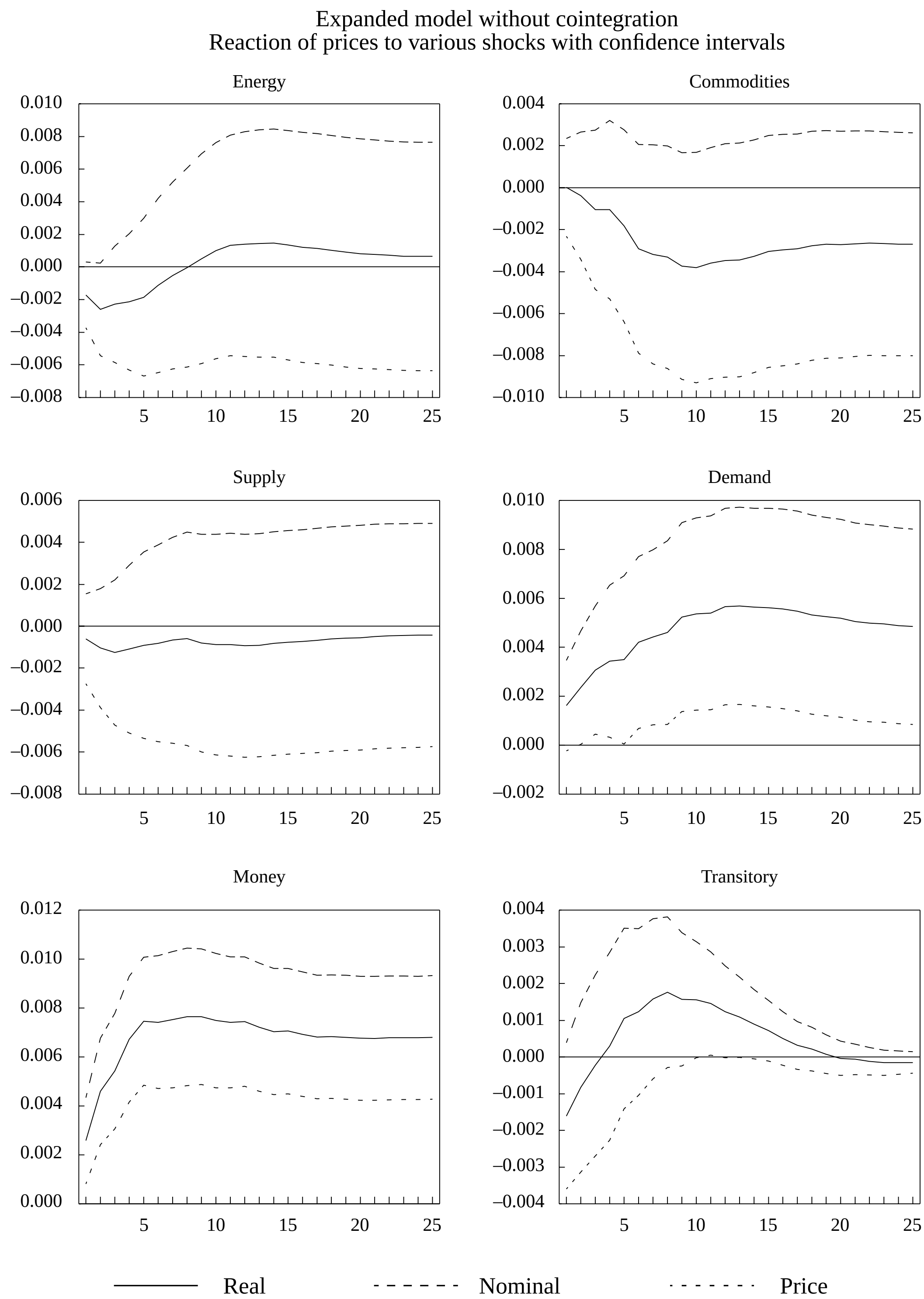
Expanded model without cointegration
Reaction of interest rate differential to various shocks



Appendix 5
Reaction Functions for the Exchange Rate and for the Price Differential—Model Without Cointegration

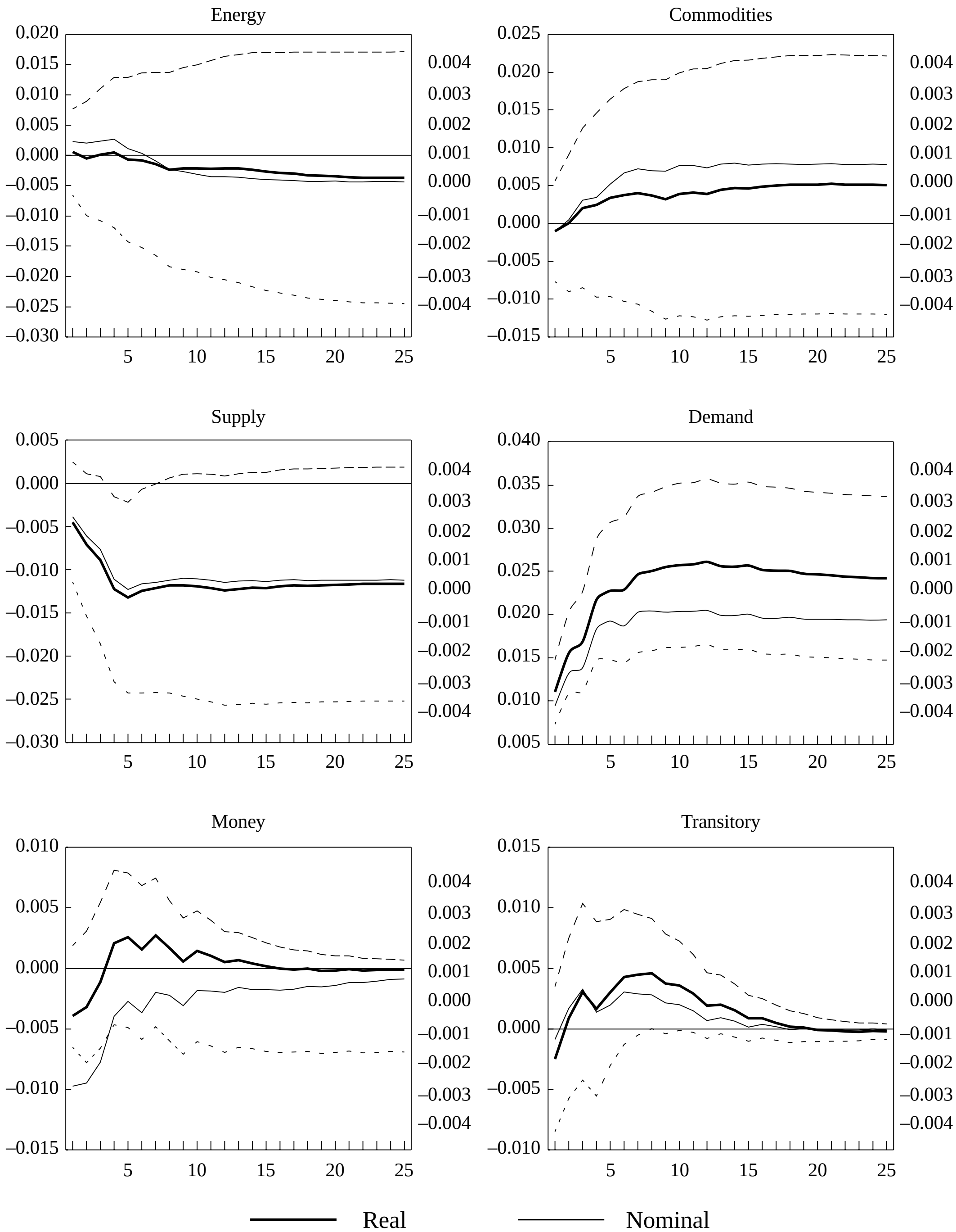
Expanded model without cointegration
Reaction of real and nominal exchange rate and prices to various shocks





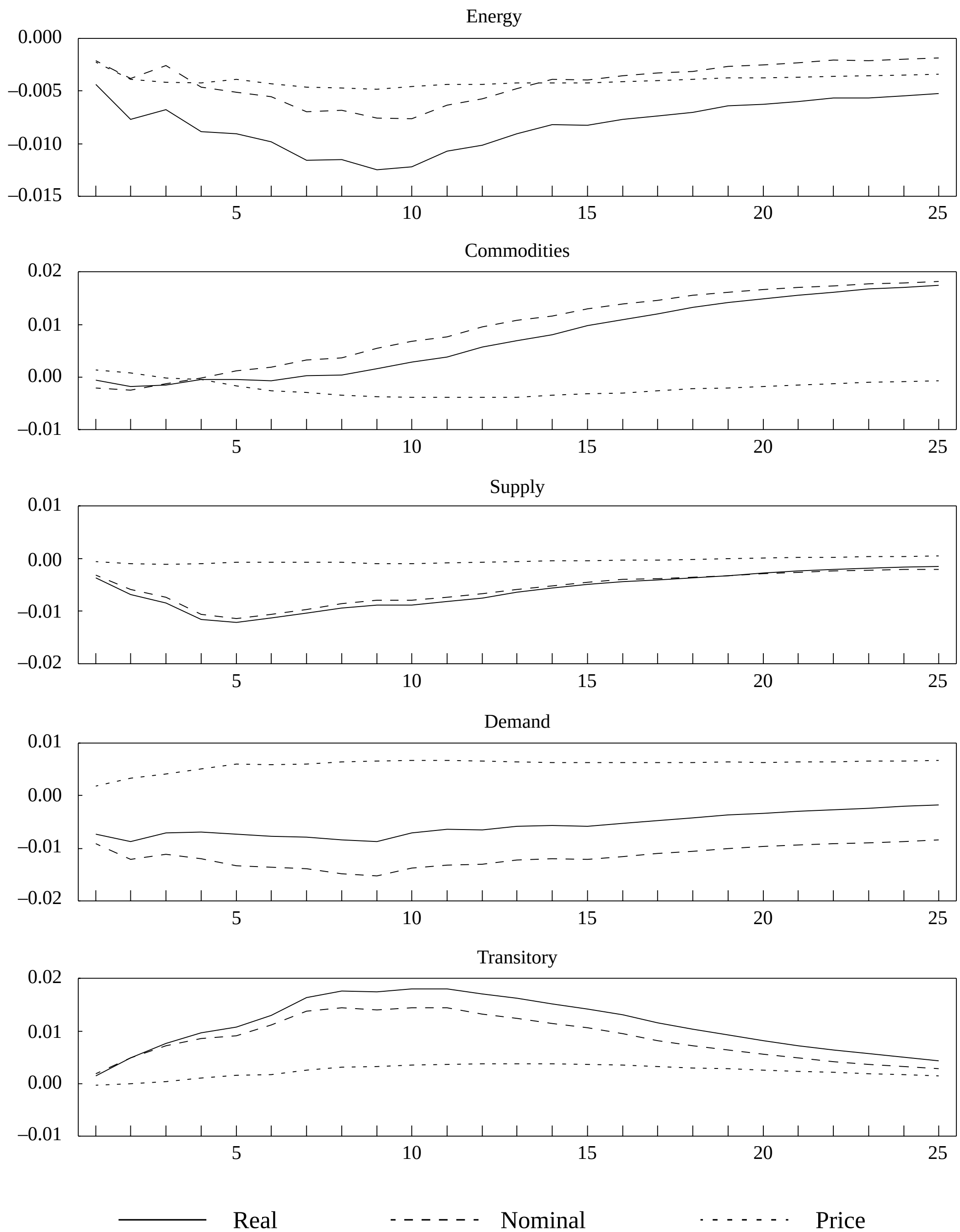
Expanded model without cointegration
Reaction of prices to various shocks with confidence intervals
Energy
0.010
0.008
0.006
0.004
0.002
0.000
–0.002
–0.004
–0.006
–0.008
5
10
15
20
25
Commodities
0.004
0.002
0.000
–0.002
–0.004
–0.006
–0.008
–0.010
Supply
0.006
0.004
0.002
0.000
–0.002
–0.004
–0.006
–0.008
Demand
0.010
0.008
0.006
0.004
0.002
0.000
–0.002
Money
0.012
0.010
0.008
0.006
0.004
0.002
0.000
Transitory
0.004
0.003
0.002
0.001
0.000
–0.001
–0.002
–0.003
–0.004
Real
Nominal
Price

Expanded model without cointegration
Reaction of real and nominal exchange rate
(with confidence intervals) to various shocks



Appendix 6
Reaction Functions for the Exchange Rate and the Price Differential—Expanded Model with Cointegration

Model with cointegration vector
Reaction of real and nominal exchange rates
and price differential to various shocks



Appendix 7
Variance Decomposition

Table A7.1
Variance decomposition of the real exchange rate—Model with cointegration

Horizon	Energy-price shocks	Commodity price shocks	Supply shocks	Demand shocks	Transitory shocks
1 quarter	14	0	10	38	39
4 quarters	20	1	26	22	33
8 quarters	21	0	24	15	40
20 quarters	19	13	14	10	44
Long term	5	95	0	0	0

Table A7.2
Variance decomposition of real GDP—Model with cointegration

Horizon	Energy-price shocks	Commodity price shocks	Supply shocks	Demand shocks	Transitory shocks
1 quarter	5	0	17	2	77
4 quarters	3	0	17	7	73
8 quarters	6	8	19	6	61
20 quarters	10	35	28	3	24
Long term	14	51	35	0	0

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Discussion

Daniel Racette

A little over a decade ago, the Bank of Canada decided to demonstrate its openness and transparency by holding annual conferences at which academics, colleagues from other central banks, and market actors would be given the opportunity to explore subjects of interest to the researchers and officers of the Bank in their conduct of monetary policy. The topics of these conferences have included the following: understanding the mechanisms of policy transmission, the role of money in those mechanisms, costs associated with fighting inflation, an acceptable definition of price stability, determinants of the exchange rate, and the choice of an exchange rate regime.

Although relatively technical in nature, these subjects are central to the conduct of monetary policy, and the conference participants deal with issues on which reasonable people may have differing opinions. As reading the various submissions reveals, this year's conference was no exception in that respect.

The issue on this year's agenda, addressed squarely by Djoudad, Gauthier, and St-Amant, is not new. I recall having dealt with it myself, along with two co-authors (Racette, Raynauld, and Lalonde 1993), in comments on a text about optimal currency zones (Fenton and Murray 1993) on the occasion of the Bank's second conference in June 1992. In that submission, we reiterated the importance of the Canadian dollar as an adjustment mechanism—examining the issue from the perspective of asymmetrical regional shocks within North America. Using results from a similar model applied to Europe, we also expressed doubts about the merits of the European monetary union, which was at that time taking its first halting steps. I should point out in passing that I had expressed these same concerns at a Banque de France-Université conference in 1989 (Banque de France

1990), where my comments were received with some hostility, since they coincided with the Delors report's hour of glory.

We observe that, far from disappearing, the issue has acquired greater relevance in Canada for at least two reasons. On the one hand, the debate has grown more heated and has increasingly seen respected economists, sometimes representing schools of thought that appear closely related, express diametrically opposed views. On the other hand, this discussion has overflowed into the political arena, occasionally even impinging on the realm of our age-old constitutional debate, making the issue a particularly sensitive one for the people of the central bank.

Fundamentally, I remain a fan of the flexible exchange rate (at least for Canada), no doubt because of my Friedmanian roots. However, I must admit here that my convictions are not as strong as they once were—despite a year spent at the Bank of Canada—owing to the credibility of economists on both sides of the debate, as well as to the fact that the situation may have changed in Canada, leaving the benefits of a dollar that is floating (or should I say sinking like a stone at the time of this conference) less obvious.

In light of what I have just said, it should be clear that this year's conference is of particular interest to me, either to corroborate or refute my opinion. In this context, I need convincing results—more convincing, at least, than those Macklem et al. (2001) presented in a paper earlier in this conference, when they attributed annual welfare gains of about Can$1 billion to the maintenance of a flexible exchange rate regime. Despite the many virtues of the work done by Djoudad, Gauthier, and St-Amant, I remain unsure that their approach is sufficiently convincing, if only because of its partial nature—examining the issue exclusively from the perspective of the exchange rate's impact on macroeconomic adjustment. I am aware, however, that this criticism applies equally to some of my own work.

After this lengthy introduction, let us turn our attention to the concerns this study raises for me.

- First of all, and as is always the case at the Bank of Canada, this study was conducted in an expert fashion—one might say, by the book! Its scientific merit is indisputable.
- This study pushes the use of the VAR model to its limits in relating the differentials of important macroeconomic variables (real GDP, inflation rates, and those interest rates most associated with the process of monetary policy) to the real exchange rate. Furthermore, acting on Jacques Raynauld's (1997) suggestion in his discussion on the Dupasquier, Lalonde, and St-Amant (1997) submission to the 1996 conference, the authors incorporate commodity price shocks. Indeed,

they almost reach the limits of this approach's applicability to such an extent—especially since their results generally confirm those of previous studies—that one might wonder whether we have not reached the point of decreasing returns in the usefulness of such models.

- It should be mentioned that the authors' confirmation of Clarida and Galí's results concerning the negative impact of a positive supply shock on the exchange rate raises concerns as to identification of these shocks. From this perspective, a graphic representation of the behaviour of the shocks would have left room for visual interpretation to the reader.
- The great strength of this paper, of course, is the inclusion of shocks to energy and non-energy commodity prices. The results seem to demonstrate that, in the absence of cointegration, this inclusion does not fundamentally alter previously established results indicating the dominance of real demand shocks in the determination of the real exchange rate. That said, when the authors impose cointegration with commodity prices, the results are very different, with shocks to the price of non-energy commodities dominating. They place very little emphasis on this result, however, deeming that "results supporting cointegration are weak" (pp. 100). Researchers at the Bank of Canada assign considerable importance to the Amano and van Norden model, as witnessed by frequent references made to this model throughout the conference.

  Since this model is characterized by the inclusion of a cointegrating vector, I would have appreciated a greater effort by Djoudad, Gauthier, and St-Amant to reconcile their somewhat contradictory results. Should we conclude that the cointegration result in the Amano and van Norden model is attributable to the exclusion of the other elements of the information set used by the authors, and is thus fortuitous? Either it raises doubts about the pertinence of using Amano and van Norden's equation for modelling the real exchange rate of the Canadian dollar, or should we question Djoudad, Gauthier, and St-Amant's analysis for failing to find a cointegrating vector incorporating such important variables as commodity prices. If Amano and van Norden's model is called into dispute because of Djoudad, Gauthier, and St-Amant's inability to find a cointegrating vector, should we then also doubt the Bank of Canada's recent defence of flexible rates based on benefits to the Canadian economy of exchange rate adjustments in the context of the crisis in Southeast Asia and its impact on commodity prices. I feel the authors might also have considered the results obtained by Smets (1997), who, comparing the case of Canada with that of Australia, found a much smaller role for commodity prices in the determination of the Canadian dollar's exchange rate than do Amano and van Norden.

- Moreover, the results of the study by Djoudad and his co-authors clearly point to price rigidity in Canada, since real shocks do not induce any meaningful reaction in prices. The authors state that "relative price movements contribute little to exchange rate adjustment" (p. 109). On these grounds, we could ask the people at the Bank to measure the implications of this rigidity for the choice of the price-stability goal (the subject of the Bank's recent conference in June 2000), or for the real impact of an inflation rate that is systematically below the mean of the inflation-control band targeted over the course of the past 10 years. Could this be grist for the mill of the supporters of Akerlof, Dickens, and Perry (1996)?
- On another level, the period under examination is that of the flexible exchange rate regime, but can one really speak of a "constant" regime? The various phases of the period between 1970 and the present have been characterized by shocks of qualitatively differing natures and, examining a graph of the real GDP differential between Canada and the United States, we can even doubt the stationarity of this variable in first difference, at least in recent times. Similarly, comparing a graph of the real GDP differential with one of the real exchange rate reveals a striking parallelism. This parallelism may be what keeps the authors from finding a cointegrating relationship with commodity prices. The resulting model is thus dominated by one variable, the exogeneity of which is difficult to justify.

In conclusion, we are witness to an interesting exercise, well carried out and generally supportive of the results of previous studies on the merits of a flexible exchange rate for the Canadian dollar. Nonetheless, given the partial nature of this analysis, it is only after examining the entirety of the studies presented here that we will be able (or not) to strengthen our convictions on this matter. That being said, it is very possible that, whatever results we economists may bring to this debate, ultimately, as in Europe, political considerations will weigh heavily in the final choice of an exchange rate regime for Canada.

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