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Abstract

In this paper, we study the impact of supply shocks on the Canadian real exchange rate. We specify a structural vector-error-correction model that links the real exchange rate to different fundamentals. The identification scheme we use to recover the different shocks is based on long-run restrictions and allows us to decompose the real exchange rate according to different long-run trends, basically defined in terms of permanent shocks. Two main results emerge from our analysis. First, a positive supply shock in favour of Canada leads to a real exchange rate appreciation. Although consistent with the Balassa-Samuelson hypothesis, this result contradicts previous findings that have used a similar methodology. Second, commodity price shocks tend to dominate exchange rate movements over the short and medium run, but supply shocks have the largest impact over the long run. In particular, supply shocks explain most of the stochastic depreciation of the Canadian real exchange rate since the beginning of the 1990s.

JEL classification: F31, C32
Bank classification: Exchange rates

Résumé

Les auteurs étudient l'incidence de chocs d'offre sur le taux de change réel du dollar canadien. Ils élaborent à cette fin un modèle vectoriel autorégressif structurel à correction d'erreurs qui met en relation le taux de change réel et diverses variables fondamentales. Le schéma qu'ils utilisent pour identifier les chocs repose sur l'imposition de restrictions de long terme et permet de décomposer l'évolution du taux de change réel en ses différentes tendances de longue période, définies essentiellement en fonction de chocs permanents. Deux points majeurs ressortent de l'analyse des auteurs. Premièrement, un choc d'offre positif en faveur du Canada entraîne une appréciation du taux de change réel. Bien que conforme à l'hypothèse de Balassa-Samuelson, cette conclusion va à l'encontre des résultats antérieurs obtenus au moyen de méthodes analogues. Deuxièmement, les variations des prix des produits de base ont tendance à déterminer les mouvements du taux de change à court et à moyen terme, mais les chocs d'offre jouent un rôle prépondérant dans son comportement en longue période. Ainsi, les chocs d'offre expliquent la majeure partie de la composante stochastique de la dépréciation du taux de change réel du dollar canadien depuis le début des années 1990.

Classification JEL : F31, C32
Classification de la Banque : Taux de change

1. Introduction

After 30 years of widespread experience with floating exchange rates, the role of economic fundamentals in exchange rate dynamics continues to raise questions. Among recent papers analyzing this controversial issue, MacDonald (1999) underlines two points of particular interest for real exchange rate dynamics: (i) determining significant (long-run) relationships between real exchange rates and fundamentals, and (ii) identifying the relative importance of shocks in explaining real exchange rate volatility. These two questions are obviously linked, given that shocks must be identified in terms of some fundamental variables.

A major issue is the relevance of the purchasing-power-parity (PPP) hypothesis as an empirical approximation of real exchange rate dynamics, which implies that the real exchange rate fluctuates around a constant level. Dixon (1999), however, notes that: "the key finding in this literature is that real exchange rates are mean-reverting but the magnitude of such reversion is far too slow to be consistent with a traditional form of PPP such as that formulated by Cassel." This finding implies that shocks might have highly *persistent* (if not *permanent)* effects on real exchange rates and that equilibrium real exchange rates should be modelled as time-varying. This is consistent with the view that real exchange rate volatility mainly reflects real shocks, as in Stockman (1980).

Because real exchange rates tend to deviate from PPP over time, two different lines of research have been undertaken to identify the underlying factors that could explain such deviations. In the first approach, research has focused on establishing significant relationships between fundamentals and real exchange rates, including supply factors (e.g., the Balassa-Samuelson hypothesis) and demand-side variables, such as government spending and terms of trade (Chinn and Johnston 1997, Strauss 1999, Alexius and Nilsson 2000, and MacDonald 1998). By looking for long-run relationships, those studies involve cointegration tests in terms of the levels of the variables.[1]

A second approach tries to identify real shocks that could have generated real exchange rate fluctuations. Information about the source of those fluctuations is also useful in evaluating the empirical relevance of different classes of models of real exchange rate determination. For example, Clarida and Galí (1994) specify a structural vector autoregression (VAR) using the Blanchard-Quah approach that allows them to identify supply, real demand, and nominal (or monetary) shocks. The theoretical restrictions required for the identification of the structural form

1. Alternative specifications exist involving variables in first-differences that imply no specific long-run relationship (Hsieh 1982, Asea and Mendoza 1994).

are based on the Mundell-Fleming framework. Clarida and Galí's main conclusion is that almost all of the real exchange rate fluctuations are generated by shocks from business cycle components (real demand and/or monetary). Numerous papers have followed this line of research (Chadha and Prasad 1997, Dupasquier, Lalonde, and St-Amant 1997, Weber 1998, Rogers 1999, and Djoudad, Gauthier, and St-Amant 2000), and they have confirmed the original conclusion. Thus, the conventional wisdom is that supply shocks do not drive real exchange rate fluctuations.

This finding is at odds with empirical research that supports supply-side factors as key determinants of real exchange rates, in line with the Balassa-Samuelson predictions. A number of studies (De Gregorio and Wolf 1994, Strauss 1995, 1999, and Alexius and Nilson 2000) have found significant cointegration relationships between productivity measures and real exchange rates. Not only is the magnitude of a supply shock's effects controversial for real exchange rate dynamics, but so is its sign. Indeed, in Clarida and Galí's theoretical framework, a supply shock is expected to lead to a permanent depreciation of the real exchange rate, while in the Balassa-Samuelson framework a supply shock leads to a permanent appreciation. Failing to take into account these long-run relationships in structural VARs is likely to alter the sign and the importance of productivity shocks in explaining real exchange rate fluctuations, especially for low-frequency cycles. This paper attempts to verify this conjecture by examining the long-run factors that could have driven Canada's real exchange rate to determine whether supply-side components played a significant role. We find that supply shocks tend to dominate and that, in line with the Balassa-Samuelson hypothesis, they have had a positive effect on the real exchange rate. This result, concurrently documented by Alquist and Chinn (2002) for the euro-dollar exchange rate, is consistent with the Balassa-Samuelson framework. These findings contrast with previous studies that concluded that real demand shocks accounted for most of the movements in the real exchange rate (Clarida and Galí 1994, Dupasquier, Lalonde, and St-Amant 1997, and Djoudad, Gauthier, and St-Amant 2000).

In section 2, we discuss the choice of appropriate variables that might explain the evolution of the real exchange rate. In section 3, given the set of fundamentals retained, we test for the existence of cointegration relation(s). Following this, we incorporate the cointegrating vector(s) into a structural VAR framework to estimate the dynamics and the permanent impact of the identified shocks. The identification procedure, using long-run restrictions, was developed by King et al. (1991). Section 4 offers some conclusions.

2. Theoretical Considerations

This section seeks guidance from theory in developing an empirical specification for exchange rate dynamics. We begin by formalizing the real exchange rate dynamics, based on Dornbusch

(1976).[2] The expected change of the real exchange rate, q_t, is proportional to deviations from its equilibrium level:

$$E_t[q_{t+k}] - q_t = \theta(\bar{q}_t - q_t) , \tag{1}$$

where $\bar{q}_t$ is the fundamental (or equilibrium) value of the real exchange rate, which may be subject to permanent shifts. Using the uncovered real interest rate parity condition (r_t and r_t^* represent the home and the foreign real interest rates, respectively):

$$E_t[q_{t+k}] - q_t = r_t - r_t^* , \tag{2}$$

we can easily rearrange these equations into an expression for the real exchange rate:

$$q_t = \bar{q}_t - \alpha(r_t - r_t^*) . \tag{3}$$

This formulation incorporates a time-varying equilibrium value ($\bar{q}_t$) related to long-run movements, combined with a short-run component ($r_t - r_t^*$) that takes into account the monetary or asset-price perspective of exchange rates. MacDonald (1999) reports that, when a relatively rich set of variables is used to model the equilibrium value, $\bar{q}_t$, this equation proves to be empirically relevant.[3]

Although we can accept the validity of a constant equilibrium value under some specific tests (such as the PPP hypothesis), the speed of convergence towards the equilibrium is far too slow to be meaningful, especially given the large swings that characterize the post–Bretton Woods period. Consequently, it seems more appropriate to identify the sources of these equilibrium fluctuations in terms of economic fundamentals. We can choose from a number of theories. Balassa (1964) and Samuelson (1964) argue that, if productivity trends in tradable and non-tradable goods industries differ, then those differences will affect the relative price of non-tradable goods and consequently the real exchange rate.[4] In effect, the tradable sector (mainly manufacturing) tends to have a higher trend in productivity than the non-tradable sector (mainly services), characterized by a more sluggish productivity growth. We would thus expect that high-growth countries

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2. This framework has often been adopted to analyze real exchange rate dynamics; for a more complete discussion, see Baxter (1994) or Obstfeld and Rogoff (1996).
3. Amano and van Norden (1995) also add an interest rate differential term to their fundamental exchange rate specification, to control for monetary policy stances at home and abroad.
4. Productivity growth affects the relative price of non-tradables through economy-wide increases in nominal wages that are assumed to be equal between the different sectors.

experience real appreciations over time, and numerous studies have supported this (Hsieh 1982, Asea and Mendoza 1994, and De Gregorio and Wolf 1994). Given the inherent problems in adequately measuring relative productivity in tradables and non-tradables, a number of alternative measures have been proposed. One relevant measure that captures the Balassa-Samuelson effect is relative output (real GDP) per capita, which can be interpreted as a broad measure of labour productivity for the overall economy that takes into account the degree of labour-force participation. This approximation is appropriate to the extent that the productivity growth in the non-tradable sector is similar across countries and accounts for a small proportion of the total factor productivity growth (see Alexius and Nilson 2000 for more details).

Rogoff (1992) generalizes the Balassa-Samuelson model by allowing for aggregate demand shocks, and shows that they, as well as aggregate supply shocks, matter for real exchange rate dynamics. Empirically, the ratio of government spending to GDP is used to proxy the demand-side component, and it affects the real exchange rate through its impact on the relative price of non-tradables.[5] Under this framework, a positive fiscal shock leads to an appreciation as government spending falls heavily on non-tradable goods. An increase in government spending, however, might have a perverse impact on the exchange rate by increasing the tax burden that would likely reduce incentives to work and invest. As this could hamper future productivity growth, it might entail a real depreciation under the Balassa-Samuelson channel. Thus, government activities have an ambiguous impact on real exchange rates, as is often reported in empirical research.

Changes in the terms of trade can also affect the real exchange rate, since shocks to the terms of trade will disrupt both the internal and external balance of the economy. In the case of a small open economy, terms of trade reflect exogenous movements in world prices of exports and imports. As Canada’s exports are more commodity-intensive, many studies have used real commodity prices as a proxy for the terms of trade (Amano and van Norden 1995, Murray, Zelmer, and Antia 2000, and Clinton 2001).

Consistent with equation (3), we allow the equilibrium real exchange rate, $\bar{q}_t$, to be driven by terms of trade shocks (proxied by commodity prices), supply shocks (which imply permanent shifts in relative output per capita), and real demand shocks (captured by permanent shifts in relative government expenditures as a proportion of GDP). Following Blanchard and Quah (1989), shocks that have permanent effects on output are classified as supply (or technology) shocks. The inclusion of real interest rate differentials captures monetary policy impulses and is a key variable suggested by a broad class of monetary exchange rate models (Frankel 1979 and

5. The inclusion of government spending as a proportion of GDP is particularly interesting in the case of the Canada-U.S. real exchange rate, given the rather different trends between the two countries.

Lafrance and Racette 1985).[6] Because we are interested in capturing permanent shifts in the fundamentals, the structural VAR that we use to decompose the real exchange rate will be identified by imposing restrictions on the long-run effects of shocks (King et al. 1991). This methodology considers only the stochastic trends of the variables, as the deterministic trend component remains unexplained.

3. The Structural Vector-Error-Correction Model of the Real Exchange Rate

We estimate the following vector-error-correction model (VECM):

$$\begin{bmatrix} \Delta pcom_t \\ \Delta Y_t \\ \Delta G_t \\ r_t \\ \Delta q_t \end{bmatrix} = \sum_{i=1}^{p-1} \Gamma_i \begin{bmatrix} \Delta pcom_{t-i} \\ \Delta Y_{t-i} \\ \Delta G_{t-i} \\ r_{t-i} \\ \Delta q_{t-i} \end{bmatrix} + \alpha\beta' \begin{bmatrix} pcom_{t-1} \\ Y_{t-1} \\ G_{t-1} \\ q_{t-1} \end{bmatrix} + \mu + e_t, \tag{4}$$

where e_t is a white noise process and the following five variables are in the VECM: the log of real commodity prices (*pcom*)[7], the log of the ratio of U.S. over Canadian real per-capita GDP (*Y*), the difference between U.S. and Canadian ratios of government spending to GDP (*G*), the real Canada-U.S. interest rate (three-month treasury bill) differential (*r*), and the bilateral real exchange rate (*q*). The model is estimated with seven lags on quarterly data over the 1961–2000 period with a constant inside and outside of the cointegration vector.[8,9] Given the clear tendency

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6. There is still a lot of controversy concerning the relationship between real interest rate differentials and the real exchange rate, depending on the frequency considered (see Baxter 1994 for a detailed discussion).
7. In previous research, energy- and non-energy-related commodity prices were found to have separate and distinct effects on Canada's real exchange rate. The effect of energy prices, however, may be less robust than previously thought (Aba and Laidler 2001). Working with aggregate commodity prices facilitates comparisons with related theoretical work.
8. Seven lags is the minimum number necessary to obtain white noise residuals. As Enders (1995, 98) notes: "It is particularly important that the residuals from an estimated model be serially uncorrelated. Any evidence of serial correlation implies a systematic movement [in the variables] that is not accounted for by the model. Hence, any of the tentative models yielding nonrandom residuals should be eliminated from consideration."
9. The simulation results in Macklem (1993) suggest that the new real exchange rate equilibrium level following the shock takes a long time to come about. An adequate model thus requires a long span to capture the long-run dynamics adequately. The non-availability of Canadian government spending data before 1961 prevented us from going back further.

for some variables to increase or decrease over the sample, the model we estimate allows for deterministic trends in the variables.

Unit root tests indicate that all the variables can be characterized as non-stationary variables except for the real interest rate differential, where the results are more ambiguous. Consequently, all variables but the interest rate differential are included in first differences. Because the evidence is mixed on whether real interest differentials are I(0) or I(1),[10] we will perform a robustness check on the degree of integration assumed. Johansen's cointegration tests indicate the presence of one cointegration vector, as Table 1 shows.[11]

Table 1: Cointegration Results

L-max	Trace	H_0: r=	L-max90	Trace90	RATR[a]
53.02	97.11	0	30.90	64.84	70.69
25.65	44.09	1	24.73	43.95	32.09
8.76	18.44	2	18.60	26.79	13.42
6.19	9.69	3	12.07	13.33	7.05
3.49	3.49	4	2.69	2.69	2.54

a. RATR is a small sample correction of the Trace statistic.

Table 2: The Cointegration Vector

pcom	*Y*	*G*	*q*
2.5	10.5	-2.3	1
(**)	(**)	(**)	

Note: (**) means statistically significant at a level of 5 per cent

A common, though incorrect, inclination is to interpret the cointegration vector coefficients (Table 2) as partial derivatives, for example by saying that a 1 per cent increase in total commodity prices induces a permanent 2.5 per cent depreciation of the Canadian dollar. Wickens (1996), however,

10. For almost half of a panel of 14 countries, including Canada, MacDonald and Nagayasu (1999) present statistical evidence that real interest differentials are non-stationary.
11. The Trace and Lambda-max tests suggest a marginally significant second cointegration vector. This second vector, however, is not robust to a small sample correction of the Trace test. We thus proceed under the assumption that there is one cointegration vector in the model.

shows that reduced-form cointegration vectors should not be interpreted without further structural assumptions. Intuitively, given the endogeneity characterizing the set of variables, a shock to each variable induces movements in the others.

3.1 The identification methodology

King et al. (1991) develop an identification methodology that allows for a structural interpretation of a cointegrated VAR.[12] As one cointegration vector has been identified, the stochastic trend in the real exchange rate can be expressed as a linear combination of the three other stochastic trends. This reduced-form cointegration vector is combined with long-run restrictions to identify three permanent shocks.[13] In structural VAR models, the order of the variables matters, and in the context of long-run restrictions the variables are put in decreasing order of long-run exogeneity. To the extent that economic theory involves mainly long-run relationships between variables, relying on restrictions on the long-run structure of the model is considered to be less ad hoc than its contemporaneous counterpart. In the present case, with four I(1) variables and one cointegration relation, we need to impose three constraints. The first two restrictions, corresponding to the two zeros in the first row of Table 3, are that commodity prices are not affected in the long run by permanent shocks to output and government spending. This assumes that commodity prices are the most exogenous variable in the long run and that they are driven mainly by exogenous factors (advances in extraction technology, declining trade barriers, and falling transport costs).[14] The third constraint (the zero in the second row of Table 3) implies that only commodity price shocks and supply shocks can have a long-run impact on the output differential. Thus, technology shocks that improve efficiency in commodity production are allowed to have a permanent impact on output. The short-run dynamics are unrestricted and the other long-run relations are estimated freely.

These constraints, with the exception of the order of the output and fiscal variables, are consistent with a theoretical model initially developed by Rogoff (1992) and applied by Rogers (1999) to identify structural VARs. In Rogoff's model, because governments are not assumed to optimize, supply shocks are not allowed to affect public spending in the long run. But, in turn, this implies that fiscal shocks can have a permanent effect on supply. We nevertheless believe that such effects

12. Details of King et al.'s identification methodology are given in Appendix A. We have modified CATS in RATS procedures to implement it.

13. The use of long-run restrictions to identify structural shocks in a VAR model without cointegration has been proposed by Blanchard and Quah (1989).

14. While the world demand for commodities has soared since the end of World War II, prices have generally declined, suggesting that improvements in supply have more than compensated for the greater demand.

should be small compared with those associated with purely supply disturbances.[15] Furthermore, this alternative ordering is more consistent with a widely recognized historical regularity; that is, a net tendency for the public sector to grow relative to national income in the long run, known as Wagner's Law (Atkinson and Stiglitz 1980). As citizens of a country get richer, they are likely to increase their demand for public goods (for example, a clean environment, the creation of new social programs, and foreign aid).

3.2 Results

3.2.1 The estimated long-run impact of typical structural shocks

As shown in Table 3, our results suggest that a permanent 3.34 per cent increase in commodity prices leads to a permanent fall in relative output of 0.74 per cent (i.e., an increase in relative Canadian output), and a small appreciation of 0.07 per cent of the Canadian real exchange rate. The small appreciation of the real exchange rate is consistent with a fully specified dynamic model calibrated for the Canadian economy (see Macklem 1993), in which a permanent deterioration in the terms of trade leads to a small appreciation in the long run.[16] By cashing in on higher export prices, the positive effect of commodity prices on Canadian income is easily understandable. Furthermore, not only are commodity price shocks positive for Canada, but they negatively impact the United States, which is a net importer of primary products. In that context, it is not surprising to find an asymmetrical reaction favourable to Canada.

Table 3: Long-Run Matrix of the Structural Shocks

	η^c	η^y	η^g
pcom	3.34	0	0
Y	-0.74	0.5	0
G	0.34	1.55	0.62
q	-0.07	1.8	-1.4

15. Blanchard and Quah (1989) show that this argument is sufficient to adequately identify these shocks.
16. Given that the imported good is fixed as the numeraire in this model, terms-of-trade movements correspond to movements in the real price of commodities. Thus, our results are directly comparable. This result is discussed further in section 3.2.2.

The estimated long-run effect of the identified supply shock, η^y, indicates that a 0.5 per cent fall in Canadian output relative to the United States leads to a real depreciation of the Canadian dollar of 1.8 per cent. This result, recently documented by Alquist and Chinn (2002) for the euro-dollar exchange rate, is consistent with the Balassa-Samuelson framework. This result, however, is at odds with previous work using a similar approach, which found that a positive supply shock induced a real exchange rate depreciation (Dupasquier, Lalonde, and St-Amant 1997). The latter result was interpreted in the context of a demand-side model, in which a permanent shift to output requires a real exchange rate depreciation to clear the resulting excess supply via an improvement in the trade balance. This argument, however, is valid only in the short run, and sets aside resource reallocation that will occur to push the economy towards a new equilibrium.

On the fiscal side, a positive supply shock (favouring the United States) is associated with an increase in the relative size of U.S. government expenditures. Thus, over the sample, as a country becomes richer (poorer), its government's share of GDP tends to increase (decrease). This fact results directly from our identification hypothesis discussed earlier, in which we allow fiscal authorities to respond to output shocks by allocating more or less resources to the public sector. For us, this seems more in line with historical facts than to suppose that government expenditures are unlikely to respond to permanent changes in national income.

A decrease of 0.6 per cent in the relative size of Canadian government expenditures (η^g) leads to a real appreciation of the Canadian dollar of 1.4 per cent, which is consistent with the view that financial markets see governments as being less efficient in allocating resources than the private sector.

3.2.2 Variance decomposition of the real exchange rate

As shown in Table 4, we find that an important part of the short-run forecast error variance of the real exchange rate is explained by commodity price shocks and transitory shocks.[17] Commodity price shocks are one of the dominant sources of the real exchange rate's unexpected movements in the first three years. However, they explain none of the real exchange rate movements over the long run. This suggests that the disequilibrium induced by a permanent shift in commodity prices is absorbed over the medium term by the real exchange rate, presumably because of price rigidities in goods and labour markets. But in the long run, once the necessary adjustments in the economy have been completed, the final effect on the real exchange rate tends to be very small. As stated earlier, this interpretation is consistent with a fully specified dynamic model calibrated

17. The persistence of transitory shocks is explained mostly by movements in the differential of real interest rates, which have been at times very persistent. When the model is estimated under the assumption of non-stationarity of the interest rate differential, the transitory component is actually much less persistent. These results can be obtained from the authors.

for the Canadian economy (see Macklem 1993), in which a permanent deterioration in the terms of trade leads to a small appreciation of the real exchange rate in the long run. This result contrasts with the standard argument that suggests that a permanent terms-of-trade deterioration would require a depreciation in the equilibrium real exchange rate.[18] According to the model simulations, the negative impact of a permanent terms-of-trade deterioration on real wages in the resource sector is outweighed by the positive impact in the manufacturing sector (since resources are an input), and creates an excess demand for non-tradables. Therefore, an increase in the relative price of non-tradables (a real exchange rate appreciation) is required to equate demand and supply in this market.

Table 4: Variance Decomposition of the Canadian Real Exchange Rate

Horizon	η^c	η^y	η^g	Transitory shock
1 year	27	39	14	20
2 years	32	35	19	14
3 years	29	31	25	15
5 years	18	36	30	16
∞	0	61	39	0

In the long run, the main contribution to the variance of the real exchange rate, 61 per cent, comes from supply shocks. The predominance of productivity factors over terms-of-trade effects can be explained by the fact that the real exchange rate is more than a relative price reflecting trading sector activities. By restricting our attention to trade, we neglect the financial aspects of the exchange rate, the key determinant of which is the rate of return on capital. Hence, when a persistent gap emerges between Canada and the United States in terms of their per-capita output growth, Canada is faced with a relative impoverishment, which could be reflected negatively in the rate of return of capital in the overall economy (see the interest rate differential over the 1990s in Figure 1). This makes the Canadian economy less attractive to foreign investors, putting downward pressure on its currency.

These results are in stark contrast with the results of Amano and van Norden (1995), who found that commodity prices are the key long-run determinant of the Canadian real exchange rate. Their exchange rate equation was based on a long-run relationship with real commodity prices that were split between energy and non-energy components.[19] According to their equation, the Canadian

18. The required depreciation is noticeable through short-run effects.
19. In this equation, short-run dynamics are captured by a nominal interest rate differential, while we use a real interest rate differential.

dollar's depreciation (in real terms) has been driven mainly by the decline in real commodity prices. By focusing only on commodity prices as fundamentals, however, the equation obviously overemphasizes their importance.[20] As our framework incorporates a richer menu of shocks, the relative importance of commodity prices is consequently reduced.

Another important difference concerns the specification of deterministic trends. At the time of the initial estimation of the Amano-van Norden equation (the early 1990s), there was no clear deterministic trend in the real exchange rate over their sample, which would justify its omission. However, almost 10 years later, with persistent depreciation of the Canadian dollar, its absence is more problematic. A significant deterministic trend also appears in the non-energy component of commodity prices, and is clearly reflected in its relative contribution in the real exchange rate historical decomposition. By failing to account for a deterministic trend in the real exchange rate, the long-run contribution of any explanatory variable that also has a deterministic trend is overestimated. Chen and Rogoff (2002) arrive at a similar conclusion when they examine the importance of commodity prices in determining the real exchange rates in the case of three small open economies. In particular, they show that the relationship between the Canada-U.S. real exchange rate and commodity prices is very sensitive to detrending and, once correctly detrended, the observed correlation between the two series tends to be not significantly different from zero.

To correctly specify a time-series model, we have to take into account any deterministic trend, even though there might not be an economic rationale for it (Campbell and Perron 1993, Hamilton 1994, Enders 1995, and Hendry and Juselius 2001). To the extent that statistical analysis is essentially concerned with stochastic behaviour, it has absolutely no ability to explain the deterministic component of the series. As Chen and Rogoff emphasize, "the downward drift in both series [commodity prices and real exchange rate] may be intimately connected; we simply cannot statistically demonstrate any such connections."

3.2.3 Historical decomposition of the real exchange rate

Figure 1 shows four main periods in the evolution of the real exchange rate. The first, stretching from the beginning of the 1960s to the mid-1970s, is characterized by a tendency for the Canadian dollar to appreciate. This is followed by a second episode from the mid-1970s to the mid-1980s, where it depreciates by about 25 per cent. In the third period, from 1985 until the beginning of the 1990s, the Canadian dollar recovers, and finally, in the 1990s, it depreciates by about 35 per cent.

20. Murray, Zelmer, and Antia (2000) and Djoudad and Tessier (2000) have tried, without success, to find a significant role for productivity within the Amano-van Norden model.

To isolate the relative contribution of the structural shocks over these periods, we decompose the real exchange rate into three components: commodity prices, supply factors, and fiscal policy. Each of these components represents the cumulative contribution over time of a specific "permanent" structural shock on the Canadian real exchange rate. The summation of these three components, together with the transitory component, constitutes the stochastic component of q.

Our results suggest that supply shocks dominated in the 1960s to the mid-1970s and again in the 1990s (Figure 2). Over the first part of the sample (until the mid-1970s), Canada's real GDP per capita was catching up with that of the United States and was contributing to a 15 per cent real appreciation of the Canadian dollar. Then, from around 1975 until the beginning of the 1990s, both economies grew (in per-capita terms) at approximately the same rate. Finally, in the 1990s, Canada lagged the United States in terms of growth, and this was reflected in a strong depreciation of the currency. If we restrict our analysis to the more recent period, it is clear that the Canadian economy, while improving over the period, has not performed as well as that of the United States.

The contribution of government shocks to movements in the real exchange rate has also been important. These shocks explain a depreciation of almost 15 per cent over the 1975–85 period, as well as the subsequent appreciation in the second half of the 1980s. Fiscal consolidation in the 1990s also provided some support for the currency over the same period.

In structural VARs with long-run restrictions, shocks from exogenous sources other than those specifically identified in the model tend to be incorporated in the shock associated with the first variable in the model. If the degree of integration of a series seems to be ambiguous, that means that the series is clearly driven by a persistent shock.[21] To the extent that the modelization is dichotomic in terms of transitory and permanent shocks, it is possible that part of these persistent shocks affecting a stationary series would be identified as permanent shocks and therefore unidentified in terms of the well-defined shocks. In our model, permanent shocks to the real interest differential are not allowed, since we assume that this series is stationary in our base case. But borderline unit root tests show that this series presents some degree of persistence. Consequently, a lot of this persistence over the sample may be "wrongly" attributed to the other permanent shocks and bias upward their explanatory power. By specifying real interest rate differentials as a non-stationary series, we can formally identify permanent shocks to the real interest rate differential, and the permanent component is now shared between four instead of three identified shocks. To verify the robustness of the model to the degree of integration of this series, we have estimated the model under the assumption that the real interest rate differentials are rather non-stationary. The results, shown in Figure 3, seem very robust to this new specification, particularly for the supply

21. Formally, such a series is likely fractionally integrated.

and fiscal component that turn out to be a bit more important for the historical decomposition, to the detriment of commodity price shocks (particularly over the past decade).

4. Conclusion

In this paper, we studied the impact of supply shocks on the Canadian real exchange rate. We specified a structural vector-error-correction model that links the real exchange rate to different fundamentals (commodity prices, productivity, government size, and real returns). The identification scheme we used to recover the different shocks was based on long-run restrictions and allowed us to decompose the real exchange rate according to different long-run trends, basically defined in terms of permanent shocks.

Two main results emerge from our analysis. First, a positive supply shock in favour of Canada leads to a real exchange rate appreciation. Although consistent with the Balassa-Samuelson hypothesis, this result contradicts previous findings that have used a similar methodology. Second, commodity price shocks tend to be an important determinant of exchange rate movements over the short and medium run, but supply shocks have the largest impact over the long run. In particular, supply shocks explain most of the *stochastic* depreciation of the Canadian real exchange rate since the beginning of the 1990s.

We can explain the predominance of productivity factors over terms-of-trade effects over the long run by recognizing that the real exchange rate is more than just a relative price that reflects trading sector activity. Restricting our attention to trade sets aside financial aspects (e.g., capital flows) of the exchange rate for which the key determinant is the relative rate of return of capital. The latter is likely dependent upon the productivity of the overall economy, which includes non-tradable sectors, usually excluded from explanations of exchange rate dynamics.

Over the past decade, it has become clear that the Canadian economy has underperformed relative to the United States—labour productivity and the employment rate have not grown as impressively—and our research results suggest that this underperformance has contributed to a significant part of the depreciation. This is not to deny the importance of commodity prices in the depreciation, as we estimate that they explain a big part of the short-run dynamics. But our results somehow relativize the contribution of commodity prices in light of other potential determinants of the Canadian real exchange rate. Even though there has been a clear downward trend in commodity prices, the Canadian economy has proven to be flexible enough to reallocate productive factors towards more profitable sectors, as is reflected by the declining share of primary products in our exports. It is, however, difficult to imagine how the exchange rate could recover persistently without sound structural reforms aimed at improving the overall efficiency of the Canadian economy. This is beyond the scope of this paper and is left for future research.

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Figure 1: Data

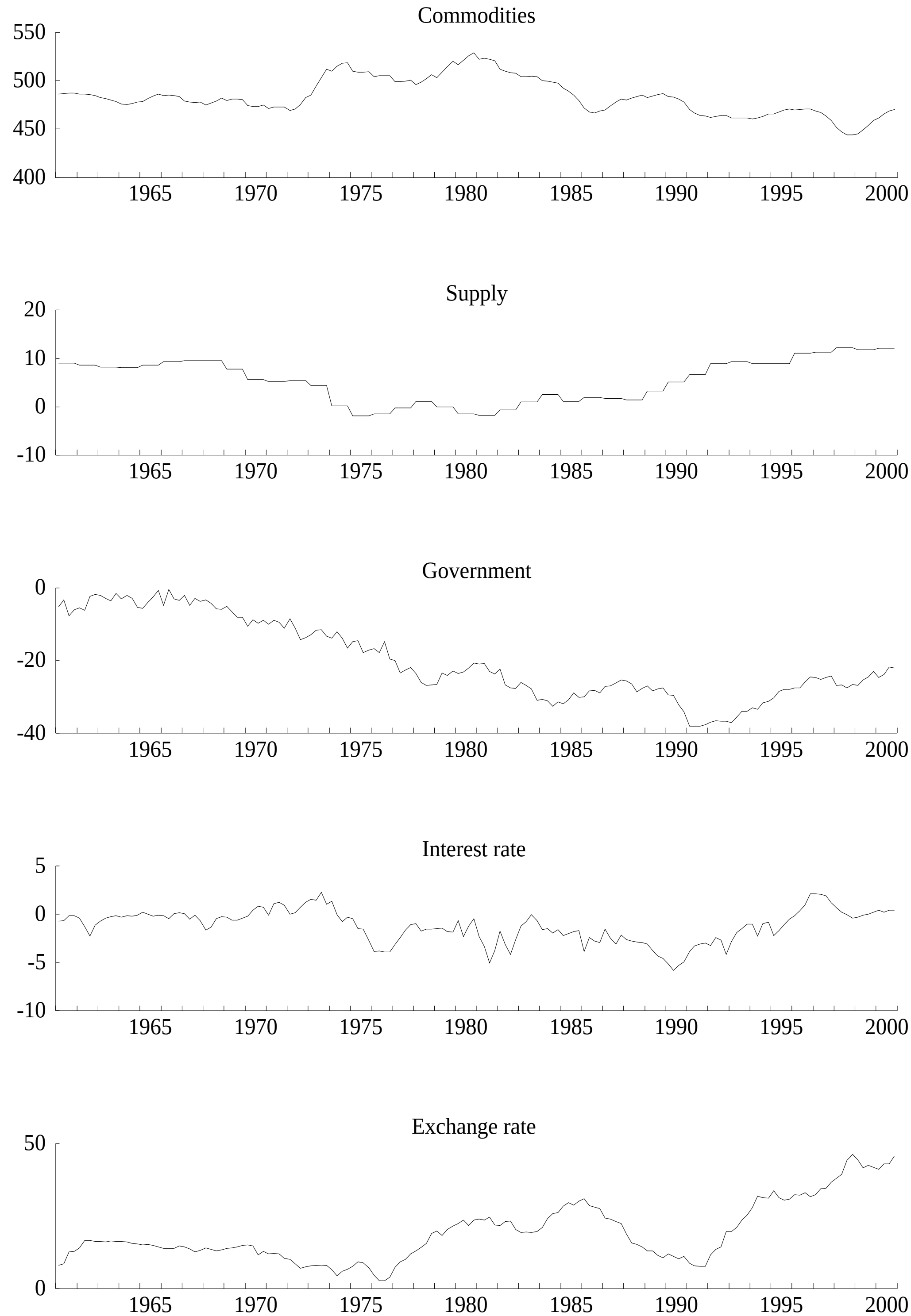

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Figure 2: Historical Components of the Canadian Real Exchange Rate

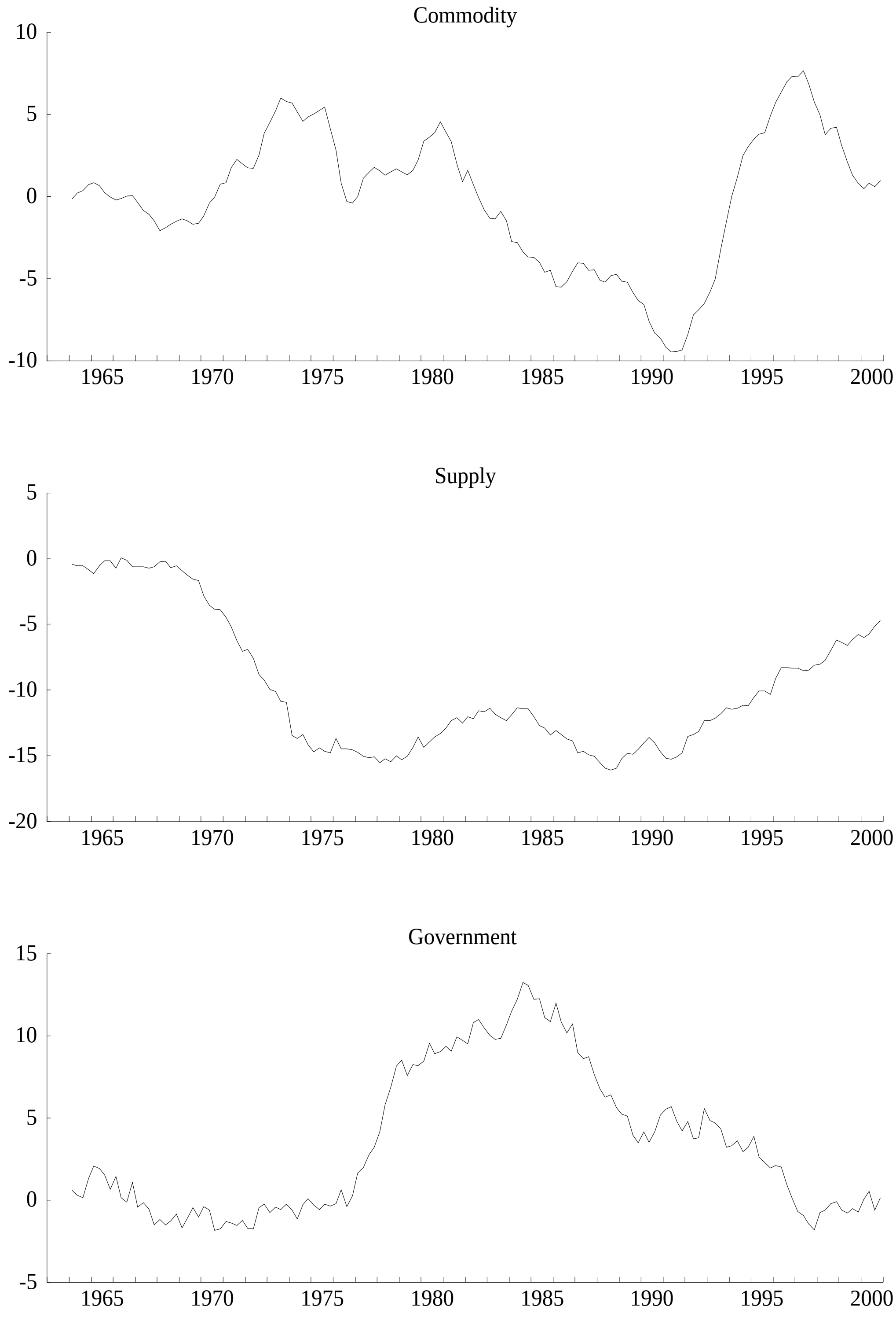
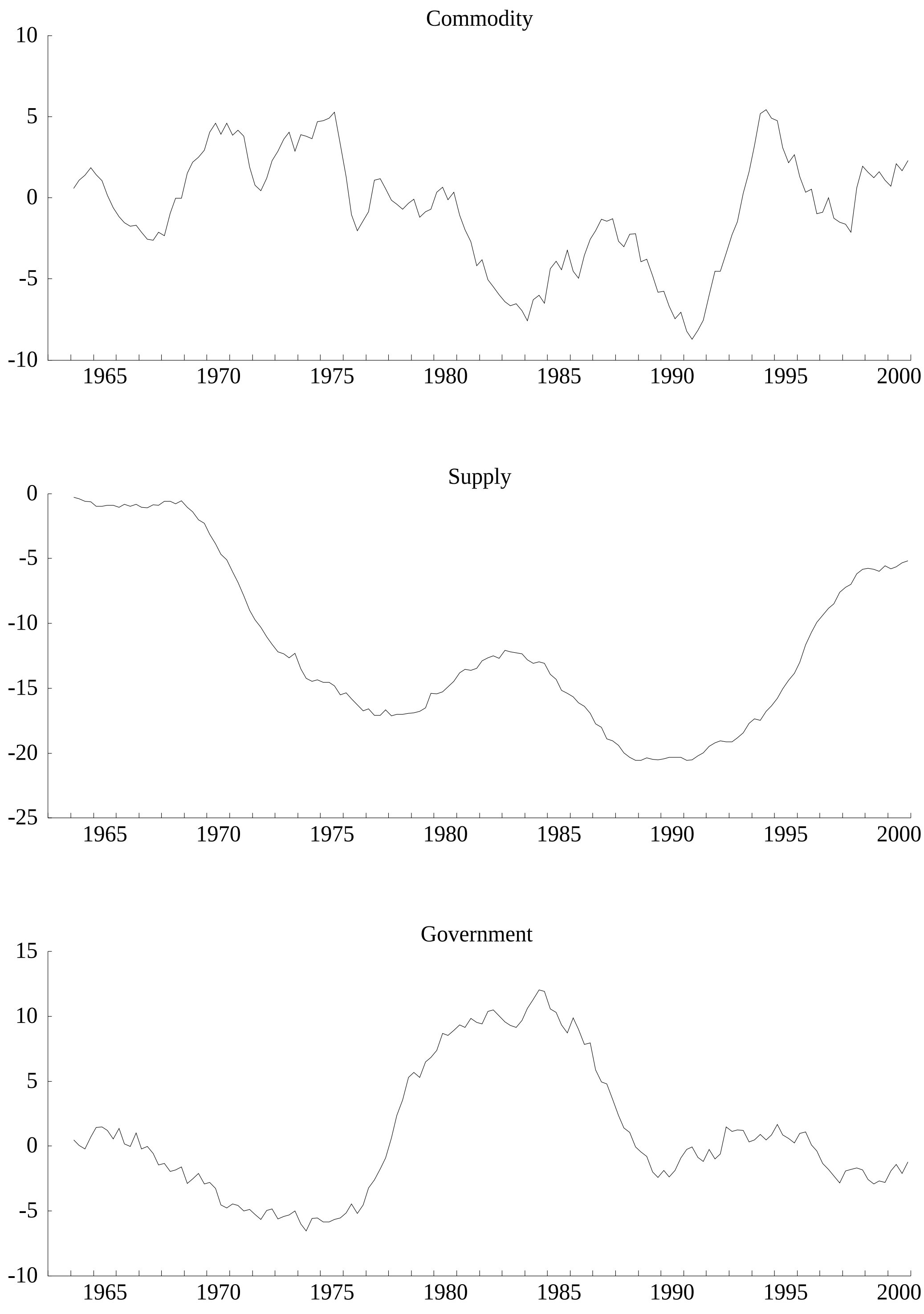


Figure 3: Historical Components of the Canadian Real Exchange Rate

Interest rate I(1)



Appendix A: King et al.'s (1991) Identification Methodology

The reduced-form VECM can be inverted to obtain the following MA representation:

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

where e_t is an (nx1) vector of innovations. We want to identify the following structural model:

$$X_t = \Gamma_0 \varepsilon_t + \Gamma_1 \varepsilon_{t-1} + \ldots = \sum_{i=0}^{\infty} \Gamma_i \varepsilon_{t-i} = \Gamma(L)\varepsilon_t, \tag{A.2}$$

where both the structural shocks, ε_t, and Γ_i matrices are unknown.

The first identification constraint is that $Var(\varepsilon_t) = \Sigma_\varepsilon$ is block-diagonal, the two blocks corresponding to the partition $\varepsilon_t = (\varepsilon_t^{p\prime}, \varepsilon_t^{t\prime})'$, where ε_t^p is the vector of (kx1) permanent shocks, and ε_t^t is a vector ((n-k) x 1) of transitory shocks.

The other identification restrictions are

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

where $\tilde{A}$ is a known (nxk) full-rank matrix, whose columns are orthogonal to the cointegration vectors; i.e., $\beta'\tilde{A} = 0$. Π is a lower triangular (kxk) matrix, and 0 is an nx(n-k) matrix of zeros. Given that Π is usually not diagonal, the variable ordering becomes important, since the lower a variable is in the system, the bigger are the number of permanent shocks that can influence it in the long run.

We will now show that these restrictions are sufficient to identify the structural model. Equations (A.1) and (A.2) are related by:

$$\Gamma_0 \varepsilon_t = e_t, \tag{A.4}$$

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

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

Let D be any (kxn) solution of $C(1) = \tilde{A}D$. Since $C(1)e_t = \Gamma(1)\varepsilon_t = \tilde{A}\Pi\varepsilon_t^p$, we can write

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

$$\text{and } D\Sigma_e D' = \Pi\Sigma_{\varepsilon'}\Pi'. \tag{A.8}$$

Let $\overline{\Pi} = chol(D\Sigma_e D') = \Pi\Sigma_{\varepsilon'}^{1/2}$. Since Π is a triangular matrix, and $\Sigma_{\varepsilon'}$ is diagonal, we obtain a unique solution for Π and $\Sigma_{\varepsilon'}$. By (A.3), we can thus identify the permanent shocks:

$$\varepsilon_t^p = \Pi^{-1}De_t = Ge_t. \tag{A.9}$$

We can easily show (see King et al.) that the dynamic multipliers of η_t^p are identified by

$$\Gamma(L) = C(L)\Sigma_e G'\Sigma_{\varepsilon_t^p}^{-1}. \tag{A.10}$$

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