Trade and GDP Growth: Causal Relations in the United States and Canada

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Causal relations between the growth rates of exports, imports, and the GDP of Canada and the United States are studied using the vector error correction (VEC) model. Utilizing time-series annual data (1948–1996), Granger causality tests are performed within the framework of the VEC model. Bidirectional causality is supported for Canada from the foreign sector to GDP and vice versa. A weaker relationship between the foreign sector and GDP is statistically supported for the United States. These results are also supported by comparing the total trade (exports plus imports) shares to GDP of the two neighboring economies. The Granger causality tests suggest that Canada is a more open economy than the United States and more trade dependent.

1. Introduction

Economic policies leading to economic growth and development have been studied by many economists for a long time. The literature in this area is rich; a number of candidate variables that may be related to economic growth have been considered and carefully examined. Some of these variables are investment, saving, inflation, inflation variability, governmental expenditures as a percentage of GDP, government deficit, and other mainly macroeconomic variables. Many economic models were constructed for the purpose of understanding economic growth and to shed light on this issue.¹ A group of economists has focused exclusively on the foreign sector, particularly on the relationship of exports, imports, and GDP growth. Emphasis on international trade dates back to the mercantilists more than two centuries ago. Mercantilists were firm believers that trade surpluses were the only favorable outcome for the domestic economy from international trade relations. Mercantilists supported export promotion and pro-

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¹ A representative sample of these models is the work of Grier and Tullock (1989); Kormendi and Meguire (1985); Barro (1991); Mankiw, Romer, and Weil (1992); and Fischer (1993). Recently, endogenous growth models are becoming popular. A good example of this is Romer (1979, 1986).
tection of domestic industries since they were preoccupied with the accumulation of gold reserves and not necessarily with the standards of living or the growth and economic development of the country per se. Many other authors, since the mercantilists, support the expansion of the foreign sector for a variety of reasons. One of these reasons is that expansion of the export sector allows countries to attain economies of scale by specializing in production. This is particularly important for smaller countries where the national markets are too small to allow specialization. Some economists in favor of expansion of the export sector stress the common belief that the export sector is the most efficient sector of the economy. It is the sector where workers enjoy the highest wages and firms earn the highest profits since only the most efficient firms can compete successfully in the global market. Other supporters of export promotion point out that development of the export sector permits countries to have access to higher levels of technology and technologically rich capital. This access is crucial to developing countries. Such inflow of foreign capital and transfer of technology would not be possible without the export sector providing the means for payment since exports constitute the main source of foreign exchange. Export expansion allows countries to follow a speedier pace toward industrialization and economic growth.

A variety of models have been suggested in the literature to study the effects of the foreign sector on the domestic economy and vice versa. A group of econometric models rely on Granger causality tests to explain relations between trade and the domestic economy. Three studies from the literature that employed similar methodology are reviewed herein. Ahmad and Harnhirun (1996) examined causality between exports and economic growth for five countries of the Association of Southeast Asian Nations (ASEAN). The countries were Indonesia, Malaysia, the Philippines, Singapore, and Thailand. Their model is a bivariate two-equation vector autoregression (VAR) covering the period 1966–1986. Ahmad and Harnhirum were able to test for cointegration in only four of the countries since exports and GDP for Thailand were not integrated in the same order. In the remaining four countries, they found that exports and GDP were not cointegrated; consequently, the error correction term could not be included in their model. Based on their results, Granger causality is supported from GDP to exports for each of the four countries. This finding runs against the common belief that Southeast Asian countries were exceptionally successful in achieving economic growth by following export promotion policies.

Dutt and Ghosh (1996) studied causality between exports and economic growth for a relatively large sample of countries using the methodology of the error correction model (ECM). For the countries in which they found cointegration, the VEC model was estimated, and tests for Granger causality were performed. Canada and the United States were two of the countries in their sample, which covered the period 1953–1991. Dutt and Ghosh found no causality for Canada between exports and GDP in either direction, but they found causality from GDP to exports for the United States. In other countries the results were mixed. Some countries experienced export-led growth, others the opposite (growth-led exports), some showed bidirectional causality, and others demonstrated no causality. Their model differs from the present analysis since Dutt and Ghosh utilized a bivariate two-equation ECM model. An interesting feature of the empirical part of this paper is that the authors pointed out the source of causality for each country, that is, short- or long-run causality. This was based on the F- and t-tests, respectively.

Restricted and unrestricted VAR models were employed by Ghartey (1993) to examine any causal relation between exports and economic growth for Taiwan, Japan, and the United States. Ghartey utilized Hsiao’s version of Granger causality (Hsiao 1979). The three endoge-
nous U.S. variables were GDP growth, export growth, and capital stock or the terms of trade as the third variable. For the United States, it was found that economic growth causes export growth, while the opposite is true for Taiwan. A feedback causal relationship or bidirectional causality between exports and economic growth was found for Japan. It is clear from these and other studies not reported here that there exists inconclusive evidence regarding the causal relations of trade and GDP growth. Such inconclusiveness should be attributed partly to different methodologies and periods covered by these studies as well as to genuine differences between these economies. Similar results with the present study for Canada and the United States were found in another study by Tao and Zestos (1999) for Japan and Korea. For Korea, a country that has a more trade-dependent economy than Japan, Granger causality tests indicate stronger causal relations.

This paper investigates causal relations between the growth of GDP, exports, and imports for Canada and the United States, using a trivariate VEC model. Evidence of cointegration for both countries allowed us to estimate the VEC model. Granger causality tests were performed on the basis of the estimated VEC model. The model distinguishes two types of causality: long-run causality and short-run causality. The Granger causality tests reveal that the existence, direction, and degree of Granger causality in the two countries differ substantially. These results can be explained by historical differences of the two countries’ economies. Stronger causal relations were revealed in the growth of GDP, exports, and imports for Canada than for the United States. These differences are attributed mainly to differing degrees of openness of the two countries to the world economy.

This paper is structured as follows. In section 2, we discuss international trade and development theories. Granger causality tests, cointegration, and the VEC model are also presented in this section since they are the main tools of our analysis. In section 3, we describe and present graphically the Canadian and the U.S. data and report the unit root tests for all variables. Since the variables, exports, imports, and GDP were integrated of the same order and cointegrated, the model was estimated. The estimated VEC model is presented in section 4 together with the results of the Granger causality tests. In section 5, a conclusion and a summary of the paper are given.

2. International Trade and Economic Development Theories

Many authors have stressed the positive effects of the export sector to the rest of the economy, including Balassa (1978, 1985), Krueger (1980), Feder (1983), and Bhagwati and Shrinivasan (1978). It has also been suggested that growth of output causes growth of exports (Jung and Marshall 1985). Other groups of economists have opposed the export-led growth approach. Nurkse (1961) advocated the “balanced growth” theory, while Prebisch (1962) supported the import substitution approach; the latter is diametrically opposite to the export-led growth hypothesis. The import substitution approach dictates self-sufficiency of the country and thus absolute trade protection. These trade and development theories have had an unparalleled influence on long-run economic policies adopted by countries. The two polar cases, export-oriented growth and import substitution, have split the developing countries into two distinct groups. The first is represented mainly by the Southeast Asian countries and the second by the Latin American countries.

Economists have constructed many models for the sole purpose of explaining how trade
expansion contributes to economic growth. Estimation of a single equation and correlation analysis dominated the early contributions. A few authors, such as Kwak (1994), adopted the factor growth accounting method, while other economists, such as Pack and Page (1994) and Esfahani (1991), utilized the neoclassical growth model. Some of these models employ cross-section multicountry data (see Afxentiou and Serletis 1991), while other models utilize time-series data for one country or a selected group of countries.

Granger Causality Models

Several econometric studies focus exclusively on Granger causality (Granger 1969). Granger causality from a variable $X$ to a variable $Y$ is established when knowledge of past values of $X$ improve the prediction of future values of $Y$, over and above the prediction that is based on knowledge of past values of $Y$ alone.\(^2\)

The simplest standard causality test is the pairwise Granger causality test. This is a bidirectional test for Granger causality regarding only two variables. Granger causality from $X$ to $Y$ is established when the coefficients of the lagged differences of $X$ are found to be jointly statistically significant and therefore help explain and predict $Y$, over and above what the lagged differences of $Y$ can predict.

Another standard causality test similar to the pairwise Granger causality test is based on a model including more than one independent variable. The explicit format of this standard causality model is constructed according to the empirical evidence of the stability properties of the time-series variables involved (see Serletis 1992); thus, if the variables are not cointegrated, the model must be expressed only in first differences. The null hypothesis is examined ($F$-test) to determine whether the coefficients of the lagged differences of an independent variable are equal to zero in a single-equation model, including the lagged differences of the dependent variable and the lagged differences of at least another independent variable.

Cointegration and the ECM

Another causality test was developed by Engle and Granger (1987). In a bivariate setting, Engle and Granger introduced a new causality test while simultaneously introducing cointegration. Generally stated, two variables are cointegrated if they have a common stochastic trend, that is, if they move together for a long period of time. More formally, two variables that are stationary in their first differences but nonstationary in their levels are said to be cointegrated if there exists a stationary linear combination between them. To test for cointegration in the bivariate case, one has only to find statistical evidence that the residuals of a linear combination of the two variables are stationary. If cointegration is statistically established, this constitutes evidence that there exists a long-run equilibrium relationship between the two economic variables.

For two cointegrated variables, according to Engle and Granger (1987), causality from $X$ to $Y$ can be established not only from finding jointly significant the coefficients of the lagged differences of the variable $X$ but also from finding significant the coefficient of the one-period lagged error term of the cointegrating equation of the two variables. The idea is

\(^2\)This definition of Granger causality is different and weaker from what is usually meant by causality in general. Similarly, we can define causality from $Y$ to $X$ simply by reversing the two variables in the previous definition.
rather simple: Since the variables are cointegrated, any equation describing a relation among them should include the one-period lagged stationary error term, $\theta_{t-1}$ (e.g., see Eqn. 5).

**VEC Models**

The error correction model described for the bivariate case can be generalized to include many variables. A VEC model is a VAR model corrected by simply including the one-period lagged error term (the cointegrating equation). The VEC models are based on the cointegration theory (see Johansen 1991). A general VEC model is a system in $n$ variables and $n$ equations where each variable is a function of its own lagged differences, the lagged differences of the other endogenous variables, and the error correction term. The number of cointegrating vectors is called the cointegrating rank and cannot exceed $n - 1$.

There are a few versions of the cointegration model that can be estimated depending on the assumptions of the type of the cointegrating equation and the time plots of the time-series variables. Once cointegration is established, the VEC model can be constructed. In our case, it is a system of equations with the logarithmic first differences of each endogenous variable on the left-hand side of each equation. On the right-hand side are the lagged logarithmic differences of all the endogenous variables and the one-period lagged error term $\theta_{t-1}$.

The VEC model is presented in Equations 1 to 3 in first differences:

$$\Delta \text{LGDP}_t = \alpha_1 + \alpha_{\text{LGDP}}\theta_{t-1} + \sum_{i=1}^r \alpha_{1i}\Delta \text{LGDP}_{t-i} + \sum_{i=1}^r \beta_{1i}\Delta \text{Export}_{t-i}$$

$$+ \sum_{i=1}^k \gamma_{1i}\Delta \text{Import}_{t-i} + \epsilon_{1t} \quad (1)$$

$$\Delta \text{Export}_t = \beta_2 + \beta_{\text{Export}}\theta_{t-1} + \sum_{i=1}^r \alpha_{2i}\Delta \text{LGDP}_{t-i} + \sum_{i=1}^r \beta_{2i}\Delta \text{Export}_{t-i}$$

$$+ \sum_{i=1}^k \gamma_{2i}\Delta \text{Import}_{t-i} + \epsilon_{2t} \quad (2)$$

$$\Delta \text{Import}_t = \gamma_3 + \gamma_{\text{Import}}\theta_{t-1} + \sum_{i=1}^r \alpha_{3i}\Delta \text{LGDP}_{t-i} + \sum_{i=1}^r \beta_{3i}\Delta \text{Export}_{t-i}$$

$$+ \sum_{i=1}^k \gamma_{3i}\Delta \text{Import}_{t-i} + \epsilon_{3t} \quad (3)$$

In this three-equation model, the three endogenous variables are the growth rate of the GDP ($\Delta \text{LGDP}$), the growth rate of exports ($\Delta \text{Export}$), and the growth rate of imports ($\Delta \text{Import}$). Each of the three variables is a function of the one-period lagged error correction term and the

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3 EViews, the econometrics package used to carry out most of the empirical work, automatically estimates up to five different models; these include possible combinations of linear or quadratic trend for the time-series variables and linear trend in the cointegration equation in the presence or absence of an intercept.

4 The notation $r,s,k$ refers to the optimum number of lagged differences included for each of the three endogenous variables.
lagged logarithmic differences of the other two dependent variables. Each equation also includes a random error term \( \epsilon \).

The three coefficients of the error correction term, \( \alpha_{\text{GDP}} \), \( \beta_{\text{export}} \), and \( \gamma_{\text{import}} \), are often referred to as speed-of-adjustment parameters. They reflect the response with which the system of the cointegrated variables GDP, exports, and imports move back to their long-run equilibrium relation. The larger the three coefficients of the error correction term, \( \theta_{t-1} \), the greater the response of the cointegrated variables to move back to their long-run equilibrium relation. Thus, the three coefficients capture the effect of the deviation of the variables from their long-run equilibrium on the rate of growth of each left-hand-side variable.

The estimation of the model allows testing for Granger causality. Particularly, each equation can be tested to determine whether any of the two right-hand-side variables cause the left-hand-side variable. The null hypothesis of noncausality can be rejected not only if one finds significant the lagged logarithmic differences (F-test) of a particular variable in any of the three equations but also if one finds significant the coefficient of the lagged error correction term \( \theta_{t-1} \) (t-test).

3. Data

A data set of the real variables, exports, imports, and GDP was constructed for each country consisting of 49 observations (1948–1996). In Figure 1, real exports, real imports, and total trade (the sum of real exports and real imports) are presented each as a percentage of real GDP. The three trade variables (ratios) of both countries have been increasing during the entire sample period. As can be seen from Figure 1, there is a substantial difference between the Canadian and the U.S. trade data. According to the graphs in Figure 1, Canada was always a more open economy than the United States. For example, in the last year of the sample (1996), total trade as a percentage of GDP for Canada was approximately 80%; this is much higher than the corresponding U.S. total-trade-to-GDP ratio, which was approximately 25%.

We chose to employ annual instead of quarterly data since we believe that Granger causality is a timely phenomenon and that the interaction of economic variables cannot work in short periods of a few quarters. In fact, it takes years for the complete interaction effects to materialize. For this reason, we are in agreement with Dutt and Ghosh (1996), who also utilize annual instead of quarterly data.

Stability Properties of the Variables

When formulating models with time-series variables, one must be concerned with the stability properties of the variables. According to Phillips (1987), for a set of variables found to be integrated of order one or I(1) but not cointegrated, any regression involving the levels of these variables is spurious. This implies that only cointegrated variables can be used in a

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5 It is possible to find more than one cointegrating vector; then equal numbers of error correction terms have to be included in the VEC model.

6 All data are from the International Financial Statistics of the International Monetary Fund (IMF), the CD-ROM database. We transformed nominal exports and imports to real by dividing by the export and import price indices; all real variables are expressed in 1990 national currency units. In this study, we use only real data.
model that is expressed in levels of the variables. However, if the variables are not cointegrated, any model involving these variables should be stated in their first differences.

All variables used in this study are the logarithms of the original data. We performed unit root tests and cointegration for all variables. The three variables—GDP, exports, and imports—
were found to be I(1) and cointegrated; consequently, a VEC model was formulated and estimated. Causality tests were performed on the basis of the estimated VEC model.

**Unit Root Tests**

Table 1 reports the empirical results of the unit root tests for the real Canadian and U.S. data. The augmented Dickey–Fuller (ADF) and the Phillips–Perron (1988) tests were performed. Two versions of both tests were performed, that is, with a constant only and with a constant and trend. The Phillips–Perron test is robust in the presence of both serial correlation and time-dependent heteroscedasticity. To further enhance the quality of the results in the ADF test, we included a number of lagged differences according to the Schwarz Information Criterion (SIC; Schwarz 1978). Inclusion of the optimum number of lagged differences ensures that the error becomes approximately white noise. The regression equation for the ADF test is as follows:

$$\Delta X_t = \beta_0 + \beta_1 t + \beta_2 X_{t-1} + \sum_{i=1}^{n} \phi_i \Delta X_{t-i} + \epsilon_t \quad (4)$$

where $\epsilon_t$ is the regression error assumed to be stationary with zero mean and a constant variance. A unit root test is a significance test on the coefficient of $X_{t-1}$. This is performed using the MacKinnon (1991) critical values and not the standard t-table since the left-hand-side variable under the null hypothesis is nonstationary. The Phillips–Perron test is based on the same regression as the ADF test but without the lagged differences. The t-statistic of the $\beta_2$ coefficient
Table 2. Cointegration Results of Canadian Data

<table>
<thead>
<tr>
<th>H0: Rank = r</th>
<th>Eigenvalue</th>
<th>$\lambda_{max}$</th>
<th>1% Critical Values</th>
<th>$\lambda_{trace}$</th>
<th>1% Critical Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>r = 0</td>
<td>0.4577</td>
<td>28.76***</td>
<td>22.99</td>
<td>40.63***</td>
<td>29.75</td>
</tr>
<tr>
<td>r $\leq$ 1</td>
<td>0.2040</td>
<td>10.72</td>
<td>15.69</td>
<td>11.87</td>
<td>16.31</td>
</tr>
<tr>
<td>r $\leq$ 2</td>
<td>0.0241</td>
<td>1.15</td>
<td>6.59</td>
<td>1.15</td>
<td>6.51</td>
</tr>
</tbody>
</table>

*** Significant at the 1% level.

is corrected for serial correlation using the Newey-West (1987) procedure by adjusting the standard errors.

From Table 1, it is clear that all the variables have a unit root in their levels, but they are stationary in their first differences. This permits us to perform cointegration tests using Canadian and U.S. data.

4. Cointegration and Causality Tests

The cointegration tests were performed utilizing the Johansen (1991, 1995) methodology. The Johansen methodology is a generalization of the Dickey–Fuller test. Two likelihood ratio tests, $\lambda_{max}$ and $\lambda_{trace}$, were used to test the hypotheses regarding the number of cointegrating vectors. The cointegration results obtained using the Canadian and U.S. data are reported in Tables 2 and 3, respectively. To decide on the final format of the cointegration model, a search to determine the optimum number of lags to be included in the equations of the model was performed. Once the optimum number of lags and the cointegrating rank are determined, the appropriate cointegration model can be chosen. The appropriate cointegration model for Canada was one in which the time-series variables had nonzero means and the cointegration equation had no intercept.

According to the results reported in Table 2, there is only one cointegrating equation, as indicated by both the $\lambda_{max}$ and $\lambda_{trace}$ tests. This is given in the following in terms of the one-period lagged error term $\theta_{t-1}$ in the left-hand side of the equation:

$$\theta_{t-1} = LGDP_{t-1} - 0.6739Lexport_{t-1} - 0.4371Limport_{t-1}. \quad (5)$$

The results indicate that both exports and imports enter with positive signs in the cointegrating equation and with coefficients very close to each other in magnitude. The interpretation of this relationship is that Canadian GDP is positively related to both exports and imports. While the positive relation between GDP and exports is plausible, the positive relation between GDP and imports can be explained as a long-run phenomenon where imports are a major source of new technology and physical capital investment for the Canadian economy.

The cointegration test with the real U.S. data revealed one cointegrating vector, as indicated in Table 3. The appropriate cointegration model was one in which the series had intercept and trend and the cointegration equation had only intercept.

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5 This was accomplished following a common procedure. We estimated a VAR model with undifferenced data; then, by varying the number of lags sequentially and using the Schwarz Information Criterion (SIC), we chose the optimum number of lags. These happened to be equal to one for both the Canadian and the U.S. data. The $\lambda_{trace}$ test was performed with EViews and utilized the Osterwald-Lenum (1992) critical values; $\lambda_{max}$ was performed using the econometric package PcGive (Doornik and Hendry 1991–1994), which also utilized the Osterwald-Lenum (1992) critical values.
Table 3. Cointegration Results for U.S. Data

<table>
<thead>
<tr>
<th>$H_o$: Rank = r</th>
<th>Eigenvalue</th>
<th>$\lambda_{max}$</th>
<th>5% Critical Values</th>
<th>$\lambda_{bes}$</th>
<th>5% Critical Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r = 0$</td>
<td>.3760</td>
<td>22.17**</td>
<td>21.17</td>
<td>35.51**</td>
<td>29.69</td>
</tr>
<tr>
<td>$r \leq 1$</td>
<td>.2441</td>
<td>13.15</td>
<td>14.1</td>
<td>13.35</td>
<td>15.41</td>
</tr>
<tr>
<td>$r \leq 2$</td>
<td>.0041</td>
<td>.19</td>
<td>3.8</td>
<td>.19</td>
<td>3.76</td>
</tr>
</tbody>
</table>

** Significant at the 5% level.

The cointegrating equation is presented in Equation 6, with the one-period lagged error term $\theta_{t-1}$ in the left-hand side of the equation:

$$\theta_{t-1} = LGDP_{t-1} - .851\text{Lexport}_{t-1} + .3750\text{Limport}_{t-1} - 5.6699.$$  (6)

For the U.S. data, exports and GDP are positively related, whereas imports and GDP are negatively related. Comparing these results with those obtained for Canada reveals a major difference, as imports in the United States do not play a positive role in explaining GDP. A possible explanation for this is that the United States has been a major industrial country for the period covered by our sample and was not relying on imported technology and physical capital.

According to Granger (1988), causality within the framework of the VEC model can occur in two different ways. The first way is through the impact of the lagged differences of a right-hand-side variable. The second way is through the error correction term, which is a function of the one-period lagged values of the variables. Granger suggested that the impact of the lagged differences of a right-hand-side variable on the left-hand-side variable captures the short-run dynamics of the system and therefore can be interpreted as short-run causality. The impact of the one-period lagged error correction term on the left-hand-side variable captures the extent that the variables are out of equilibrium; thus, it can be interpreted as long-run causality. Toda and Phillips (1994), who discuss the asymptotics for causality tests with a VEC model, distinguish the two parts of the hypothesis as “short-run noncausality” and “long-run noncausality.”

We reproduce the VEC model in Equations 1′–3′ without the summation sign before the right-hand-side variables since the optimum number of lagged differences for all variables was found to equal one. Such presentation of the model will facilitate the understanding of the Granger causality tests:

$$\Delta LGDP_t = \alpha_1 + \alpha_{LGDP}\theta_{t-1} + \alpha_{11}\Delta LGDP_{t-1} + \beta_{11}\Delta Lexport_{t-1} + \gamma_{11}\Delta Limport_{t-1} + \epsilon_{1t},$$  (1′)

$$\Delta Lexport_t = \beta_2 + \beta_{Lexport}\theta_{t-1} + \alpha_{21}\Delta LGDP_{t-1} + \beta_{21}\Delta Lexport_{t-1} + \gamma_{21}\Delta Limport_{t-1} + \epsilon_{2t},$$  (2′)

$$\Delta Limport_t = \gamma_3 + \gamma_{Limport}\theta_{t-1} + \alpha_{31}\Delta LGDP_{t-1} + \beta_{31}\Delta Lexport_{t-1} + \gamma_{31}\Delta Limport_{t-1} + \epsilon_{3t},$$  (3′)

In terms of our model, the null hypothesis of short-run noncausality, based on Equation 1′ from exports to GDP, is stated as $\beta_{11} = 0$. Similarly from Equation 1′, the null hypothesis of short-run noncausality from imports to GDP is stated by setting $\gamma_{11} = 0$. The null hypothesis for long-run noncausality is stated by setting each coefficient, $\alpha_{LGDP}$, $\beta_{Lexport}$, or $\gamma_{Limport} = 0$, separately in each equation.

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*This division of the two sources of causality is not totally settled in the literature, unless the decomposition of the frequency of the error correction term is studied carefully (see Granger 1988). See also Jones and Joulfaian (1991) on this issue, who also distinguish between short-run and long-run Granger causality.

*At least one of the three coefficients must be significantly different than zero to support long-run causality.
Interestingly, standard asymptotics apply here for purposes of hypothesis testing. Since the variables exports, imports, and GDP growth are cointegrated, their error correction term is a stationary variable with zero mean. According to Sims, Stock, and Watson (1990), the t-ratio of the coefficient of the error correction term follows an asymptotic standard normal distribution.

Similarly, since each variable was found to be I(1), each lagged difference is a stationary variable, and testing their joint significance can be accomplished using a standard F-test.

A test for overall Granger causality that combines the two sources of causality was also constructed. If the coefficients of the error correction term and the coefficients of the lagged differences of a right-hand-side variable are jointly significant, Granger causality is established. The null hypothesis of Granger noncausality in our model from exports to GDP based on Equation 1’ can be stated as $\alpha_{1,\text{GDP}} = \beta_{11} = 0$. On the other hand, the null hypothesis of Granger noncausality from imports to GDP can be stated as $\alpha_{2,\text{GDP}} = \gamma_{11} = 0$. The appropriate test is an F (Wald)-test. Since this test considers both sources of causality, it is the only test reported by some authors to test for Granger causality, especially when these authors are not interested in the long- and short-run impacts of the variables.

The Estimated VEC Model and Causality Tests with Canadian and U.S. Data

Since it was found that the Canadian and U.S. variables were cointegrated, this suggested that the VEC model of Equations 1’–3’ is valid and can be estimated. The estimated model is presented in Tables 4 and 5.

Three causality tests are reported in Tables 4 and 5. The first test is a t-test on the coefficient of the error correction term $\theta_{-1}$; this is a test for long-run noncausality. The second test is an F-test for short-run noncausality. In our model, this turns out to be a t-test as well, but since the two tests are equivalent, we report only the F-test. The third test is a joint F-test on the coefficients of the error correction term and the lagged differences of each relevant right-hand-side variable in each equation. The calculated values of the joint F-statistic are reported under the columns $F_1$ and $F_2$ since two such tests must be performed in each equation. In Equation 1’, for instance, we test the null hypothesis $\alpha_{1,\text{GDP}} = \beta_{11} = 0$ using $F_1$ and the null hypothesis $\alpha_{2,\text{GDP}} = \gamma_{11} = 0$ using $F_2$. In the first hypothesis we test whether exports Granger cause GDP, while in the second we test whether imports Granger cause GDP. Similar interpretations apply for $F_1$ and $F_2$ in each of the other two equations.

From the estimated VEC model in Table 4 for the Canadian data, one observes that the lagged error term $\theta_{-1}$ is significant in all three equations. This finding alone implies long-run causality from the right-hand-side variables to the three left-hand-side variables, but it alone cannot reveal the exact direction of the causality. From Equation 7, it is uncertain whether causality is implied from exports or imports to GDP, according to the F-test on the lagged logarithmic difference of exports and imports, respectively. According to the joint F-test for Granger causality, however, each right-hand-side variable, exports and imports, separately

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10 The ratio $[\text{RSS}_j - \text{RSS}_s]/(j+1)/(\text{RSS}_s/T - r - s - k - 2)$, where $j = r,s,k$ has an asymptotic F-distribution with $j+1$ and $T - r - s - k - 2$ degrees of freedom, $j$ is an index taking values equal to the number of lags of the right-hand-side variable, $s$, $r$, and $k$, where RSS = unrestricted residual sum of squares, RSS, = restricted residual sum of squares, and $r$, $s$, and $k$ is number of included lags for GDP, exports, and imports.

11 From Equation 2’, we test the null hypothesis $\beta_{1,\text{export}} = \alpha_{21} = 0$ using $F_1$ and the null hypothesis $\beta_{1,\text{export}} = \gamma_{21} = 0$. The first hypothesis tests whether GDP Granger causes exports, while in the second we test the hypothesis of whether imports Granger cause exports. Similarly from Equation 3’, we test the null hypothesis of whether GDP causes imports and the null hypothesis of whether exports cause imports.
### Table 4. Estimated Vector Error Correction (VEC) Model with Canadian Dataa

<table>
<thead>
<tr>
<th>Equation</th>
<th>Variable</th>
<th>$\theta_{t-1}$</th>
<th>$\Delta\text{LGDP}_{t-1}$</th>
<th>$\Delta\text{export}_{t-1}$</th>
<th>$F_1$</th>
<th>$F_2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>$\Delta\text{LGDP}_t$</td>
<td>0.026</td>
<td>0.09</td>
<td>0.09</td>
<td>12.72***</td>
<td>-0.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4.33)***</td>
<td>[0.17]</td>
<td>[1.74]</td>
<td>[0.11]</td>
<td>[0.11]</td>
</tr>
<tr>
<td>8</td>
<td>$\Delta\text{export}_t$</td>
<td>0.059</td>
<td>-1.14</td>
<td>0.60</td>
<td>11.09***</td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(4.48)***</td>
<td>[7.78]***</td>
<td>[16.03]***</td>
<td>[0.46]</td>
<td>[0.46]</td>
</tr>
<tr>
<td>9</td>
<td>$\Delta\text{import}_t$</td>
<td>0.04</td>
<td>-0.63</td>
<td>0.43</td>
<td>4.77**</td>
<td>0.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(2.47)***</td>
<td>[0.88]</td>
<td>[4.69]**</td>
<td>[0.46]</td>
<td>[0.46]</td>
</tr>
</tbody>
</table>

*a The figures in parentheses and brackets are the $t$- and $F$-statistics, respectively.

** Significant at the 5% level.

*** Significant at the 1% level.

### Table 5. Estimated Vector Error Correction (VEC) Model with U. S. Dataa

<table>
<thead>
<tr>
<th>Equation</th>
<th>Variable</th>
<th>$\theta_{t-1}$</th>
<th>$\Delta\text{LGDP}_{t-1}$</th>
<th>$\Delta\text{export}_{t-1}$</th>
<th>$F_1$</th>
<th>$F_2$</th>
<th>Constant</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>$\Delta\text{LGDP}_t$</td>
<td>-0.04</td>
<td>0.34</td>
<td>-0.14</td>
<td>6.02***</td>
<td>-0.02</td>
<td>1.26</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-1.28)</td>
<td>[2.93]**</td>
<td>[8.23]***</td>
<td>[0.08]</td>
<td>[0.08]</td>
<td>[0.08]</td>
</tr>
<tr>
<td>11</td>
<td>$\Delta\text{export}_t$</td>
<td>0.33</td>
<td>1.05</td>
<td>-0.10</td>
<td>7.42**</td>
<td>-0.13</td>
<td>8.08***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3.76)***</td>
<td>[3.65]**</td>
<td>[0.56]</td>
<td>[0.35]</td>
<td>[0.35]</td>
<td>[0.35]</td>
</tr>
<tr>
<td>12</td>
<td>$\Delta\text{import}_t$</td>
<td>-0.05</td>
<td>-0.07</td>
<td>-0.24</td>
<td>.19</td>
<td>0.05</td>
<td>1.83</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(-0.61)</td>
<td>[0.01]</td>
<td>[2.67]</td>
<td>[0.04]</td>
<td>[0.04]</td>
<td>[0.04]</td>
</tr>
</tbody>
</table>

*a The figures in parentheses and brackets are the $t$- and $F$-statistics, respectively.

* Significant at the 10% level.

** Significant at the 5% level.

*** Significant at the 1% level.
Granger causes GDP. Equation 8 indicates inverse causality from GDP to exports. Imports were found not to cause exports according to the $F$-test on the lagged logarithmic difference of imports. The joint $F$-tests for Granger causality, however, suggest that GDP and imports each separately Granger cause exports. Finally, Equation 9 indicates that exports Granger cause imports, but GDP does not Granger cause imports, according to the $F$-test on the lagged differences of each of these variables separately. The joint $F$-test for Granger causality suggests that both GDP and exports each separately cause imports at the 5% and 1% levels of significance, respectively.

We interpret these results as a strong case of causality in a complete circle from the domestic growth of the Canadian economy to the foreign sector and vice versa. Export expansion secured the necessary foreign exchange to pay for Canadian imports, which facilitated domestic economic growth. It is very likely that the original exports were mainly from the primary sector, that is, agricultural commodities, lumber, minerals, and so on, since Canada has always been a country rich in natural resources. On the other hand, Canadian imports were manufacturing products, either final consumer goods or tools and machinery, which contributed to industrialization and growth of the domestic economy. This process gradually transformed the Canadian economy with imports playing a favorable role in domestic growth. The latter point is supported by the positive relationship in the cointegrating vector between GDP growth and the growth of imports and by the historical trade data of exports, imports, and total trade, which amounted to a large and increasing percentage of Canadian GDP during the entire sample period (Figure 1).

The estimated VEC model for the U.S. data is reported in Table 5. The results suggest strong Granger causality from exports to GDP as shown in Equation 10. There is no evidence of Granger causality from imports to GDP, according to the $F$-test on the lagged difference of imports and according to the joint $F$-test of Granger causality as indicated by $F_2$. It is unlikely that the growth of imports Granger caused the growth of GDP, especially in our sample period 1948–1996. It is, however, plausible that in the early years of the United States, before and after independence, imports played an important role in affecting GDP growth. The error correction term in Equation 10 is insignificant, implying lack of long-run causality from the growth of exports or imports to GDP. The question arises, What can be said for Granger causality in such a case? To answer this question, we rely on both the joint $F$-test for Granger causality and the $F$-test on the lagged differences of exports and imports. It is seen in Table 5, according to the results of the joint $F$-test for Granger causality, that exports Granger cause GDP but that imports do not cause GDP. This was based on the test statistics $F_1$ and $F_2$. Interestingly, these results are in agreement with the individual $F$-tests of the two variables, which suggest that exports cause GDP but that imports do not.

In Equation 11, the error correction term $\theta_{v,1}$ is highly significant, and the lagged differences of GDP are also significant. According to the joint test for Granger causality, both GDP and imports are also highly significant, therefore causing exports. Finally, Equation 12 indicates that no statistically significant relationship exists between imports and either of the other two variables.

These results are plausible. The result that exports Granger cause GDP is in agreement with the positive relationship between exports and GDP in the cointegrating equation. In Equation 12, no variable is statistically significant, thus causing imports. It is very logical that exports did not cause imports. The United States, as a key currency country, for a large part of the sample period did not experience foreign exchange constraints that were alleviated by U.S.
exports. The U.S. dollar was, and still is, a widely accepted currency for international payments. These results are congruent with the joint $F$-test, which also indicated that no other variable causes imports, and the growth of imports did not cause GDP growth as shown in Equation 10. In Equations 10 and 12, the significance of the constant terms implies that there are possible omitted variables in the model. For example, in Equations 10 and 12, the U.S. capital account surplus may be an omitted variable that caused both growth of GDP and growth of imports. We included the real U.S. capital account surplus in lieu of U.S. imports in the VEC model and estimated this model for the period 1960–1966. We found that U.S. capital account surplus does not Granger cause, or is caused by, U.S. GDP or exports.\textsuperscript{12}

The interpretation of the two sources of causality is meaningful. In Canada, a country very much dependent on trade, the growth of exports, imports, and GDP is in a long-run equilibrium relationship, as indicated by a highly significant cointegrating equation and error correction term in all three equations. According to the joint $F$-test for Granger causality, every right-hand-side variable was also significant. For the United States, we found a weaker relation between foreign trade and growth of the domestic economy. The cointegrating equation was significant at the 5\% level. The error correction term was significant in only one of the three equations of the VEC model, and only one right-hand-side variable was highly significant in both Equations 10 and 11.

5. Conclusion

On the basis of a VEC trivariate model, which includes the growth variables of GDP, exports, and imports, Granger causality tests were performed to reveal possible directions of causality. The VEC model was estimated for the period 1948–1996 for Canada and the United States. The results for Canada show that the three variables are closely related and that causality is established in every possible direction. For the United States, exports were found to cause GDP. Comparing the Canadian and U.S. Granger causality tests, strong causality is supported for Canada, but not an equally strong relation is supported for the United States. This is consistent with the fact that Canada is more trade dependent and has a more open economy than the United States. This is clearly indicated in Figure 1, where the exports, imports, and trade shares of the two neighboring countries are presented.

Three explanations are provided for the weaker case of Granger causality in the United States. First, the United States is a large industrial country with a large national market that has been in some ways in the past economically isolated from the rest of the world. Second, the United States, as a key currency country for a long period, was able to import goods and services and invest in foreign countries regardless of the level of its exports. As a result, exports and imports in the United States were not closely related. In other countries, exports provide the required foreign exchange to pay for their imports. Third, prolonged U.S. government deficits since the early 1980s resulted in high U.S. interest rates, which attracted foreign financial capital in the United States. The exceptionally large U.S. capital surplus has most likely distorted the long-run relationship between U.S. exports, imports, and GDP.

\textsuperscript{12} It was not possible to find data for the entire 1948–1996 sample for the U.S. capital account surplus. A smaller data set for 1960–1996, however, was constructed for the U.S. real capital account surplus in constant 1990 dollars from the Economic Report of the President (1999).
References


