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Aims and Scope

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   - avoid symbols above letters and use acceptable alternatives (Y*) where possible,
   - mathematical formulae are set out and numbered; these numbers should be placed against the right margin as (1),
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Co-movements of NAFTA stock markets: Granger-causality analysis

Paweł Folfas

Abstract: The paper scrutinizes the causal relationship between performance of American, Canadian and Mexican stock markets. It is aimed at answering the question as to whether there is a one way or two way causal link between the performance of stock markets (or possibly no causality at all) in the case of NAFTA members during 1992–1993 (pre-NAFTA period) and 1994–2013 (NAFTA in force).


Keywords: NAFTA, stock markets, Granger-causality.

JEL codes: F15.

Introduction

Regional integration (especially Regional Trading Arrangements – RTAs) appears to be one of the most significant topics in international economics. There are a lot of studies, both theoretical and empirical, concerning various aspects of RTA activities. The majority of studies focus on trade (FDI or migration) issues but it is also interesting as to whether economic integration is accompanied by causal links between indexes of national stock markets.

This paper scrutinizes the causal relationship between the performance of American, Canadian and Mexican stock markets. The analysis is based on the Granger causality test and it is aimed at answering a question as to whether there are one way or two way causal links between the performance of stock markets.

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1 Article received 30 March 2015, accepted 11 January 2016.
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(or possibly no causality at all) in the case of NAFTA members. The value-added of this article concerns the choice of specific periods of analysis based on the intensity of trade and FDI integration within NAFTA. Consequently, trade and FDI become a background of a Granger-causality analysis between indexes of national stock markets. The text includes three major sections: (1) literature review, (2) methodological considerations concerning testing Granger causality in the case of non-stationary time series and finally (3) an empirical study of NAFTA stock market exchange indexes. The paper ends with conclusions.

1. Literature review

The co-movements of national stock markets seem to be a popular topic in international finance [see e.g. Makridakis and Wheelwright 1974; Meric and Meric 1989; Meric et al. 2002; Sabri 2002; Dorodnykh 2014]. There are probably two fundamental areas of concern in studies on the co-movements of national stock markets: (1) low correlation between markets as evidence of the benefit of global portfolio diversification, (2) high correlation between markets as a result of globalization and economic integration.

The second area of concern covers the topic of the co-movements of stock markets in a free trade area, in a customs union, in a common market or in within bloc of countries. Studies of the co-movements between stock markets in RTAs probably still are in the minority (the majority of studies focus on the co-movements between the largest markets), but we can find a number of papers concerning RTAs from different parts of the world. Namely Meric and Meric [1997], and also Kim, Moshirian, and Wu [2005] analyze correlation between the EU stock markets. Also Horobet and Lupu [2009] focus on capital market integration in the European Union. Additionally Meric, Meric, and Ratner [2000] and also Click and Plummer [2005] scrutinize linkages between the ASEAN stock markets. Moreover Harrison and Moore [2010] study the co-movements between stock markets of CARICOM members. Additionally Menezes [2013] investigates cointegration and Granger-causality between stock market indexes for the G7 countries. Olbrys and Majewska [2013] conduct a Granger causality analysis of the CEE (Central and Eastern Europe) stock markets including the nonsynchronous trading effect. Rec [2009] scrutinizes the financial integration of stock markets in the former Yugoslav countries. Finally Vyrost, Lyocsa, and Baumohl [2014] analyze Granger causality networks constructed amongst 20 developed stock markets.

In case of NAFTA, Aggarwal and Kyaw [2005] examine the integration of NAFTA equity markets in the periods 1988–1993 (pre-NAFTA) and

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3 North American Free Trade Agreement (NAFTA) is an agreement signed by Canada, Mexico and the United States which superseded the Canada–United States Free Trade Agreement.

2. Toda-Yamamoto procedure for testing Granger causality

Granger [1969] defined a concept of causality which has become popular in recent years. In the case of two time-series variables (X and Y), X is said to Granger-cause Y if Y can be better predicted using the histories of both X and Y than it can by using the history of Y alone. The idea is that the cause cannot come after the effect. Thus if variable X affects a variable Y, the former should help improving the predictions of the latter variable (Table 1).

Testing for the presence or absence of Granger causality is linked with the construction of VAR (sometimes also VEC) models. The most common test for Granger causality is a Wald test. One of the most important assumptions of the Wald test for Granger-causality is stationarity of time series X and Y [see more Lütkepohl 2007: 41–51, 102–103].

When using the Wald test in the usual way to test linear restrictions on the parameters of a VAR (VEC) model, and if (some of) data are non-stationary, then the Wald statistics do not follow their usual asymptotic chi-square distribution under the null (zero). One of the approaches that can be taken to make sure that a causality test (based on the Wald test) is done properly, in spite of non-stationarity time series, is the Toda-Yamamoto [1995] procedure. The Toda-Yamamoto (T-Y) procedure assumes estimation of a modified VAR (VEC) model with $k+d_{\text{max}}$ lags, where $k$ is the optimal lag length in the original (CUSFTA). It came into force on January 1, 1994. According to the World Trade Organization it is classified as a FTA&EIA (free trade area with economic integration agreement). For more about economic integration in the framework of NAFTA see: [Czarny 2013; Hufbauer and Schott 2005; Zahniser 2005; Zahniser et al. 2015].
VAR (VEC) model and $d_{\text{max}}$ is the maximal order of integration of the variables included in VAR (VEC) model. It is essential that additional $d_{\text{max}}$ lags of variables are treated as exogenous variables. The coefficients of these extra lags are not included when the subsequent Wald test is conducted. They are there just to set the asymptotic. Thanks to these additional lags, the Wald test is asymptotically chi-square distributed under the null (zero). The basic steps for the T-Y procedure are illustrated by Table 1.

Table 1. T-Y procedure for testing Granger causality between time series ln INDEX1 and ln INDEX2

<table>
<thead>
<tr>
<th>Time series:</th>
<th>ln INDEX1 and ln INDEX2</th>
</tr>
</thead>
<tbody>
<tr>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Testing the stationarity of both time series using the ADF test</td>
<td>↓</td>
</tr>
<tr>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Both time series are stationary</td>
<td>At least one time-series is not stationary</td>
</tr>
<tr>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Determination of $d_{\text{max}}$ (maximal order of integration)</td>
<td>↓</td>
</tr>
<tr>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Determination of appropriate maximum lag length in the VAR model ($k$) using information criteria such as: AIC, HQIC and SBIC</td>
<td>↓</td>
</tr>
<tr>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Estimation of the VAR model with $k$ lags ln INDEX1$<em>t = \gamma + \sum</em>{i=1}^{k} \alpha_i \ln INDEX1_{t-i} + \sum_{i=1}^{k} \beta_i \ln INDEX2_{t-i} + \varepsilon_t$ ln INDEX2$<em>t = \delta + \sum</em>{i=1}^{k} \sigma_i \ln INDEX2_{t-i} + \sum_{i=1}^{k} \mu_i \ln INDEX1_{t-i} + \theta_t$</td>
<td>Estimation of the VAR model with $k+d_{\text{max}}$ lags (additional $d_{\text{max}}$ lags are treated as exogenous variables) ln INDEX1$<em>t = \gamma + \sum</em>{i=1}^{k+d_{\text{max}}} \alpha_i \ln INDEX1_{t-i} + \sum_{i=1}^{k+d_{\text{max}}} \beta_i \ln INDEX2_{t-i} + \varepsilon_t$ ln INDEX2$<em>t = \delta + \sum</em>{i=1}^{k+d_{\text{max}}} \sigma_i \ln INDEX2_{t-i} + \sum_{i=1}^{k+d_{\text{max}}} \mu_i \ln INDEX1_{t-i} + \theta_t$</td>
</tr>
<tr>
<td>↓</td>
<td>↓</td>
</tr>
<tr>
<td>Granger causality tests (Wald test)</td>
<td>Granger causality tests (Wald test)</td>
</tr>
</tbody>
</table>

Source: Author’s study based on: [Lütkepohl 2007: 41–51, 102–103; Toda and Yamamoto 1995].
In analysed VAR models there were two variables: the stock market exchange index for country 1 (in logarithmic version – ln INDEX1) and the index for country 2 (in logarithmic version – ln INDEX2). Firstly, both time series were tested (the ADF test) to determine their order of integration. According to the ADF test results the $d_{\text{max}}$ (maximal order of integration) was determined. Secondly, the appropriate maximum length for the variables in the VAR model ($k$) was chosen thanks to the information criteria (AIC, HQIC and SBIC). Thirdly, the VAR model with $k+d_{\text{max}}$ lags was estimated (additional $d_{\text{max}}$ lags were treated as exogenous variables). Finally, the Wald test for Granger causality was conducted.

To sum up, thanks to the T-Y procedure, testing for Granger causality is possible despite the non-stationarity of time series. Moreover, the T-Y procedure appears to be simple and does not need any complicated modification in VAR models. This procedure might be problematic only in the case of very short time-series as additional lags have to be included.

As with every econometric procedure, Granger-causality naturally has its limitations and weaknesses. Consequently, Granger-causality (or lack of it) should not be interpreted as unequivocal proof of the existence (lack) of causality. However it brings a useful set of information about reality and is quite simply to conduct.

3. Data and estimation results

The empirical study concerns the existence and the direction of Granger causality between stock market exchange indexes in NAFTA members. Three indexes were used in the research: S&P TSX for Canada, IPC for Mexico and S&P 500 for the US. In the case of Canada and the US daily time series began on 2nd January 1980 and ended on 31st December 2013 but the daily time series for Mexico was shorter as it begins on 2nd January 1992.

In the study the daily average values of indexes (extracted from the websites feeding the NAFTA stock market exchange) were used in terms of natural logarithm (daily data were not adjusted in any way). Data for days in which at least one stock market exchange was closed (e.g. due to holidays) were excluded from the time series. In the text S&P TSX index is denoted as Canada, IPC index as Mexico and the S&P 500 index as US.

Granger causality analysis between stock market exchange indexes of NAFTA members was conducted for the periods: 1992–1993 (pre-NAFTA period) and 1994–2013 (NAFTA in force). Additionally, for Canada and the US analysis was conducted also for periods: 1980–1988 (pre-CUSFTA period), 1989–1993 (CUSFTA in force). Period selection was based on external criterion (trade and

\[ \text{Data concerning IPC for earlier years are not available.} \]
FDI intensity). Consequently, any statistical tool was specifically used (for example structural break model) for period selection.

Moreover a separate Granger causality analysis (value-added of the article mentioned in the introduction) was conducted for the years 2001–2003 during which trade and FDI intensity indexes concerning intra-NAFTA flows used to be the highest. The relative intensity of regional trading versus trading with the outside world was measured by the regional trade introversion index (RTII) first proposed by Iapadre [2006]. This index allows the measurement of the relative intensity of regional trading versus trading with the outsiders. The RTII can range from –1 to 1 and is independent of the size of the region. The index rises (or falls) only if the intensity of intraregional trade grows more (or less) rapidly than that of extraregional trade. If the index is equal to zero, then the region's trade is geographically neutral (it grows similarly in intraregional as well as in extraregional terms). If the index is a positive number, the region’s trade has an intraregional bias. If RTII is less than zero, then the region’s trade has an extraregional bias. The formula for the regional trade introversion index is:

\[ RTII_i = \frac{HI_i - HE_i}{HI_i + HE_i}, \]  
\[ HI_i = \frac{T_{ii}}{T_i} \quad \text{and} \quad HE_i = \frac{1 - T_{ii}}{T_o}, \]  

where:

- \( T_{ii} \) – exports of region \( i \) to region \( i \) plus imports of region \( i \) from region \( i \),
- \( T_i \) – total exports of region \( i \) to the world plus total imports of region \( i \) from the world,
- \( T_{oi} \) – exports of region \( i \) to outsiders plus imports of region \( i \) from outsiders,
- \( T_o \) – total exports of outsiders plus total imports of outsiders.

The formula described by equations (1a) and (1b) can be also implemented for FDI – exports are substituted by FDI outflows and imports by FDI inflows – and regional FDI introversion index (RFDIII) can be constructed. Values of regional trade introversion and regional FDI introversion indexes for NAFTA are shown in Figure.

The regional trade introversion index remained quite stable as the FDI index fluctuates sharply. Consequently it was not easy to find a small number of -years period with both high indexes. However three-year period 2001–2003 was worthy of notice. During this period the FDI index was positive (the regional FDI introversion index was positive also only in single years 1992,
2005 and 2007) and simultaneously the trade index was not lower than 0.65. Consequently, period 2001–2003 was chosen as a period with the most intensive trade and FDI relationships within NAFTA. During years 2001–2003 there was a slowdown in the world economy and it is quite typical that poorer economic performance encouraged NAFTA members to tighten regional relationships (something similar can be noticed during the last economic crisis however it was shorter (only in year 2009) than during the slowdown at the beginning of 21st century).

After choosing the periods for the Granger causality study, statistical tests were conducted. Firstly, the order of integration for all the time series was established. The ADF test (for which null hypothesis is non-stationarity) was carried out. The results are reported in Table 2.

According to the ADF tests (Table 2) all the included time series were not stationary (only in three cases does the ADF test, including trend and a drift, confirm the integration of order zero (I(0)). Consequently, the T-Y procedure was necessary to check Granger causality between stock market exchange indexes of NAFTA members (Table 3).

Secondly, the optimal number of lags in the VAR model using AIC, HQIC and SBIC information criteria was found. Table 3 presents the output of the choice criteria for selecting the number of lags in the VAR model. In the majority of cases, two out of three information criteria suggest the same number of lags which was finally chosen. However, there were exceptions in which the highest number of lags (the maximum number of lags does not exceed 30) was chosen. Finally, the number of lags in the VAR model including the order of integration of times series was established (see last column in Table 3).
Table 2. The ADF test results

<table>
<thead>
<tr>
<th>Variable</th>
<th></th>
<th>( H_0 ): unit root – I(1)</th>
<th>( H_1 ): time series stationary – I(0)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>without drift and trend</td>
<td>with drift</td>
<td>with drift and trend</td>
</tr>
<tr>
<td></td>
<td>number of lags</td>
<td>levels</td>
<td>1st differences</td>
</tr>
<tr>
<td>ln Canada (1980–1988)</td>
<td>1</td>
<td>1.124</td>
<td>(-30.449^{***})</td>
</tr>
<tr>
<td>ln Canada (1989–1993)</td>
<td>1</td>
<td>0.952</td>
<td>(-20.389^{***})</td>
</tr>
<tr>
<td>ln Canada (1992–1993)</td>
<td>1</td>
<td>1.360</td>
<td>(-14.000^{***})</td>
</tr>
<tr>
<td>ln Canada (1994–2013)</td>
<td>1</td>
<td>1.315</td>
<td>(-48.339^{***})</td>
</tr>
<tr>
<td>ln Canada (2001–2003)</td>
<td>1</td>
<td>1.604</td>
<td>(-17.139^{***})</td>
</tr>
<tr>
<td>ln Mexico (1992–1993)</td>
<td>1</td>
<td>1.376</td>
<td>(-14.250^{***})</td>
</tr>
<tr>
<td>ln Mexico (1994–2013)</td>
<td>1</td>
<td>2.053</td>
<td>(-48.192^{***})</td>
</tr>
<tr>
<td>Country</td>
<td>Period</td>
<td>$a$</td>
<td>$t$-statistic</td>
</tr>
<tr>
<td>-----------------</td>
<td>---------------</td>
<td>------</td>
<td>---------------</td>
</tr>
<tr>
<td>ln Mexico</td>
<td>(2001–2003)</td>
<td>1.00</td>
<td>0.389</td>
</tr>
<tr>
<td>ln US</td>
<td>(1994–2013)</td>
<td>1.508</td>
<td>-49.833***</td>
</tr>
</tbody>
</table>

Significance level: *(10%), **(5%), ***(1%).

Source: Author’s calculation in STATA.
Table 3. Selection of the optimal number of lags for variables in VAR model

<table>
<thead>
<tr>
<th>Model</th>
<th>Optimal number of lags according to AIC</th>
<th>Optimal number of lags according to HQIC</th>
<th>Optimal number of lags according to SBIC</th>
<th>Optimal number of lags (k)</th>
<th>Optimal number of lags plus additional lags (k + d\textsuperscript{max}) – T-Y procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td>CUSFTA 1980–1988</td>
<td>8</td>
<td>5</td>
<td>4</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>CUSFTA 1989–1993</td>
<td>6</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>NAFTA 1992–1993</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>NAFTA 1992–1993</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>NAFTA 1992–1993</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>NAFTA 1994–2013</td>
<td>13</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>NAFTA 1994–2013</td>
<td>13</td>
<td>4</td>
<td>3</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>NAFTA 1994–2013</td>
<td>14</td>
<td>4</td>
<td>3</td>
<td>14</td>
<td>15</td>
</tr>
<tr>
<td>NAFTA 2001–2003</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>NAFTA 2001–2003</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>NAFTA 2001–2003</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

Source: Author’s calculation in STATA.

Thirdly, the Granger causality test including the T-Y procedure was conducted. The results of the Wald test are presented in Table 4. The study finds bivariate Granger causality for American and Canadian indexes in the periods: 1980–1988 and 1994–2013. Additionally, the American index Granger-caused Mexican index during all periods included apart from 1992–1993, but the Canadian index did not Granger-cause the Mexican index at all. Moreover, the Mexican index was as a Granger-cause of the Canadian index in the years 1994–2013 and a Granger-cause of the American index during the period 1992–1993.
Conclusions

Making one general conclusion concerning causal links between NAFTA stock market exchange indexes in NAFTA is not possible. Firstly, study generally confirms bivariate Granger causality for the American and Canadian indexes, but during the periods 1989–1993 and 2001–2003 there were no causal links between them. Thus in the long-term Canadian and American stock exchange markets seem to be strongly related, however causality did not take place during the period with the strongest intra-NAFTA trade and FDI (2001–2003) and for the years 1989–1993 (CUSFTA in force). Secondly, the American index generally is a Granger cause of the Mexican index, but the reverse causality is only confirmed during the years 1992–1993 (and only at a 10% level of significance). Thirdly, causality between the Mexican and Canadian indexes is only one-way causality.

According to the Granger-causality analysis there are no two-way causal links between all NAFTA stock market exchange indexes. Additionally the

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5 Wald tests confirm bivariate Granger causality between American and Canadian index for period 1980–2013.
presence of Granger-causality between indexes is not always accompanied by an intensification of trade and FDI relationships between NAFTA members (lack of causality during 2001–2003). Also a free trade agreement in force is not accompanied by Granger causal links between stock market indexes. It is worth remembering that a Granger-causality analysis, as with every econometric procedure, naturally has its limitations and weaknesses. Consequently Granger-causality (or lack of it) should not be interpreted as unequivocal proof of the existence (lack) of causality. However it brings a useful set of information about reality. The reality seems to be quite complicated as there is no simple connection between the integration in the framework of NAFTA and the integration of stock market exchanges in Canada, Mexico and the United States.

References


Aims and Scope

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