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Real exchange rate volatility impact on exports: A comparative study 1990-2013

Ronald Miranda (*)
Gabriela Mordecki (**)

Resumen

Las exportaciones de los países exportadores de materias primas dependen de la demanda mundial y de los precios de estos bienes, pero la creciente volatilidad del tipo de cambio real (TCR) ha llevado a incluir en los modelos el impacto que la volatilidad del TCR pueda tener sobre estas exportaciones. Así, aquí se estudia el comportamiento de la volatilidad del TCR, modelizándola a través de modelos GARCH, para un conjunto de países exportadores de materias primas: Brasil, Chile, Nueva Zelanda y Uruguay en el período 1990-2013. Luego se estudia para cada país el posible impacto de la volatilidad del TCR en las exportaciones de cada país utilizando la metodología de Johansen y el análisis de las funciones de impulso-respuesta, incluyendo también variables representativas de la demanda mundial y de los precios internacionales de los principales productos de exportación de cada país. Los resultados sugieren que las exportaciones dependen de forma positiva de la demanda mundial y de los precios internacionales, sin embargo no resulta significativa la volatilidad condicional del tipo de cambio real para el conjunto de países seleccionados, con la excepción de Uruguay, en el que tiene efectos negativos tanto en el corto como en el largo plazo.

Palabras clave: Exportaciones, tipo de cambio real, GARCH, cointegración

Código JEL: C55, F31, F41

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Abstract

Raw materials exports depend on global demand and prices, but the increasing volatility of real exchange rates (RER) introduces an additional factor which impact varies according to the situation and the country. Thus, this paper studies the RER volatility dynamics, estimated through GARCH and IGARCH models for Brazil, Chile, New Zealand and Uruguay during the period 1990-2013. Then, for each country, we study the potential impact of exchange rate volatility on total exports using Johansen's methodology and the analysis through impulse response functions, including proxies for global demand and international prices. The results suggest that exports depend positively on global demand and international prices; however conditional RER volatility resulted not significant for the group of selected countries, with the exception of Uruguay, where RER volatility affects negatively exports, in the short and long term.

Palabras clave: Exports, real exchange rate, GARCH, cointegration.

Código JEL: C55, F31, F41

1. Introduction

Raw materials exports depend on global demand and prices, but the increasing volatility of real exchange rates (RER) introduces an influence which impact varies according to the situation and the country.

In line with the theory evidence, exchange rates volatility is a source of risk and has consequences on the volume of international trade, and therefore the balance of payments. The relationship between greater volatility of exchange rates and international trade has been widely analyzed by multiple studies since the 70s (see e.g. Ozturk, I., 2006 for a literature review, and Hooper, P. and Kohlhagen, S., 1978).

The main argument is as follows: greater exchange rate volatility leads to higher costs for risk-averse traders which implies less foreign trade. This is because the exchange rate is agreed at the time of the commercial contract, but payment is not made until delivery actually takes place. If changes in exchange rates become unpredictable, this creates uncertainty about the benefits and, therefore, reduces international benefits from trade. Even if hedging in the forward markets was possible, there are limitations and costs. On the other hand, other theoretical developments suggest that there are situations where you could expect volatility in the exchange rate has both negative and positive effects on trade volumes. De Grauwe, P. (1988) emphasized that if the impact of income effect is greater than substitution effect, this may lead to a positive relationship between trade and exchange rate volatility, which depends on the degree of exporters risk aversion. This is because, if exporters are enough risk takers, increased exchange rate volatility raises expected marginal utility of increased export earnings and thus induces them to increase exports.

Therefore, this paper seeks to estimate the impact of exchange rate volatility on exports for a set of countries: Uruguay, Brazil, Chile and New Zealand, selected as commodity exporting countries. The reporting period is from January 1990 to December 2013. So, this article studies the behavior of the exchange rate volatility, and following the literature (trying to overcome RER heteroscedasticity), estimated by a GARCH model (generalized autoregressive conditional heteroskedasticity model), according to Bollerslev, T. (1986), or IGARCH (integrated GARCH), depending on the case. Then we study for each country the possible impact of estimated RER volatility on each country's exports, using Johansen, S. (1988, 1992) methodology.

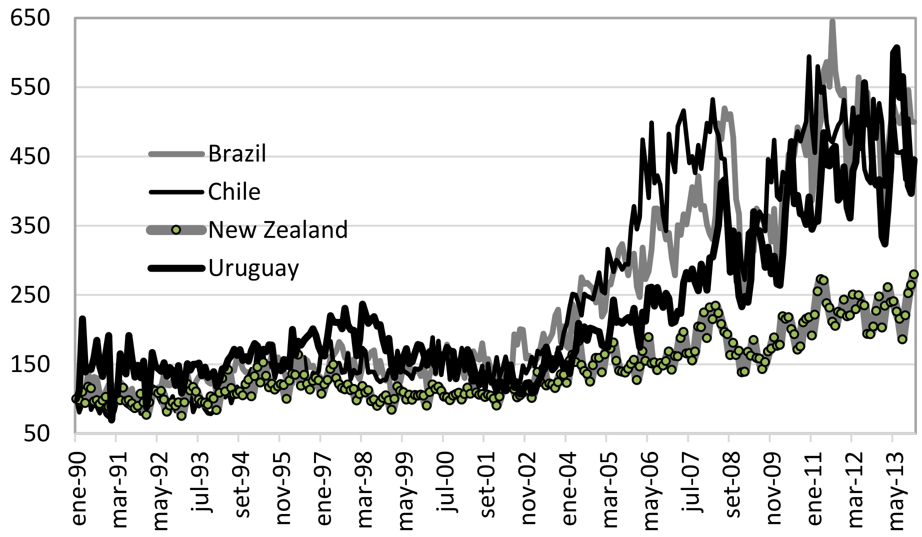
Thus, the article includes Chapter 2 an exports characterization for the different countries considered. In Chapter 3 we include a survey of the main background on the issue, in Chapter 4 we discuss the methodology, in Chapter 5 we define data sources, in Chapter 6 we report the main results and finally, in Chapter 7, we include some conclusions.

2. Exports characterization

- **Evolution**

Figure one shows Brazil, Chile, New Zealand and Uruguay total exports, throughout the period 1990-2013. Analyzed by sub-periods, until early 2000 exports are stagnated and in the case of Uruguay and New Zealand they fall since the late 90's. Since 2003, exports grow, although all recorded a fall in 2008-2009 because of the international crisis.

Figure 1: Exports in constant dollars 1990-2013 (Jan-90=100)



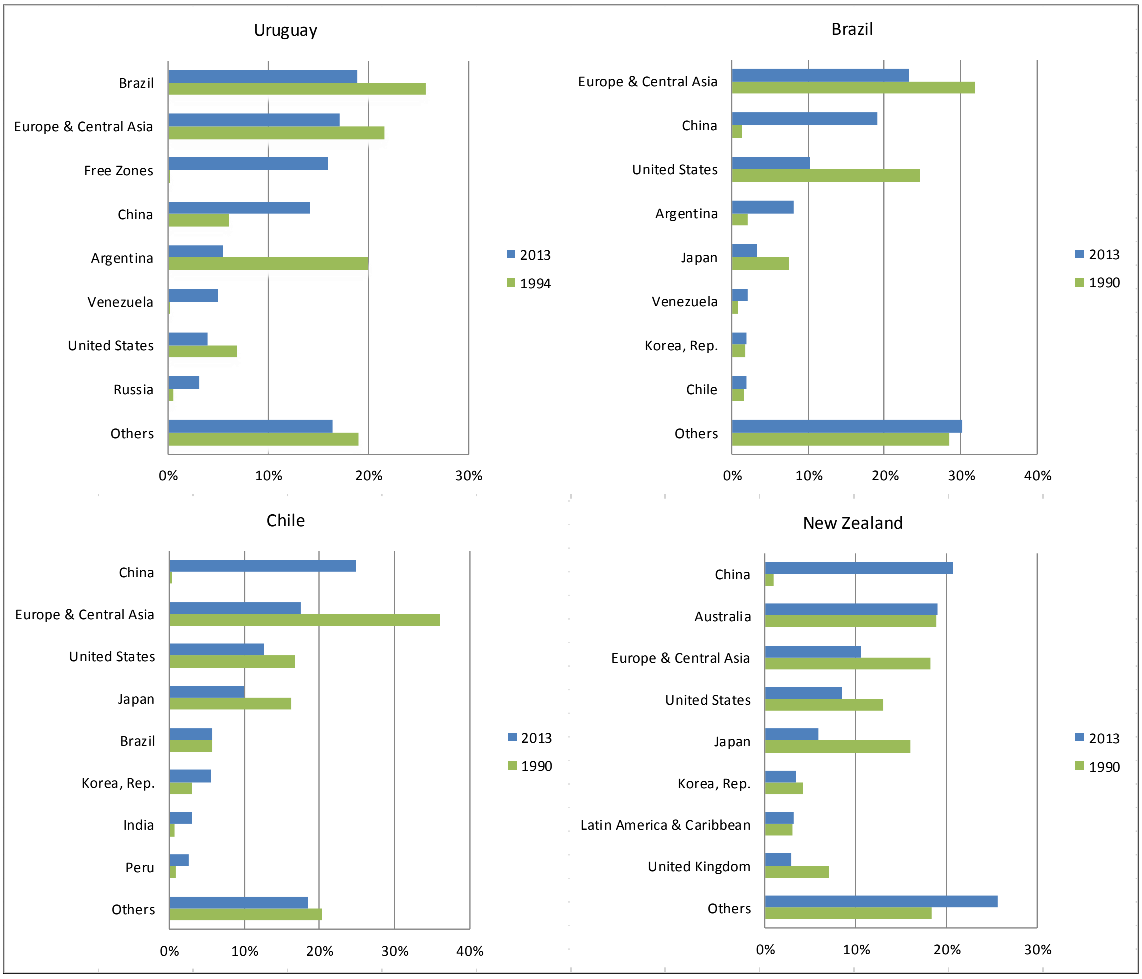
Source: CEI and BLS

- **Exports destinations**

In Figure 2, we can see the main export destinations selected by countries. It compares the year 2013 to 1990.[1]

[1] World Bank data for Uruguay is from 1994.

Figure 2: Exports Destinations by countries



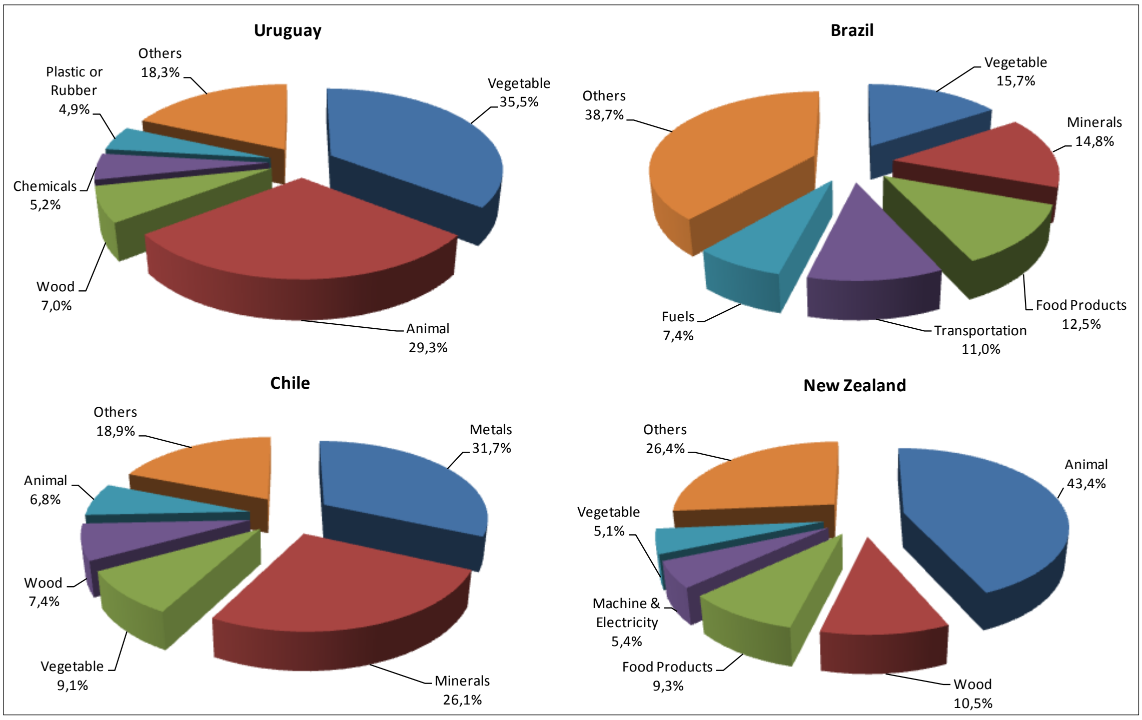
Source: Own calculations based on World Bank

One of the most relevant features of selected countries is the large share of exports to China at the end of the period, when at the beginning sales were virtually nonexistent to this country. On the other hand, we can see a decline in the share of exports to Europe and the United States during the period. In the case of Uruguay, in addition to the high participation of China in exports, it highlighted the loss of share of sales to the region (Argentina and Brazil). Also the importance acquired by the Free Zones, which hardly contained in the 1990, and in 2013 passed to be placed in the third position as a destination of Uruguayan exports, products that are then re-exported to China, Brazil and Argentina, sorted according to their share in the total.

- **Exports composition**

According to the classification used by the World Bank as the main area of origin of products exported in 2013, in the case of Uruguay they are mainly concentrated in the category of vegetable oils (soybeans and cereals) and animal (beef and dairy), representing about 65% of total exports. Meanwhile, Brazil has a more diversified distribution as vegetable exports represented 15.7% (soybeans, corn and sugar), minerals (iron) contributes 14.8%, food products 12.5% transport (cars and boats) 11.0% and fuels (oil) 7.4%, representing approximately 62% of total exports. Chile's main exports are metals (31.7%) and minerals (26.1%), particularly copper and its by-products, reflecting the importance of the mining sector exports, representing more than 50%. Finally, for New Zealand the most significant share in exports is animals (43.4%), mainly frozen meat and dairy products. Below we present in Figure 3 the composition of exports by country.

Figure 3: Exports by country



Source: Own calculations based on World Bank (for more detail see Annex A)

3. Background

With the adoption of floating exchange rate regimes since 1973, it has increased concerns about the study associated with exchange rate volatility both nominal and real influence international trade. The theoretical and empirical literature is inconclusive regarding the effects of such an impact. The evidence shows positive results, negative, neutral, a combination of the previous three and not significant (Ozturk, I., 2006; Coric, B. and Pugh, G., 2010). This can be consequence of methodological differences in terms of the number of countries considered, the specification of the exchange rate volatility used or the sample periods (Ozturk, I., 2006).

Hooper, P. and Kohlhagen, S. (1978) developed one of the first works that explores the relationship between nominal exchange rate volatility (measured by standard deviation) and trade. The study is for developed countries and covers the period from the mid-sixties to the mid-seventies. The results shed no significant evidence of the sign of the impact. From this work Cushman, D. (1983) advances in a similar line, but analyzing real exchange rate volatility on trade. He finds that an unexpected movement in the RER has a significant and negative effect on trade. Akhtar, M. and Hilton, R. (1984) also found a negative correlation, but unlike previous studies, they use as a measure of volatility the standard deviation of effective exchange rate. The study was conducted for bilateral trade between the United States and Germany in the period 1974-1981.[2] Similar results obtained Chowdhury, A. (1993) who finds a negative impact of exchange rate volatility on the volume of exports to the G-7 countries for the 1973-1990 period.[3] They build a volatility temporary variable through a moving average of standard deviation of real exchange rate growth rate.

For Asian countries, the evidence of exchange rate volatility impact on exports points to the predominance of adverse effects [Baak, S., et al. (2003), Chit, M., et al. (2010), Masron, T. and Mohd, A. (2009), Ramli, N. and Podivinsky, J. (2011) and Cheung, Y. W. and Sengupta, R. (2012)]. Cheung, Y. W. and Sengupta, R. (2012) studied the effect of RER and RER volatility in export shares of nonfinancial Indian companies for the period 2000-2010. The empirical analysis shows that there has been a significant negative impact of exchange rate volatility in exports of Indian companies. Moreover, Baak, S., et al. (2003) find negative impact of exchange rate volatility (measured by the standard deviation of RER) in exports to four East Asian countries (Hong Kong, South Korea, Singapore and Thailand) and its bilateral trade with Japan and the United States for the period 1990-2001. Similarly Ramli, N. and Podivinsky, J. (2011) conducted a study, but unlike the previous they consider first five countries of the Association of South East Asian Nations (ASEAN) (Malaysia, Singapore, Philippines, Indonesia and Thailand), and its bilateral trade with the United States for the period 1990-2010; secondly they consider the RER volatility estimated through a GARCH (1,1) process. The result they obtain is that the volatility of the bilateral real exchange rate has a significant impact on exports, mainly negative (except for Indonesia that is positive).

Chit, M., et al. (2010) unlike previous studies found a greater number of countries, taking into account bilateral trade in some East Asian countries together (China, Indonesia, Malaysia, Philippines and Thailand), as well as thirteen industrial countries. For this he uses a panel with information for the period 1982-2006, specifying three measures of volatility. They get that regardless of the proxy used as exchange rate volatility, the impact generates a negative effect on exports from emerging countries of East Asia or East Asia. Meanwhile, Masron, T. and Mohd, A. (2009) note that the exchange rate volatility (GARCH (1,1)) has a negative effect on the demand for exports from Malaysia and Turkey for the period 1970- 2004.

However, when studies incorporate a variable reflecting regional economic integration (ASEAN Malaysia, and Turkey with the European Union), the negative impact becomes insignificant in Turkey. Moreover, Zakaria, Z. (2013) points out that the effect is ambiguous for Malaysia, and this is explained on the basis that the exchange rate volatility has a negative effect on bilateral trade with the US, while , with Japan it is positive. Malaysia's exports to the UK and Singapore show no evidence of any connection with exchange rate volatility. The period considered was 2002-2012, and exchange rate volatility is modeled through a GARCH (1,1). [4] [5]

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[2] The effective exchange rate is defined as the exchange rate of a country against other currencies weighted by their importance in the country's trade (Frieden, J. 2014).

[3] G-7 group is formed by: Germany, Canada, France, Italy, Japan, United States and United Kingdom. https://www.imf.org/external/np/exr/facts/spa/groupss.htm#G7

[4] Association of South East Asian Nations (ASEAN): Brunei, Darussalam, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam. https://www.wto.org/spanish/thewto_s/glossary_s/asean_s.htm

[5] In Chit, M., et al., 2008 they use the standard deviation of the first difference of the logarithm of the real exchange rate, the moving average of the standard deviation and conditional volatility (GARCH): three measures of volatility for

Moreover, Mustafa K. and Nishat, M. (2004) conducted the study for Pakistan and its major trading partners for the period 1991-2004. They specify the risk associated with RER movements through the standard deviation. They found negative effects of the empirical relationship between the exports' growth and exchange rate volatility for Australia, New Zealand, UK and USA. However, with regard to Bangladesh and Malaysia they found no evidence for this relationship. Mukhtar, F. and Malik, S. (2010) also study the case of Pakistan while addressing global exports and volatility through GARCH specification for the period 1960-2007. They found negative impact, and for India and Sri Lanka, they found similar results.

For Latin America empirical evidence, Adamo, A. and Silva, M. (2008), Aguirre, A., et al. (2007) and Berrettoni, D. and Castresana, S. (2007) study the exchange rate fluctuations impact on manufacturing exports. The first explores for Peru over the 1994-2004 period, the second studies Brazil from 1986 to 2002 and the third analyzes Argentina for 1992-2006 period. They use the standard deviation for modeling exchange rate volatility; additionally, Adamo, A. and Silva, M (2008) and Aguirre, A., et al. (2007) specify a model with the conditional variance (GARCH). Moreover, Arize, A., et al. (2008) study it for global exports of eight countries in Latin America: Bolivia, Colombia, Costa Rica, Dominican Republic, Ecuador, Honduras, Peru and Venezuela, for the period 1973 - 2004. They use an ARCH (1) specification to model the exchange rate volatility, with the exception of Honduras. They obtain similar results: a significant and negative effect of exchange rate volatility on exports, with the exception of Aguirre, A., et al. (2007) when using the GARCH specification that obtain no significant results. Other study, in Huchet-Bourdon, M. and Korinek, J. (2012), analyze the impact of exchange rates and their volatility on bilateral trade in Chile and New Zealand (small and open economies) with China, Euro Area and U.S. (large partners) for two sectors: agriculture and nomanufacturing-mining. It finds that exchange volatility (moving standard deviation and GARCH model) impacts trade flows in the small, open economies more than was found for larger economies. Findings do not clearly indicate the direction of the impact (increases or decreases) in all countries and sectors.

The literature also points the existence of works that find positive effects of exchange rate volatility on exports. Bredin, D., et al. (2002) study the impact of exchange rate volatility both short and long term global and sectoral Irish exports to the European Union for the period 1979 to 1992 (Irish national and multinational companies sectors). RER volatility is modeled via mobile standard deviation of the growth rate of RER. In the short term, they found that volatility has a negative effect on multinational firms' exports, has no effect on national firms, generating a negative impact on overall exports. In the long, term the exchange rate volatility has no effect on multinational firms' exports, but they found a positive effect on exports of domestic firms, and therefore, the effect on global exports is positive.

Baum, C., et al. (2004) found that on average the effects of exchange rate volatility on exports is positive for a sample of 13 developed countries in the period 1980-1998. The originality of his analysis is the model for the exchange rate volatility from daily frequency by an AR (2) process. Moreover, Baum, C. and Caglayan, M. (2007) analyze the effect of exchange rate volatility (GARCH specification) in bilateral trade and fluctuations in trade flows for a group of developed countries in the 1980-1998 period. They find that the volatility of the exchange rate has both positive and negative impacts on bilateral trade; however, the effect is predominantly positive with respect to fluctuations of trade.

Moreover, the literature also records the existence of no significant impact of exchange rate volatility on global exports. Serenis, D. and Serenis, P. (2008) pointed out by analyzing the case

the exchange rate.

of four European countries: Norway, Poland, Hungary and Switzerland for the period 1973 - 2006. Bouoiyour, J. and Selmi, R. (2014b) estimate through several econometric methods (ordinary least squares, OLS), instrumental variables, autoregressive distributed lag (ARDL), spectral analysis of the evolution and decomposition of wavelet) to relate the volatility of the exchange rate and exports for Tunisia. Regarding exchange rate volatility measures they use the moving average of standard deviation and GARCH model. The overall result is a negative effect in the short term, but no significance in the long term.

With regard to the empirical evidence, a set of meta-analysis present an extensive study regarding the effects of exchange rate volatility on international trade, including Ozturk, I. (2006), was also present, Coric, B. and Pugh, G. (2010) and Bouoiyour, J. and Selmi, R. (2014a). Predominantly they show a negative effect of exchange rate volatility on international trade. Ozturk, I. (2006) conducts a review of 42 documents during the period from 1978 - 2005. Coric, B. and Pugh, G. (2010) consider a set of 49 studies published from 1978 to 2002, and further notes that the dummy variable representing the exchange rate regime, regularly was found significant. Finally, Bouoiyour, J. and Selmi, R. (2014a) analyzed 59 publications from 1984 to 2014. The evidence regarding the impact is: 29 (negative), 6 (positive), 6 (not significant) and 18 (ambiguous).

Moreover, we found no works linking RER volatility and exports in Uruguay, however, in Daude, C., et al. (2000) they study the Uruguay bilateral RER volatility (with Argentina and Brazil) to explain the evolution of the real exchange rate. They found that bilateral RER presents conditional heteroskedasticity and can be modeled through a GARCH.

4. Methodology

4.1 Theoretical model specification

This section presents the main methodological aspects considered in the models. First, we made a univariate analysis of the series analyzing the presence of unit roots through the Dickey and Fuller test, in order to determine the order of integration of each series.

Subsequently, taking into account the results the order of integration of the series, applying Johansen methodology, we made a multivariate analysis to capture the effects of relationships both short and long term between exports and the considered determinants. For this we inquired about the existence of cointegration relationships in the case of countries with all its series integrated of first order, I (1).

Following Enders, W. (1995), cointegration analysis is based on autoregressive vector with a vector error correction (VEC) specified in a model of endogenous variables. The VEC modeling can be represented as:

$$\Delta X_{it} = A_1 \Delta X_{it-1} + \cdots + A_k \Delta X_{it-k+1} + \prod X_{it-k} + \mu + \Gamma D_t + \varepsilon_t \qquad t = 1, \ldots, T$$

where Δ denotes difference variables, X is a vector of endogenous de variables, μ is a vector of constants and D_t contain a set of instrumental variables (*dummies*) seasonal and intervention, ε_t is the error term and is distributed $N(0, \sigma^2)$.

Information on long-term relationships is included in the $\prod = \alpha\beta'$ matrix, where β is the vector of coefficients for the existing equilibrium relations and α is the coefficients vector of the adjustment mechanism in the short term. Identifying the range of the matrix Π determines the total of existing cointegrating relationships between the variables.

Having examined the long-term relationship, we proceed to the analysis of short-term, showing the adjustment mechanism of the variables in the short run to the long-term equilibrium relationship. The existence of cointegrating vectors is analyzed through the Johansen Test, through the trace and eigenvalues of matrix Π.

Moreover, when countries did not submit all of its series I (1), we proceeded to specify a vector autoregression model (VAR).[6] A VAR is a system in which each variable is returned on its own constant and delays on each of the other variables. So a VAR would represent the relationship between the variables of interest. A crucial aspect of these models is to select the optimal number of delays; the criteria generally used are the Akaike information criterion and Schwartz. The VAR modeling in general terms can be represented:

$$VAR(p): \qquad X_t = c + \sum_{h=1}^{p} \varphi_h X_{t-h} + \gamma Z_t + \tau D_t + \varepsilon_t$$

where X_t is a vector of endogenous variables, c is a vector of constants, D_t contains a set of dummy variables (seasonal and interventions) and p the number of lags of the variables included in the model, φ_h is a matrix of autoregression coefficients (h = 1,2, ...p), $Z_t$is a deterministic set of exogenous variables and ε_t is the error term.

The VEC model, unlike VAR includes not only the short-term dynamic adjustment of the variables in the face of unexpected shocks, but also captures the long run dynamic adjustment to restore equilibrium relationship.

4.2 Real exchange rate volatility measurement

The estimate of RER volatility was made through a GARCH Model (generalized autoregressive conditional heteroskedasticity), according to Bollerslev, T. (1986), or IGARCH (integrated GARCH), depending on the case.

In order to analyze the RER impact and its volatility on exports, we estimated cointegration models of each country exports, taken in constants dollars (deflated by the US CPI), the overall RER with major trading partners in each country, its volatility estimated through a GARCH and world demand, estimated by global imports considered in constant dollars.

Regarding the literature on how to measure the RER volatility there is no consensus, therefore, studies choose to use multiple approaches. Among the most common specifications are: the standard deviation, moving average of the standard deviation, and the conditional variance specified by the squared residuals of ARIMA (Autoregressive Conditional Heteroskedasticity processes, ARCH, Engle, R., 1982; Generalized ARCH, GARCH, Bollerslev, T., 1986 or some variant GARCH).

In this work, we consider the RER conditional volatility as a measure of uncertainty, and is estimated through a GARCH process variant, called Integrated GARCH (IGARCH) introduced by Bollerslev, T. and Engel, R. (1986). The GARCH model has been widely used in the literature on time series models to model volatility. Overall, the GARCH model for the exchange rate can be

[6] The VAR is formulated for stationary variables, hence the importance of knowing the order of integration of the series.

represented as follows:

$$y_t = \delta_0 + \sum_{i=1}^{k} \delta_i . y_{t-i} + \varepsilon_t \; ; \qquad \varepsilon_t \sim N(0, \sigma_t^2)$$

$$GARCH(p,q): \quad \sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i . \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_i . \sigma_{t-i}^2$$

The first equation represents a process autoregressive *(AR)* of order k, *AR (k)*. Where y_t is the real exchange rate, expressed in logarithm; the parameter δ_0 is the constant, k is the number of delays; and ε_t is the heteroscedastic term of error of the conditional variance (σ_t^2).

The second equation specifies a conditional variance GARCH (p, q), where q is the number of ARCH terms, p is the number of GARCH terms. The conditional variance is represented by three terms: i) the average, α_0; ii) the ARCH term, which measures the previous period volatility by squared residuals delays in the first equation; iii) the GARCH term, which captures the previous error variance prediction (σ_{t-i}^2). As the conditional variance is positive, it is required that the parameters, α_0, α_i y β_i to be ≥ 0; and further that $\sum \alpha_i + \sum \beta_i < 1$ to ensure the process to be stationary in covariance.

Moreover, in the literature investigating the empirical relationship between exports and exchange rate volatility, it is widely used GARCH (1,1) for its significant results. However, in some applications it has been found that the estimates of $\hat{\alpha}_1$ and $\hat{\beta}_1$ tend to approach $\hat{\alpha}_1 + \hat{\beta}_1 = 1$, indicating that the GARCH (1,1) process is no longer stationary. That is why it is more appropriate to specify a regressive process IGARCH (1,1) to model the conditional variance, whose expression has the following form:

$$IGARCH(1,1): \quad \sigma_t^2 = \alpha_0 + \sigma_{t-1}^2 + \alpha_1(\varepsilon_{t-1}^2 - \sigma_{t-1}^2)$$

The peculiarity of the regressive process IGARCH (1,1) is the presence of a unit root, that is, the process is I (1), indicating the persistence of the conditional variance over time (Bolleslev, T., et al., 1994).

5. Definition and data sources

In this paper, we consider four countries: Brazil, Chile, Nueva Zealand and Uruguay. The criteria for selecting them respond first of all to analyzed commodities exporting countries, it is a similitude for all; in the second place, Uruguay, Chile and New Zealand have small and open economies´ trade –smaller domestic market and depends on international prices- in contrast to Brazil where it have a large economy, included Brazil allowed to contrast both kind of economies; and in the third place we could show the results for some countries in the Latin American region against other country out of them, it is the main reason to include New Zealand.

The starting point considered for this analysis is 1990 when Latin American economies return to growth. At the beginning of the 1980s a profound crisis of external financing in Latin America was resolved at the end of the decade with the implementation of a consistent external opening and the return of international capital, rushed the 1990s with a period of growth led mainly by export growth (CEPAL, 2003a and CEPAL, 2003b).

The series used correspond to total goods exports, world imports, international prices of most important raw materials and real exchange rate (used also to build the real exchange rate volatility). In all cases it is considered the monthly frequency of the series for the period 1990-2013 (288 observations) and log transformations.

First, as a proxy for world demand we use world imports, measured in constant dollars, deflated by the US CPI. World imports are from the International Monetary Fund (IMF) and the US CPI from the US Bureau of Economic Analysis.

Second, export the data correspond to total goods exports in constant dollars, deflated by the US CPI, provided by the Centre for International Economics (CEI) and the IMF.

The Brazilian real exchange rate is from IPEA, and volatility is calculated from GARCH (1,1) methodology. In the case of Chile's real exchange rate is from ECLAC and volatility is estimated through a IGARCH (1,1). For New Zealand the real change rate is from the Reserve Bank of New Zealand and volatility is calculated using a IGARCH (1,1). Finally, for Uruguay the real exchange rate is from IECON, using retail prices (CPI) and official exchange rates of 9 major trading partners. The volatility of the real exchange rate was calculated from a IGARCH (1,1) process.

Finally, a proxy of the most important export prices for each country was included. In the case of Brazil, New Zealand and Uruguay, the food price index compiled by the IMF and in the case of Chile's metals price index compiled by the Central Bank of Chile. This last one was included, because in Chile more than 50% of exports are metals.

5.1 Series analysis

First, we analyzed the series stationarity through the Dickey-Fuller test. Below in Table 1 and Table 2 we can see the results:

Table 1 – Unit Root Test

Unit root test – Augmented Dickey-Fuller (ADF)

H_0 = There is a Unit Root

	Statistical value of the series in levels	Reject H_0 at 95%	Statistical value of the series in first differences	Reject H_0 at 95%
World imports (LM)	2.5865	No	-5.0464	Yes
	(15 lags, no constant)		(14 lags, no constant)	
International food prices index (LPR)	0.4090	No	-11.3406	Yes
	(0 lags, no constant)		(1 lag, no constant)	
International metals price index (LPRM)	0.5116	No	-11.9865	Yes
	(1 lag, no constant)		(0 lags, no constant)	

The numbers of lags was determined according to the Akaike criterion.

From the information provided in Table 1 we conclude that all the variables are first-order integrated, I (1).

Table 2 – Unit Root Test

Unit root test – Augmented Dickey-Fuller (ADF) H_0 = There is a Unit Root				
	Statistical value of the series in levels	**Reject H_0 at 95%**	**Statistical value of the series in first differences**	**Reject H_0 at 95%**
		Uruguay		
Exports (X_URU)	1.8648	No	-4.8120	Yes
	(13 lags, no constant)		(12 lags, no constant)	
RER (RER_URU)	-1.8584	No	-8.5237	Yes
	(5 lags, no constant)		(4 lags, no constant)	
RER volatility (RERV_URU)	-0.6302	No	-15.4245	Yes
	(0 lags, no constant)		(0 lags, no constant)	
		Brazil		
Exports (X_BRA)	1.8675	No	-3.9901	Yes
	(13 lags, no constant)		(15 lags, no constant)	
RER (RER_BRA)	0.5596	No	-11.8911	Yes
	(2 lags, no constant)		(1 lags, no constant)	
RER volatility (RERV_BRA)	-5.4063	Si	-9.5735	Yes
	(1 lags, no constant)		(4 lags, no constant)	
		Chile		
Exports (X_CHI)	1.2434	No	-3.4074	Yes
	(13 lags, no constant)		(15 lags, no constant)	
RER (RER_CH)	-2.6344	No	-10.2483	Yes
	(3 lags, with constant)		(2 lags, no constant)	
RER volatility (RERV_CHI)	-0.4942	No	-5.8877	Yes
	(5 lags, no constant)		(4 lags, no constant)	
		New Zealand		
Exports (X_NZEL)	1.2617	No	-4.1282	Yes
	(13 lags, no constant)		(15 lags, no constant)	
RER (RER_NZEL)	0.4558	No	-7.4189	Yes
	(3 lags, no constant)		(2 lags, no constant)	
RER volatility (RERV_NZEL)	0.4459	No	-7.4459	Yes
	(0 lags, no constant)		(3 lags, no constant)	
The numbers of lags was determined according to the Akaike criterion.				

In the case of Uruguay, New Zealand and Chile all the series studied were not stationary, integrated of first order. As a result, the study was done via the methodology of Johansen, S. (1988), trying to find a long-term relationship through a cointegrating vector, estimating an error correction model (VECM Model) (Engle, R. and Granger, C., 1987 and Johansen, S., 1992).

In the case of Brazil the series of exports and the real exchange rate were not stationary and integrated of first order, although exchange rate volatility was stationary, so it was included as exogenous in the model.[7]

[7] See Annex C for cointegration results.

6. Main results

Table 3 summarizes the main results of Johansen cointegration test for Brazil, Chile, New Zealand and Uruguay:

Table 3 - Johansen cointegration test results

Country	H_0)	$r = 0$	$r \leq 1$	$r \leq 2$
Trace Test				
Brazil		34.3377	6.6631	0.0757
		(0.0140)	(0.6171)	(0.7831)
Chile		68.0501	21.8260	7.5592
		(0.0002)	(0.3083)	(0.5137)
New Zealand		61.0786	33.0221	10.9865
		(0.0105)	(0.0842)	(0.5434)
Uruguay		53.6809	15.6916	5.0212
		(0.0129)	(0.7338)	(0.8066)
Maximum eigenvalue test				
Brazil		27.6747	6.5873	0.0757
		(0.0052)	(0.5390)	(0.7831)
Chile		46.2241	14.2669	7.1923
		(0.0001)	(0.3435)	(0.4666)
New Zealand		28.0417	14.0695	2.9080
		(0.0437)	(0.3594)	(0.9527)
Uruguay		37.9893	10.6704	5.0098
		(0.0016)	(0.6801)	(0.7406)

Notes: r represents the number of cointegrating vectors. p-value in parentheses.

The significance level for rejecting H_0) is 5%.

Since cointegration tests indicate a long-term relationship for each country exports equation, we estimated a vector error correction model (VECM) for each country.

In the case of **Uruguay**, the final adjustment was for the period January 1993 to December 2013, because the Uruguayan economy had strong adjustments in the early 90s, due to high inflation and beginning the stabilization plan with exchange rate anchor. After adjusting the residuals, including seasonal dummies, and to dummies to correct outliers in the series. After exclusion tests performed for coefficients β, the RER was not significant in the equation, and it was not significant as an exogenous variable so the cointegrating vector for Uruguay was:

$$X_{URU_t} = 0.5024LM_t + 0.9279LPR_t - 0.1917RERV\_URU_t - 5.1385$$

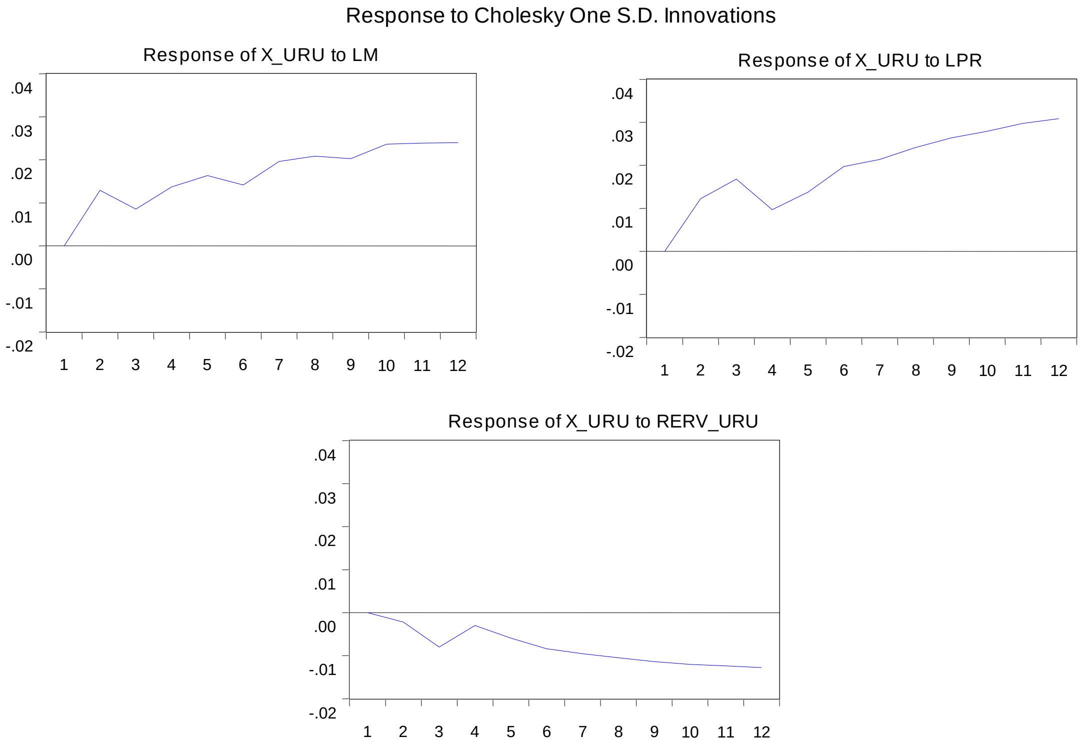
$$(5.220) \qquad (6.935) \qquad (-5.067)$$

From the tests of weak exogeneity LM and LPR coefficients were zero, so only RER volatility acts in the short term on exports, with a coefficient of -0.20.

The cointegrating equation represents the long-term relationship between the variables, where the impact of global demand, represented by world imports (LM) is positive and equal to 0.50, while international food prices (LPR) impact with a 0.93 coefficient and RER volatility (RERV_URU) has a negative impact, with a 0.19 coefficient. The full model is presented in Annex D.

According to this result, it is not rejected the existence of a cointegrating vector among the variables, and the sign of the coefficients are as expected. In addition, we made the corresponding exclusion tests for β and α for weak exogeneity.

Figure 2: Impulse-response functions



Analyzing impulse-response functions (Figure 2) from exports to international food prices, global demand and exchange rate volatility, the positive and permanent effect of the first two variables is confirmed, reaching 3% in the first 12 months for international food prices and 2.4% for global demand. Moreover, the impact is negative and permanent when a shock on RER volatility, reaching 1.3% after 12 months.

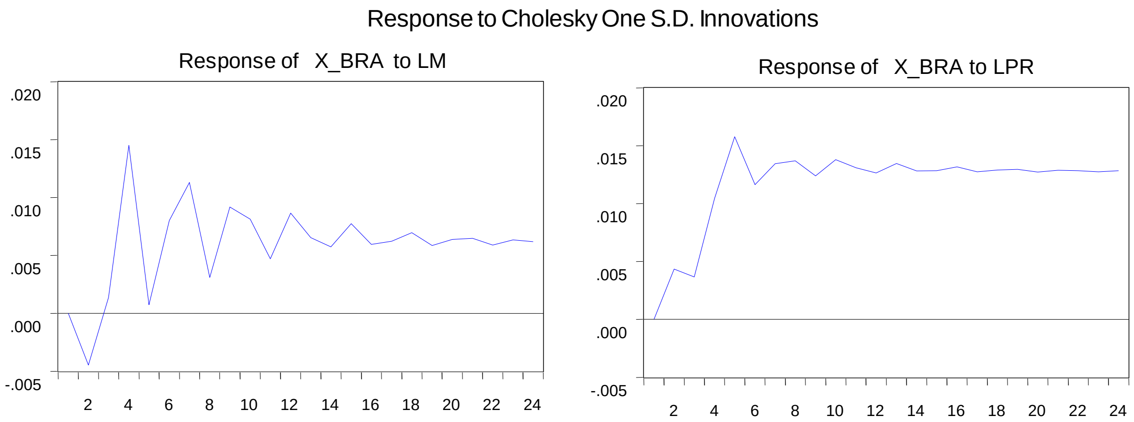
In the case of **Brazil**, as the volatility of the real exchange rate was stationary, I (0), the model is estimated for the other four variables (X_BRA, RER_BRA, LM and LPR), with RER volatility as exogenous. However, we could not detect statistically significant relationship between RER or RER volatility and exports in the model, similar results found Aguirre, A., et al. (2007) in the case of GARCH model for the RER volatility, so the resulting equation for Brazil is:

$$X_{BRA_t} = 1.071LM_t + 0.452LPR_t - 7.586$$
$$(15.673) \qquad (4.293)$$

According to the coefficients estimated value, the greatest impact in the case of Brazil comes from global demand, with an elasticity of about 1, while food international prices have a significant impact, but less so, with a coefficient 0.45.

Below they are presented in Figure 3 the impulse response functions:

Figure 3: impulse-response functions



The impact of a shock to either variables on exports is positive after 12 periods for global demand and impact below 1% and 6 periods for prices, with a close final effect 1.5 %.

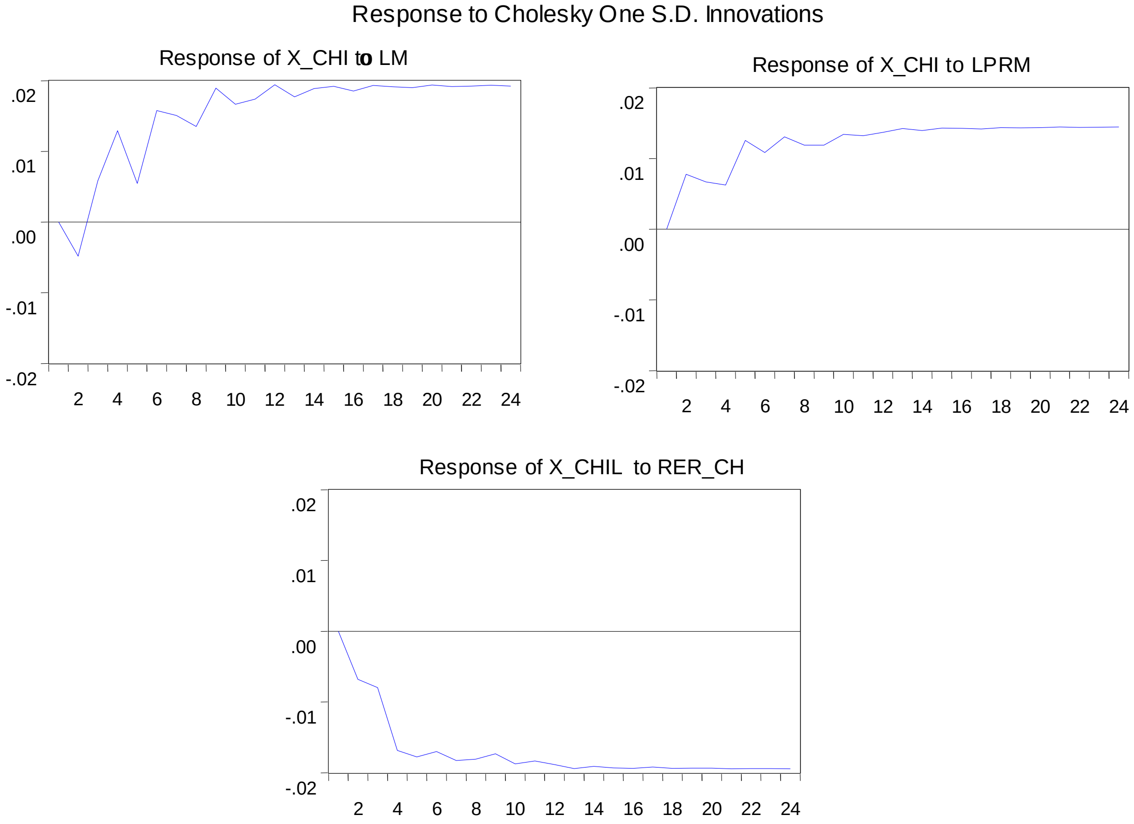
In the case of **Chile**, after analyzing the series stationarity included in the model (Tables 1 and 2), all variables were not stationary, so we investigated the existence of co-integration between variables and estimated a cointegration vector, where volatility was not significant and the real exchange rate was significant, but with negative sign.

So the resulting equation is:

$$X_{CHI_t} = 1.317LM_t + 0.167LPRM_t - 0.539RER\_CH_t - 8.041$$
$$(14.819) \qquad (2.354) \qquad (-3.622)$$

The cointegrating vector estimated for Chilean exports shows a positive coefficient 1.3 for world imports, near 0.15 for international metals prices, and negative near 0.5 for RER. Similar results found Huchet-Bourdon, M. y Korinek, J. (2012) for the impact of RER on exports in Chile, they explain that for the bilateral trade between Chile and China´s price inelastic demand and the impact of the copper price on the Chilean peso.

Figure 4: impulse response functions



In the impulse-response functions, which show the shock impact of different variables on exports indicate that despite an initial negative impact on global demand then the impact is positive, reaching 2%. In the case of metals prices, the impact is from the early months and remains positive, somewhat below 2%. In the case of the real exchange rate, the impact is negative, coming from 4 months to an effect of 2%.

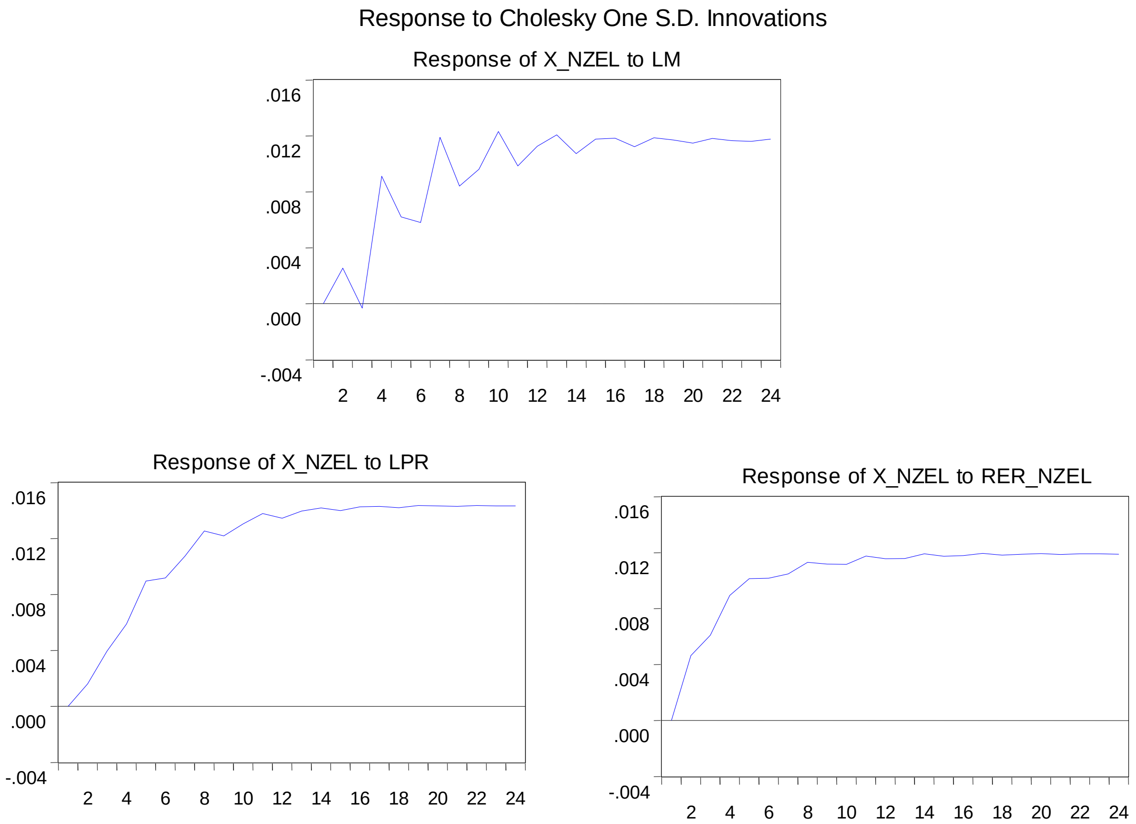
For **New Zealand** exports cointegrating vector, estimated RER volatility resulted not significant.

$$X_{NZEL_t} = 0.4484LM_t + 0.3176LPR_t + 0.235RER\_NZEL_t - 1.6093$$
$$(11.0534) \qquad (2.6943) \qquad (2.0505)$$

The global demand coefficient was somewhat higher than 0.4, the international food prices coefficient close to 0.3 while the elasticity of response of exports to changes in the real exchange rate was estimated slightly above 0.2. We found similar results as Huchet-Bourdon, M. y Korinek, J. (2012) for the RER positive effects (as economic theory) and RER volatility insignificant effects on the exports, since commodities exports depends on international prices in this kind of economic.

The following figure presents the impulse response functions:

Figure 5: impulse-response functions



Impulse response functions show a moderate impact of the three variables, but positive and sustained over time, somewhat higher in the case of food prices than international demand and real exchange rate.

Finally, it is necessary to check the direction of the causality to determine whether it is from the variables (World imports (LM), International food prices index (LPR) or International metals price index (LPRM), real exchange rate (RER) and RER volatility (RERV)) to the exports or vice versa.

The Granger causality *F*-statistics tests for the variables in levels are presented in Table 4:

Table 4: Granger causality *F*-statistics in levels

Variable/Exports	Brazil	Chile	New Zealand	Uruguay
LM	8.24834*	4.87922*	10.8901*	4.30695*
LPR/LPRM	5.03617*	7.12267*	4.34733*	3.05936*
RER	-----	1.07848	6.41637*	-----
RERV	-----	-----	-----	2.37653*
Exports/Variable	LM	LPR/LPRM	RER	RERV
Brazil	2.73805*	1.97013*	-----	-----
Chile	8.78288*	3.36855*	1.08574	-----
New Zealand	7.13552*	2.66992*	0.82036	-----
Uruguay	3.73174*	1.03228	-----	1.04823

Notes: H_0): X_{it} does not Granger cause X_{jt} $(i \neq j)$, where $\mathrm{X_{it}}$ represents the variables in the row and $\mathrm{X_{jt}}$ represents the variables in the column. 12 lags. 276 observations in each series. Sample: 1990.01 – 2013.12. *significant at 5%.
Source: Own elaboration.

According to the Granger test, in the case of the Brazilian economy, we found non-causality of global demand and international prices for Brazilian exports but also is rejected causality in the other direction, so from this test we cannot draw conclusions. This result may be because Brazil is a large economy and exports affect both global demand and international food prices.

In the case of Chile, Granger test provides no results, as all options are rejected (except for RER which is statistically insignificance), so we reject that some variables do not cause the other, but in every way.

For New Zealand is rejected (in the sense of Granger) both international food prices and global demand, they do not cause the country's exports. Respect to the real exchange rate it is rejected that the real exchange rate does not cause exports.

Finally, for Uruguay, according to the Granger test, it rejected that volatility does not affect exports. It is also rejected that global imports and international food prices do not cause, in the sense of Granger, Uruguayan exports.

7. Final remarks

While in economic literature there is consensus on the sign of global demand and international prices affecting exports, the evidence is less conclusive when real exchange rate volatility is incorporated to the analysis. From this work, we can conclude that global demand and international prices influence goods exports for all the selected countries. But only in the case of Uruguay the impact of RER volatility was significant both in the short and long-term and with a negative sign.

In the case of Brazil, Chile and New Zealand we did not find evidence of RER volatility impact on exports. This fact could indicate that the exchange rate uncertainty does not affect the export decisions in these countries, as if it happens in Uruguay, although in the case of New Zealand and Chile it was found impact of real exchange rate in exports. Although the sign of the coefficient was negative in the case of Chile.

In the case of Uruguay, which is a small open economy, the RER volatility negative impact on exports may suggests that economic policy must not disregard the importance of preserving the real exchange rate stability as a source of export stability, hence exports impact on macroeconomic variables.

Additionally, the failure to find evidence of the relationship between exchange rate volatility and exports in the rest of the studied countries can respond to the methodology used, remains to test in future studies as other volatility specifications that may modify the models.

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Annex A – Exports characterization

Table A.1: Exports share by country or destination area

Origin: Uruguay Destination	2013	1994	Origin: Chile Destination	2013	1990
Brazil	18,9%	25,8%	China	24,8%	0,4%
Europe & Central Asia	17,2%	21,6%	Europe & Central Asia	17,4%	36,0%
Free Zones	16,0%	0,1%	United States	12,7%	16,8%
China	14,2%	6,0%	Japan	9,9%	16,2%
Argentina	5,4%	20,0%	Brazil	5,7%	5,8%
Venezuela	4,9%	0,1%	Korea, Rep.	5,5%	3,0%
United States	3,9%	6,9%	India	3,0%	0,7%
Russia	3,1%	0,5%	Peru	2,5%	0,9%
Others	16,4%	19,1%	Others	18,4%	20,3%

Origin: Brazil Destination	2013	1990	Origin: New Zealand Destination	2013	1990
Europe & Central Asia	23,3%	31,9%	China	20,7%	1,0%
China	19,0%	1,2%	Australia	19,0%	19,0%
United States	10,3%	24,6%	Europe & Central Asia	10,6%	18,2%
Argentina	8,1%	2,1%	United States	8,5%	13,1%
Japan	3,3%	7,5%	Japan	5,9%	16,1%
Venezuela	2,0%	0,9%	Korea, Rep.	3,4%	4,2%
Korea, Rep.	2,0%	1,7%	Latin America & Caribbean	3,2%	3,0%
Chile	1,9%	1,5%	United Kingdom	2,9%	7,0%
Others	30,2%	28,6%	Others	25,7%	18,4%

Note: The term "Other" refers to the rest of the World.
Source: Own elaboration, data from World Bank.

The following table details the composition of the exported products:[8]

Table A.2: Description of exported products

Product group	Product group description	Product group	Product group description
Animal	Live animals	Textiles and Clothing	Silk
	Meat and edible meat offal		Wool, fine/coarse animal hair
	Fish & crustacean, mollusc & other aquatic		Cotton
	Dairy prod; birds' eggs; natural honey		Other vegetable textile fibres; paper yarn
	Products of animal origin, nes or included		Man-made filaments
Vegetable	Live tree & other plant; bulb, root		Man-made staple fibres
	Edible vegetables and certain roots and tubers		Wadding, felt & nonwoven; yarns; twine
	Edible fruit and nuts; peel of citrus fruit		Carpets and other textile floor coverings
	Coffee, tea, matï and spices		Special woven fab; tufted tex fab; lace
	Cereals		Impregnated, coated, cover/laminated textile
	Prod.mill.indust; malt; starches; inulin		Knitted or crocheted fabrics
	Oil seed, oleagi fruits; miscell grain, seed		Art of apparel & clothing access, knitted
	Lac; gums, resins & other vegetable saps & ext		Art of apparel & clothing access, not knitted
	Vegetable plaiting materials; vegetable produc		Other made up textile articles; sets
	Animal/veg fats & oils & their cleavage produc	Footwear	Footwear, gaiters and the like
Food Products	Prep of meat, fish or crustaceans, molluscs		Headgear and parts thereof
	Sugars and sugar confectionery		Umbrellas, walking-sticks, seat-sticks, whips
	Cocoa and cocoa preparations		Prepr feathers & down; arti flower
	Prep.of cereal, flour, starch/milk; pastrycook	Stone and Glass	Art of stone, plaster, cement, asbestos
	Prep of vegetable, fruit, nuts or other parts		Ceramic products
	Miscellaneous edible preparations		Glass and glassware
	Beverages, spirits and vinegar		Natural/cultured pearls, prec stones & metals
	Residues & waste from the food indust	Metals	Iron and steel
	Tobacco and manufactured tobacco substitutes		Articles of iron or steel
Minerals	Salt; sulphur; earth & ston; plastering mat		Copper and articles thereof
	Ores, slag and ash		Nickel and articles thereof
Fuels	Mineral fuels, oils & product of their distill		Aluminium and articles thereof
Chemicals	Inorgn chem; compds of prec mtl, radioact element		Lead and articles thereof
	Organic chemicals		Zinc and articles thereof
	Pharmaceutical products		Tin and articles thereof
	Fertilisers		Other base metals; cermets; articles thereof
	Tanning/dyeing extract; tannins & derivs		Tool, implement, cutlery, spoon & fork
	Essential oils & resinoids; perf, cosmetic		Miscellaneous articles of base metal
	Soap, organic surface-active agents	Mach and Elec	Nuclear reactors, boilers
	Albuminoidal subs; modified starches; glues		Electrical mchy equip parts thereof
	Explosives; pyrotechnic prod; matches	Transportation	Railw/tramw locom, rolling-stock
	Photographic or cinematographic goods		Vehicles o/t railw/tramw roll-stock, pts
	Miscellaneous chemical products		Aircraft, spacecraft, and parts thereof
Plastic or Rubber	Plastics and articles thereof		Ships, boats and floating structures
	Rubber and articles thereof	Miscellaneous	Optical, photo, cine, meas, checking
Hides and Skins	Raw hides and skins (other than furskins)		Clocks and watches and parts thereof
	Articles of leather; saddlery/harness		Musical instruments
	Furskins and artificial fur		Arms and ammunition; parts and accessories
Wood	Wood and articles of wood; wood charcoal		Furniture; bedding, mattress, matt support
	Cork and articles of cork		Toys, games & sports requisites; parts
	Manufactures of straw, esparto		Miscellaneous manufactured articles
	Pulp of wood/of other fibrous cellulosic		Works of art, collectors' pieces and antiques
	Paper & paperboard; art of paper pulp, paper		UN Special Code
	Printed books, newspapers, pictures		UN Special Code

Source: World Bank.

[8] http://wits.worldbank.org/referencedata.html

Annex B – Modeling conditional heteroskedasticity

It is usually assumed distribution process variance as a constant series over time (homoskedasticity), however, not all series have constant variance over time (heteroscedasticity).

That is why in this study the conditional variance of the real exchange rate is modeled through a GARCH variant process, introduced by Bollerlev, T. (1986), and widely used to estimate the volatility of some variables in time series models.

Consider a univariate stochastic process AR (1):

$$y_t = \delta_0 + \delta_1 . y_{t-1} + \varepsilon_t \qquad t = 1, \dots, n$$

where ε_t is a white noise $\quad \varepsilon_t \sim i.i.d.N(0, \sigma_t^2)$

and $Cov(\varepsilon_t, \varepsilon_s) = 0$ if $t \neq s$ (no serial autocorrelation)

so that the process y_t to be stationary it must satisfy that $|\delta_1| < 1$.

The mathematical unconditional (or marginal) expectation of the stochastic process y_t can be expressed as:

$$E(y_t) = E(\delta_0 + \delta_1 . y_{t-1} + \varepsilon_t) = \delta_0 + \delta_1 . E(y_{t-1}) \rightarrow E(y_t) = \frac{\delta_0}{1 - \delta_1}$$

and the unconditional variance of the stochastic process y_t is:

$$V(y_t) = V(\delta_0 + \delta_1 . y_{t-1} + \varepsilon_t) = \delta_1^2 . V(y_{t-1}) + V(\varepsilon_t) = \delta_1^2 . \sigma_y^2 + \sigma_\varepsilon^2 \rightarrow$$

$$\sigma_y^2 = \delta_1^2 . \sigma_y^2 + \sigma_\varepsilon^2 \rightarrow \sigma_y^2 = \frac{\sigma_\varepsilon^2}{1 - \delta_1^2}$$

Moreover, it could also determine the conditional expectation and variance, conditional understood in the term of the variable past information or until the previous period $t - 1$.

Consider Ω_{t-1} the set of information including all last variabley_t: $\Omega_{t-1} = \{y_{t-1}, y_{t-2}, \dots y_{t-n}\}$. The conditional expectation and variance can be represented respectively as follows:

$$E(y_t|\Omega_{t-1}) = E_{t-1}(y_t) = \delta_0 + \delta_1 . y_{t-1}$$

$$V(y_t|\Omega_{t-1}) = Var_{t-1}(y_t) = E_{t-1}[y_t - E_{t-1}(y_t)]^2 = E_{t-1}(\varepsilon_t^2) = \sigma_\varepsilon^2$$

In this case shows that both conditional and unconditional variance are constant over time, however, the conditional variance need not to be constant over time (Gracia-Diez, M. and Novales, A., 1993).

ARCH model

The univariate ARCH processes (autoregressive conditional heteroskedasticity) allow the conditional variance error term ε_t changing over time, for it is considered the set of information available at the time t-1, $\sigma_\varepsilon: \Omega_{t-1} = \{\varepsilon_{t-1}, \varepsilon_{t-2}, \ldots \varepsilon_{t-n}\}$ and a specification of the square of the prediction errors of previous periods $\sigma_\varepsilon^2 = \sigma_t^2 = f(\varepsilon_{t-1}^2, \varepsilon_{t-2}^2, \ldots)$. This way it is assigned greater weight to more recent past.

Consider the univariate model ARCH (1):

$$\sigma_t^2 = \alpha_0 + \alpha_1 . \varepsilon_{t-1}^2$$

with $\delta_0 \geq 0$ and $\delta_1 \geq 0$, where conditional variance depends on one lag of ε_t. The conditional distribution of ε_t, assuming normality is:

$$\varepsilon_t|\Omega_{t-1} \sim N(0, \sigma_t^2)$$

$\sigma_t^2 > 0$ is the conditional variance of $\varepsilon_t \rightarrow \alpha_1$ must be non-negative.

Estimating the expectation $E(\sigma_t^2) = \alpha_0 + \alpha_1 . E(\varepsilon_{t-1}^2)$, the ARCH (1) process must satisfy $|\alpha_1| < 1$ to obtain a stationary model in variance and prevent σ_t^2 to be explosive.

From equation $\sigma_t^2 = \alpha_0 + \alpha_1 . \varepsilon_{t-1}^2$, appears that a high value of $\varepsilon_{t-1}^2 \rightarrow$ the variance σ_t^2 conditioned to that value of ε_{t-1}^2 would be higher $\rightarrow$ a high σ_t^2.

In a generalized way we can expressed an ARCH (q) as follows:

$$\sigma_t^2 = \delta_0 + \sum_{i=1}^{q} \delta_i . \varepsilon_{t-i}^2$$

with $\delta_0 \geq 0$, $\delta_i \geq 0 \quad i = 1, \ldots, q$

GARCH model

The GARCH (p, q) process (Generalized Autoregresive Conditional Heteroskedasticity) is a technique developed by Bollerslev, T. (1986) from the works of Engel, R. (1972) that allows the conditional variance (volatility) of the y_t sequence constitutes an ARMA process. For it is estimated $\{y_t\}$ as an ARMA process. If the model is suitable $\{y_t\}$, the autocorrelation function (ACF) and partial autocorrelation function of residuals should behave like a white noise process. The ACF of the squared residuals helps to identify the order of the GARCH process.

The conditional variance GARCH specification of $\varepsilon_t: \{\sigma_t^2\}$ depends on the residuals lags and the their own values lags:

As $E_{t-1}.\varepsilon_t^2 = \sigma_t^2$, is possible to write:

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i.\varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_i \sigma_{t-i}^2$$

This equation is similar to an ARMA (p, q) in the sequence $\{\varepsilon_t^2\}$. If there are conditional heteroskedasticity, the correlogram should continue the process.

GARCH (1,1) model

Following Gracia-Diez, M. and Novales, A. (1993), considerer the GARCH (1,1) specification:

$$\sigma_t^2 = \alpha_0 + \alpha_1.\varepsilon_{t-1}^2 + \beta_1.\sigma_{t-1}^2$$

$$\alpha_0 > 0, \alpha_1 > 0, \beta_1 > 0$$

$$\text{and } \varepsilon_t | \Omega_{t-1} \sim N(0, \sigma_t^2)$$

Observe that $|\beta_1| < 1$ is a necessary condition for the stability of the model:

$$\sigma_t^2 - \beta_1.\sigma_{t-1}^2 = \alpha_0 + \alpha_1.\varepsilon_{t-1}^2$$

$$\sigma_t^2 - \beta_1 L \sigma_t^2 = \alpha_0 + \alpha_1.\varepsilon_{t-1}^2$$

$$(1 - \beta_1 L)\sigma_t^2 = \alpha_0 + \alpha_1.\varepsilon_{t-1}^2$$

$$\sigma_t^2 = \frac{\alpha_0}{1-\beta_1} + \frac{\alpha_1}{1-\beta_1 L}.\varepsilon_{t-1}^2$$

and the GARCH (1,1) process can be approximated by an ARCH (p) process if p is large.

Moreover, in a horizon of forecast *s* for the GARCH (1,1) we have that:

$$E_t \sigma_{t+s}^2 = \alpha_0 + \alpha_1 E_t \varepsilon_{t+s-1}^2 + \beta_1 E_t \sigma_{t+s-1}^2 = \alpha_0 + (\alpha_1 + \beta_1) E_t \sigma_{t+s-1}^2$$

Therefore, for the conditional variance process to be stationary that must be satisfied $|\alpha_1 + \beta_1| < 1$.

IGARCH model

It is common to find empirical evidence that GARCH (1,1) models introduced an estimation of the parameters $\hat{\alpha}_1$ and $\hat{\beta}_1$ values of $|\alpha_1 + \beta_1|$ close to one, which makes the process integrated in variance and no stationary. In the literature is called IGARCH (*Integrated* GARCH).

Consider a GARCH (1,1) process:

$$\sigma_t^2 = \alpha_0 + \alpha_1.\varepsilon_{t-1}^2 + \beta_1 \sigma_{t-1}^2$$

if $\alpha_1 + \beta_1 = 1$, we have:

$$\sigma_t^2 = \alpha_0 + \alpha_1 \varepsilon_{t-1}^2 + (1 - \alpha_1)\sigma_{t-1}^2$$

$$\sigma_t^2 = \alpha_0 + \sigma_{t-1}^2 + \alpha_1 \varepsilon_{t-1}^2 - \alpha_1 \sigma_{t-1}^2$$

$$IGARCH(1,1): \quad \sigma_t^2 = \alpha_0 + \sigma_{t-1}^2 + \alpha_1(\varepsilon_{t-1}^2 - \sigma_{t-1}^2)$$

Annex C – Johansen cointegration test results

Table C.1: Uruguayan model

Cointegration test of unrestricted range (Trace)				
Hypothesis Nº of Eq(s)	Eigenvalue	Trace	0.05 Critical value	Prob.**
None *	0.140975	53.68091	47.85613	0.0129
At least 1	0.041784	15.69157	29.79707	0.7338
At least 2	0.019840	5.021150	15.49471	0.8066
At least 3	4.52E-05	0.011308	3.841466	0.9151
Cointegration test of unrestricted range (Maximum eigenvalue)				
Hypothesis Nº of Eq(s)	Eigenvalue	Maximum eigenvalue	0.05 Critical value	Prob.**
None *	0.140975	37.98934	27.58434	0.0016
At least 1	0.041784	10.67042	21.13162	0.6801
At least 2	0.019840	5.009842	14.26460	0.7406
At least 3	4.52E-05	0.011308	3.841466	0.9151

Table C.2: Brazilian model

Cointegration test of unrestricted range (Trace)				
Hypothesis Nº of Eq(s)	Eigenvalue	Trace	0.05 Critical value	Prob.**
None *	0.104005	34.33773	29.79707	0.0140
At least 1	0.025802	6.663086	15.49471	0.6171
At least 2	0.000301	0.075740	3.841466	0.7831
Cointegration test of unrestricted range (Maximum eigenvalue)				
Hypothesis Nº of Eq(s)	Eigenvalue	Maximum eigenvalue	0.05 Critical value	Prob.**
None *	0.104005	27.67465	21.13162	0.0052
At least 1	0.025802	6.587346	14.26460	0.5390
At least 2	0.000301	0.075740	3.841466	0.7831

Table C.3: Chilean model

Cointegration test of unrestricted range (Trace)				
Hypothesis Nº de Eq(s)	Eigenvalue	Trace	0.05 Critical value	Prob.**
None *	0.153694	68.05011	47.85613	0.0002
At least 1	0.050201	21.82604	29.79707	0.3083
At least 2	0.025631	7.559157	15.49471	0.5137
Cointegration test of unrestricted range (Maximum eigenvalue)				
Hypothesis Nº de Eq(s)	Eigenvalue	Maximum eigenvalue	0.05 Critical value	Prob.**
None *	0.153694	46.22407	27.58434	0.0001
At least 1	0.050201	14.26688	21.13162	0.3435
At least 2	0.025631	7.192327	14.26460	0.4666

Table C.4: New Zealand model

Cointegration test of unrestricted range (Trace)				
Hypothesis Nº de Eq(s)	Eigenvalue	Trace	0.05 Critical value	Prob.**
None *	0.094067	61.07859	54.07904	0.0105
At least 1	0.074656	33.02212	35.19275	0.0842
At least 2	0.028089	10.98649	20.26184	0.5434
Cointegration test of unrestricted range (Maximum eigenvalue)				
Hypothesis Nº de Eq(s)	Eigenvalue	Maximum eigenvalue	0.05 Critical value	Prob.**
None *	0.094020	28.04172	27.58434	0.0437
At least 1	0.048333	14.06953	21.13162	0.3594
At least 2	0.010187	2.908050	14.26460	0.9527

Annex D – Models Results

Table D.1: Uruguayan model

Vector Error Correction Estimates
Sample (adjusted): 1993M03 2013M12
Included observations: 250 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegration Restrictions:
B(1,1)=1, A(2,1)=0, A(3,1)=0,
Convergence achieved after 6 iterations.
Restrictions identify all cointegrating vectors
LR test for binding restrictions (rank = 1):

Chi-square(2)	1.551365
Probability	0.460389

CointegratingEq:	CointEq1
X_URU(-1)	1.000000
LM(-1)	-0.502423
	(0.09624)
	[-5.22027]
LPR(-1)	-0.927918
	(0.13380)
	[-6.93516]
RERV_URU(-1)	0.191734
	(0.03784)
	[5.06706]
C	5.138552

Error Correction:	D(X_URU)	D(LM)	D(LPR)	D(RERV_URU)
CointEq1	-0.207329	0.000000	0.000000	-0.203877
	(0.04668)	(0.00000)	(0.00000)	(0.06048)
	[-4.44137]	[NA]	[NA]	[-3.37071]

Residual test:

Normality

VEC Residual Normality Tests
Orthogonalization: Cholesky (Lutkepohl)
Null Hypothesis: residuals are multivariate normal
Sample: 1993M03 2013M12
Included observations: 250

Component	Skewness	Chi-sq	df	Prob.
1	-0.085123	0.301916	1	0.5827
2	-0.144562	0.870763	1	0.3507
3	0.108172	0.487549	1	0.4850
4	0.994500	41.20961	1	0.0000
Joint		42.86983	4	0.0000

Component	Kurtosis	Chi-sq	df	Prob.
1	3.237702	0.588564	1	0.4430
2	3.190737	0.378966	1	0.5382
3	3.085267	0.075734	1	0.7832
4	4.216044	15.40378	1	0.0001
Joint		16.44704	4	0.0025

Component	Jarque-Bera	df	Prob.
1	0.890480	2	0.6407
2	1.249729	2	0.5353
3	0.563283	2	0.7545
4	56.61338	2	0.0000
Joint	59.31687	8	0.0000

Autocorrelation

VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Sample: 1993M03 2013M12
Included observations: 250

Lags	LM-Stat	Prob
1	23.70344	0.0962
2	20.09245	0.2161
3	30.80591	0.0142
4	25.95701	0.0546
5	17.49204	0.3545
6	21.10790	0.1744
7	22.66119	0.1231
8	11.49250	0.7781
9	16.73246	0.4031
10	23.35148	0.1047
11	22.07018	0.1409
12	28.93485	0.0244

Probs from chi-square with 16 df.

Table D.2: Brazilian model

Vector Error Correction Estimates
Sample (adjusted): 1990M06 2013M12
Included observations: 283 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1		
X_BRA(-1)	1.000000		
LM(-1)	-1.070672		
	(0.06831)		
	[-15.6731]		
LPR(-1)	-0.452393		
	(0.10537)		
	[-4.29324]		
C	7.586089		
Error Correction:	**D(X_BRA)**	**D(LM)**	**D(LPR)**
CointEq1	-0.118187	0.044218	0.056922
	(0.05965)	(0.02315)	(0.01851)
	[-1.98123]	[1.91019]	[3.07458]

Residual test:

Normality

VEC Residual Normality Tests
Orthogonalization: Cholesky (Lutkepohl)
Null Hypothesis: residuals are multivariate normal
Sample: 1990M01 2013M12
Included observations: 283

Component	Skewness	Chi-sq	df	Prob.
1	-0.078317	0.289296	1	0.5907
2	0.061815	0.180226	1	0.6712
3	0.201455	1.914208	1	0.1665
Joint		2.383731	3	0.4967

Component	Kurtosis	Chi-sq	df	Prob.
1	3.700502	5.786212	1	0.0162
2	3.217635	0.558514	1	0.4549
3	3.139177	0.228406	1	0.6327
Joint		6.573132	3	0.0868

Component	Jarque-Bera	df	Prob.
1	6.075508	2	0.0479
2	0.738741	2	0.6912
3	2.142614	2	0.3426
Joint	8.956863	6	0.1760

Autocorrelation

VEC Residual Serial Correlation LM Tests

Null Hypothesis: no serial correlation at lag order h

Sample: 1990M01 2013M12

Included observations: 283

Lags	LM-Stat	Prob
1	4.997619	0.8345
2	10.17259	0.3367
3	13.65610	0.1351
4	9.110659	0.4271
5	10.85226	0.2860
6	5.165150	0.8197
7	5.296782	0.8077
8	10.18649	0.3356
9	21.84128	0.0094
10	8.604039	0.4746
11	7.826809	0.5517
12	10.79665	0.2899

Probs from chi-square with 9 df.

Table D.3: Chilean model

Vector Error Correction Estimates
Sample (adjusted): 1990M06 2013M12
Included observations: 277 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegration Restrictions:
B(1,1)=1, A(2,1)=0,
Convergence achieved after 4 iterations.
Restrictions identify all cointegrating vectors
LR test for binding restrictions (rank = 1):

Chi-square(1)	1.769021
Probability	0.183503

Cointegrating Eq:	CointEq1
X_CHI(-1)	1.000000
LM(-1)	-1.316998
	(0.08887)
	[-14.8189]
LPRM(-1)	-0.166941
	(0.07093)
	[-2.35376]
RER_CH(-1)	0.539220
	(0.14887)
	[3.62200]
C	8.040838

Error Correction:	D(X_CHI)	D(LM)	D(LPRM)	D(RER_CH)
CointEq1	-0.233239	0.000000	0.074113	-0.043966
	(0.05856)	(0.00000)	(0.02656)	(0.01238)
	[-3.98285]	[NA]	[2.79033]	[-3.55260]

Residual test:

Normality

VEC Residual Normality Tests
Orthogonalization: Cholesky (Lutkepohl)
Null Hypothesis: residuals are multivariate normal
Sample: 1990M01 2013M12
Included observations: 277

Component	Skewness	Chi-sq	df	Prob.
1	-0.185299	1.585161	1	0.2080
2	-0.071681	0.237211	1	0.6262
3	-0.183284	1.550878	1	0.2130
4	0.105833	0.517099	1	0.4721
Joint		3.890348	4	0.4210

Component	Kurtosis	Chi-sq	df	Prob.
1	2.859900	0.226540	1	0.6341
2	3.220555	0.561440	1	0.4537
3	3.772636	6.889987	1	0.0087
4	3.346623	1.386701	1	0.2390
Joint		9.064667	4	0.0595

Component	Jarque-Bera	df	Prob.
1	1.811701	2	0.4042
2	0.798651	2	0.6708
3	8.440865	2	0.0147
4	1.903800	2	0.3860
Joint	12.95502	8	0.1134

Autocorrelation

VEC Residual Serial Correlation LM Tests

Null Hypothesis: no serial correlation at lag order h

Sample: 1990M01 2013M12

Included observations: 277

Lags	LM-Stat	Prob
1	23.87143	0.0924
2	22.28878	0.1341
3	14.32512	0.5745
4	22.42527	0.1300
5	19.72569	0.2328
6	23.05194	0.1124
7	21.49179	0.1604
8	10.93513	0.8135
9	28.45800	0.0279
10	35.92216	0.0030
11	18.85981	0.2760
12	24.14159	0.0865

Probs from chi-square with 16 df.

Table D.4: New Zealand model

Vector Error Correction Estimates
Date: 05/13/15 Time: 17:03
Sample (adjusted): 1990M05 2013M12
Included observations: 284 after adjustments
Standard errors in ( ) & t-statistics in [ ]

CointegrationRestrictions:
B(1,1)=1, A(2,1)=0, A(4,1)=0
Convergence achieved after 4 iterations.
Restrictions identify all cointegrating vectors
LR test for binding restrictions (rank = 1):

Chi-square(2)	1.135440
Probability	0.566816

Cointegrating Eq:	CointEq1
X_NZEL(-1)	1.000000
LM(-1)	-0.448953
	(0.04062)
	[-11.0538]
LPR(-1)	-0.315355
	(0.11802)
	[-2.67199]
RER_NZEL(-1)	-0.236838
	(0.11478)
	[-2.06342]
C	1.614207

Error Correction:	D(X_NZEL)	D(LM)	D(LPR)	D(RER_NZEL)
CointEq1	-0.323280	0.000000	0.061456	0.000000
	(0.07324)	(0.00000)	(0.02884)	(0.00000)
	[-4.41382]	[NA]	[2.13080]	[NA]

Residual test:

Normality

VEC Residual NormalityTests

Orthogonalization: Residual Covariance (Urzua)

Null Hypothesis: residuals are multivariate normal

Sample: 1990M01 2013M12

Included observations: 284

Component	Skewness	Chi-sq	df	Prob.
1	-0.019800	0.018953	1	0.8905
2	-0.056990	0.157008	1	0.6919
3	0.130703	0.825848	1	0.3635
4	-0.090402	0.395077	1	0.5296
Joint		1.396887	4	0.8447

Component	Kurtosis	Chi-sq	df	Prob.
1	2.779313	0.497113	1	0.4808
2	2.879669	0.122941	1	0.7259
3	3.471625	3.027686	1	0.0819
4	3.568841	4.340417	1	0.0372
Joint		7.988157	4	0.0920

Component	Jarque-Bera	df	Prob.
1	0.516066	2	0.7726
2	0.279949	2	0.8694
3	3.853534	2	0.1456
4	4.735494	2	0.0937
Joint	48.84045	55	0.7077

Autocorrelation

VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Date: 05/14/15 Time: 18:56
Sample: 1990M01 2013M12
Includedobservations: 284

Lags	LM-Stat	Prob
1	17.97660	0.3253
2	30.22301	0.0169
3	17.69669	0.3420
4	19.83141	0.2279
5	24.78242	0.0738
6	16.33738	0.4297
7	18.52146	0.2943
8	13.14609	0.6620
9	24.39440	0.0812
10	33.53211	0.0063
11	30.55773	0.0153
12	40.59445	0.0006

Probs from chi-square with 16 df.

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