The impact of exchange rate uncertainty on exports: a panel VAR analysis*

El impacto de la incertidumbre del tipo de cambio sobre las exportaciones: un análisis de panel VAR

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ABSTRACT

In this paper we analyze the impact of exchange rate uncertainty on export flows among a panel of 27 countries throughout the 1994/01-2014/12 period. In order to do this, we apply a panel vector autoregressive model approach. By dividing the panel into two subgroups that involve manufacturing-exporting and commodity-exporting economies, we observe a different effect of exchange rate uncertainty on exports. This has a negative impact in manufacturing-exporting countries, but does not affect commodity-exporting countries. This result appears to be explained by countries' economics characteristics, involving the flexibility or rigidities of the export adjustment arising exchange rate uncertainty.

Key words: *Exchange rate uncertainty, exports, panel vector autoregressive, manufacture-exporting economies, commodity-exporting economies.*

JEL Classification: *C33; F31; F41.*

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Resumen

En este artículo analizamos el impacto de la incertidumbre del tipo de cambio sobre los flujos de exportaciones en un panel de 27 países durante el período 1994/01-2014/12. Para ello, aplicamos un enfoque de vectores autoregresivos con datos panel. Dividiendo el panel en dos subgrupos que incluyen economías exportadoras de manufactureras y economías exportadoras de productos básicos, observamos un efecto diferencial de la incertidumbre del tipo de cambio sobre las exportaciones. Esta incertidumbre tiene un impacto negativo en los países exportadores de manufacturas, pero no afecta de forma significativa a los países exportadores de productos básicos. Este resultado parece explicarse por las características económicas de los países, las cuales involucran la flexibilidad o rigidez del ajuste de las exportaciones a la incertidumbre del tipo de cambio.

Palabras clave: *Incertidumbre del tipo de cambio, exportaciones, panel de vectores autorregresivos, economías exportadoras de manufacturas, economías exportadoras de productos básicos.*

Clasificación JEL: *C33; F31; F41.*

1. Introduction

The collapse of the exchange rate system adopted at the Bretton Woods Conference had as one of its consequences the free floating of the majority of currencies in the world, generating concern about the effects that exchange rate uncertainty could have on international trade flows. From that moment forward, an extensive literature has analyzed the economic effects of this exchange rate uncertainty (Arize *et al*., 2008; Kandilov, 2008).

Since the concept of uncertainty is difficult to quantify precisely, exchange rate volatility (*i.e.* variability) has commonly been used by the literature on trade as a proxy of it and refers to the risk associated with unexpected exchange rate movements (McKenzie, 1999). However, there is no consensus in the empirical literature about which statistical measure to use to measure exchange rate volatility (Arize, 1997; Hall *et al*., 2010) and also about the significance and sign of the impact of exchange rate volatility on exports (Bahmani-Oskooee and Hegerty, 2007; Bouoiyour and Selmi, 2016; Bayar, 2018).

The main aim of this paper is to analyze how exchange rate uncertainty impacts exports among a novel panel of European, South American and Oceanian countries throughout the 1994/01-2014/12 period. While prior empirical studies (Sauer and Bohara, 2001; Grier and Smallwood, 2007; Hall *et al*., 2010) generally consider a group of developed countries and a group of developing countries, in this paper we focus on a novel classification of countries in a panel of manufactures-exporting economies (mainly European countries) and a panel of commodity-exporting economies (South American and Oceanian countries).

This novel categorization allows us to more deeply analyze the effects of exchange rate uncertainty on exports in countries with different production structures.

The empirical methodology applied is a Panel Vector Autoregressive model (P-VAR) developed by Abrigo and Love (2016). Specifically, the macroeconomic analysis consists of studying the dynamics of short- and medium-term relationships between exports and real effective exchange rate volatility, as well as the dynamics of a set of macroeconomic variables. In addition, impulse-response functions (IRF's) and Granger causality are examined.

The contributions of our study are fourfold. First, we provide novel empirical evidence about the effects of real effective exchange rate volatility on exports for a set of countries with different production patterns. Second, given that there is no consensus about exchange rate uncertainty specification, this paper aims to contribute to the debate by using and arguing in favour of specific measures of real effective exchange rate volatility. Third, the dynamics between exports and real effective exchange rate volatility are studied over a long period of time (1994/01 to 2014/12) with monthly data frequency, covering several macroeconomic shock events, which enables us to discuss episodes such as the Great Recession (the international financial crisis of 2008/2009). Finally, we applied the P-VAR methodology which is not yet explored in the international trade literature and which allows us to analyze the dynamics of short- and medium-term relationships between exports and real effective exchange rate volatility.

We observe a group-specific impact of real effective exchange rate volatility on exports. Manufactures-exporting economies show a negative effect of real effective exchange rate volatility on exports, while this effect is not significant for the commodity-exporting economies. There is also evidence that the Great Recession of 2008/2009 negatively impacts exports flows among manufactures-exporting economies but does not significantly affect commodity-exporting countries.

The paper is organized as follows. Section 2 reviews the related literature. Data and variables are presented in Section 3. The measures of volatility of real exchange rates are discussed in Section 4. The methodology is presented in Section 5. Section 6 presents the main findings. Finally, Section 7 presents conclusions and policy implications.

2. Exchange rate volatilities and its impact on international trade: background

There is an extensive and inconclusive literature about the impact of exchange rate volatility on international trade.[1] Theoretical literature has not been able to consistently support a strong relationship between these variables and

1 Literature reviews of such studies are provided by Ozturk (2006), Bahmani-Oskooee and Hegerty (2007), Coric and Pugh (2010), Bouoiyour and Selmi (2016) and Bayar (2018).

this continues to be a controversial issue.[2] The most common hypothesis is a negative effect of real exchange rate (RER) volatility on exports. In this sense, some scholars have argued that RER volatility affects the behavior of traders in response to the risk of their international trade activities through the uncertainty of benefits and costs denominated in foreign currency (Ethier, 1973; Clark, 1973; Gagnon, 1993; Aftab *et al.*, 2012; Nazlioglu, 2013). More specifically, risk averse traders respond negatively to unanticipated exchange rate fluctuations and move to less risky activities (e.g. agents choose internal trade instead of foreign trade), leading to change in the size/contribution of economic activities to relevant macroeconomic variables such as the trade balance or the balance of payments (Were, 2015). However, other researchers point out that there can be positive effects on international trade, because some agents see exchange rate variability as an opportunity to increase benefits from international trade. Specifically, De Grauwe (1988) argues that the increase in foreign exchange risk can be decomposed into a substitution and an income effect. Due to an increase in risk, the substitution effect operates by reducing export activities in favor of less risky local activities. However, the income effect operates in the opposite direction: if producers are sufficiently risk-averse, an increase in exchange rate risk raises the expected marginal utility of exports revenue and therefore induces them to increase their export activity. Consequently, if the income effect is high and dominates, an increase in foreign exchange risk has a positive effect on export trade flows. Similarly, Broll and Eckwert (1999) point out that the effect will depend on the firm’s behavior vis-à-vis the risk, which is why they conclude that volatility may increase exports since an increment of the exchange risk can enhance the potential gains of trade. Sercu (1992) shows that exchange rate volatility can in some cases increase the volume of trade rather than penalize it. If, on average, high volatility increases the probability that the price received by exporters exceeds the costs of tariffs or transportation in trade, trade is likely to be stimulated. Dellas and Zilberfarb (1993), using a theoretical asset market approach, explain a positive effect of exchange rate volatility on exports based on the risk aversion parameter of the traders. Finally, Serenis and Tsounis (2013) point out the existence of studies that suggest that the effect might be expected to be insignificant due to use of futures markets instruments to hedge the uncertainty associated with exchange rate movements (Willett, 1986; Nazlioglu, 2013).

The empirical literature has also undergone significant evolution. Earlier studies used simple regression methods to assess the effects of exchange rate volatility on exports and employed standard measures to model exchange rate volatility.[3] For example, Hooper and Kohlhagen (1978) find no evidence that exchange rate volatility, measured as the standard deviation of the nominal

[2] See, for comprehensive surveys, McKenzie (1999) and Bahmani-Oskooee and Hegerty (2007).

[3] See Bayar (2018) and Bahmani-Oskooee and Hegerty (2007) for a comprehensive surveys of these empirical studies.

exchange rate, affects bilateral and multilateral exports in developed countries between the mid-1960s and mid-1970s. However, Cushman (1983) follows the work of Hooper and Kohlhagen (1978) to analyze the impact of exchange rate variability, in this case measured as the standard deviation of the RER, on US bilateral trade with five other industrialized countries (Canada, France, Germany, Japan and the United Kingdom) over 1965-1977. For this group of countries, unexpected movements in the RER generally have a significant and negative impact on international trade. Akhtar and Hilton (1984) find a negative relationship when analyzing the impact of exchange rate volatility, measured as the standard deviation of the nominal effective exchange rate, on bilateral trade between the United States and Germany over 1974-1981.

Both the techniques for measuring volatility and also the available sources of information have evolved significantly in recent decades, enabling a significant evolution in the empirical trade literature. For example, Kroner and Lastrapes (1993) estimate exchange rate volatility using a Generalized Autoregressive Conditional Heteroskedasticity (GARCH) multivariate process, while Chowdhury (1993) estimates the volatility using a moving standard deviation of the RER. Arize (1997 and 2008) examines the volatility of the real effective exchange rate (REER) using an ARCH (Autoregressive Conditional Heteroskedasticity) process. Most of these studies find a negative effect of exchange rate volatility on exports flows. More recently, some studies tackle this issue using panel data analysis. For instance, Sauer and Bohara (2001) empirically analyze the effect of real effective exchange rate volatility (REERV) on exports for a panel of 91 developed and developing countries during the 1966-1993 period. They estimate exchange rate volatility using an ARCH process and two variants to the moving standard deviation of the REER. They find a negative effect of the REERV on exports. When the sample is divided into developed and developing countries, the impact for developing countries (Latin American and African countries) is negative.[4] However, they find no effect in advanced economies. Situ (2015) considers the bilateral trade of the United States with two groups of countries with different characteristics, developed and least-developed export-oriented countries, for two periods: 1994-2007 and 2008-2014. Using panel data techniques and modeling the volatility of the RER through a GARCH process, he finds a negative impact of RER volatility on exports (except for the first period for least developed countries), with a larger result for the developed countries, mainly in the 2008-2014 period. This is explained by the fact that firms in advanced countries have a greater capacity relative to export-oriented developing economies to adjust exports when facing variability in the RER. Furthermore, Vilela and MacDonald (2016) analyze the effect of REERV, estimated as the moving standard deviation and also using a GARCH process, on exports for a panel of 106 countries over 2000-2011. They find a negative impact for the sample as a

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4 See also a study for African countries by Bahmani-Oskooee and Gelan (2018).

whole and also for the developing and emerging economy sub-samples, which is attributed to the oil-exporting economies.

Other closely related literature provides insight into the relationship between exchange rate movements and trade balance, based on the so-called J- and S-curve concepts (Bahmani-Oskooee and Ratha, 2004; Bahmani-Oskooee and Hegerty, 2010). While the J-curve depicts the potential time path of a country's trade balance after a change in the exchange rate, the S-curve reflects what happens before and after a change in the exchange rate. A depreciation or devaluation should make imports more expensive in the short run and increase a country's exports in the long run (due to some delays in adjusting consumption and producers' contracts). That worsens the trade balance first and improvement comes afterward; this is a J-curve pattern. As the trade balance improves, the initial depreciation is reversed (a negative correlation), and it might always lead to a second period of depreciation (a positive correlation), *i.e.*, an S-curve pattern. However, the empirical evidence about the effect of exchange rate movements on a trade balance is still an unanswered question (Arize *et al*., 2017; Yazgan and Ozturk, 2019).

As a general observation, we can state that although most of the empirical studies reviewed show that negative effects of REERV on exports prevail, they are difficult to compare and generalize since they differ in terms of sample periods, the variables used, the countries considered, the volatility specifications, the type of exports (aggregated, bilateral or sector-specific), the exchange rate (nominal, real or effective), and methodologies and estimation methods. In addition, the previous empirical evidence describes the importance of economies' characteristics; however, this issue has not been sufficiently examined. In this context, this paper pursues analysis on this important issue.

3. Data and variables

The sample used in this paper consists of a monthly frequency panel dataset of 27 countries, including 15 European (E-15), 10 South American and two Oceanian, over 1994-2014.[5] The panel selection criteria pertained to the export-related macroeconomic characteristics of the economies, in order to analyze different effects of REERV on exports for a sample of countries (Figure 1, panel a). In so doing, we distinguish between manufactures-exporting (MXE) and commodity-exporting (CXE) countries following the criteria established in the World Economic Outlook's Statistical (IMF, 2015). Therefore, we categorize a country as a commodity exporter if it satisfies two conditions: 1) at least 35% of total goods exports are classified as commodities; 2) net commodities exports represent at least 5% of total trade in goods, on average, during the 1994-2014 period. By using 1994-2014 averages and according

5 See Table A.1 in the appendix for the list of countries considered.

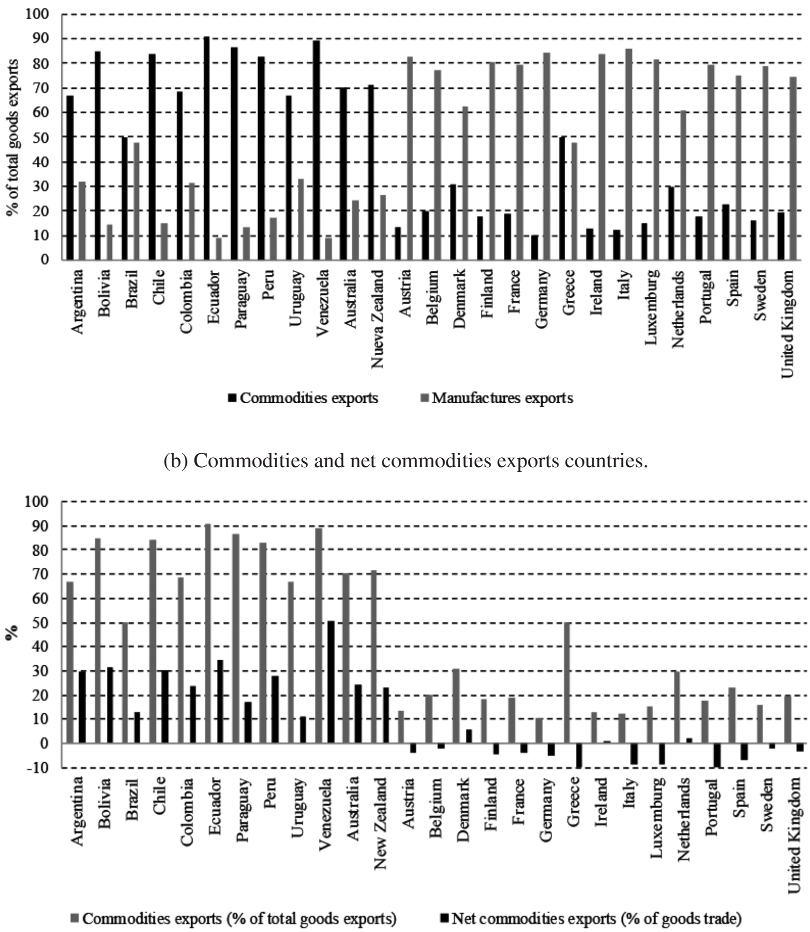
to IMF data, the E-15 countries are classified into the MXE group and the South American and the two Oceanian countries are classified into the CXE group (Figure 1, panel b).

Following Miranda and Mordecki (2019), the main series used in this study correspond to: total goods exports (*X*), world goods imports (*M**), international commodity prices indices disaggregated into non-fuel prices (*P*) and fuel prices

FIGURE 1
CHARACTERISTICS OF COUNTRIES' EXPORTS OVER 1994-2014

(a) Manufactures and commodities exports countries

(b) Commodities and net commodities exports countries.



Source: Developed by authors based on IMF data.

(P^*), and REER is used to calculate the different measures of REERV.[6] The international trade literature typically uses GDP as a proxy of economies' demand at the country level; however, as monthly world GDP is not available to approximate world demand, in this paper we use world goods imports. The other series considered are the commodity prices indices, disaggregated into non-fuel and fuel commodities price indices. Both indices are relevant to explain export earnings in South American and Oceanian countries, while the fuel commodities price index is relevant in explaining E-15 export costs.

4. Measures of real exchange rate volatility

We considered two groups of univariate measures to quantify the REERV. First, a measure of historical volatility, quantified as the sample moving standard deviation of the growth rate of real effective exchange rate (REER). Second, a measure of conditional variance, specified as the squared residuals of the ARIMA model.

4.1. Historical volatility

As a measure of historical volatility, we consider the moving standard deviation:

$$Vm_t = \sqrt{\frac{1}{m} \cdot \sum_{i=1}^{m} [\ln(REER_{t+i-1}) - \ln(REER_{t+i-2})]^2} \tag{1}$$

where V_{mt} is the moving sample standard deviation of the growth rate of REER, m refers to the order of the moving averages at m = 4, 8, 12 and 24 months and t represents time.[7] This type of measure allows the average of the series to vary, and will indicate different sensitivity of exports to exchange rate volatility depending on which moving average is used. In this sense, the longer the time used for the moving average of the standard deviation, the more difficult to capture variability, and vice-versa. Given the impact of exchange rate volatility on a macroeconomic variable such as exports, a relatively short time period for the moving average *a priori* would be meaningless in the export decision, since it is difficult to respond to a phenomenon of very short-term volatility. Analogously, a longer period for the moving average may not reflect such variability. For these reasons, in order to eliminate arbitrary selection of m, in this study we evaluate: m = 4, 8, 12 and 24 periods.

6 Table A.2 in appendix presents the definitions and sources of all variables; while and Table A.3 and Table A.4 provide the main summary statistics.

7 Similar procedures for obtaining a measure of exchange rate volatility are presented in Koray and Lastrapes (1989) and Arize (1997).

4.2. Conditional variance

In traditional time series models,[8] it is common to assume that the distributions of the conditional and unconditional variance are heteroscedastic. For this reason, and based on a linear function of the expected square of the lagged value of the error term from an ARIMA regression of the REER (Engle, 1982), we introduce a GARCH process in order to estimate the REERV:

$$\varepsilon_t / \psi_{t-1} \sim N(0, V_t), \qquad (2)$$

$$V_t = \alpha_0 + \sum_{i=1}^{q} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{p} \beta_i V_{t-i} = \alpha_0 + A(L)\varepsilon_{t-i}^2 + B(L)V_{t-i} \qquad (3)$$

Equation 2 denotes the distribution of the error term, ε_t, with a mean of zero and conditional variance V_t. Equation 3 specifies the conditional variance of a GARCH process (p, q), where $q > 0$ is the number of ARCH terms and $p > 0$ is the number of GARCH terms. In this sense, the conditional variance is represented by three terms: a) the mean of the conditional variance, α_0; b) the ARCH term, which measures the volatility of the previous time period as the squared residuals of an autoregressive process (ε_{t-1}^2); c) the GARCH term, which captures the prediction error of the variance of the previous period (V_{t-1}). Thus, the GARCH process (p, q) expressed in Equation 3 will be stationary in the broader sense if and only if $A(L) + B(L) < 1$.

A substantial number of works have also used this type of measures. In this sense, Bollerslev *et al*. (1992) argue that it is common to find, in the empirical evidence, a certain persistence of the variance over time in GARCH processes estimations. That is, the autoregressive polynomial has a unit root, which means that the GARCH process is integrated and not stationary, I (1), in which case it is called an Integrated GARCH (IGARCH). In consideration of this context, we also use this IGARCH process to specify the REERV for all countries in the sample.

Nelson (1991) introduced a nonlinear process called an Exponential GARCH model (EGARCH). In contrast with a GARCH model, that ensures positive conditional variance by employing a linear combination of positive random variables, it adopts an alternative specification, which does not restrict the α and β parameters to be non-negative, but ensures that the conditional variance is non-negative. This procedure gives us an alternative measure to estimate REERV when GARCH or IGARCH models do not satisfy the conditions described.

Considering the above, we then estimated the conditional volatility of the REER by country over 1994/01-2014/12 and plot them in Figures 2 and 3.[9]

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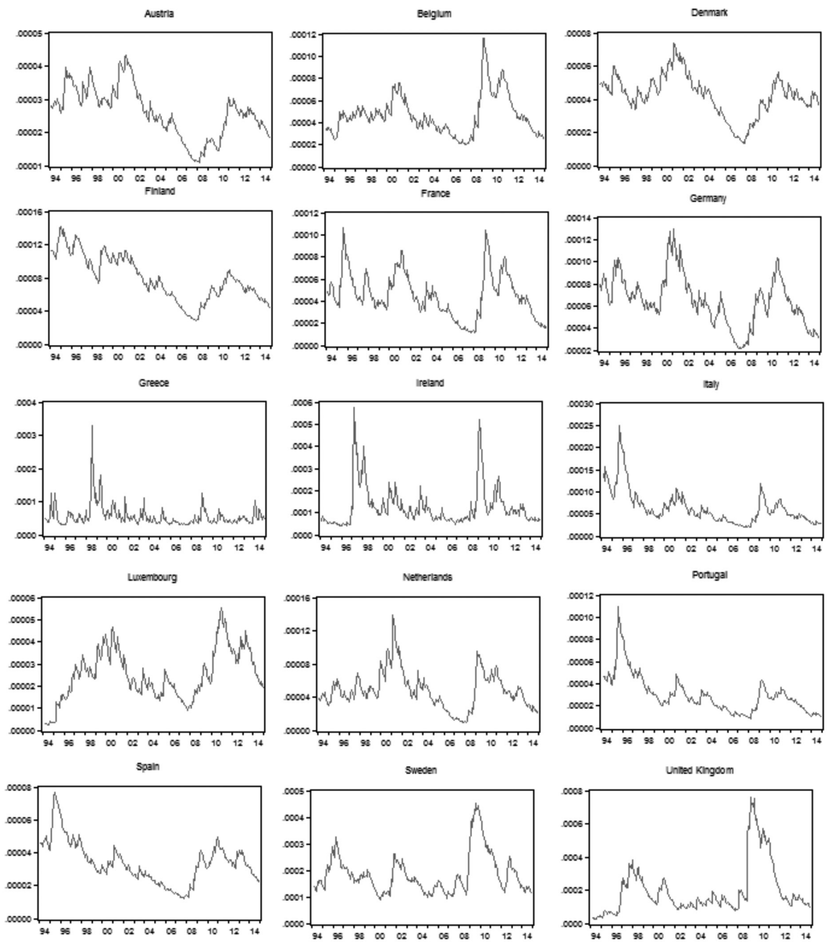
8 See, for example, Bollerslev (1986).

9 Tables A.5 and A.6 in appendix show the selected specification of estimate the conditional volatility of the REER by country.

FIGURE 2
CONDITIONAL VARIANCE OF THE REER OF THE MXE COUNTRIES OVER 1994-2014
(monthly data)

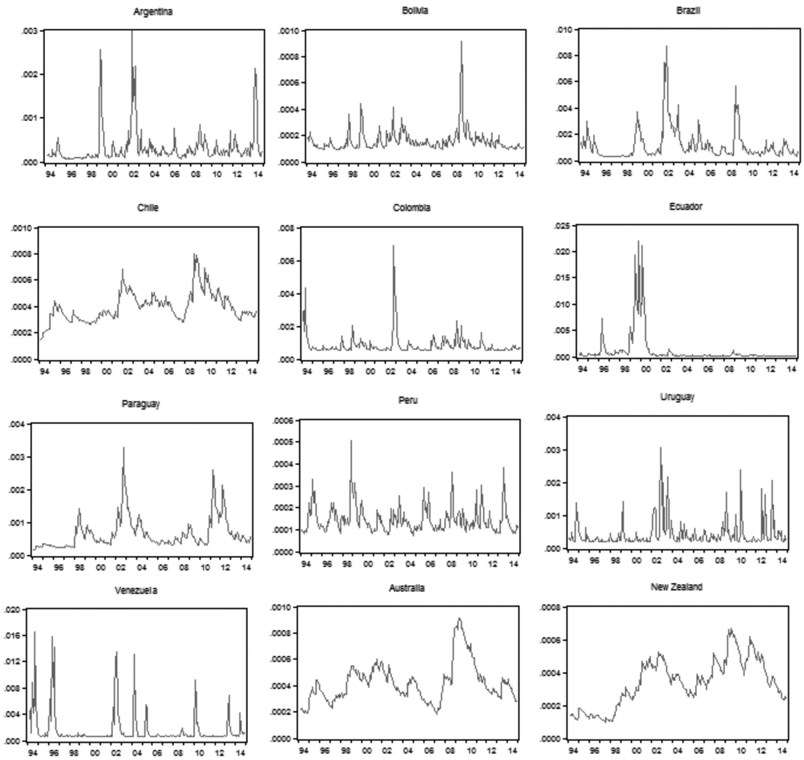


Source: Developed by authors based on IMF data.

The peaks and troughs that occur in the progression of the series represent the episodes of high or low volatility in the sample period.

From a visual inspection of both figures, we identified the main international crisis episodes that occurred in the sample period: the 1994/1995 Mexican crisis, the 1997/1998 Asian crisis, the 1999 Brazilian crisis, the 2001/2002 Argentinean crisis, the Great Recession (or 2008/2009 international financial crisis) and contagion effects. In addition, we also see the effects of the incorporation of Austria, Finland and Sweden into the European Union in 1995 and circulation of

FIGURE 3
CONDITIONAL VARIANCE OF THE REER OF THE CXE COUNTRIES OVER 1994-2014
(monthly data)



Source: Developed by authors based on IMF data.

the Euro currency. Finally, note that the conditional variance of REER is much higher for South American countries than European and Oceanian countries.

5. Empirical strategy

In the macroeconomic literature, there are basically two ways of considering the interdependence of relationships between variables. One option is to build a general equilibrium model, where there are specified optimizer agents, preferences, technologies and constraints. These models are extremely useful because they provide answers to economic policy issues and allow a clear understanding of welfare issues. However, by construction, these models impose certain constraints that are not always compatible with the statistical properties of the data. In this context, the policy prescriptions that can be derived are strongly related to the related assumptions (Canova and Ciccarelli, 2013). An alternative approach is to construct vector autoregressive models (VAR). All variables in a VAR system are typically treated as endogenous, although identification restrictions based on theoretical models or on statistical procedures may be imposed to disentangle the impact of exogenous shocks to the system (Sims, 1980).

In this paper we additionally develop the method, by performing a dynamic empirical analysis of simultaneous equations using the Panel-VAR (P-VAR) approach (as done by Love and Zicchino, 2006).[10] P-VAR analysis combines traditional VAR methodology, considering the whole set of system variables as endogenous and interdependent, with a panel data technique, which allows to control for individual and temporal heterogeneity and to estimate causality of relationships between endogenous variables (Canova and Ciccarelli, 2013). P-VAR methodology, first, allows us to specify the model with little theoretical information about the relationships among the variables. Second, it is also useful to deal with the endogeneity problem, given that all variables are potentially endogenous. Finally, the P-VAR model allows us to make more complete use of the information available in the data since it exploits the time-series and cross-sectional dimensions of our database (Grossmann *et al.*, 2014).

The original P-VAR model can be specified as a model of k endogenous variables with an order of lags p, as follows:

$$Y_{it} = Y_{it-1}A_1 + Y_{it-2}A_2 + \ldots + Y_{it-p}A_p + X_{it}B + u_i + d_t + e_{it} \quad (4)$$

where $i = 1, \ldots, N$ represents the country and t is the time over 1994/01-2014/12. Y_{it} is the 1 x k vector of endogenous variables, X_{it} is the 1 x m vector of exogenous variables, d_t is a 1 x N temporal dummy that captures the specific shocks that affect all countries in period t, while u_i represents the country-effects variable that captures unobservable individual heterogeneity, and e_{it} are idiosyncratic errors, both of dimensions 1 x k. The k x k matrices $A_1, A_2, \ldots A_p$ m x k matrix B are the parameters to be estimated. Finally, it is assumed that $E(e_{it}) = 0$, $E(e_{it}, e_{it}) = \Sigma$ and $E(e_{it}, e_{iS}) = 0 \ \forall \ t > s$.

The Y_{it} vector of endogenous variables is comprised of: total goods exports, REER volatility and commodity non-fuel price index. The exogenous variables are global demand for goods and the commodity fuel price index. Finally, d_t is a temporal exogenous shock that reflects the impact of the international financial crisis of 2008/2009 that takes the value of 1 from August 2008 to December of 2014, and 0 otherwise.

Following prior trade literature, we specify the total goods export equation as:[11]

10 Love and Zicchino (2006) make the STATA pvar code available for the use of researchers; the most recent version of this pvar code is in Abrigo and Love (2016).

11 See also Chowdhury (1993), Arize (1997), Arize and Malindretos (1998), Arize *et al.* (2008), as well as Bayar (2018) for an excellent survey.

$$X_{it} = \alpha_1 X_{it-p} + \alpha_2 P_{it-p} + \alpha_3 Vol_{it-p} + \beta_1 M^*_{it} + \beta_2 P^*_{it} + u_i + d_t + e_{it} \quad (5)$$

with *p* lags, where $i = 1, \ldots, 27$ represents the country and *t* is the time between 1994/01 and 2014/12. The endogenous variables are total goods exports (*X*), the non-fuel commodity price index (*P*) and the different measures of REERV (*Vol*). The exogenous variables of the model are world goods imports (M^*) and the fuel commodity price index (P^*). In this case, u_i represents the country effects that capture unobservable individual heterogeneity, the dummy variable d_t captures the international financial crisis of 2008/2009,[12] and e_{it} contains the idiosyncratic errors. Finally, the coefficients α_1, α_2, α_3, β_1 and β_2 are the parameters to be estimated.

Specifically, we estimate a dynamic P-VAR model with country effects to preserve the orthogonality between the regressors (lags of the dependent variables). Also, and following Love and Zicchino (2006), Love and Turk (2014) and Grossmann *et al*. (2014), in order avoid biases in coefficients, we use the Helmer transformation to remove the forward mean, *i.e.*, the mean of all the future observations available for each country-year. This transformation preserves the orthogonality between transformed variables and lagged regressors, making it possible to use lagged regressors as instruments and estimate coefficients by Generalized Method of Moments (GMM) (Arellano and Bover, 1995).[13] Additionally, once P-VAR models have been estimated, we perform simulation exercises using impulse response functions (IRF's). Finally, it is important to point out that the P-VAR methodology also allows us to include supposedly exogenous variables in our model.

6. Empirical results

In this section, first, we present the results of the unit root test. Second, we report the estimations for the panels of commodity-exporting countries

12 Situ (2015) and Vilela and MacDonald (2016) take into account the effects of the 2008/2009 international financial crisis on exports. To capture this effect, the first article subdivides the analysis period and the second article introduces an intervention to the model. Here, we follow the second one by introducing a dummy variable that take the value 1 from August 2008 to December of 2014 and 0 otherwise (in a model specified in levels). However, when we estimate our empirical model following the methodology of Situ (2015), the estimations results doesn't change. These last results are not reported due to space problems, but are available upon request.

13 The GMM estimation deals with potential endogeneity issues (Arellano and Bond, 1991; Arellano and Bover, 1995; Blundell and Bond, 1998). More specifically, both are general estimators designed for situations with: 1) a linear functional relationship; 2) one left-hand-side variable that is dynamic, depending on its own past realizations; 3) independent variables that are not strictly exogenous, meaning they are correlated with past and possibly current realizations of the error; 4) fixed individual effects; and 5) heteroskedasticity and autocorrelation within individuals but not across them.

(CXE) and manufactures-exporting countries (MXE). Third, we show the post-estimation outcomes. Finally, an extension of the empirical analysis is conducted; specifically, we report the estimates splitting the panel of countries by development level following the classification of the International Monetary Fund (see Nielsen, 2011).

6.1 Unit root test

In order to estimate the P-VAR model, the integration order of the series (stationarity) was analyzed. Following Grossmann *et al.* (2014), a first-generation panel unit root tests is used. We have information from a strongly balanced macro-panel for MXE ($n1$ = 15) and for CXE ($n2$ = 12) over the 1994/01-2014/12 period (t = 252). The t dimension is sufficiently large, and larger than both the $n1$ and $n2$ dimensions. Therefore, the Levin, Lin and Chu (2002) (LLC) unit root test is used (Levin *et al.*, 2002).[14]

Table 1 presents the main results of the unit root test for the MXE and CXE panels of countries for the entire 1994/01-2014/12 period. It is found that the export series is integrated of first order, I (1). The REER volatility series estimated as the standard deviation moving averages with 4, 8, 12 and 24 periods (*V4*, *V8*, *V12* and *V24*, respectively) are stationary, *i.e.* I (0).

Table 2 presents the results of the unit root test for those series which are common to all countries in the panel $\{M^*, P, P^*\}$. The results of the Augmented Dickey-Fuller test show that this set of level variables have units roots and are stationary in the first difference, *i.e.* I(1).

In the case of the REER conditional volatility (V), the MXE and CXE panels are no longer balanced, since the data does not contain the basis of observation for all 27 countries and all months throughout the 1994/01-2014/12 period. The t dimension is sufficiently large and greater than the $n1$ and $n2$ dimensions, so the Fisher-type unit root test is used (see Choi, 2001).[15] Table 3 presents the results of the unit root test for REER conditional volatility (V), and we reject the null hypothesis that all panel series contain unit roots for the MXE and CXE panels.

It should be noted that by construction the GARCH processes are stationary, I (0), and therefore at least one panel series is stationary; also, the IGARCH processes are first order integrated, I(1). Thus, we consider V to be a first order integrated process for both panels.

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[14] There is a wide variety of unit root tests for panel data. The tests present different assumptions for implementation (whether the panel is balanced or not; whether the panel number ratio, n, divided by the size of the temporal dimension, t, tends to infinity; whether n or t is fixed) (Maddala and Wu, 1999). Moreover, see Hurlin (2010) for a discussion about use of first- and second-generation panel unit root tests.

[15] Choi (2001) describes four ways of combining the p-value: when n is finite the inverted chi-squared test, the inverted normal test and the inverted logit test, and when n tends to infinity, suggests to use a modified inverted chi-squared test.

TABLE 1

LLC UNIT ROOT TEST RESULTS: CXE AND MXE PANELS

Variable	Level		First Difference	
	Adjusted statistic t*	Integration order	Adjusted statistic t*	Integration order
Panel: MXE				
X	2.544 [0.995]	I(1)	–31.737 [0.000]	I(0)
V4	–8.347 [0.000]	I(0)		
V8	–8.146 [0.000]	I(0)		
V12	–9.208 [0.000]	I(0)		
V24	–5.499 [0.000]	I(0)		
Panel: CXE				
X	1.260 [0.896]	I(1)	–33.546 [0.000]	I(0)
V4	–10.171 [0.000]	I(0)		
V8	–8.069 [0.000]	I(0)		
V12	–10.264 [0.000]	I(0)		
V24	–6.748 [0.000]	I(0)		

Note: LLC refers to Levin-Lin-Chu unit root test. Null hypothesis: panels contain the integrated series. Level of significance of the test is 95%. In […] p-value. Number of panels A = 12 and number of panels B = 15. The number of delays was selected by the Akaike criterion, max. delays = 10. The variables were considered as logarithm. Cross-sectional dependence was eliminated (as per Levin *et al* 2002). Sample: 1994/01-2014/12.

Source: Developed by authors.

TABLE 2

ADF UNIT ROOT TEST: UNIVARIATE ANALYSIS

Variable	Level		First Difference	
	Statistical value	Integration order	Statistical value	Integration order
M*	1.835 (15 lags)	I(1)	–4.507 (14 lags)	I(0)
P	0.553 (14 lags)	I(1)	–3.847 (13 lags)	I(0)
P*	–0.941 (13 lags)	I(1)	–4.728 (12 lags)	I(0)

Note: Augmented Dickey-Fuller (ADF). Null hypothesis: there is a unit root. The number of delays was determined according to the Akaike criterion. The ADF model was specified without a constant; it was non-significant/insignificant in all cases. The variables were considered as logarithm. Level of significance: 10% (*), 5% (**) and 1% (***).

Source: Developed by authors.

TABLE 3
FISHER-TYPE UNIT ROOT TEST: CONDITIONAL VOLATILITY

Test		Statistic	
		MXE panel	CXE panel
Inverse chi-squared	P	178,141***	319,687***
Inverse normal	Z	–10,483***	–15,412***
Inverse logit	L*	–12,735***	–25,640***
Modified inv. chi-squared	Pm	19,125***	42,679***

Note: Fisher-type unit root test based on augmented Dickey-Fuller tests. Null hypothesis: All panels contain unit roots; alternative hypothesis: at least one panel is stationary. Specification with constant, no trend and removed cross-sectional shear mean. Level of significance: 10% (*), 5% (**) and 1% (***).
Source: Developed by authors based on IMF data.

Consequently, and based on the above unit root tests results, we include the stationary I (0) variables in levels and the non-stationary I (1) variables in first differences in equation 5 (see, for example, Love and Turk, 2014 and Gevorkyan, 2019, for a similar analysis).

6.2. Estimation results

P-VAR estimation was carried out for five different specifications of the REERV. Specifically, models 1 to 5 differ only in the way in which the measure of volatility was built. From the first to the fourth estimated equations, the REERV was calculated using the moving standard deviation for 4, 8, 12 and 24 periods, respectively. The fifth specification used the measure of conditional volatility.[16]

6.1.1. *Manufactures-exporting countries*

Table 4 presents the estimation results of Equation 7 for the MXE panel of countries using the alternative measures of REERV. The main findings of models 1 to 5 can be summarized as follows. On the one hand, regarding endogenous variables, firstly, the export variable lag is positive and significant at 1%. In other words, past changes in exports are relevant in explaining the contemporary exports. Secondly, the non-fuel commodity price index is negative and significant at 1%, except for model 5 where it is significant at 5%. These results are consistent with the fact that non-fuel commodities price

[16] Since we use a P-VAR model, *i.e.* a reduced and unrestricted simultaneous equations model, all endogenous variables affecting the model should be represented. However, for simplicity, we only report the equation that has exports as a variable to be explained; the rest of estimations of the different equations are available upon request.

index represent a loss of term of trade for these MXE countries. Thirdly, the volatility variable measured as the moving standard deviation of the REER is negative and significant at 1% (models 1-4) and is insignificant in the case of the conditional volatility specification (model 5). This result is associated with risk averse traders; therefore, episodes of high (low) exchange rate volatility are followed by a reduction (increase) of export flows. Likewise, the negative effect can be explained by the greater capacity to adjust production in response to exchange rate variability which is partly determined by the type of goods they export. Among the empirical literature that supports this negative result we can mention Chowdhury (1993) for the G-7 countries over the 1973-1990 period, Arize (1997) for seven industrial economies over 1973-1992, Verheyen (2012) for the bilateral trade from 11 countries of the European Monetary Union to US from 1995 to 2010, and Situ (2015) for developed countries during 1994-2014.

Regarding exogenous variables, first, the fuel commodity price index has negative and significant (at 1%) coefficients from models 1 to 5. This is due

TABLE 4
ESTIMATION RESULTS: MXE COUNTRIES

Equation: X	*V4* *(1)*	*V8* *(2)*	*V12* *(3)*	*V24* *(4)*	*V* *(5)*
L1.X	0.959*** (0.008)	0.922*** (0.014)	0.568*** (0.036)	0.579*** (0.035)	0.971*** (0.006)
L1.P	–0.057*** (0.019)	–0.076*** (0.020)	–0.087*** (0.018)	–0.089*** (0.019)	–0.041** (0.018)
L1.Volatility	–1.332*** (0.310)	–1.554*** (0.405)	–1.985*** (0.380)	–2.098*** (0.658)	–0.010 (0.008)
*M**	0.183*** (0.027)	0.257*** (0.034)	0.665*** (0.041)	0.669*** (0.041)	0.141*** (0.024)
*P**	–0.060*** (0.008)	–0.057*** (0.008)	–0.078*** (0.007)	–0.075*** (0.008)	–0.055*** (0.008)
d_t	–0.104*** (0.010)	–0.094*** (0.012)	–0.059*** (0.012)	–0.066*** (0.011)	–0.112*** (0.010)
No. of obs.	3615	3495	3390	3210	3693
No. of countries	15	15	15	15	15
Avg. no. of T	241.000	233.000	226.000	214.000	246.200

Note: We considered the first difference of the variables' logarithms. Level of significance: 10% (*), 5% (**) and 1% (***). Equations 1, 2, 3 and 4 use the volatility of the REER calculated through the 4-, 8-, 12- and 24-period standard deviation moving averages, respectively. Equation 5 uses the measure of conditional volatility.

Source: Developed by authors.

to the fact that the MXE countries are mainly net importers of fuels; therefore, an increase in that index raises production and transportation costs, negatively affecting exports. Second, the global demand conditions have a positive impact on variation in exports, at a 1% significance level. Finally, the Great Recession variable had a clear negative effect on changes in exports, at a 1% significance level. This result is in line with prior theoretical and empirical trade literature. The impacts of the international financial crisis in 2008/2009 occurred in advanced economies, which in this sample of countries coincide mainly with the MXE countries panel. One possible explanation for the negative effect on exports involves the role of bank financing in trade.[17] According to Shelburne (2010), if an import transaction (the other side of the export transaction) is guaranteed by the banks' financing, there is a lower risk for the exporter to obtain the payment, whereas in the international financial crisis context, bank lending became more expensive, and export activity was reduced as a result of increased risk of and reduced access of importers to bank financing. However, even though bank financing has contributed as one of the mechanisms through which crises could affect exports, this is not the only one. In this sense, the OECD (2010) describes important additional channels through which crisis have affected exports. Firstly, crisis affects international trade indirectly through reduced consumption and therefore through the decline in demand for goods. With a declining demand for foreign goods, fewer imports are purchased and fewer exports are sold.[18] Secondly, the OECD (2010) argues that the way international trade reacts to financial crisis depends on the economic development level of the exporting country. Developing countries can be more dependent on trade exports relative to their GDP than developed economies. A trade slump therefore can have an amplified affect for developing countries. Available data indicates that trade in some regions –Asia, Middle East and Northern Africa and South America– was more severely impacted by changes in short-term trade finance than other regions (Europe and North America).[19] This may be due to the fact that some countries in these regions were considered higher risk, or their level of risk was re-evaluated after the onset of the crisis and thus due to increasing trade finance prices it became unaffordable for those countries. On the other hand the lack of integration with the international financial system could have been a blessing in disguise in protecting developing and emerging countries against negative chain reactions and providing those countries with a regional advantage and a gain in a competitive edge that would lead to a lesser decline

17 According to the IMF (2009a, 2009b) several banks reported sharp increases in the cost of trade finance-70% of the surveyed banks reported that the price for trade finance services has increased.

18 For more detailed analysis of this point see, for example, Eaton *et al*. (2016) and Cheung and Guichard (2009).

19 See Didier *et al*. (2012)

in trade and faster recovery. Finally, also is important to note that some studies have detailed additional mechanisms through which crises could affect exports. For example, Berman *et al*. (2012) analyzes the effect of the financial crisis on international trade covering the whole post-war era on a global scale and using a gravity-based approach. The fall in trade caused by financial crises is magnified by the time-to-ship goods between the origin and the destination country. In this sense, these authors strongly suggest that financial crises affect trade not only through demand but also through financial frictions that are specific to international trade.

6.1.2. *Commodity-exporting countries*

Table 5 shows the results of the P-VAR estimations for the different measures of the REERV for the CXE countries panel (models 1 to 5). On the one hand, the lag of the endogenous variables, such as exports, is significant at 1%. Moreover, the non-fuel commodity price index is significant at 5% in models 3 and 4. The positive sign on the non-fuel commodity price index means that the increase in prices encourages producers to increase exports. The REERV impact is not significant allowing us to disregard this variable as relevant in the model to explain the export variations (except in model 4). In other words, these results are consistent with prior evidence of a not insignificant effect. More specifically, this finding is consistent with the theoretical works of Clark (1973) and Ethier (1973), whose models suggest a negative or insignificant effect. In addition, Grier and Smallwood (2007) argue that it is possible that such an effect of exchange rate uncertainty on exports may be because export contracts are possible to adjust only in the long term. Finally, results are consist with the conclusion of Vilela and MacDonald (2016), who argue that there is no negative and significant effect of exchange rate volatility on exports for emerging and developing countries when oil export countries are excluded; our CXE country sample does not include them.

The exogenous variable, the fuel commodity price index is positive and significant. In other words, an increase in it leads to a rise in the energy commodities exports, and consequently, in total exports. This is because the share of fuel commodities in the exports of many of these economies is high, so rather than being a cost, it is an opportunity to increase their exports earnings. Moreover, the global demand conditions variable positively impacts exports and is the major determinant of them –a similar finding is reported in Bahmani-Oskooee and Gelan (2018) for African countries. Finally, we found the Great Recession to have negatively affected the exports of both MXE and CME countries, but it had only an insignificant impact on exports for the CXE countries. This is in line with the fact that agricultural and processed foods exports (relevant for CXE) experienced a smaller decline than manufactures exports (relevant for MXE) during the 2008 crisis.

TABLE 5
ESTIMATION RESULTS: CXE COUNTRIES

Equation: X	*V4* *(1)*	*V8* *(2)*	*V12* *(3)*	*V24* *(4)*	*V* *(5)*
L1.X	0.892*** (0.016)	0.812*** (0.029)	0.566*** (0.021)	0.564*** (0.021)	0.918*** (0.012)
L1.P	–0.006 0.029	–0.010 (0.032)	0.080*** (0.029)	0.071** (0.030)	0.006 (0.028)
L1.Volatility	0.038 (0.088)	–0.002 (0.087)	–0.123 (0.089)	–0.271** (0.131)	0.010 (0.007)
*M**	0.107** (0.045)	0.209*** (0.061)	0.302*** (0.044)	0.319*** (0.046)	0.066* (0.039)
*P**	0.023* (0.014)	0.029** (0.014)	0.054*** (0.013)	0.051*** (0.014)	0.020 (0.014)
d_t	–0.064 (0.043)	–0.056 (0.041)	–0.026 (0.039)	–0.024 (0.039)	–0.066 (0.043)
No. of obs.	2885	2793	2712	2568	2945
No. of countries	12	12	12	12	12
Avg. no. of T	240.417	232.750	226.000	214.000	245.417

Note: We considered the first difference of the variables' logarithms. Level of significance: 10% (*), 5% (**) and 1% (***). Equations 1, 2, 3 and 4 use the volatility of the REER calculated through the 4-, 8-, 12- and 24-period standard deviation moving averages, respectively. Equation 5 uses the measure of conditional volatility.
Source: Developed by authors.

6.3. Post-estimation tests

In this subsection, first, we report the Granger causality test, and then the IRF's of the endogenous and exogenous series for the MXE and CXE panels of countries.[20]

6.3.1. *Granger test*

The presence of correlation between two variables does not always imply causality (where changes in one of them determine the changes in the values of the other). In order to observe if causality exists between variables, we carried out a Granger causality test (Granger, 1969). Rejecting the null hypothesis implies that past changes in one variable affect, or precedes the changes of the other variable. Table 6 shows the results of the Granger causality test for the MXE and CXE panels; they are reported for REERV and exports.

[20] Variance decomposition results are not reported for brevity, but are available upon request.

TABLE 6
GRANGER CAUSALITY TEST (WALD)

H_0: Excluded variable does not Granger-cause equation variable **H_1: Excluded variable Granger-cause equation variable**			
Equation	*Excluded*	*Panel MXE*	*Panel CXE*
X	*V4*	18.526***	0.180
V4	*X*	16.424***	0.270
X	*V8*	14.753***	0.001
V8	*X*	7.517	0.082
X	*V12*	27.299***	1.917
V12	*X*	0.894	0.310
X	*V24*	10.175***	4.249**
V24	*X*	9.975***	0.111
X	*V*	1.500	2.112
V	*X*	1.707	3.239*

Notes: Rejection of the null hypothesis: 10% (*), 5% (**) and 1% (***) of significance (prob.>chi2). Sample: 1994/01-2014/12. The variables were considered as logarithm. Results are reported for exports and the different measures of volatility. V4, V8, V12, V24, and V refer to the 4-, 8-, 12- and 24-period standard deviation moving averages and the conditional volatility, respectively.
Source: Developed by authors.

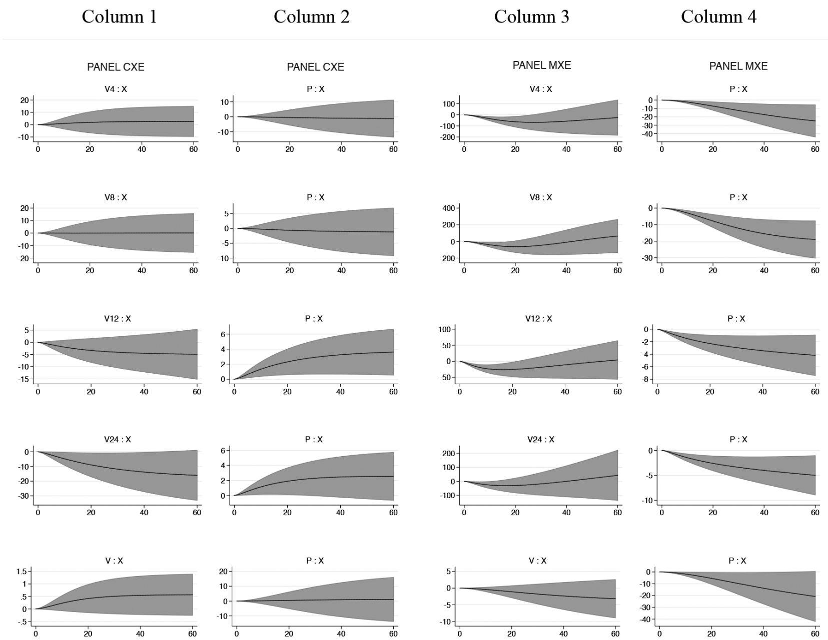
Here, we find a unidirectional significant relationship wherein the 8- and 12-period moving standard deviations Granger-cause exports for the MXE countries panel. While bidirectional Granger causality is found for the 4- and 24-period moving standard deviations, causality in these relationships is not conclusive. As far as CXE countries are concerned, the 24-period moving standard deviation causes exports in the Granger sense.

6.3.2. *Impulse-response functions*

Here, we discuss the simulation of the accumulated IRF's. The focus of the analysis is to quantify macroeconomic shocks one at a time to see how they affect exports, with particular interest in the impact of an exchange rate volatility shock. In the IRF's graphs, the export response is represented by an orthogonal impulse or shock, one standard deviation in magnitude, to the non-fuel commodity price index and the REERV measures. The exports response is considered for a period of 60 months (5 years). We assume the following recursive order to construct the IRF:

$$P \rightarrow V \rightarrow X$$

FIGURE 4
ACCUMULATED IMPULSE RESPONSE FUNCTION: ENDOGENOUS VARIABLES



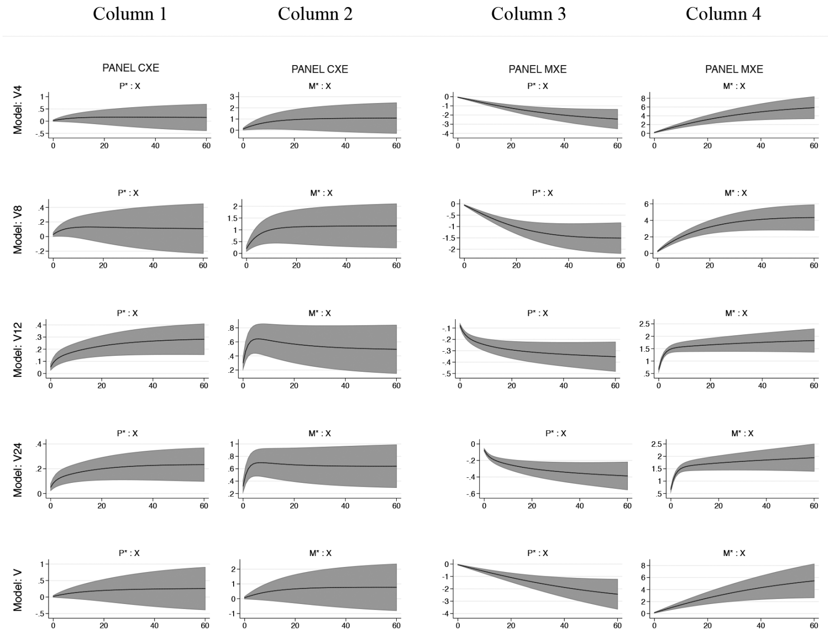
Note: The impulse is the endogenous variable and the response variable is exports. The band containing the cumulative IRF corresponds to the 95% confidence.
Source: Developed by authors.

The economic intuition of this Cholesky order can be expressed as follows: firstly, the non-fuel commodities price index is the most important variable for the MXE and CXE panels, based on its effect on the terms of trade and thus on the decision of the countries to export.[21] Secondly, due to the effect of uncertainty on exports, the exchange rate volatility cannot be accurately predicted. Given that exports are presumed to respond at the same time as the rest of the variables in the system, it is in last position in Cholesky's order.

Figure 4 illustrates the accumulated IRF's of the endogenous variables pertaining to the non-fuel commodity price index and REERV (by row) for the MXE panel (columns 1-2), and the CXE panel (columns 3-4). Meanwhile, an REERV shock generates an export response in the short- and medium-term for the MXE panel, but this is not significant for the CXE panel.

21 See Gevorkyan (2019), for more detailed explanation of the Cholesky order considered.

FIGURE 5
ACCUMULATED IMPULSE RESPONSE FUNCTION: EXOGENOUS VARIABLES



Note: The impulse is the exogenous variable and the response variable is exports. The band containing the cumulative IRF corresponds to the 95% confidence.
Source: Developed by authors.

In addition, the P-VAR methodology allows an IRF to simulate a shock (here, a twofold increase) to the exogenous variable and its effects on the endogenous variable of interest. The results are illustrated in Figure 5: REERV specifications are depicted in each row, and the accumulated IRF's of the exogenous variables associated with the fuel commodity price index is shown in columns 1-2 for the MXE panel and those associated with global demand in columns 3-4 (CXE panel).

A shock to global demand generates a positive short- and medium-term exports response for both panels. Specifically, a one-standard deviation unit shock to global demand results in about 0.8% increase in exports for the CXE in twenty periods (months), and a one standard deviation shock to global demand results in about 3% increase in export for MXE in twenty periods (months), where the shocks seem to stabilize. Both short- and medium-term negative export responses are generated by an impulse of the exogenous variable (the fuel commodity price index) for the MXE panel, and positive or insignificant export responses for the CXE panel. Particularly, a visual inspection of IRF's allow us to observe that a one standard deviation shock to fuel commodity price index causes a significant decrease in exports for MXE countries for twenty periods after which the effect dissipates. The decrease peaks is in period twelve. And a one standard deviation shock to fuel commodity price index cause significant increase in exports for CXE countries for twenty periods after which the effect dissipates. The increase peak is in period ten.

6.4. Extension: Advanced economies vs. developing and emerging economies

In this subsection we propose an additional empirical analysis. Now, instead of focusing on the export-related characteristics of our sample of countries, we split the sample by development level of countries, *i.e.* advanced economies and developing and emerging economies. Therefore, Australia and New Zealand are excluded from the CXE sample and included in the MXE sample.

General speaking, the impact of REERV on exports does not change when excluding Australia and New Zealand from the CXE sample (see Table 7), significance and sign do not change relative to the reference model (see Table 5). When Australia and New Zealand are grouped together with the European countries, significance and sign do not change relative to the reference model (see Table 4). Thus, these results suggest that the level of development does affect the relationship between REERV and exports for this sample of countries; significant for advances economies and insignificant for developing and emerging economies.

7. Conclusions

This paper focused on the relationship between exchange rate uncertainty and exports for a novel panel of 27 countries over 1994/01–2014/12 using the P-VAR empirical methodology. This issue was tackled by building a high frequency dataset and employing a novel empirical methodology (P-VAR). Also, differently from prior empirical analysis that focuses on the level of development of economies (see, for example, Sauer and Bohara, 2001 and Grier and Smallwood, 2007); we provide novel insight into the relationship between exchange rate volatility and exports by considering the production characteristics of the countries, *i.e.* manufactures-exporting economies (MXE) and commodity-exporting economies (CXE).

Our main empirical findings suggest the following conclusions. First, REERV is important for modeling the exports of MXE countries, but is not relevant in the case of CXE countries. The economic interpretation of the results obtained could be based on the response in the "average" exporting country with respect to exchange rate risk. While the negative effect of REERV on exports in the MXE sample appears to be associated with countries that display risk-averse behaviors or have some contract flexibility to adjust their exports in the short term, the lack of the effect of REERV on exports in the CXE sample seems to

TABLE 7
ESTIMATION RESULTS: ADVANCED ECONOMIES VS. DEVELOPING AND EMERGING ECONOMIES

Equation: X	*V4* *(1)*	*V8* *(2)*	*V12* *(3)*	*V24* *(4)*	*V* *(5)*
Advanced economies					
L1.X	0.959*** (0.008)	0.919*** (0.014)	0.582*** (0.032)	0.586*** (0.032)	0.970*** (0.006)
L1.P	–0.048*** (0.018)	–0.061*** (0.018)	–0.062*** (0.017)	–0.065*** (0.018)	–0.032* (0.017)
L1.Volatility	–1.130*** (0.232)	–1.299*** (0.299)	–1.532*** (0.294)	–2.232*** (0.498)	–0.008 (0.008)
*M**	0.166*** (0.025)	0.234*** (0.032)	0.598*** (0.036)	0.606*** (0.036)	0.125*** (0.022)
*P**	–0.052*** (0.008)	–0.497*** (0.007)	–0.064*** (0.007)	–0.061*** (0.007)	–0.047*** (0.008)
d_t	–0.086*** (0.018)	–0.078*** (0.018)	–0.047*** (0.018)	–0.046*** (0.018)	–0.094*** (0.017)
No. of obs.	4097	3961	3842	3638	4183
No. of countries	17	17	17	17	17
Avg. no. of T	241.000	233.000	226.000	214.000	246.059
Developing and emerging economies					
L1.X	0.891*** (0.018)	0.811*** (0.032)	0.560*** (0.022)	0.559*** (0.023)	0.918*** (0.013)
L1.P	–0.010 (0.033)	–0.022 (0.037)	0.068** (0.034)	0.056 (0.035)	0.001 (0.032)
L1.Volatility	0.054 (0.091)	0.019 (0.089)	–0.112 (0.090)	–0.222* (0.134)	0.008 (0.007)
*M**	0.106** (0.052)	0.223*** (0.071)	0.336*** (0.052)	0.351*** (0.054)	0.066 (0.045)
*P**	0.024 (0.016)	0.031* (0.016)	0.057*** (0.016)	0.054*** (0.016)	0.020 (0.016)
d_t	–0.086* (0.048)	–0.078* (0.047)	–0.044 (0.045)	–0.043 (0.045)	–0.088* (0.049)
No. of obs.	2403	2327	2260	2140	2455
No. of countries	10	10	10	10	10
Avg. no. of T	240.300	232.700	226.000	214.000	245.500

Note: We considered the first difference of the variables' logarithms. Level of significance: 10% (*), 5% (**) and 1% (***). Equations 1, 2, 3 and 4 use the volatility of the REER calculated through the 4-, 8-, 12- and 24-period standard deviation moving averages, respectively. Equation 5 uses the measure of conditional volatility. Advanced economies: European countries, Australia and New Zealand. Developing and emerging economies: South American countries (see Table A.1).
Source: Developed by authors.

be associated with countries that have contract rigidities, which enables them to adjust exports in the short term. Second, this paper also reports evidence of the relationship between exports and other explanatory macroeconomic variables. Furthermore, world demand conditions are one of the most important factors explaining variations in exports. In contrast with Vilela and MacDonald (2016), who argue for an increase in exports after the financial crisis period, our finding reveals that the Great Recession reduced exports of MXE countries.

Our results provide important insights in relation to macroeconomic policy. Note that REERV is not a policy variable directly controlled by policymakers. If policymakers ignore the unpredictability of exchange rate movements, however, export markets may underlie the uncertainty of outcomes. Thus, this empirical analysis leads us to suggest to minimize exchange-rate volatility and its persistence, by mitigating nominal exchange rate fluctuations, in order to reduce the risks associated with export activity, and consequently, to stabilize the external trade position. Finally, it is important to note that using the same policies would likely have divergent effects on the two panels of countries, particularly given that MXE countries have higher market integration and more advanced production than CXE countries.

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APPENDIX

TABLE A.1
COUNTRY LIST

Panel: CXE		*Panel: MXE*	
South América	*Oceanía*	*Europe*	
Argentina	Australia	Austria	the Netherlands
Bolivia	Nueva Zealand	Belgium	Portugal
Brazil		Denmark	Spain
Chile		Finland	Sweden
Colombia		France	United Kingdom
Ecuador		Germany	
Paraguay		Greece	
Peru		Ireland	
Uruguay		Italy	
Venezuela		Luxemburg	

TABLE A.2
DEFINITIONS AND VARIABLE SOURCES

Variable	*Description*	*Source*
Exports (*X*)	Total exports of goods in millions of constant dollars (Base January 1994 = 100) (exports in millions of current FOB dollars, deflated by the US CPI).	IMF; Luxemburg 1994/01-1996/12 and Greece 1994/09 and 1994/10, source Eurostat.
World Demand (*M**)	World imports of goods in millions of constant dollars (Base January 1994 = 100) (imports in millions of current CIF dollars, deflated by the US CPI).	IMF
CPI	United States Consumer Price Index (US CPI) (Base January 1994 = 100).	Department of Labor Bureau of Labor Statistic U.S.
Real Effective Exchange Rate (*REER*)	The index considers the weighted average of the bilateral real exchange rates with the main trading partners (using as weighting the share of trade in the economies) (Base January 1994 = 100).	IMF; Perú (ECLAC); Argentina (CEI).
Volatility (*V4*)	Volatility of the real effective exchange rate average, 4 periods.	IMF; Perú (ECLAC); Argentina (CEI).
Volatility (*V8*)	Volatility of the real effective exchange rate average, 8 periods.	IMF; Perú (ECLAC); Argentina (CEI).
Volatility (*V12*)	Volatility of the real effective exchange rate average, 12 periods.	IMF; Perú (ECLAC); Argentina (CEI).
Volatility (*V24*)	Volatility of the real effective exchange rate average, 24 periods.	IMF; Perú (ECLAC); Argentina (CEI).
Volatility (*V*)	Standard deviation of the conditional variance.	IMF; Perú (ECLAC); Argentina (CEI).
P	Index of non-fuel commodities prices (Base January 1994 = 100).	IMF
*P**	Index of fuel commodities prices (energy) (Base January 1994 = 100).	IMF

Source: Developed by authors.

TABLE A.3
SUMMARY STATISTICS: CXE AND MXE PANELS

Variable		*Averages*	*Standard deviation*	*Minimum*	*Maximum*	*Observations*
Panel: CXE						
X	Overall	7.050	1.293	4.162	9.734	*N = 3024*
	Between		1.234	5.227	8.803	n = 12
	Within		0.525	5.842	8.435	*T = 252*
V4	Overall	0.022	0.023	0.002	0.247	*N = 2976*
	Between		0.007	0.011	0.038	*n = 12*
	Within		0.022	–0.013	0.248	*T = 248*
V8	Overall	0.023	0.022	0.003	0.179	*N = 2928*
	Between		0.008	0.012	0.042	*n = 12*
	Within		0.021	–0.013	0.180	*T = 244*
V12	Overall	0.024	0.021	0.003	0.147	*N = 2880*
	Between		0.009	0.012	0.044	*n = 12*
	Within		0.019	–0.014	0.147	*T = 240*
V24	Overall	0.026	0.020	0.004	0.108	*N = 2736*
	Between		0.010	0.012	0.048	*n = 12*
	Within		0.017	–0.015	0.105	*T = 228*
V	Overall	4.753	0.518	3.569	6.622	*N = 3007*
	Between		0.429	3.845	5.433	*n = 12*
	Within		0.315	4.056	6.830	*T–bar = 250.583*
Panel: MXE						
X	Overall	8.943	1.229	5.638	11.463	*N = 3780*
	Between		1.237	6.537	10.904	*n = 15*
	Within		0.284	7.624	9.706	*T = 252*
V4	Overall	0.008	0.005	0.001	0.059	*N = 3720*
	Between		0.003	0.005	0.013	*n = 15*
	Within		0.005	–0.003	0.054	*T = 248*
V8	Overall	0.008	0.005	0.001	0.046	*N = 3660*
	Between		0.003	0.005	0.014	*n = 15*
	Within		0.004	–0.001	0.040	*T = 244*
V12	Overall	0.008	0.005	0.002	0.039	*N = 3600*
	Between		0.003	0.005	0.014	*n = 15*
	Within		0.004	0.000	0.033	*T = 240*
V24	Overall	0.008	0.004	0.002	0.031	*N = 3420*
	Between		0.003	0.005	0.014	*n = 15*
	Within		0.003	0.001	0.025	*T = 228*
V	Overall	4.659	0.432	3.651	6.193	*N = 3759*
	Between		0.376	4.141	5.578	*n = 15*
	Within		0.234	3.555	5.592	T-bar = 250.6

Note: All variables are expressed as logarithm. Period: 1994 to 2014.
Source: Developed by authors based on IMF data.

TABLE A.4
SUMMARY STATISTICS

Variable		*Averages*	*Standard deviation*	*Minimum*	*Maximum*	*Observations*
P	Overall	4.855	0.308	4.396	5.473	*N = 6804*
	Between		0.000	4.855	4.855	*n = 27*
	Within		0.308	4.396	5.473	*T = 252*
*P**	Overall	5.582	0.697	4.331	6.756	*N = 6804*
	Between		0.000	5.582	5.582	*n = 27*
	Within		0.697	4.331	6.756	*T = 252*
*M**	Overall	13.308	0.359	12.599	13.848	*N = 6804*
	Between		0.000	13.308	13.308	*n = 27*
	Within		0.359	12.599	13.848	*T = 252*

Note: All variables are expressed as logarithm and are the same for each country. Period: 1994 to 2014.
Source: Developed by authors based on IMF data.

TABLE A.5
EQUATIONS OF THE CONDITIONAL VARIANCE

Country	Specification	Coefficients		
		C	$RESID^2_{t-1}$	$GARCH_{t-1}$
Argentina	GARCH(1,1)	3.78E-05** (1.78E-05)	0.4647*** (0.1280)	0.4508*** (0.1147)
Bolivia	GARCH(1,1)	3.86E-05* (2.16E-05)	0.1817*** (0.0656)	0.5758*** (0.1766)
Brazil	GARCH(1,1)	0.0001** (3.98E-05)	0.3189*** (0.0793)	0.6142*** (0.0855)
Chile	GARCH(1,1)	2.74E-05* (1.57E-05)	0.0568* (0.0327)	0.8764*** (0.0611)
Colombia	GARCH(1,1)	0.0002*** (5.54E-05)	0.1895*** (0.0450)	0.5009*** (0.0770)
Ecuador	GARCH(1,1)	3.31E-05** (1.47E-05)	0.4190*** (0.1089)	0.5598*** (0.0974)
Paraguay	GARCH(1,1)	4.46E-05*** (1.61E-05)	0.1517*** (0.0405)	0.7846*** (0.0617)
Uruguay	GARCH(1,1)	0.0002*** (2.52E-05)	0.4784*** (0.1243)	0.2000** (0.0842)
Venezuela	GARCH(1,1)	0.0004*** (3.76E-05)	0.4454*** (0.1180)	0.3355*** (0.0597)
Australia	IGARCH(1,1)	—	0.0632*** (0.0227)	0.9368*** (0.0227)
New Zealand	IGARCH(1,1)	—	0.0587** (0.0233)	0.9413*** (0.0233)
Germany	IGARCH(1,1)	—	0.0785*** (0.0284)	0.9215*** (0.0284)

Table A.5 (Cont.)

Country	Specification	Coefficients		
		C	$RESID^2_{t-1}$	$GARCH_{t-1}$
Austria	IGARCH(1,1)	——	0.0433*** (0.0146)	0.9567*** (0.0146)
Belgium	IGARCH(1,1)	——	0.0727*** (0.0259)	0.9273*** (0.0259)
Denmark	IGARCH(1,1)	——	0.0540*** (0.0142)	0.9460*** (0.0142)
Spain	IGARCH(1,1)	——	0.0553*** (0.0191)	0.9447*** (0.0191)
Finland	IGARCH(1,1)	——	0.0454*** (0.0145)	0.9546*** (0.0145)
France	IGARCH(1,1)	——	0.1007*** (0.0249)	0.8993*** (0.0249)
Greece	GARCH(1,1)	1.27E-05* (7.36E-06)	0.2075*** (0.0710)	0.5661*** (0.1721)
Ireland	GARCH(1,1)	8.89E-06** (4.41E-06)	0.1835*** (0.0547)	0.7514*** (0.0772)
Italy	GARCH(1,1)	1.85E-06** (2.1181)	0.0935*** (0.0296)	0.8703*** (0.0340)
Luxemburg	IGARCH(1,1)	——	0.0853*** (0.0206)	0.9147*** (0.0206)
the Netherlands	IGARCH(1,1)	——	0.1023*** (0.0227)	0.8977*** (0.0227)
Portugal	IGARCH(1,1)	——	0.0689*** (0.0129)	0.9311*** (0.0129)
United Kingdom	IGARCH(1,1)	——	0.0958*** (0.0166)	0.9042*** (0.0166)
Sweden	IGARCH(1,1)	——	0.0802*** (0.0243)	0.9198*** (0.0243)

Note: Model parameters were estimated by Maximum likelihood (ML) - Normal distribution. Level of significance to: 10% (*), 5% (**) and 1% (***).
Source: Developed by authors based on IMF data.

TABLE A.6
CONDITIONAL VARIANCE EQUATION FOR PERU

Variable	Coefficient	Std. Error	Prob.
C(3)	–2.4353	1.3962	0.0811*
C(4)	0.2947	0.1330	0.0267**
C(5)	–0.1659	0.0885	0.0610*
C(6)	0.7531	0.1532	0.0000***

Note: LOG(GARCH) = C(3)+C(4)*ABS(RESID(-1)/@SQRT(GARCH(-1)))+C(5)*RESID(-1)/@SQRT(GARCH(-1))+C(6)*LOG(GARCH(-1)).
Source: Developed by authors based on IMF data.

TABLE A.7
EIGENVALUE STABILITY CONDITION

Model	Eigenvalue		Modulus
	Real	Imaginary	
Panel: MXE			
V4	0.9625	–0.0120	0.9625
	0.9625	0.0120	0.9625
	0.8394		0.8394
V8	0.9545	–0.0290	0.9550
	0.9545	0.0290	0.9550
	0.8846		0.8846
V12	0.9842		0.9842
	0.9009		0.9009
	0.5595		0.5595
V24	0.9952		0.9952
	0.9316		0.9316
	0.5686		0.5685
V	0.9750		0.9750
	0.9572		0.9572
	0.9174		0.9174
Panel: CXE			
V4	0.9608		0.9608
	0.8921		0.8921
	0.8553		0.8553
V8	0.9547		0.9547
	0.9372		0.9372
	0.8109		0.8109
V12	0.9542		0.9542
	0.9400		0.9400
	0.5701		0.5701
V24	0.9568	–0.0122	–0.9568
	0.9568	0.0122	0.9568
	0.5687		0.5687
V	0.9579		0.9579
	0.9203		0.9203
	0.7940		0.7940

Source: Developed by authors.