FACULTAD DE CIENCIAS ECONÓMICAS Y DE ADMINISTRACIÓN

IECON INSTITUTO DE ECONOMÍA

UNIVERSIDAD DE LA REPÚBLICA URUGUAY

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INSTITUTO DE ECONOMÍA
Serie Documentos de Trabajo

Diciembre, 2019
DT 29/2019

ISSN: 1510-9305 (en papel)
ISSN: 1688-5090 (en línea)

Agradecemos el apoyo financiero del Programa de Iniciación a la Investigación de CSIC-UDELAR (Comisión Sectorial de Investigación Científica – Universidad de la República). También queremos agradecer los comentarios y sugerencias recibidos en la V Jornadas Argentinas de Econometría de la Universidad de Buenos Aires (Buenos Aires, octubre de 2019). Como es de uso, somos responsables de todos los errores que aún permanecen.

Forma de citación sugerida para este documento: Miranda, R. and Muinelo-Gallo, L. (2019) "Exchange rate uncertainy and cereal exports: a panel VAR approach". Serie Documentos de Trabajo, DT 29/2019. Instituto de Economía, Facultad de Ciencias Económicas y Administración, Universidad de la República, Uruguay.

Exchange Rate Uncertainty and Cereal Exports: A Panel VAR Approach

Ronald Miranda Lescano*
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Resumen

Este documento investiga empíricamente el efecto de la incertidumbre del tipo de cambio en las exportaciones de cereales para una amplia muestra de países durante el período 2010/01 - 2016/12. Para ello, primero se estima la volatilidad del tipo de cambio utilizando el desviación estándar móvil del tipo de cambio real efectivo (TCRE), y luego se estima la demanda de exportaciones de cereales utilizando un modelo de datos de panel con vectores autorregresivos (P-VAR). Esta estrategia de análisis se aplica a diferentes grupos de países, que se obtienen mediante un análisis de cluster basado en el nivel de volatilidad del TCRE y el nivel del volumen de exportaciones de cereales. En general, los resultados empíricos sugieren un efecto negativo y significativo de la incertidumbre del tipo de cambio sobre las exportaciones de cereales en países caracterizados por una alta y persistente volatilidad del TCRE o un alto volumen de exportaciones de cereales (es decir, con poder de mercado).

Palabras clave: Incertidumbre del tipo de cambio; Exportaciones de cereales; Datos de panel; Vectores autorgresivos; Análisis de cluster.

Código JEL: C33; F31; F41.

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Abstract

This paper investigates empirically the effect of exchange rate uncertainty on cereal export flows for a broad sample of countries during the period 2010/01 – 2016/12. To do this, we first estimate the exchange rate volatility using the moving standard deviation of the real effective exchange rate (REER), and then, we estimate the cereal export demand by using a panel data model with autoregressive vectors (P-VAR). This strategy of analysis is applying over different groups of countries, which are obtained by cluster analysis based on the level of REER volatility and the level of cereal export volume. In general, the empirical results suggested a significative negative effect of exchange rate uncertainty on cereal exports in countries characterized by high and persistent REER volatility or high volume of cereal exports (i.e. with market power).

Keywords: Exchange rate uncertainty; Cereal exports; Panel data; Vector Autoregressive; Cluster analysis.

JEL Classification: C33; F31; F41.

1. Introduction

Since the adoption of floating exchange rate regimes in 1973, as collapse of the fixed exchange rate system adopted in Bretton-Woods, the effect of exchange rate uncertainty on international trade become relevant for economies (Kandilov 2008). As well, an extensive theoretical and empirical literature studies have emerged on this issue. Theoretical works describe the possibility of negative, positive or neutral impacts of exchange rate uncertainty on international trade. But most of the scholars try to obtain a conclusive empirical result of the effect of exchange rate uncertainty on international trade, and generally find a negative impact. Nevertheless, the empirical evidence has not been able to support completely this negative relationship and continue being a controversial issue in the empirical literature (McKenzie 1999).

This paper analyses empirically the effect of real effective exchange rate volatility, as a proxy of exchange rate uncertainty, on cereals exports for 75 countries during the period 2010/01 – 2016/12. To do this, we proceed as follows. First, we estimate the REER volatility using the moving standard deviation of REER (using a 4- and 8-months order of the moving average). Second, we estimate the cereal export demand by using panel data models with autoregressive vectors (Abrigo and Love 2016). And we analyse the impulse-response functions.

This strategy of analysis is applying over different groups of countries, which are obtained by cluster analysis. On the one hand, we group countries according to the level of REER volatility. On the other hand, we group countries based on the level of cereal export volume.

Examining cereal exports is important for at least two important reasons. In the first place, cereals are crucial as source of food in the world, both for human consumption and as input livestock production. Secondly, the whole economy of many developing countries depends to a high degree on the production of only a handful of commodities destined principally for export, which are subject to changing conditions in the world market (e.g. the supply of the main producing and exporting economies). Additionally, export is a component of GDP, therefore, it benefits the economic growth and development. Thus, it is relevant for economic policymakers to understand the effect of macroeconomic variables on cereal exports.

This paper makes a three-fold contribution to the existing literature. First, we provide empirical evidence of the relationship between cereal exports and REER volatility in a large sample of countries. To examine this issue, we analyze and compare different groups of countries. On the one hand, we select high and low REERV group of countries, and on the other hand, we consider high and low volume of cereal export groups of countries. Second, we make use of a novel high-frequency database from UN COMTRADE not yet explored in this literature. Thirdly, the dynamics between cereals exports and REER volatility is studied through the use of a novel methodology, specifically a VAR panel as initially proposed by Love and Zicchino (2006).

The remainder of the paper is organized as follows. Section 2 presents a detailed review of the related economic literature. Data and variables are described in Section 3. The empirical model and methodology are presented in Section 4 while Section 5 presents the main empirical findings. Concluding remarks can be found in Section 6.

2. Background

Since the adoption of the floating exchange rate regimes in 1973, there is a large number of scholars that have analysed the impact of exchange rate uncertainty (measures throughout exchange rate volatility), both nominal and real, on international trade, particularly on exports. However, the theoretical and empirical literature is still not conclusive regarding the sign and magnitude of this impact, reported negative, positive, neutra and non-significative effects (Bahmani-Oskooee and Hegerty 2007; Bouoiyour and Selmi 2016; McKenzie 1999).

Traditionally, in the economic literature is argued that exchange rate volatility has negative effects on international trade, due to it affects the uncertainty of economic agents regarding the risk of their activities in foreign currency, specifically benefits and costs (Clark 1973; Ethier 1973). Therefore, a mayor proportion of agents move from more to less risky activities, modifying the economic activities in the economy. Consequently, this change affects the relevant macroeconomic variables of the economy such as the trade balance and the balance of payments, which impact on economic growth.

Other scholars, in contrast to the traditional theoretical literature, expressed that it can be found a positive effect of the real exchange rate volatility on international trade. This is due to there are agents that are not risk-averse and perceive the exchange rate volatility as an opportunity to increase their profits (Broll and Eckwert 1999; De Grauwe 1988; Sercu 1992). Sercu (1992) shows that the volatility of the exchange rate may enhance the volume of trade instead of penalizing it. That could happen if high volatility increases the likelihood of the price received by exporters will exceed the costs of trade (e.g. tariffs, transportation). Moreover, De Grauwe (1988) argues that the increase in the risk can be decomposed into the substitution effect and the income effect. When the risk increase, the substitution effect operates by reducing export activities in favour of less risky local activities, meanwhile the income effect operates in the opposite direction. The decrease in the utility of the expected income from export activities makes it more attractive to invest. Thus, if the income effect outweighs the substitution effect, the increase in foreign exchange risk has a positive effect on export activities. In this sense, Broll and Eckwert (1999) point out the effect that dominates will depend on the firm's adjustment to risk, they concluded that volatility can also increase exports, given that the increase in foreign exchange risk will in some cases increase the potential gains of trade.

On the other hand, some investigations suggest the insignificant effects because future markets provided the mechanisms to cover from uncertainty exchange rate movements (Serenis and Tsounis 2013); however, there must be a developed future market (Clark 1973; Ethier 1973).

In addition, several empirical studies analyse the relationship between exchange volatility and international trade (Bahmani-Oskooee and Hegerty 2007; Coric and Pugh 2010; Ozturk 2006; Selmi and Bouoiyour 2014). For instance, Selmi and Bouoiyour (2014) examined 59 publications from 1984 to 2014. The empirical studies revised are distributed by results as follows: 29 (negative), 6 (positive), 6 (not significant) and 18 (ambiguous). Performing a meta-analysis, by the examination of the Pearson´s correlation coefficient, obtained that the prevalence of negative results is generally present for developing countries, using the real exchange rate, total or sectorial trade, and estimating exchange rate volatility through moving standard deviation. Here, the main problem of the meta-analysis is that results are difficult to compare and generalize because it involves studies that differ in the sample periods, the variables used, the countries considered, the volatility specifications, the type of exports (aggregated, bilateral or sectoral), the exchange rate (nominal, real or effective), methodologies and estimation methods (Bahmani-Oskooee and Hegerty 2007; Ozturk 2006).

Regarding the estimation methodologies used, initially empirical studies perform simple regressions to evaluate the effects of the volatility of the exchange rate on exports (Akhtar and Hilton 1984; Cushman 1983; Gotur 1985; Hooper and Kohlhagen 1978); however, the techniques have evolved over time (Bahmani-Oskooee and Hegerty 2007), incorporating Vector Error Correction Models (VECM) (Arize and Malindretos 1998; Arize 1997; Arize et al 2008; Chowdhury 1993; Kroner and Lastrapes 1993; Miranda and Mordecki 2019) and panel data models (Hall et al 2010; Sauer and Bohara 2001; Situ 2015; Vilela and MacDonald 2016).

Most of the previous studies analyse the impact of exchange rate uncertainty on export trade, but fewer studies focused on agriculture export trade (Cho et al 2002; Kandilov 2008; Pick 1990). Cho et al (2002) found that exchange rate volatility has a negative impact on agricultural trade for ten developed countries from 1974 to 1995. Kandilov (2008) extends the previous work, using a sample of developed, emerging, and developing countries from 1975 to 1997, and report the largest magnitude in the negative effect of exchange rate volatility on agricultural exports in emerging and developing countries than developed countries. Pick (1990) found for the bilateral U.S. agricultural exports trade with ten economies, from 1978 to 1987, it is not affected by the exchange rate volatility of developed countries, but it is adversely affected by the exchange rate volatility of developing countries. In our knowledge, there is no empirical study that analyse the effect of exchange rate uncertainty on cereal exports. Thus, our work aims to address this gap.

3. Data

In this section, we present the data used to empirical evaluate the effect of the REER volatility on cereal exports. To do this, we constructed a panel dataset for a group of 75 countries during the period 2010/01 – 2016/12, using monthly data.[1] The wide sample of countries allows us to examine this issue from a world trade perspective, involving more than 90% of the cereal's export trade.

The series used correspond to cereal exports (X), world good imports (M^*), international commodity prices index disaggregated in non-fuel prices (P) and fuel prices (P^*), and real effective exchange rate (REER) used to calculate the different measures of REER volatility (REERV). The REER for each country is employed because we consider the total cereals exports at the country level. For all cases, the period considered is 2010/01 – 2016/12 (monthly frequency) and the indices basis is January 2010 = 100. Cereal export data are obtained from UN Monthly Comtrade dataset in

[1] Table A.1 of Appendix presents the definition and sources of the variables used and Table A.2 of Appendix provides the main summary statistics.

current US dollars, which we convert into constant prices using the All Commodity Price Index (January 2010 = 100) from International Monetary Fund (IMF).[2] Table 1 describes the categories of cereals.[3]

Table 1 – Cereal exports description

Description
Cereals
Wheat and meslin (durum wheat, meslin and wheat other than durum)
Rye
Barley
Oats
Maize (corn, seed and other than seed)
Rice (rice in the husk, husked brown rice, semi-milled or wholly milled, whether or not polished or glazed, broken)
Grain sorghum
Buckwheat, millet and canary seed; other cereals

Source: Harmonized Commodity Description and Coding System (HS).

REER data is obtained from IMF, for the sample of selected countries, excluding Peru and Argentina, that were no data available. For Peru, the information is from ECLAC, and for Argentina, it comes from the International Center of Economics (CEI). The international literature normally uses GDP as a proxy of economies demand at a country level, however, as world GDP is not monthly frequency available to approximate the world demand conditions, we used the world good imports in constant dollars (deflated using the United States Consumer Price Index, US CPI), from IMF. Additionally, we employ the commodity price indices, disaggregated in non-fuel and fuel commodities price index, from IMF. Both indices are relevant to explain the export earnings, while the fuel commodities price index is relevant to explain export costs.

*3.1. **Measure of exchange rate uncertainty***

Exchange rate uncertainty has been a historically relevant topic in international finance, and this concern has recently extended to different areas of the economy, including the concern to understand the dynamics of the exchange rate and its impact on different macroeconomic variables (Bollerslev et al 1992).

In this study, we consider a univariate measure of historical volatility to quantify the REERV, quantified throughout the moving standard deviation (using a mobile m

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[2] UN Monthly Comtrade contains detailed merchandise trade data provided by countries to the United Nations Statistics Division, Department of Economic and Social Affairs (UNSD/DESA).

[3] Harmonized Commodity Description and Coding System (HS) is HS 10 https://unstats.un.org/unsd/tradekb/Knowledgebase/Harmonized-Commodity-Description-and-Coding-Systems-HS.

order of 4 and 8 months) of the growth rate of real effective exchange rate.[4] This paper adopts the specification of the moving standard deviation used in Chowdhury (1993) and Situ (2015):

$$V_t = \sqrt{\frac{1}{m}.\sum_{i=1}^{m}[\ln(REER_{t+i-1}) - \ln(REER_{t+i-2})\,]^2} \qquad (2)$$

where V is the real effective exchange rate volatility, m is the order of moving standard deviation and t denotes time.[5]

This type of measure is considered superior in relation to the second-order moment of the series, since using the latter would not be very useful to capture the phenomenon of variability for periods of low volatility and periods of high volatility, to calculate an average of the series of the whole period and to determine the variation with respect to the average. Therefore, using the moving standard deviation allows the average of the series to vary, and depending on the order of the moving average, it will reflect the volatility sensitivity. The higher the moving average order of the standard deviation, the more difficult to capture variability, and vice versa. Given that the impact of exchange rate volatility on a macroeconomic variable as exports, a low order of the measure *a priori* would be meaningless in the export decision since it is difficult to respond to a phenomenon of very short-term uncertainty. Similarly, a high order of the moving average may not reflect such variability. This is why in this study and according to the literature, we consider the order of the moving standard deviation at m = 4- and 8-periods.

3.2. ***Country groups***

The aim is identified groups of units (e.g. countries) that are similar to each other concerning certain characteristics. Cluster analysis is a useful technique for such a purpose. The objective of cluster analysis is to group observations into clusters such that each cluster is as homogeneous as possible with respect to the clustering variables (Everitt and Dunn 2013).

In cluster analysis, a) each group or cluster is homogeneous with respect to certain characteristic (observation in each group are similar to each other), and b) each group should be different from other groups with respect to the same characteristics (observation of one group should be different from the observations of the other groups).

Cluster analysis implicitly used the distance as measure of similarity between the units. The more similar the units, the smaller distance between them and vice versa. Several different similarity measures can be used; however, we have selected the squared Euclidian distance between one variable as a measure of similarity.

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[4] The short sample period avoids using several m horizons to eliminate an arbitrary selection of m (e.g. 12 and 24 periods).

[5] Similar procedures for obtaining a measure of exchange rate volatility are presented in Cushman (1983), Ahktar and Hilton (1984), Kenen and Rodrik (1986), Koray and Lastrapes (1989) and Arize (1997).

The formula for computing squared Euclidian distance for p variables is given by:

$$D_{ij}^2 = \sum_{k=1}^{p} \left(x_{ik} - x_{jk}\right)^2 \quad (1)$$

where D_{ij}^2 is the squared distance between country i and j, x_{ik} is the value of the kth variable for the ith unit, x_{jk} is the value of the kth variable for the jth unit, and p is the number of variables.

There are two main types of analytical clustering techniques: hierarchical and nonhierarchical. We limited to consider the first one given that we do not know the number of clusters to selected previously.

Hierarchical clustering creates hierarchically related sets of clusters. We considered a Hierarchical clustering method agglomerative. This method begins with each observation's being considered as a separate group (N groups each of size 1; in this case, 75 clusters, one per each country). The closest two groups are combined ($N - 1$ group, one of size 2 and the rest of size 1), and this process continues until all observations belong to the same group. This process creates a hierarchy of clusters.

For computing distance between two clusters, we have used the furthest neighbor or complete linkage method. This method defined the distance between two clusters as the maximum of the distance between all possible pairs of observations in the two clusters.

In general, if cluster C contains n_c units and cluster S contains n_s units then the distance between the two clusters is the maximum of the distance between $n_c * n_s$ pairs of distances. The following cluster is formed similarly, and the procedure is repeated until all the observations are merged into one cluster.

Thus, we first classify the 75 countries depending on the homogeneity level in moving standard deviation of real effective exchange rate, and second, we classify the 75 countries taking into account the volume of cereal exports.

Cluster-analysis stopping rules are used to determine and reach a decision of how many clusters select. A stopping-rule value (or index) is computed for each cluster solution (for example, at each level of the hierarchy in a hierarchical cluster analysis). Larger values (or smaller, depending on the particular stopping rule) indicate more distinct clustering.

We used two stopping rules, the Calinski and Harabasz pseudo-F index and the Duda–Hart Je(2)/Je(1) index. For both rules, larger values indicate more distinct clustering. Presented with the Duda– Hart Je(2)/Je(1) values are pseudo-T-squared values. Smaller pseudo-T-squared values indicate more distinct clustering.

Calinski–Harabasz stopping rule shows that two-group of countries is one possible solution for cereal export volume and REERV (m = 4- and 8-periods), given that the pseudo-F value is largest, indicating that the two-group solution is the most distinct compared with the three-group, see Table 2.

Table 2 – Calinski stopping rule

Number of clusters	Calinski/Harabasz pseudo-F		
	X	*V4*	*V8*
2	159.34	118.56	124.86
3	140.9	75.92	107.73
4	195.64	200.67	194.72
5	227.21	296.21	278.21
6	358.66	335.53	384.19

Note: *X*, cereal exports; *V4* and *V8* are the moving standard deviation of real effective exchange rate 4 and 8 periods respectively.
Source: Own estimations.

Duda– Hart stopping rule considers large Je(2)/Je(1) values of pseudo-T-squared values and smaller pseudo-T-squared values as indicator of more distinct clustering, see Table 3. The lower Duda–Hart pseudo-T-squared value for two groups solution for cereal export volume and REERV (m = 4 and 8 periods). The conventional wisdom for deciding the number of groups based on the Duda–Hart stopping-rule table is to find one of the largest Je(2)/Je(1) values that correspond to a low pseudo-T -squared value that has much larger T-squared values next to it. Thus, we select two clusters by these criteria.

Table 3 – Duda – Hart stopping rule

Number of clusters	Duda/Hart					
	X		*V4*		*V8*	
	Je(2)/Je(1)	pseudo T-squared	Je(2)/Je(1)	pseudo T-squared	Je(2)/Je(1)	pseudo T-squared
1	0.314	159.34	0.381	118.560	0.369	124.860
2	0.331	54.5	0.269	24.520	0.351	29.540
3	0.357	79.25	0.279	160.150	0.237	176.790
4	0.220	78.05	0.276	94.280	0.174	61.620
5	0.19	110.83	0.097	56.080	0.190	123.460
6	0.193	12.51	0.310	53.460	0.354	16.390

Note: *X*, cereal exports; *V4* and *V8* are the moving standard deviation of real effective exchange rate 4 and 8 periods respectively.
Source: Own estimations.

To sum up, both criteria indicate that the two-group solution is the most distinct from this hierarchical cluster analysis. The composition of the countries in the two clusters are given by Table 4:

Table 4 – Frequency of the countries by number of clusters

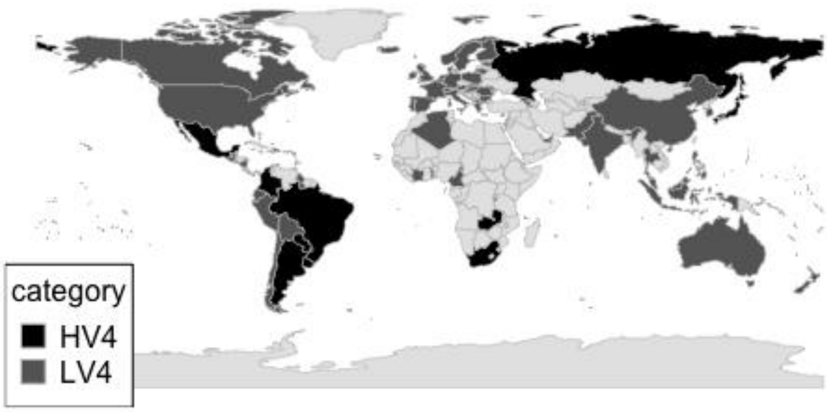
Cluster	*X*		*V4*		*V8*	
	Obs. of countries	Frequency	Obs. of countries	Frequency	Obs. of countries	Frequency
1	29	39%	64	85%	57	76%
2	46	61%	11	15%	18	24%
Total	75	100%	75	100%	75	100%

Source: Own estimations.

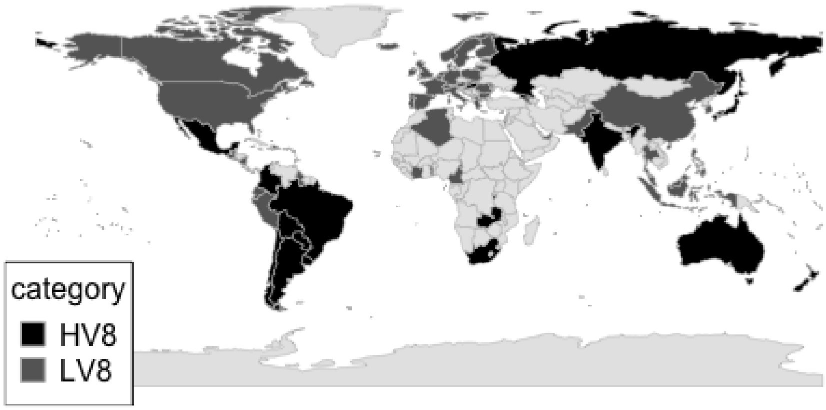
Thus, from classifying the 75 countries based on the homogeneity level in moving standard deviation of real effective exchange rate 4- and 8-periods, we identify two clusters of countries that show low and high REERV, cluster 1 and cluster 2 respectively. We denoted high REERV as *HV* and we labeled low REERV as *LV*; given that we have the moving standard deviation of real effective exchange rate 4- and 8-periods, we called them *HV4*, *HV8*, *LV4* and *LV8* respectively (see Figure 1). Meanwhile, we classify the 75 countries taking into account the volume of cereal exports, we identify two clusters of countries which depict low and high volume of cereal exports, cluster 1 and cluster 2 respectively. We denoted high level of cereal exports as *HX* and low level of cereal export as *LX* (see Figure 2).

Figure 1 – Cereal exports by high and low real effective exchange rate volatility (averages values in the period 2010 - 2016)

a) Moving standard deviation of REER 4-periods

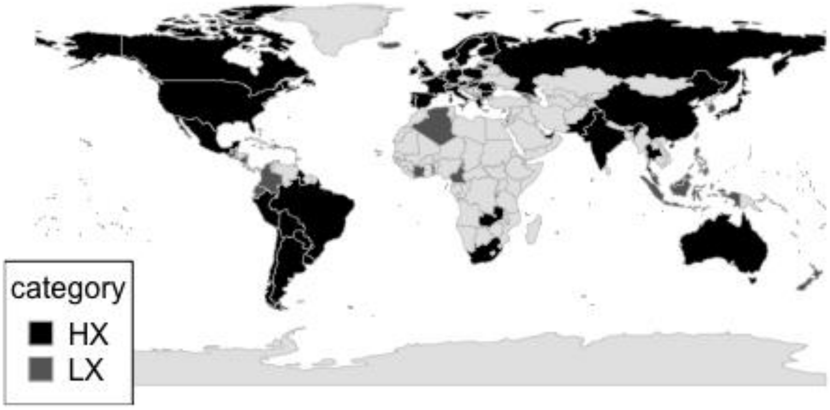


b) Moving standard deviation of REER 8-periods



Note: We denoted them HV4 and LV4 for the moving standard deviation of real effective exchange rate 4-periods, high and low REERV respectively; and HV8 and LV8 for the moving standard deviation of real effective exchange rate 8-periods, high and low REERV respectively.
Source: Own elaboration.

Figure 2 – Cereal exports by high and low real effective exchange rate volatility (averages values in the period 2010 - 2016)

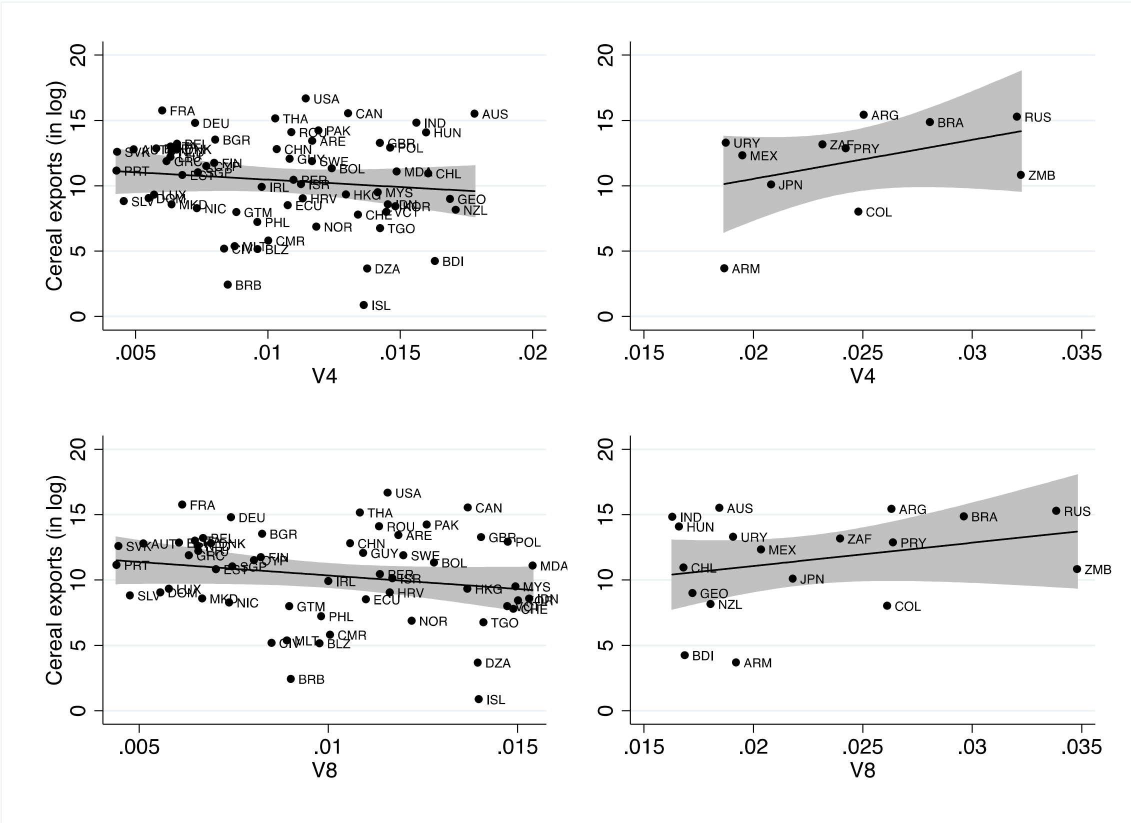


Note: High and low cereal exports, HX and LX respectively.
Source: Own elaboration.

Figure 3 illustrates the countries belong to low REERV and high REERV by the standard deviation of the moving averages of real effective exchange rate 4 and 8 periods. Meanwhile, we show the negative relationship between REERV and cereal exports in countries with low REERV, we observe a slightly positive relationship between REERV and cereal exports in countries with high REERV.

Figure 3 – Cereal exports by high and low real effective exchange rate volatility
(averages values in the period 2010 - 2016)

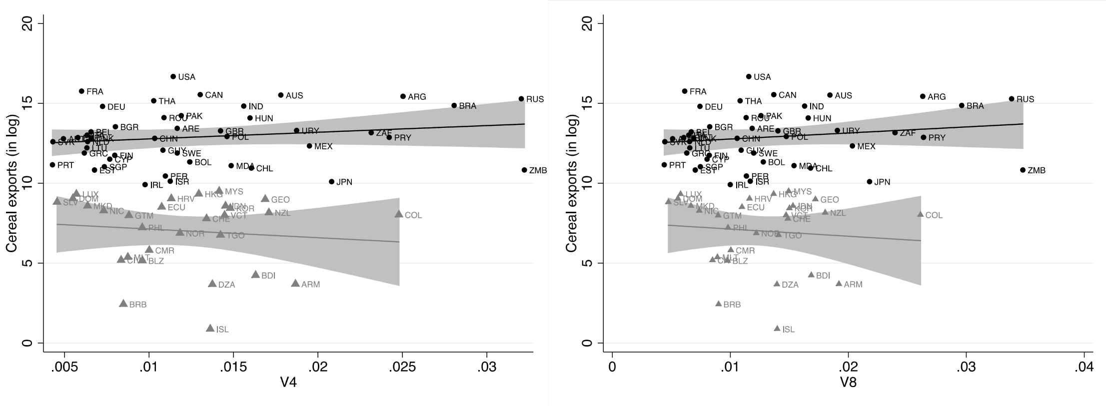
a) Countries: Low REERV b) Countries: High REERV



Note: Low REERV of *V4* (LV4) and *V8* (LV8). High REERV of *V4* (HV4) and *V8* (HV8).
Source: Own estimations.

Figure 4 shows the countries split in low and high cereal export volume by the REERV measure. While we can see a negative relationship between REERV and exports for the whole low-export countries, we observe a slightly flat relationship between REERV and exports for the whole high-export countries.

Figure 4 – High and low cereal exports by the measure of real effective exchange rate volatility (averages values in the period 2010 - 2016)



Note: REERV m = 4 and 8 periods, *V4* and *V8* respectively.
Source: Own estimations.

4. Empirical strategy

This section provides the procedures we use to analyze the effect of REERV on cereal exports. The process is as follows. First, we revise the seasonal adjustment corrections of the time series due to monthly data is used. And then, we explain the panel VAR methodology. Estimation results are reported for 70 countries in the period 2010/01 – 2016/12 (P-VAR estimation excludes Algeria, Armenia, Burundi, Colombia and Côte d´Ivoire due to cereal exports series have gaps).

4.1. *Seasonal adjustment*

The objectives of the seasonal adjustment process are to identify and subtract the seasonal components (fluctuations and calendar effects) of the unadjusted time series which can impede a clear interpretation of the time series movements. As a result, the seasonally adjusted time series is obtained.

To extract the seasonal component of the time series, we examine the signal extraction in a univariate time series $\{Y_t\}$ context of an ARIMA data generating process (DGP), this implies that components are stochastic. We can find the model-based method and the empiricist method.

The model-based methods, so-called parametric methods, to decompose the observable time series assume that each unobservable component of the time series follows a theoretical econometric model. A well-known method is TRAMO–SEATS, developed by Gómez and Maravall (1996), which is a model-based seasonal adjustment method supported by the statistical office of the European Union (Eurostat) and Bank of Spain. The TRAMO performs identifications, correct atypical (level shift, additive outlier, temporary change, innovation outliers, calendar effects) and missing, estimate and validate ARIMA seasonal models automatically, while SEATS allows extracting the unobserved components of a series from an ARIMA univariate model.

The empiricist methods, so-called non-parametric, are characterized by the analysis of the real series decomposition but do not refer explicitly to any type of theoretical model of data generation. One of the most important empirical developments in the seasonal decomposition methods is the seasonal adjustment X–13ARIMA–SEATS developed by the US Census Bureau in collaboration with the Bank of Spain in 2012, currently used by US Census Bureau. This version of the program integrates an enhanced version of regARIMA models (estimate and remove outliers and calculate calendar adjustment factors) and SEATS (ARIMA model-based seasonal adjustments and diagnostics) developed by Gómez and Maravall (1996) to estimate the different time series components (Census Bureau US 2011, 2017). Given the series are not long enough, in this study we applied the X-13ARIMA-SEATS method to seasonal adjust the time series.

4.2. ***Model specification***

In the macroeconomic literature, there are two main ways of considering the interdependent 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 (Canova and Ciccarelli 2013). An alternative approach is to construct vector autoregressive models (VAR). The VAR model is a multivariate time-series tool originally introduced by Sims (1980) for macroeconomic analysis. These models avoid making strong assumptions about the microstructure of relationships, capturing dynamic interdependence in the data using a minimal set of constraints. At the same time, the ability to evaluate policy shocks can transform these models in a reduced way into structural models, allowing the execution of impulse-response exercises (Chari et al 2008).

Thus, we perform a dynamic empirical analysis of simultaneous equations through the use of the VAR methodology applied to panel data. This type of analysis combines the traditional VAR methodology, considering the whole set of variables as endogenous in an interdependent system, with the panel data technique, which allows control by individual and temporal heterogeneity, and estimate causal relationships between endogenous variables. Additionally, the inclusion of exogenous variables in the analysis is allowed (Canova and Ciccarelli 2013).

In this paper, we propose to estimate the dynamic panel data model with autoregressive vectors using the P-VAR technique with fixed effects developed by Abrigo and Love (2016).[6] The P-VAR methodology estimates the coefficients using the

[6] Abrigo and Love (2016) provide an available STATA code for the use of researchers. https://sites.google.com/a/hawaii.edu/inessalove/home/pvar

Generalized Method of Moments using regressor lags as instruments. To guarantee orthogonality between the regressors and the fixed effects, we include the transformation of Helmert (Arellano and Bover 1995; Love and Zicchino 2006).

Once the P-VAR models have been estimated in their reduced form, simulation exercises can be performed throughout the calculation of impulse-response functions to determine and compare the magnitude, significance, and sign of a single and "unexpected" orthogonal shock of one variable over another. Besides, the decomposition of the variance of the predicted error can be examined in order to determine the cumulative relative contribution of the shock on the variable of interest.

A common specification of the export equation is (Arize and Malindretos 1998; Arize 1997; Arize et al 2008; Chowdhury 1993; Bayar 2018 for a survey):

$$X_{it} = \propto_1 X_{it-p} + \propto_2 P_{it-p} + \propto_3 REERV_{it-p} + \beta_1 M^*_{it} + \beta_2 P^*_{it} + v_i + e_{it} \quad (3)$$

with p lags, where i represents the country, t is the time between 2010/01 and 2016/12. The endogenous variables of the model are cereal exports (X), the non-fuel commodity price index (P) and the measures of REERV. The exogenous variables of the model are world goods imports (M^*) and the fuel commodity price index (P^*). v_i represents the fixed-effects variable that captures unobservable individual heterogeneity and e_{it} the idiosyncratic errors. The coefficients $\propto_1$, $\propto_2$, $\propto_3$, β_1 and β_2 are the parameters to be estimated. Here, we specify a panel model with fixed effects, which captures the specific components of each country that are invariant over time and that affect the variables to be explained (for instance: trade liberalization, level of development of financial markets, country size, production structure). Note that the P-VAR with fixed-effects estimates averages effects, through heterogeneous groups of the unit of analysis, in this case, the country unit, to characterize the country-specific differences with the average (Canova and Ciccarelli 2013).

5. Empirical results

In this section, we proceed as follows. Firstly, we report the integrated order of the time series. Secondly, we present the estimation results for the panels by high and low REERV, and then, we report the estimations for the panels by high and low levels of cereal exports. Finally, we show the post-estimations outcomes.

5.1. Unit root test

For panel data methodology, there is a wide range of unit root tests (or stationarity), among them Levin-Lin-Chu (2002), Harris-Tzavalis (1999), Breitung and Das (2005), Im-Pesaran-Shin (2003), Fisher-type (Choi 2001) and Hadri (2000). They incorporate different assumptions for its implementation (balanced or unbalance panel, the number of units N, and the size of the temporal dimension, T).

Table 5 presents the main results of the unit root test for the panels of countries throughout the 2010/01 – 2016/12 period.

Table 5 – Unit-root test results

Variable	Level		First Difference	
	Adjusted statistic t*	Integration order	Adjusted statistic t*	Integration order
X	---	I(1)	---	I(0)
LV4	-1.128 [0.130]	I(1)	-11.950 [0.000]	I(0)
HV4	-0.693 [0.244]	I(1)	-4.700 [0.000]	I(0)
LV8	2.346 [0.991]	I(1)	-6.582 [0.000]	I(0)
HV8	1.450 [0.927]	I(1)	-3.220 [0.000]	I(0)
LX-V4	-0.079 [0.468]	I(1)	-7.645 [0.000]	I(0)
HX-V4	-1.553 [0.060]	I(1)	-10.323 [0.000]	I(0)
LX-V8	0.643 [0.740]	I(1)	-4.261 [0.000]	I(0)
HX-V8	2.353 [0.991]	I(1)	-5.957 [0.000]	I(0)

Note: Levin-Lin-Chu (LLC) unit root test for variables in levels; null hypothesis: panels contain the integrated series. Im, Pesaran and Shin (IPS) unit root test for variables in first difference. Level of significance of the test 95%. In [...] p-value. The number of delays was selected by the Akaike criterion, max. delays = 10. The variables were considered in logarithm. And cross-sectional dependence was eliminated. Sample: 2010/01 – 2016/12. The cereal export series gaps avoid running panel unit root test; therefore, we assume that cereal export series behave in the panel as integrated of first order, I(1).
Source: Own elaboration.

Table 6 presents the results of the unit root test for those series which are common to all countries in the panels (*M**, *P*, *P**). The results of the Augmented Dickey-Fuller test show that this set of level variables have a unit root and are stationary in the first difference, I(1).

Table 6 – ADF unit root test: univariate analysis

Variable	Level		First Difference	
	Statistical value	Integration order	Statistical value	Integration order
*M**	-2.743* (11 lags)	I(1)	-8.186*** (10 lags)	I(0)
P	-2.018 (1 lags)	I(1)	-5.674*** (0 lags)	I(0)
*P**	-1.252 (1 lags)	I(1)	-6.211*** (0 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 (maxlag=11). The ADF model was specified with a constant. The variables were considered in logarithm. Level of significance: *: 10%, **: 5%, ***: 1%.
Source: Own elaboration.

5.2. ***High and low real effective exchange rate volatility***

Table 7 reports the P-VAR estimation results of Equation *3* for the whole sample of countries (models 1 to 2) and countries characterized by the high and low levels of REERV using the two different specifications of it (models 3 to 6). The main findings of models 1 to 6 can be summarized as follows. Regarding endogenous variables, first, the cereal export variable lag is positive and significant at 1%. Therefore, past changes in exports are relevant in explaining contemporary exports. Second, the non-fuel commodities price index is positive and insignificant, except for model 6 that is negative and significant at 5%. On the one hand, the positive sign on the non-fuel commodity price index means that the increase in prices encourages producers to increase cereal exports. On the other hand, the negative results could be associated with the fact that cereal exports have been historically restricted by the trade policy. For instance, the cereal export tax reduces the international trade volume of them due to increase the cost of exports, i.e. increase the global prices (Estrades et al 2017). Third, the REERV is negative from models 1 to 6, which is only significant at 10% in the case of model 6. This result is associated with risk-averse agents involved in international trade of cereal exports. However, exchange rate uncertainty is relevant to explain cereal exports in countries characterised by high level of REERV 8-period. Note that cereal export contract includes the requirement of quantity, price per unit, payment terms, so on; therefore, exchange rate fluctuations do not affect the volume of cereal exports in the short-term (Grier and Smallwood 2007).

Regarding exogenous variables, first, the global demand conditions have a positive impact on variation in cereal exports and is insignificant in the case of models 1 to 5 and significant at 1% in the case of model 6. Second, the fuel commodity price index represents the production and transportation costs for cereal exports, which justify the negative and significant coefficient from models 1 to 5 (except for model 6).

Table 7 – Estimation results by high/low REERV

Equation: X	V4 (1)	V8 (2)	LV4 (3)	HV4 (4)	LV8 (5)	HV8 (6)
L.X	0.341***	0.351***	0.336***	0.429***	0.366***	0.301***
	(0.050)	(0.049)	(0.052)	(0.104)	(0.057)	(0.078)
L.P	0.109	0.081	0.113	0.051	0.415	-1.054**
	(0.247)	(0.263)	(0.279)	(0.419)	(0.314)	(0.469)
L.REERV	-1.878	-4.088	-1.179	-0.231	-4.096	-4.285*
	(2.032)	(2.618)	(3.738)	(1.872)	(5.899)	(2.214)
M*	1.520	1.704	1.466	1.752	0.060	7.193***
	(1.099)	(1.373)	(1.258)	(0.279)	(1.828)	(2.068)
P*	-0.337***	-0.346***	-0.328**	-0.339*	-0.433***	-0.058
	(0.127)	(0.134)	(0.146)	(0.051)	(1.828)	(0.274)
No. of Obs.	3689	3478	3,196	493	2,638	840
No. of panels	70	70	61	9	55	15
Ave. no. of T	52.700	49.686	52.393	54.778	47.964	56

Note: We considered the first difference of the logarithm of the variable (seasonal adjusted). Level of significance: *: 10%, **: 5%, ***: 1%. Equation 3 – 6 uses the REERV (high and low) calculated through the standard deviation moving average 4 and 8 periods, respectively.
Source: Own elaboration.

5.3. High and low level of cereal exports

Table 8 shows the estimates of the whole panels (models 1 to 2, similarly model 1 and 2 of Table 7) and panels by high and low levels of cereal export volume for the two measures of the REERV (models 3 to 6). On the one hand, the lag of the endogenous variables, such as exports, was significant at 1%. Moreover, the non-fuel commodity price index was significant at 5% in models 3 – 6. Here, we observed an opposite impact of non-fuel commodities prices on cereals exports. While countries classified as high level of cereals exports, i.e. has market power in global markets, show a negative effect of non-fuel commodities prices on cereal exports, since exports restrictions reduce the volume of exports due to increase the cost of exports (and prices), countries classified as low level of cereal export volume report a positive sign of non-fuel commodity price index, therefore, the increase in prices encourages producers to increase exports (small influence on global market) (Estrades et al 2017). The REERV was significant at 5% when we use the 8-period moving standard deviation of countries characterized by high level of cereal exports (model 6), and the impact is negative. In other cases, REERV is not significant. These results are consistent with the empirical evidence of a negative or insignificant effect (Situ 2015; Vilela and MacDonald 2016; Miranda and Mordecki 2019). Thus, our finding provides a result not carried out by previous studies, this is, countries with market power on cereals exports are risk-averse under exchange rate uncertainty.

On the other hand, the exogenous variable, the fuel commodity price index is negative from models 1 to 6, and is significant in models 1, 2, 4 and 6. Specifically, an increase in it implies a reduction in the cereal exports in countries classifying as high level of cereal exports. The global demand conditions have a positive effect on countries with high level of cereal exports and negative in countries with low level of cereal exports, which are significant at 1%; the negative sign probably is explained by the economic context – a slow global demand growth and decrease in the commodities prices in this period of analysis may not affect countries with low cereal export volume.

Table 8 – Estimation results by high/low cereal exports

Equation: X	X-V4 (1)	X-V8 (2)	LX-V4 (3)	HX-V4 (4)	LX-V8 (5)	HX-V8 (6)
L.X	0.341***	0.351***	0.264***	0.512***	0.281***	0.499***
	(0.050)	(0.049)	(0.066)	(0.048)	(0.065)	(0.046)
L.P	0.109	0.081	1.928**	-0.388**	1.801**	-0.399**
	(0.247)	(0.263)	(0.812)	(0.168)	(0.876)	(0.178)
L.REERV	-1.878	-4.088	4.394	-2.359	-0.647	-3.932**
	(2.032)	(2.618)	(7.771)	(1.518)	(9.323)	(1.929)
M*	1.520	1.704	-15.858***	5.579***	-15.375***	5.839***
	(1.099)	(1.373)	(3.747)	(0.874)	(4.712)	(1.093)
P*	-0.337***	-0.346***	-0.222	-0.254***	-0.110	-0.303***
	(0.127)	(0.134)	(0.406)	(0.094)	(0.441)	(0.101)
No. of Obs.	3689	3478	977	2,712	919	2,559
No. of panels	70	70	24	46	24	46
Ave. no. of T	52.700	49.686	40.708	58.957	38.292	55.630

Note: We considered the first difference of the logarithm of the variable (seasonal adjusted). Level of significance: *: 10%, **: 5%, ***: 1%. Equation 3 – 6 uses the cereal export groups (low exports -LX- and high exports -HX-) by the standard deviation moving average 4 and 8 periods, respectively.
Source: Own elaboration.

5.4. ***Post-estimation test***

5.4.1. 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). Therefore, the Granger causality test (Granger 1969) is carried out. Rejecting the null hypothesis, in this case, implies that past changes in one variable affect or precedes the other variable, in which case it would not be exogenous. Table 9 shows the results of the Granger causality test for the high and low REERV and high and low levels of cereal export volume; they are reported for REERV and cereal exports.

Table 9 – Granger causality test (Wald)

Equation	Excluded	Chi2
Ho: Excluded variable does not Granger-cause Equation variable Ha: Excluded variable Granger-cause Equation variable		
X	LV4	0.100
LV4	X	0.146
X	HV4	1.523
HV4	X	0.063
X	LV8	0.482
LV8	X	0.261
X	HV8	3.747*
HV8	X	3.096*
LX	V4	0.320
V4	LX	0.085
HX	V4	2.416
V4	HX	0.006
LX	V8	0.005
V8	LX	0.000
HX	V8	4.156**
V8	HX	2.606

Notes: Rejection of the null hypothesis: *: 10%, **: 5% and ***: 1% of significance (Prob. > Chi2). Sample: 2010.01 – 2016.12. The variables were considered in logarithm. Results are reported for cereal exports and the different measures of volatility by high and low REERV (HV and LV, respectively) and by high and low level of cereal exports (HX and LX, respectively). V4 and V8 refer to the moving standard deviation 4 and 8 periods, respectively.
Source: Own estimations.

We find a unidirectional significant relationship wherein the 8-period moving of the standard deviation of REER Granger-cause high level of cereal exports. Bidirectional Granger causality is found for the high and 8-period standard deviation moving of REERV, i.e., causality in this is not conclusive.

5.4.2. Impulse-response functions

Here, we discuss the simulation of IRF. The focus of the analysis is to quantify macroeconomics shocks one at a time to see how they affect cereal exports, with particular interest in the impact of an exchange rate volatility shock. In the IRF graphs, the cereal 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 export response is considered for a period of 18 months (one and a half years). Here, we assume the following recursive order to construct the IRF:

$$P \rightarrow V \rightarrow X$$

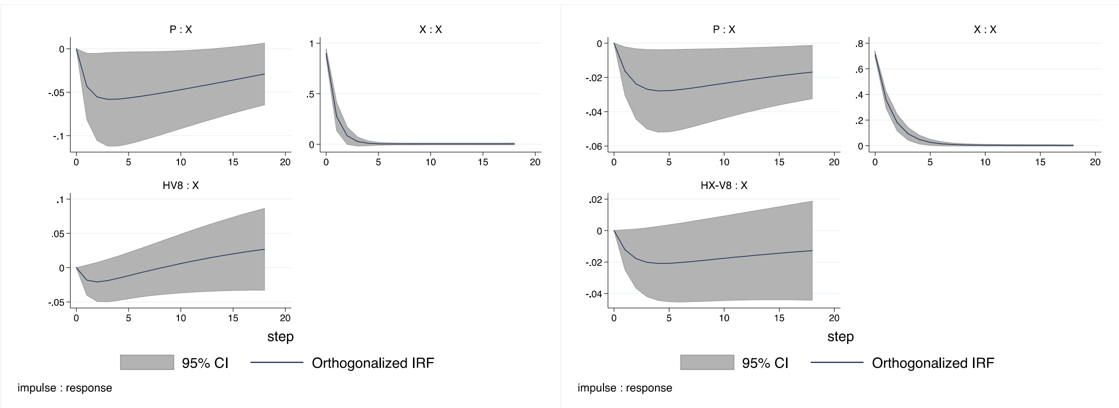
The economic intuition of this Cholesky order can be expressed as follows: firstly, the non-fuel commodities price index is the most important variable for the panels, based on its effect on the terms of trade and this on the decision of the countries to export. And secondly, due to the effect of uncertainty on cereals 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 system variables, it is in the last position in Cholesky´s order.

Following the results identified in subsections 5.1 and 5.2, Figure 5 illustrates the IRF of the endogenous variables of two selected specifications: a) countries characterized by high REERV 8-period (HV8), see model 6 in Table 7, b) countries characterized by high level of cereal export volume and REERV 8-period (HX-V8), see model 6 in Table 8.

While an impulse of the variable REERV does not have a significant export respond in the short- and medium-term, non-fuel commodities price index are significant, see subfigures a) and b).

Figure 5 – Impulse response function: endogenous variables

a) countries characterized by HV8 *b) countries characterized by HX-V8*

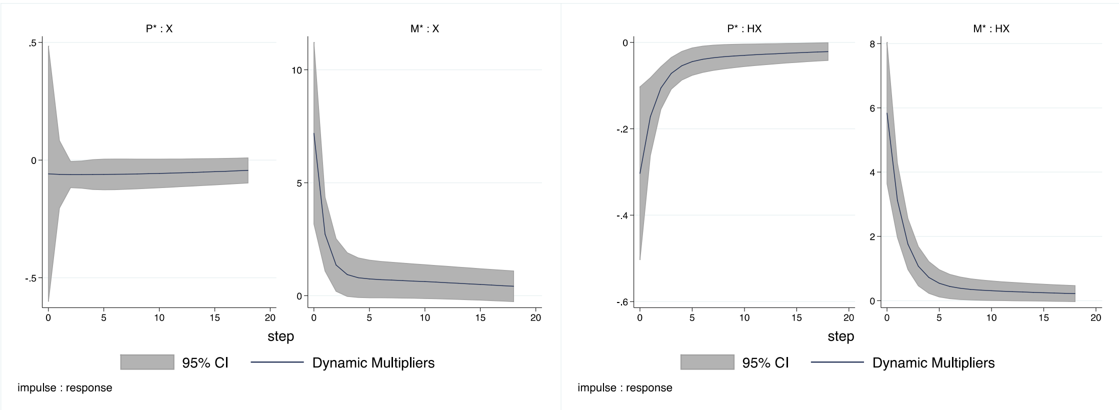


Note: Impulse (endogenous variable) : response (cereal exports). The band containing the IRF corresponds to 95% confidence.
Source: Own estimations.

Besides, the P-VAR methodology allows an IRF to stimulate a shock to the exogenous variable and its effect on the endogenous variable of interest. The results are illustrated in Figure 6.

Figure 6 – Impulse response function: exogenous variables

a) countries characterized by HV8 *b) countries characterized by HX-V8*



Note: Impulse (endogenous variable) : response (cereal exports). The band containing the IRF corresponds to 95% confidence.
Source: Own estimations.

6. Conclusions

This paper examines the relationship between exchange rate uncertainty and cereal exports for a large panel of developed and developing countries over the 2010/01 – 2016/12, using a P-VAR methodology. Although the empirical literature on this issue is extensive, in our knowledge do not exist studies that examine the links between exchange rate uncertainty and cereal exports, in which cereals are crucial for human diets, particularly, in developing countries.

Our empirical findings suggest the following conclusions. First, exchange rate uncertainty is important for modeling cereal exports in countries with high exchange rate volatility and high level of cereal export volume (i.e. with market power), with REERV 8-period. The economic interpretation of the negative impact of REERV on cereal exports appears to be associated with the "average" exporting country that display risk-averse behavior or have some contract flexibility to adjust their exports in the medium-term. Second, this paper also reports evidence of the link between cereal exports and other macroeconomic variables. While the impact of non-fuel commodities price index on cereal exports is associated with export restrictions, the fuel commodities price index represents an export cost for countries. Furthermore, global demand conditions is one of the most important factors explaining variations in cereal exports.

Thus, this empirical analysis leads us to suggest policy makers to mitigate exchange rate fluctuations to reduce the risk associated with cereal export activity, and consequently, to stabilize the external trade position, specifically in countries that can influence the cereal export markets.

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Appendix

List of countries: Algeria (DZA); Argentina (ARG); Armenia (ARM); Australia (AUS); Austria (AUT); Barbados (BRB); Belgium (BEL); Belize (BLZ); Bolivia (BOL); Brazil (BRA); Bulgaria (BGR); Burundi (BDI); Cameroon (CMR); Canada (CAN); Chile (CHL); China (CHN); Colombia (COL); Croatia (HRV); Cyprus (CYP); Côte d'Ivoire (CIV); Denmark (DNK); Dominican Republic (DOM); Ecuador (ECU); El Salvador (SLV); Estonia (EST); Finland (FIN); France (FRA); Georgia (GEO); Germany (DEU); Greece (GRC); Guatemala (GTM); Guyana (GUY); Hong Kong (HKG); Hungary (HUN); Iceland (ISL); India (IND); Indonesia (IDN); Ireland (IRL); Israel (ISR); Italy (ITA); Japan (JPN); Korea (KOR); Lithuania (LTU); Luxembourg (LUX); Macedonia (MKD); Malaysia (MYS); Malta (MLT); Mexico (MEX); Moldova (MDA); Netherlands (NLD); New Zealand (NZL); Nicaragua (NIC); Norway (NOR); Pakistan (PAK); Paraguay (PRY); Peru (PER); Philippines (PHL); Poland (POL); Portugal (PRT); Romania (ROU); Russian Federation (RUS); Singapore (SGP); Slovak Republic (SVK); South Africa (ZAF); Spain (ESP); St. Vincent and the Grenadines (VCT); Sweden (SWE); Switzerland (CHE); Thailand (THA); Togo (TGO); United Arab Emirates (ARE); United Kingdom (GBR); United States (USA); Uruguay (URY); Zambia (ZMB).

The countries that required a seasonal adjustment of the cereal export monthly series: Argentina, Australia, Austria, Belgium, Belize, Bolivia, Brazil, Bulgaria, Canada, Chile, Côte d'Ivoire, Denmark, Dominican Republic, Ecuador, El Salvador, Estonia, Finland, France, Georgia, Germany, Greece, Guatemala, Guyana, Hong Kong, Hungary, India,, Ireland, Israel, Italy, Japan, Lithuania, Luxembourg, Macedonia, Malaysia, Mexico, Moldova, Netherlands, New Zealand, Norway, Pakistan, Paraguay, Peru, Philippines, Poland, Portugal, Romania, Russian Federation, Singapore, Slovak Republic, South Africa, Spain, Sweden, Switzerland, Thailand, United Kingdom, United States, Uruguay.

Table A.1 – Definitions and variable sources

Variable	Description	Source
Exports (X)	Total cereal exports in millions of constant dollars (Base January 2010 = 100) (exports in millions of current FOB dollars, deflated by the All Commodity Price Index).	UN Monthly Comtrade
World Demand (M*)	World imports of goods in millions of constant dollars (Base January 2010 = 100) (imports in millions of current CIF dollars, deflated by the United States Consumer Price Index, US CPI) (Base January 2010 = 100).	IMF
Real Effective Exchange Rate	The index considers the weighted average of the bilateral real exchange rate with the main trading partners (using as weighting the share of trade in the economies) (Base January 2010 = 100).	IMF; Peru (ECLAC); Argentina (CEI).
Volatility (V4)	Volatility of the real effective exchange rate as a moving sample standard deviation of the growth rate of real effective exchange rate, 4 is the order of the moving average.	IMF; Peru (ECLAC); Argentina (CEI).
Volatility (V8)	Volatility of the real effective exchange rate as a moving sample standard deviation of the growth rate of real effective exchange rate, 8 is the order of the moving average.	IMF; Peru (ECLAC); Argentina (CEI).
Non-fuel commodities prices (P)	Index of non-fuel commodities prices (Base January 2010 = 100).	IMF
Fuel commodities prices (P*)	Index of fuel commodities prices (energy) (Base January 2010 = 100).	IMF

Source: Own elaboration.

Table A.2 – Descriptive statistics

Variable		Mean	Std. Dev.	Min	Max	Observations
X	Overall	11.272	3.296	-4.761	17.239	N = 5,123
	Between		3.472	0.880	16.680	n = 75
	Within		1.265	-2.201	19.249	T-bar = 68.3067
V4	Overall	0.012	0.010	0.001	0.143	N = 6,000
	Between		0.006	0.004	0.032	n = 75
	Within		0.008	-0.015	0.123	T = 80
V8	Overall	0.013	0.009	0.002	0.112	N = 5,700
	Between		0.007	0.004	0.035	n = 75
	Within		0.007	-0.015	0.090	T = 76
M*	Overall	9.517	0.041	9.397	9.571	N = 84
	Between		---	9.517	9.517	n = 1
	Within		0.041	9.397	9.571	T = 84
P	Overall	4.678	0.114	4.461	4.859	N = 84
	Between		---	4.678	4.678	n = 1
	Within		0.114	4.461	4.859	T = 84
P*	Overall	4.597	0.372	3.630	5.007	N = 84
	Between		---	4.597	4.597	n = 1
	Within		0.372	3.630	5.007	T = 84

Source: Own estimations.

Table A.3 – High and low real exchange rate volatility and level of cereal exports

Country	Low REERV		High REERV		High (H) or Low (L) Cereal Exports (*X*)
	V4	*V8*	*V4*	*V8*	
Algeria (DZA)	x	x			LX
Argentina (ARG)			x	x	HX
Armenia (ARM)			x	x	LX
Australia (AUS)	x			x	HX
Austria (AUT)	x	x			HX
Barbados (BRB)	x	x			LX
Belgium (BEL)	x	x			HX
Belize (BLZ)	x	x			LX
Bolivia (BOL)	x			x	HX
Brazil (BRA)			x	x	HX
Bulgaria (BGR)	x	x			HX
Burundi (BDI)	x			x	LX
Cameroon (CMR)	x	x			LX
Canada (CAN)	x	x			HX
Chile (CHL)	x			x	HX
China (CHN)	x	x			HX
Colombia (COL)			x	x	LX
Côte d'Ivoire (CIV)	x	x			LX
Croatia (HRV)	x	x			LX
Cyprus (CYP)	x	x			HX
Denmark (DNK)	x	x			HX
Dominican Republic (DOM)	x	x			LX
Ecuador (ECU)	x	x			LX
El Salvador (SLV)	x	x			LX
Estonia (EST)	x	x			HX
Finland (FIN)	x	x			HX
France (FRA)	x	x			HX
Georgia (GEO)	X			x	LX
Germany (DEU)	x	x			HX
Greece (GRC)	x	x			HX
Guatemala (GTM)	x	x			LX
Guyana (GUY)	x	x			HX
Hong Kong (HKG)	x	x			LX
Hungary (HUN)	x			x	HX
Iceland (ISL)	x	x			LX
India (IND)	x			x	HX
Indonesia (IDN)	x	x			LX
Ireland (IRL)	x	x			HX
Israel (ISR)	x	x			HX
Italy (ITA)	x	x			HX
Japan (JPN)			x	x	HX
Korea (KOR)	x	x			LX
Lithuania (LTU)	x	x			HX
Luxembourg (LUX)	x	x			LX

Table A.3 (Continuation) – High and low real exchange rate volatility and level of cereal exports

Country	Low REERV		High REERV		High (H) or Low (L) Cereal Exports (*X*)
	V4	V8	V4	V8	
Macedonia (MKD)	x	x			LX
Malaysia (MYS)	x	x			LX
Malta (MLT)	x	x			LX
Mexico (MEX)			x	x	HX
Moldova (MDA)	x	x			HX
Netherlands (NLD)	x	x			HX
New Zealand (NZL)	x			x	LX
Nicaragua (NIC)	x	x			LX
Norway (NOR)	x	x			LX
Pakistan (PAK)	x	x			HX
Paraguay (PRY)			x	x	HX
Peru (PER)	x	x			HX
Philippines (PHL)	x	x			LX
Poland (POL)	x	x			HX
Portugal (PRT)	x	x			HX
Romania (ROU)	x	x			HX
Russian Federation (RUS)			x	x	HX
Singapore (SGP)	x	x			HX
Slovak Republic (SVK)	x	x			HX
South Africa (ZAF)			x	x	HX
Spain (ESP)	x	x			HX
St. Vincent and the Grenadines (VCT)	x	x			LX
Sweden (SWE)	x	x			HX
Switzerland (CHE)	x	x			LX
Thailand (THA)	x	x			HX
Togo (TGO)	x	x			LX
United Arab Emirates (ARE)	x	x			HX
United Kingdom (GBR)	x	x			HX
United States (USA)	x	x			HX
Uruguay (URY)			x	x	HX
Zambia (ZMB)			x	x	HX

Note: Low REERV of V4 and V8, LV4 and V8 respectively; high REERV of V4 and V8, HV4 and HV8 respectively.
Source: Own elaboration.

Table A.4 – Eigenvalue stability conditions

Eigenvalue				Modulus	
Real		Imaginay			
High and Low REERV					
LV	HV	LV	HV	LV	HV
V4					
0.935	0.957	0	0	0.935	0.957
0.844	0.873	0	0	0.844	0.873
0.336	0.427	0	0	0.336	0.427
V8					
0.980	0.979	0	-0.050	0.980	0.980
0.945	0.979	0	0.050	0.945	0.980
0.367	0.304	0	0	0.367	0.304
High and Low Cereal Exports					
LX	HX	LX	HX	LX	HX
V4					
0.945	0.939	0	0	0.945	0.939
0.887	0.858	0	0	0.887	0.858
0.263	0.509	0	0	0.263	0.509
V8					
0.959	0.992	0.013	0	0.959	0.992
0.959	0.959	-0.013	0	0.959	0.959
0.283	0.499	0	0	0.283	0.499

Note: High and low REERV, HV and LV respectively. High and low cereal exports, HX and LX respectively. All the eigenvalues lie inside the unit circle. P-VAR satisfies stability condition.
Source: Own estimations.