Real exchange rate volatility and Argentine sectoral exports: evidence of a long-run relationship

Fernando Andrés Grosz* and Ignacio Warnes**

Buenos Aires, August 2023

JEL Classifications: F10, F31

Abstract

In this paper we analyze whether there is a long-run relation between real exchange rates, exchange rate volatility and total as well as sectoral Argentine exports. When we analyze each of the sectoral exports and real exchange rate volatility, we find a cointegrating vector that passes all diagnosis tests in three cases: total exports and volatility, hydrocarbons and volatility, and heavy industry and volatility. In these cointegrating vectors the coefficients of exchange rate volatility are significant and the sign coincides with most empirical findings, namely that more volatility will be associated with a decrease in exports in the corresponding sector. Nevertheless, these results are not robust to the introduction of the variable real exchange rate into the system, suggesting that more research should be performed. We also find that for the food sector there is a cointegrating vector relating sectoral exports, real exchange rate and its volatility measure.

I. Introduction

After the breakdown of the Bretton Woods system of international exchange rates, several scholars started to question whether the new prevailing exchange rate movements and its volatility have negative effects on foreign trade. This point has great significance because if this negative relationship can be proven, the design of

* Universidad de San Andrés, Escuela de Negocios and Universidad Católica Argentina, Departamento de Economía y Finanzas.

** Universidad Católica Argentina, Departamento de Economía y Finanzas. Corresponding author. E-mail address: ignaciowarnes@uca.edu.ar

exchange rates and monetary policy regimes should consider that effect. Several researchers have studied this problem both with a theoretical and with an empirical approach. Among these works, it is important to highlight the theoretical and empirical work of Caballero and Corbo (1989) as well as the empirical works of Arize, Osang and Slottje (2000) and Arize, A.C. Malindretos J. and Kasibhatla, K.M. (2003). Also, the works of Eichengreen and Gupta (2012) and Serven (2003) which show that foreign exchange volatility is detrimental to exports. Our work is part of a literature that attempts to capture the costs in terms of foreign trade associated with exchange rate uncertainty. As Bagella, Beccheti and Hassan (2006) have shown, the existence of these costs to economic activity of excessive real exchange rate volatility is compatible with the simultaneous existence of costs to economic growth associated with the adoption of fixed exchange rate regimes as documented, among others by Edwards and Yeyati (2003), since in those regimes, typically it is the nominal rate that constitutes the anchor, rather than the real multilateral exchange rate. Arize et al (2003) argue that "most empirical works treat exchange rate volatility as a risk: higher risk leads to higher cost for risk averse traders and to less foreign trade. This is because the exchange rate is agreed on at the time of the trade contract, but payment is not made until the future delivery takes place." Their work is a relevant precursor of our study, in which the authors, using cointegration methods, analyzed ten developing countries. They found out a stable long-term relationship between exports, and economic activity in foreign markets, exchange rates and the volatility of exchange rates. In their sample, for all but one of the ten countries studied, the coefficient for volatility of real exchange rates is statistically significant with a negative sign. Similar results were found by Pino, Tas y Sharma (2016), Arize, Osang and Slottje (2000), and Sukar and Hassan (1999) among others. A survey by Warnes I. (2022) summarizes many of the papers in this literature, and particularly those works which focus on developing countries. We attempt to shed light, for Argentina, on the following questions: what is the incidence of the macroeconomic factors, represented by the real exchange rate level as well as its volatility, on the growth of the country's total exports, and also, if there was a relation on the growth of export capacity in each of several specific sectors, such as heavy industry, agriculture, food industry or the mining and hydrocarbon sectors. Do we find consistent effects and are these effects dependent on the specific economic sector under consideration? We aim to answer these questions from a long-run perspective using Vector Error Corrections Models.

The rest of the paper is organized as follows: section II describes the data and provides summary statistics. Section III computes unit root tests for all variables. Next, section IV presents the estimation results for a two-variable system of sectoral exports and real exchange rate volatility, while Section V adds to the analysis a third variable, the real exchange rate. Section VI concludes.

II. Data

In this section we explain the sources of the data that has been used to examine the relation between sectoral exports, real exchange rate, our real exchange rate volatility measure and we provide descriptive statistics. The period that has been analyzed was January 2010 to December 2020, with monthly frequency.

II. a. Data sources and description

Two variables are considered, at different stages, as determinants of sectoral exports: a measure of real exchange rate, and a proxy for real exchange rate volatility.

The measure of real exchange rate used in the empirical analysis was the real broad effective exchange rate (RBEER) published by the Bank of International Settlements (BIS). BIS publishes data on 60 RBEER of countries and the Euro Area with a monthly frequency. This real exchange rate is a multilateral one, which is constructed as a weighted average of bilateral real exchange rates of a country, in which the weights are the shares of this country with the others cross section units.[1] The shares are calculated as the sum of exports plus imports of a country with each trading partner – cross section unit – as a fraction of total exports plus imports of the country. BIS employs a methodology where the shares are fixed within three-year periods in the RBEER calculation.[2]

It should be noted from its definition that an increase in real exchange rate denotes a real exchange rate appreciation vis a vis the country´s trading partners currencies.

[1] The term *cross section unit* is used instead of *country* because BIS publishes data on the EURO area as well.
[2] Shares are fixed in BIS methodology between years 2008-2010, 2011-2013, 2014-2016, 2017 and 2019.

Throughout this paper, we will use its natural logarithm and will refer to it as LRBEER.

The measure of volatility used in this paper follows Arize et. al. (2000). It is calculated as the square root of the average over twelve (monthly) squared first differences in LRBEER, and we will refer to this measure of real exchange rate volatility as SD12, which we define as:

$$SD12_t = \sqrt{\frac{1}{12}\sum_{i=0}^{11}(LRBEER_{t-i} - LRBEER_{t-i-1})^2}$$

As mentioned above, in this paper we explore whether there is a relation between sectoral exports, real exchange rate, and real exchange rate volatility of Argentina. We explore the possibility that some of the variables mentioned above may or may not affect exports and analyze sectoral exports as well as total exports. In other words, we search to determine whether there are empirical asymmetries when analyzing sectoral exports´ determinants, namely real exchange rate level and its volatility.

Data on sectoral exports was obtained from United Nations Comtrade Database and since it is expressed in US dollars, exports were converted at constant prices - January 2010 prices- using the Producer Price Index for the United States, which was obtained from the Federal Reserve from St. Louis.

In this paper, we classify sectoral exports in six different categories, which are:

- Category AHX (agriculture and husbandry exports): agriculture, live animals, fish, and other aquatic invertebrates.[3]
- Category FPX (Food products exports): milk and dairy products, Animal or Vegetable Fats and Oils, Prepared Foodstuffs, Beverages, Spirits, and Vinegar; Tobacco and Manufactured Tobacco Substitutes.[4]

[3] Category AHX comprises UN Harmonized Tariff Schedule´ (UN HS) two-digit codes 01, 02, 03, 05, 06, 07, 08, 09, 10, 12, 13 and 14.
[4] Category FPX includes UN HS two-digit codes 04, 11, 15, 16, 17, 18, 19, 20, 21, 22, 23 and 24.

- Category HCX (hydrocarbons exports).[5]
- Category MINX (mineral exports other than hydrocarbons).[6]
- Category HIX heavy industry.[7]
- Category LIX: light industry.[8]

II. b. Descriptive statistics

Table 2.1 shows descriptive statistics for the variables: the real broad effective exchange rate, referred to as RBEER, its natural logarithm, denoted by LRBEER, our measure of real exchange volatility, SD12, as well as the natural logarithm of Argentina´s monthly total (TX) and sectoral exports. The first column on Table 2.1 shows the variable. The second column shows the mean value of each variable, where the mean value is calculated as the average of the 132 observations (11 years of monthly observations). The third column on the table shows, for each variable, its coefficient of variation, i.e., sample standard deviation divided by sample mean. The next two columns exhibit the sample minimum and maximum values of each variable.

Table 2.1. Main Summary Statistics for Variables for Argentina

Variable	Mean	Stand. Dev.	Coef. of Variation	Min	Max
RBEER	141.66	29.48	0.208	89.60	185.4
LRBEER	4.34	0.219	0.050	3.90	4.63
SD12	0.0093	0.0052	0.560	0.0035	0.0211
ln(TX)	22.34	0.173	0.0078	21.89	22.74
ln(AHX)	20.94	0.331	0.0158	19.89	21.52
ln(FPX)	21.12	0.245	0.0116	20.14	21.55
ln (HCX)	19.10	0.604	0.0316	17.51	20.31
ln(MINX)	17.67	1.298	0.0735	15.18	19.82
ln(HIX)	20.89	0.327	0.0157	19.62	21.45
ln(LIX)	19.45	0.261	0.0134	18.65	19.85

Source: Own computation based on data from Bank of International Settlements and Comtrade.

[5] This category comprises UN HS two-digit code 27 for hydrocarbons´ exports (HCX).
[6] Sector MINX includes codes 25 and 26.
[7] UN HS two-digit codes 28, 29, 31, 32, 34, 35, 36, 38, 39, 40, 68, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88 and 89 were considered as heavy industry´ exports sector (HIX).
[8] Light industry comprises UN HS two-digit codes 30, 33, 37, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 69, 90, 91, 92, 94 and 95.

The RBEER reported by BIS satisfies that the sample mean for the 12 months in 2020 is normalized to 100 for each country. An increase of the value of RBEER represents a real exchange rate appreciation in Argentina vis a vis their trading partner´s currencies whereas a real exchange rate depreciation will reduce its value. Since real exchange rate variability during the period 2010-2020 has been considerable for Argentina, Table 2.1 reports the coefficient of variation as well, which tells us how much the standard deviation of each variable as a fraction of its sample mean has been.

Table 2.1 shows that the mining (other than hydrocarbons) sector presents a considerable higher coefficient of variation than all other sectors and is followed by the hydrocarbons sector. It should also be stressed that the coefficient of variation of our measure of real exchange rate volatility, SD12, is considerable higher than that of the logarithm of exports of all the sectors.

III. Augmented Dickey Fuller Tests

In order to be able to perform cointegration analysis we need to show that the variables are integrated of order one, I(1). To do this, we perform an Augmented Dickey Fuller (ADF) test on each of the variables using the modified Akaike lag length criterion.

We run the ADF test, first on the variables in levels and, since we do not reject the null hypothesis of non-stationarity for any of the variables in levels, we perform an ADF test on each variable in first differences. We observe the results of these tests on Table 3.1.

A deterministic trend was included in all ADF tests that were performed and was later discarded when the deterministic trend coefficient was not statistically different from zero.

Table 3.1. Augmented Dickey Fuller for Unit Root Tests

	Level	First Differences
	ADF Stat	ADF Stat
LRBEER	-3.10	-3.46***
SD12	-1.36	-4.32***
ln(TX)	-0.25	-3.40**
ln(AHX)	-2.18	-3.55***
ln(FPX)	-1.94	-4.56***
ln(HCX)	-1.78	-10.40***
ln(MINX)	-2.33	-3.98***
ln(HIX)	0.69	-3.46***
ln(LIX)	2.21	-4.54***

Note: ***, ** indicates significant at 1% and 5% significance level, respectively.

Table 3.1 shows that all variables, in levels, are I(1). The next step consists of analyzing whether there is a cointegrating relation between each sectoral export - as well as total exports-, the logarithm of the real exchange rate level and our measure of real exchange rate volatility.

IV. Cointegration analysis: exports and real exchange rate volatility

Johansen´s procedure delves into cointegration in general multivariate systems where there are at least two integrated series. In this section we analyze systems of two variables, namely, sectoral and total exports and real exchange rate volatility.

The standard references are Johansen (1988, 1991) and Johansen and Juselius (1990). We will next apply the Johansen procedure to determine whether the variables are cointegrated, that is, if there is a linear combination of the I(1) variables that is integrated of order zero or I(0). We will perform the trace and the maximal eigenvalue tests. Johansen and Juselius (1990) recommend using the trace test, since the maximal eigenvalue test does not have nested hypotheses and in some cases the trace and maximal eigenvalue tests reach different conclusions. These tests are sequential. We first evaluate the null hypothesis that there are zero cointegrating vectors; if we reject the null, we then turn to the next line and test whether there is at most one cointegrating vector. Note that the null hypothesis is the same for the trace and maximal eigenvalue tests -the alternative hypothesis, however, is different.

We next show the results when we specify the system with two variables: one of the sectoral exports or the total exports on one hand, and our measure of real exchange rate volatility on the other hand. We perform all tests using a 5% significance level. In all cases, real exchange rate volatility was lagged 12 months to avoid or reduce cases in which there is autocorrelation in the vector error correction model estimation that will be introduced later. Furthermore, the number of lags specified in the vector error correction model followed Akaike Information Criterion optimal length.

Table 4.1 Cointegration Tests for Total Exports (TX)

Trace				**Maximal Eigenvalue**			
H_0	H_1	Stat	5%	H_0	H_1	Stat	5%
$r = 0$	$r > 0$	23.20	15.41	$r = 0$	$r = 1$	20.77	14.07
$r \leq 1$	$r > 1$	2.43	3.76	$r \leq 1$	$r = 2$	2.43	3.76

Table 4.1 shows there is one cointegrating relation between the natural logarithm of total exports and real exchange rate volatility according to both, trace and maximal eigenvalue tests.

Table 4.2 Cointegration Tests for Agriculture and husbandry Exports (AHX)

Trace				**Maximal Eigenvalue**			
H_0	H_1	Stat	5%	H_0	H_1	Stat	5%
$r = 0$	$r > 0$	38.05	15.41	$r = 0$	$r = 1$	34.54	14.07
$r \leq 1$	$r > 1$	3.50	3.76	$r \leq 1$	$r = 2$	3.50	3.76

Table 4.2 provides evidence that there is one cointegrating relation between the natural logarithm of agriculture and husbandry exports and real exchange rate volatility according to both, trace and maximal eigenvalue tests.

Table 4.3 Cointegration Tests for Food Product Exports (FPX)

Trace				**Maximal Eigenvalue**			
H_0	H_1	Stat	5%	H_0	H_1	Stat	5%
$r = 0$	$r > 0$	15.29	15.41	$r = 0$	$r = 1$	13.50	14.07
$r \leq 1$	$r > 1$	1.79	3.76	$r \leq 1$	$r = 2$	1.79	3.76

Table 4.3 reveals that we are not able to reject the null hypothesis that the number of cointegrating vectors is zero. Therefore, there is no cointegrating relation between the natural logarithm of food product´ exports and real exchange rate volatility according to both, trace and maximal eigenvalue tests.

Table 4.4 Cointegration Tests for Hydrocarbons Exports (HCX)

Trace				Maximal Eigenvalue			
H_0	H_1	Stat	5%	H_0	H_1	Stat	5%
$r = 0$	$r > 0$	17.13	15.41	$r = 0$	$r = 1$	13.99	14.07
$r \leq 1$	$r > 1$	3.13	3.76	$r \leq 1$	$r = 2$	3.13	3.76

According to Table 4.4, there is a cointegrating relation between the natural logarithm of hydrocarbons exports and real exchange rate volatility according to the trace statistic, but none according to the maximal eigenvalue tests.

Table 4.5 Cointegration Tests for Mining Exports (MINX)

Trace				Maximal Eigenvalue			
H_0	H_1	Stat	5%	H_0	H_1	Stat	5%
$r = 0$	$r > 0$	8.74	15.41	$r = 0$	$r = 1$	7.72	14.07
$r \leq 1$	$r > 1$	1.01	3.76	$r \leq 1$	$r = 2$	1.01	3.76

According to Table 4.5, we are not able to reject the null hypothesis that the number of cointegrating vectors is zero. Therefore, there is no cointegrating vector between the natural logarithm of mining (other than hydrocarbons) exports and real exchange rate volatility according to both, trace and maximal eigenvalue tests.

Table 4.6 Cointegration Tests for Heavy Industry Exports (HIX)

Trace				Maximal Eigenvalue			
H_0	H_1	Stat	5%	H_0	H_1	Stat	5%
$r = 0$	$r > 0$	19.57	15.41	$r = 0$	$r = 1$	17.17	14.07
$r \leq 1$	$r > 1$	2.40	3.76	$r \leq 1$	$r = 2$	2.40	3.76

Table 4.6 shows that there is one cointegrating vector between the natural logarithm of heavy industrial exports and real exchange rate volatility according to both, trace and maximal eigenvalue tests.

Table 4.7 Cointegration Tests for Light Industrial Exports (LIX)

Trace				Maximal Eigenvalue			
H_0	H_1	Stat	5%	H_0	H_1	Stat	5%
$r = 0$	$r > 0$	13.59	15.41	$r = 0$	$r = 1$	12.11	14.07
$r \leq 1$	$r > 1$	1.48	3.76	$r \leq 1$	$r = 2$	1.48	3.76

According to Table 4.7, there is no cointegrating vector between the natural logarithm of light industrial exports and real exchange rate volatility, according to both, trace and maximal eigenvalue tests.

In summary, when we consider a system of two variables, in which one variable are sectoral exports or total exports, on one hand, and the real exchange rate volatility, on the other hand, we find that there is a cointegrating vector in four instances: when we specify a system with variables (i) exchange rate volatility and total exports; (ii) exchange rate volatility and agriculture and husbandry exports; (iii) exchange rate volatility and hydrocarbons exports ; and (iv) exchange rate volatility and heavy industrial exports.

Table 4.8 presents the cointegrating vectors that have been estimated using Vector Error Correction Models (VECM) for each specification. These are the linear combinations of the non-stationary variables that turn out to be integrated of order zero or I(0). These linear combinations should be understood as a path of the variables that achieve a long-run equilibrium.

In all cases, a Lagrange Multiplier test has been employed to test for serial correlation in the residuals. Whenever there is serial correlation, of any order, then the estimated model would be misspecified. Since there are several lags accounted in VECM estimations, we only inform when there is autocorrelation of any lag order at the 5% significance level.[9]

Table 4.8: Cointegrating Relations

	Cointegrating Equations	LM Test for Autocorr.
Total X:	$\ln(TX)_t + 17.30^{***}\, SD12_{t-12} - 22.48 \sim I(0)$ (5.63)	No autocorrelation
AHX X:	$\ln(AX)_t - 8.99\ \ SD12_{t-12} - 20.86 \sim I(0)$ (7.57)	AR(1) & AR(4)
Hydroc. X:	$\ln(HyX)_t + 54.44^{**}\, SD12_{t-12} - 19.50 \sim I(0)$ (23.65)	No autocorrelation
Heavy Ind X:	$\ln(HeX)_t + 51.18^{***}\, SD12_{t-12} - 21.31 \sim I(0)$ (10.55)	No autocorrelation

Note: standard errors in parenthesis. ***, ** indicates significant at 1 and 5% significance level, respectively.

The first cointegrating equation states that there is a long-run equilibrium path relating the logarithm of total exports and real exchange rate volatility, with an estimated parameter, statistically significant at a 1% significance level, that indicates that higher real exchange rate volatility is related to lower total exports along this path in the long run.

The second cointegrating relation rejects the null hypothesis of no autocorrelation at lag orders 1 and 4, and therefore, we find evidence of model misspecification and further analysis is required regarding how agriculture and husbandry exports and exchange rate volatility are related.

The third cointegrating equation involving hydrocarbons exports and exchange rate volatility results again in a statistically significant parameter estimate at the 5% significance level, stating that an increase in exchange rate volatility will reduce hydrocarbons exports along an equilibrium path in the long run.

[9] The VECM that were estimated and are shown on Table 4.8 satisfy stability conditions as well.

Finally, the last cointegrating relation, encompassing heavy industrial exports and exchange rate volatility, indicates that a rise in exchange rate volatility will result in lower industrial exports in the long run. The parameter estimate is statistically different form zero at the 1% significance level.

V. Cointegration analysis: exports, LRBEER and real exchange rate volatility

In this section we include in our analysis the natural logarithm of the real exchange rate, LRBEER, together with the same variables of exports, total and sectoral, as well as exchange rate volatility SD12, which we were using in the previous section. Both LRBEER and SD12 are lagged 12 months to avoid autocorrelated residuals in the VECM estimation. We start by presenting Johansen cointegration tests for each specification to test if there is a cointegrating vector involving the three variables. Table 5.1 to Table 5.7 show, for total exports and for each sectoral export, both the Trace and Maximal eigenvalue statistics and the 5% significance levels. Whenever there is a cointegrating vector, Table 5.8 shows the parameter estimates.

Table 5.1 Cointegration Tests for Total Exports (TX)

Trace				Maximal Eigenvalue			
H_0	H_1	Stat	5%	H_0	H_1	Stat	5%
$r = 0$	$r > 0$	32.07	29.68	$r = 0$	$r = 1$	26.09	20.97
$r \leq 1$	$r > 1$	5.98	15.41	$r \leq 1$	$r = 2$	5.98	14.07
$r \leq 2$	$r > 2$	0.0003	3.76	$r \leq 2$	$r = 3$	0.0003	3.76

Table 5.2 Cointegration Tests for Agricultural and Husbandry Exports (AHX)

Trace				Maximal Eigenvalue			
H_0	H_1	Stat	5%	H_0	H_1	Stat	5%
$r = 0$	$r > 0$	33.87	29.68	$r = 0$	$r = 1$	27.62	20.97
$r \leq 1$	$r > 1$	6.25	15.41	$r \leq 1$	$r = 2$	6.20	14.07
$r \leq 2$	$r > 2$	0.05	3.76	$r \leq 2$	$r = 3$	0.05	3.76

Table 5.3 Cointegration Tests for Food Products Exports (FPX)

Trace				Maximal Eigenvalue			
H_0	H_1	Stat	5%	H_0	H_1	Stat	5%
$r = 0$	$r > 0$	38.08	29.68	$r = 0$	$r = 1$	32.18	20.97
$r \leq 1$	$r > 1$	5.90	15.41	$r \leq 1$	$r = 2$	5.84	14.07
$r \leq 2$	$r > 2$	0.06	3.76	$r \leq 2$	$r = 3$	0.06	3.76

Table 5.4 Cointegration Tests for Hydrocarbons Exports (HCX)

Trace				Maximal Eigenvalue			
H_0	H_1	Stat	5%	H_0	H_1	Stat	5%
$r = 0$	$r > 0$	22.78	29.68	$r = 0$	$r = 1$	15.81	20.97
$r \leq 1$	$r > 1$	6.97	15.41	$r \leq 1$	$r = 2$	6.91	14.07
$r \leq 2$	$r > 2$	0.063	3.76	$r \leq 2$	$r = 3$	0.063	3.76

Table 5.5 Cointegration Tests for Mining Exports (MINX)

Trace				Maximal Eigenvalue			
H_0	H_1	Stat	5%	H_0	H_1	Stat	5%
$r = 0$	$r > 0$	16.79	29.68	$r = 0$	$r = 1$	10.36	20.97
$r \leq 1$	$r > 1$	6.42	15.41	$r \leq 1$	$r = 2$	6.24	14.07
$r \leq 2$	$r > 2$	0.18	3.76	$r \leq 2$	$r = 3$	0.18	3.76

Table 5.6 Johansen Cointegration Tests for Heavy Industry Exports (HIX)

Trace				Maximal Eigenvalue			
H_0	H_1	Stat	5%	H_0	H_1	Stat	5%
$r = 0$	$r > 0$	26.13	29.68	$r = 0$	$r = 1$	19.88	20.97
$r \leq 1$	$r > 1$	6.25	15.41	$r \leq 1$	$r = 2$	6.20	14.07
$r \leq 2$	$r > 2$	0.05	3.76	$r \leq 2$	$r = 3$	0.05	3.76

Table 5.7 Johansen Cointegration Tests for Light Industrial Exports (LIX)

Trace				Maximal Eigenvalue			
H_0	H_1	Stat	5%	H_0	H_1	Stat	5%
$r = 0$	$r > 0$	24.59	29.68	$r = 0$	$r = 1$	18.40	20.97
$r \leq 1$	$r > 1$	6.22	15.41	$r \leq 1$	$r = 2$	6.21	14.07
$r \leq 2$	$r > 2$	0.01	3.76	$r \leq 2$	$r = 3$	0.01	3.76

Tables 5.1 to 5.3 show that, according to both the Trace and Maximal Eigenvalue Tests, there is exactly one cointegrating vector in each case, i.e., a long run relation, that is, a linear combination of TX, LRBEER and SD12 that is I(0) -Table 5.1-, a linear combination of AHX, LRBEER and SD12 that is I(0) -Table 5.2- and a linear combination of FPX, LRBEER and SD12 that is I(0) -Table 5.3.

However, Tables 5.4 to 5.7 show that according to the Trace and to the Maximal Eigenvalue Tests, there are no cointegrating vectors in the other four cases. In other words, the cointegrating vector found in Section IV for the hydrocarbons Exports (HCX) and for the Heavy Industry Exports (HIX) when the systems only considered as a second variable the exchange rate volatility SD12, does no longer hold. There is no linear combination of the three variables such that the linear combination is I(0), when LRBEER is added to the systems.

Table 5.8 shows the parameter estimates for the three cointegrating vectors that were found. The first one, involving TX, LRBEER and SD12, the second one, relating AHX, LRBEER and SD12 and the last one, the linear combination of FPX, LRBEER and SD12.[10]

Table 5.8: Cointegrating Relations (RBEER & SD12)

	Cointegrating Equations	Lagr.Mult. Test for Auto Corr
Total X:	$\ln(TX)_t - 0.888^{***}\, LRBEER_{t-12} - 14.53\, SD12_{t-12} - 18.29 \sim I(0)$ (0.29) (10.56)	No autocorrelation
Agric X:	$\ln(AHX)_t - 0.33\, LRBEER_{t-12} - 18.65\, SD12_{t-12} - 19.33 \sim I(0)$ (0.58) (21.12)	No Autocorrelation
Food X:	$\ln(FPX)_t - 1.47^{***}\, LRBEER_{t-12} - 26.21^{**}\, SD12_{t-12} - 14.45 \sim I(0)$ (0.327) (11.90)	No autocorrelation

Note: standard errors in parenthesis. ***, ** indicates significant at 1 and 5% significance level, respectively.

[10] The VECM shown on Table 5.8 satisfy stability conditions. Also, in all cases, at no lag order has the null hypothesis of no autocorrelation been rejected.

These cointegrating vectors are long-run equilibrium paths of the variables. As for the first one, the estimate on SD12 is no longer statistically significant, whereas that of LRBEER is statistically significant at the 1% level and states that along this long run equilibrium path, a more appreciated real exchange rate is consistent with a higher level of total exports.

On the other hand, the second cointegrating vector, that shows a long run relation of AHX, LRBEER and SD12, does not have any statistically significant parameter estimates.

Last, the cointegrating vector characterizing a long run equilibrium path of FPX, LRBEER and SD12 presents statistically significant parameter estimates on LRBEER and SD12. The sign on the estimates indicates that along this long run equilibrium path, a more appreciated real exchange rate is consistent with a higher level of FPX or lower exchange rate volatility, or both. As for the parameter estimate on SD12, its statistically significant negative sign suggests that higher exchange rate volatility is consistent with a more depreciated real exchange rate or higher food product exports, or both.

VI. Concluding Remarks and Future Research

In this paper we use Vector Error Correction Models to study if there is a long-run relation of real exchange rates, real exchange rate volatility and total and sectoral Argentine exports using monthly data from 2010 to 2020. Both real exchange rate and real exchange rate volatility are lagged 12 months to avoid autocorrelated residuals in the vector error correction models.

We divide exports products into six different categories, namely, agriculture and husbandry goods, food products, hydrocarbons exports, mining exports other than hydrocarbons, heavy industry, and light industry exports. We consider total exports as well.

When we analyze each of the sectoral exports and real exchange rate volatility (SD12), we find a cointegrating vector that passes all diagnosis tests in three cases: total exports and SD12, hydrocarbons and SD12, and heavy industry and SD12. In these cointegrating vectors the coefficients of exchange rate volatility are significant and possess the sign that coincides with most empirical findings namely that more volatility will be associated with a decrease in exports, in the different categories.

However, when we also include real exchange rate into the systems, two of these long-run relations of the variables no longer hold. Both the Trace and Maximal Eigenvalue Tests show that there is no longer a cointegrating vector for hydrocarbons exports and SD12 and heavy industry exports and SD12 when the real exchange rate is included in the system.

Notwithstanding, when we include real exchange rate to the system, there is a new cointegrating vector involving food products´ exports, SD12 and the real exchange rate. In this case, the parameter estimates in the cointegrating vector are statistically significant and suggest that along this long-run equilibrium path, a more appreciated real exchange rate is consistent with lower real exchange rate volatility and higher food product´ exports.

Overall, these findings suggest that more research needs to be performed. Other variables should be incorporated into the analysis, such as export prices or gross domestic product of the rest of the world, which are often seen as determinants of export demand. It would be valuable to estimate a VECM with these variables included in the system and test whether we still find a cointegrating vector and if we do, interpret the parameter estimates of the model.

References

Arize, A. C., Osang, T., & Slottje, D. J. (2000). Exchange-rate volatility and foreign trade: evidence from thirteen LDC's. *Journal of Business & Economic Statistics*, *18*(1), 10-17.

Arize, A. C., Malindretos, J., & Kasibhatla, K. M. (2003). Does exchange-rate volatility depress export flows: The case of LDCs. *International Advances in Economic Research*, *9*(1), 7-19.

Caballero, R. J., & Corbo, V. (1988). *Real Exchange Rate Uncertainty and Exports: Multi-Country Empirical Evidence* (No. 414). Columbia University, Department of Economics.

Bagella, M., Becchetti, L., & Hasan, I. (2006). Real effective exchange rate volatility and growth: A framework to measure advantages of flexibility vs. costs of volatility. *Journal of Banking & Finance*, *30*(4), 1149-1169.

Barry Eichengreen and Poonam Gupta1 The Real Exchange Rate and Export Growth: Are Services Different? November, 2012

Edwards, S., & Yeyati, E. L. (2005). Flexible exchange rates as shock absorbers. *European economic review*, *49*(8), 2079-2105.

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of economic dynamics and control*, *12*(2-3), 231-254.

Johansen, S. (1991). Estimation and hypothesis testing of cointegration vectors in Gaussian vector autoregressive models. *Econometrica: journal of the Econometric Society*, 1551-1580.

Johansen, S., & Juselius, K. (1990). Maximum likelihood estimation and inference on cointegration—with applications to the demand for money. *Oxford Bulletin of Economics and statistics*, *52*(2), 169-210.

Pino, G., Tas, D. and Sharma, S.C. (2016). An investigation of the effects of exchange rate volatility on exports in East Asia. *Applied Economics*, *48*(26), pp.2397-2411.

Servén, Luis (2003), “Real Exchange Rate Uncertainty and Private Investment in LDCs,” Review *of Economics and Statistics* 85, pp.492-492.

Sukar, A. H., & Hassan, S. (2001). US exports and time-varying volatility of real exchange rate. *Global Finance Journal*, *12*(1), 109-119.

Warnes, Ignacio. "The impact of exchange rate volatility on economic growth and international trade." *Cultura Económica* 40.104 (2022): 49-67.