Mexico's Trade Flows in the NAFTA era: Evidence on the Marshall-Lerner condition from a VEC-GARCH approach

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Abstract

This paper evaluates the Marshall-Lerner condition in Mexico during the NAFTA era, using monthly data over 1994-2014. Our contribution is twofold. First, we model volatility in the net trade function by using a vector error-correction model with auto regressive conditional heteroskedasticity (VEC-GARCH). Second, we test the Marshall-Lerner condition explicitly and examine its robustness. The results show strong evidence on unit roots and cointegration as well as on multivariate GARCH effects in the net trade function. While we find a long run relationship in line with economic theory as well as non-negligible conditional volatility, we do not find convincing evidence on the Marshall-Lerner condition. Only the income elasticities turn out to be statistically significant. Accordingly, the study suggests that exchange rate depreciations related to the forthcoming normalization of monetary policy in the U.S. may not improve Mexico's net export growth in the long run.

Keywords: Import and export demand, Cointegration, Vector Error Correction, GARCH, Exchange rate volatility.

JEL Classification: F10, F14.

1 Introduction

Since the financial crisis of 2008, several emerging economies around the world have experienced major currency depreciations against the U.S. dollar. For instance, between September 5th 2008 and June 30th 2015, the Brazilian Real has depreciated 84.6%; Russian Ruble, 119.4%; Indian Rupee, 43.7%; South African Rand, 51.6%; Mexican Peso, 49.2%; and Indonesian Rupiah, 42.9% (IMF, 2015). The forthcoming normalization of monetary policy in the U.S. opens up the possibility of further depreciation of these currencies in the next years.

For an individual emerging economy, one concern is the effect of this large and persistent currency depreciation on its trade balance in the long run. It is common knowledge that depreciation of the domestic currency will affect the country's trade balance if it translates into real terms. However, it is not clear that real depreciation will improve the trade balance or deteriorate it. As remarked in Onafowora (2003), a real depreciation of the domestic currency does not have an unambiguous effect on the trade balance since increases exports but it also increases the value of imports.

For years, the Marshall-Lerner condition (MLC), named after Alfred Marshall and Abba P. Lerner, has been widely used to analyse the possible effects of depreciation (devaluation) of the domestic currency in several countries. Briefly, it states that devaluation (depreciation) of the currency will improve the trade balance in the long run if the sum of the absolute values of the demand relative price elasticities for the country's exports and imports exceeds unity. Nonetheless, right after the depreciation (devaluation), the trade balance still may worsen and improve later (J-curve effects).

In the present paper, we investigate if Mexico's trade balance satisfies the MLC during the North American Free Trade Agreement (NAFTA) era. No doubt, NAFTA represents a major policy shift for the country and, since it came into force, in January 1994, the country's economy has greatly open. In 1994, merchandise trade was 27.1% of its GDP. Now, it is 63.1% of its GDP (World Bank, 2015). Thus, Mexico is actually one of the most open emerging economies and, due to its great exposure to international trade, the results of this investigation will be relevant for policy recommendations in the context of the normalization of monetary policy in the U.S.

Our work extends the related literature in two ways. First, we estimate a reduced-form equation of the trade balance and formally test the MLC. The reduced-form equation modelling is equivalent to the approach based on estimation of the relative price elasticities of imports and exports. However, unlike the latter, our approach allows proper statistical treatment of the established hypothesis. To the best of our knowledge, this is the first time that results from a reduced-form equation approach are presented for the case of Mexico.

Second, we account for possible conditional volatility of all fundamental variables of the trade balance through a model that considers, in addition to cointegration, GARCH effects in a multivariate setting. Although various studies have shown that conditional volatility, particularly of real exchange rates, plays an important role in trade functions the dynamics of volatility has not been modelled in a comprehensive way. Moreover, we have verified that the literature on the validity of the MLC does not consider explicitly the volatility phenomena. Thus, we contribute to the literature by considering a vector error-correction model with GARCH effects (VEC-GARCH).

Our empirical work involves unit root testing and cointegration analysis as well as estimation of VEC models with various multivariate GARCH specifications and formal evaluation of the MLC. It should be emphasized that the VEC-GARCH models will be estimated by Maximum Likelihood using numerical optimization algorithms. We find that the fundamental variables of the trade balance reduced-form equation do exhibit conditional volatility and that the Marshall-Lerner condition does not appear to hold. There is evidence that the trade balance equation conforms one cointegrating relationship. Also, suitable diagnosis tests reveal conditional volatility patterns in the VEC residuals. Overall, VEC and VEC-GARCH estimates provide significant long-run domestic and foreign income elasticities with the expected signs. Although the estimated real exchange rate elasticities are positive, they are found not statistically significant and, hence, formal Wald tests do not support the validity of the MLC in the long run. For certain VEC-GARCH especifications, the MLC holds but their results do not seem compelling since they are in conflict with existing empirical results, exogeneity considerations or economic theory.

The rest of the paper is organized as follows. In Section 2, we present a literature review where we address the main empirical issues concerning the MLC as well some results already found for Mexico and the issue of volatility effects in the trade equations. In Section 3, the estimation and testing strategy is outlined. In Section 4, we present the data, results on unit root and cointegration tests, VEC estimates for the reduced-form equation of the trade balance and the corresponding VEC-GARCH estimates. Various robustness checks are presented in Section 5 and some final remarks and policy recommendations are offered in Section 6.

2 A brief overview of the literature

2.1 On the Marshall-Lerner condition

Since the seminal empirical paper by Houthakker and Magee (1969), the verification of the MLC has heavily relied on the estimates of the price elasticities obtained from export and import equations derived from the "imperfect substitutes" model of trade, which relates the imports of a country to its income and to the relative price of imports. Likewise, exports of a country are related to the partner country's income and the relative price of exports.

Several studies have resorted to these equations to characterize the trade flows and the corresponding income and price elasticities of developed and emerging economies (Khan, 1974; Thursby and Thursby, 1984; Márquez and McNeilly, 1988; Senhadji and Montenegro, 1998; Arize et. al., 2008). However, this approach has a major disadvantage for testing the MLC as the price elasticities of both exports and imports are estimated from separate regressions making it impossible to assess the level of statistical significance of the sum of their absolute values.

In a different way, Rose (1991) estimated a reduced-form equation for the trade balance for five major individual OECD countries to examine how this variable is affected by movements in the real exchange rate. The equation relates trade balance to real exchange rate, domestic income and the partner country's income. Overall, his results suggest that the MLC does not hold (i. e., a real exchange rate depreciation does not cause an improvement in the trade balance) due to the lack of statistical significance of the real exchange exchange elasticity. Rose remarked the importance of unit root and cointegration testing in empirical research on trade, as he found that the relevant series can be characterized as I(1) processes. Since the 1990's, non-stationary times series methods became also the conventional framework for estimating trade equations.

Following Rose (1991) and Lee and Chinn (1998), Boyd, Caporale and Smith (2001) estimate a reduced-form equation for the trade balance for eight individual OECD countries. They test for the existence of short run J-curve effects for each country, through Generalized Impulse Response Functions (Pesaran and Shin, 1998). They find that only in four countries the MLC is satisfied in the long run and that in six countries there is evidence of J-curve effects.

More recently, Onafowora (2003) and Anastassiou and Vamvoukas (2012) have extended the methodology developed in Boyd, Caporale and Smith (2001) to emerging economies. The former analyses the MLC in the context of the large exchange rate depreciations registered in East Asian countries in the late 1990's. Onafowora's main results suggest that the MLC holds in the long run and that there is a varying degree of J-curve effects across the countries of the sample. The latter, assesses the impact of real exchange rate changes on Irish external trade performance. The authors find that Ireland's international trade satisfies the MLC during a period of high competitiveness of its economy. Unlike Onafowora, Anastassiou and Vamvoukas do not address the existence of J-curve effects.

In the case of Mexico, the empirical literature has focused on the estimation of the export and import equations in accordance with the "imperfect substitute" model of trade (Reinhart, 1995; Fullerton, Sawyer and Sprinkle, 1997; Senhadji, 1997; Garcés, 2008; Bahmani-Oskooee and Hegerty, 2009; Romero, 2010; Cermeño and Rivera, 2014). Like the international literature on trade, the studies for Mexico have adopted the non-stationary time series methodology based on the fact that trade flows, income and relative prices can indeed be characterized as I(1) processes.

In this literature, the results of Reinhart (1995) and Bahmani-Oskooee and Hegerty (2009) suggest that Mexico's trade balance does not satisfy the MLC. These authors estimate both export and import price elasticities. In each case, the sum of the absolute values of the price elasticities is less than one. However, Cermeño and Rivera (2015) find that the sum of the absolute values of their export and import price elasticities is greater than one.[1] As commented earlier, the previous outcomes lack of the required statistical significance as to establish, with some confidence, whether the MLC holds or not.

On the other hand, Galindo and Guerrero (1997) estimate a reduced-form equation of the trade balance of Mexico, similar to that of Boyd, Caporale and Smith (2003), and test the MLC condition using data from the period 1980-1995. The estimated real exchange rate elasticity is greater than one although they do not show its statistical significance. Actually, their results do not seem compelling as the authors carried a cointegration procedure to estimate elasticities despite the fact that not all the variables in the trade balance equation were shown to be I(1).

An alternative source of information about the MLC for Mexico is the literature that estimates Thirwall's (1979) balance of payments equilibrium restricted growth model (Loria, 2003; Guerrero, 2006; Ibarra and Blecker, 2014). In general, these studies are supportive of the MLC. As for the existence of J-curve effects, the literature for Mexico rarely addresses this question since it focuses on the estimation of trade elasticities.

[1] Several authors only estimate the export equation or the import equation for Mexico so it is difficult to find comparable export and imports price elasticities.

2.2 Volatility and Trade

A striking feature of the recent empirical literature based on the reduced-form equation revised so far is that it does not model volatility explicitly. In our opinion, this issue has mainly been treated, partially, in empirical studies related to the export function. For example, exchange rate volatility has been widely considered by including it as another independent variable in the respective trade equation.

Bredin et. al (2003), use the moving standard deviation of the effective exchange rate's growth rate in the export equation of Ireland. Arize et. al. (2008) resort to the predicted values of an ARCH(1) model of the conditional variance of quarterly differences of the real exchange rate in the export equations of eight individual Latin-American countries. Onafowora and Owoye (2008) use the predicted values of a GARCH(1,1) model of the conditional variance of the real exchange rate in the export equation of Nigeria. In the three cases, the long run coefficient of the exchange rate volatility is significant and only in the first case is positive. Nonetheless, one important drawback of this literature is that volatility of trade flows themselves is absent.

Grier and Smallwood (2007) extended the empirical volatility framework to include the volatility of the income variable as another independent variable in the export equation and also to model explicitly the volatility of exports. These authors estimate individual export equations for nine developed and nine developing countries. Their measure of the real exchange volatility is the predicted values of a T-GARCH model (Glosten, Jaganathan and Runkle, 1993) of the conditional variance of the effective real exchange rate. Their measure of the income volatility is constructed in the same manner. They specify the conditional variance of error as a T-GARCH model to account for the volatility of exports. Overall, exchange rate volatility has a negative and significant effect on exports of developing economies while in the case of developed countries this effect is negligible. As for the volatility of income, it has a positive and significant impact on the exports of almost all the countries of the sample.

Mexico's trade flows have also been characterized in a volatility framework. The country was part of the sample of Grier and Smallwood (2007). The particular results of this study for Mexico are that exchange rate volatility has a negative and significant effect on its exports and that foreign income volatility has a negative and significant export effect too. Bahmani-Oskooee and Hegerty (2009) estimated both Mexico's export and import equations. In each equation, they include as a measure of exchange rate volatility, the standard deviation of the monthly real exchange rate in a year. Unlike Grier and Smallwood, they did not consider the volatility of the respective income variables. Bahmani-Oskooee and Hegerty discovered that neither the real exchange rate nor its volatility affect Mexican exports or imports.

Furthermore, Cermeño, Jensen and Rivera (2010) estimated both Mexico's export and import equations. For each equation, they estimated a VEC model with multivariate GARCH effects (VEC-GARCH) and then estimated a multivariate system including the predicted values from the multivariate GARCH in the VECM in a VEC-GARCH-M fashion. They did so to consider possible volatility effects from all the fundamentals on the country's trade. The main results are that the real exchange volatility reduces imports, the volatility of imports increases imports, the volatility of exports increases exports too and the volatility of the US income reduces exports.

3 Model and Empirical Strategy

Along the lines of Rose (1991), Boyd, Caporale and Smith (2001) and Hsing (2010), among others, we begin with the following reduced-form equation of the trade balance:

$$x_t = \beta_0 + \beta_1 e_t + \beta_2 y_t^d + \beta_3 y_t^f + u_t \tag{1}$$

Where x denotes the ratio of exports to imports (X/M), e is the real exchange rate, y^d and y^f are, respectively, the domestic and foreign real income, all of them expressed in logarithms, and u is a random disturbance. As discussed elsewhere in the related literature, it is better to employ the ratio of exports to imports as a measure of the trade balance because it allows to test the M-L condition explicitly. Moreover, this definition of the trade balance does not require to measure exports and imports both in domestic or foreign currency. In the context of trade balance models, it has been shown that:

$$\beta_1 = \eta_x + \eta_m - 1 \tag{2}$$

Where η_x and η_m are the export and import price elasticities, respectively. Therefore, $\beta_1 > 0$ implies that the M-L condition holds.[2] Given the evidence on stochastic trends and cointegration reported in various studies, we consider the vector of I(1) variables $\mathbf{z} = \begin{pmatrix} x & e & y^d & y^f \end{pmatrix}^\tau$, where τ is the transposition operator. Further we consider the following VEC representation of equation (1):

[2]By construction, in this paper an upward movement of the real exchange rate means a real depreciation of the domestic currency

$$\Delta \mathbf{z}_t = \mathbf{\Gamma}_1 \Delta \mathbf{z}_{t-1} + \cdots + \mathbf{\Gamma}_{t-p+1} \Delta \mathbf{z}_{t-p+1} + \boldsymbol{\alpha}\boldsymbol{\beta}^{\tau} \mathbf{z}_{t-1} + \mathbf{u}_t \tag{3}$$

The vector $\boldsymbol{\beta}^{\tau} = \begin{pmatrix} 1 & \beta_{01} & \beta_{11} & \beta_{21} & \beta_{31} \end{pmatrix}$ contains all the parameters (constant term and elasticities) of the trade balance equation. Correspondingly, the vector $\mathbf{z}_{t-1}$ is defined as $\mathbf{z}_{t-1} = \begin{pmatrix} x_{t-1} & 1 & e_{t-1} & y_{t-1}^d & y_{t-1}^f \end{pmatrix}$, and the product $\boldsymbol{\beta}^{\tau}\mathbf{z}_{t-1}$ represents the equilibrium relationship.[3] The vector $\boldsymbol{\alpha} = \begin{pmatrix} \alpha_{11} & \alpha_{21} & \alpha_{31} & \alpha_{41} \end{pmatrix}^{\tau}$ contains the speeds of adjustment of each variable in the system whenever the equilibrium relationship is disrupted.

In order to model volatility, we assume that the disturbance vector $\mathbf{u}_t$ follows a multivariate normal distribution with a zero mean vector and conditional covariance matrix $\boldsymbol{H}_t$. For practical reasons, our benchmark specification will be the well-known constant conditional correlation (CCC) model proposed by Bollerslev (1990). Thus, the diagonal elements of $\boldsymbol{H}_t$, which represent the conditional variance of each of the variables of the trade balance function, are modelled as:

$$h_{ii,t} = \alpha_i + \delta_i h_{ii,t-1} + \gamma_i u_{ii,t-1}^2, \quad for \quad i = 1, 2, 3, 4 \tag{4}$$

The off-diagonal elements of $\boldsymbol{H}_t$, that describe the time-varying conditional covariance of each pair of variables, are given by:

$$h_{ij,t} = \rho_{ij}(h_{ii,t-1} h_{jj,t-1})^{1/2}, \quad for \quad all \quad i \neq j \tag{5}$$

Where ρ_{ij} is the constant conditional correlation coefficient among each pair of variables.[4]

In sum, our empirical model is a tetra-variate vector error-correction model with generalized autoregressive conditional heteroskedasticity (VEC-GARCH) that allows for conditional heteroskedasticity in a multivariate setting. Specifically, $h_{11,t}, h_{22,t}, h_{33,t}, h_{44,t}$ are, respectively, the time varying conditional variances of x_t (trade balance), e_t (real exchange rate), y_t^d (real domestic income) and y_t^f (real foreign income).

Following Seo's (2007) theoretical findings, the proposed VEC-GARCH model will be estimated by Maximum Likelihood, which is proven to be consistent and efficient. Furthermore, along the same guidelines, provided there is cointegration, inference will be made in a standard way.

Consequently, in order to test for the Marshall-Lerner condition we will evaluate the null hypothesis $H_0 : \beta_{11} = 0$ against the alternative $H_1 : \beta_{11} > 0$

[3]For simplicity we assume here that there is only one cointegrating vector. Later we will substantiate this assumption using formal testing.

[4]Later on, we will check if the results are robust to other, less restrictive specifications.

by means of standard Wald (W) tests. In addition, given the fact that Mexico is a small open economy and, hence, y^f is exogenous, we will test if each of the matrices $\mathbf{\Gamma}_j$ and α have, respectively, the following structure:

$$\begin{pmatrix} \gamma_{11} & \gamma_{12} & \gamma_{13} & \gamma_{14} \\ \gamma_{21} & \gamma_{22} & \gamma_{23} & \gamma_{24} \\ \gamma_{31} & \gamma_{32} & \gamma_{33} & \gamma_{34} \\ 0 & 0 & 0 & \gamma_{44} \end{pmatrix}; \begin{pmatrix} \alpha_{11} \\ \alpha_{21} \\ \alpha_{31} \\ 0 \end{pmatrix} \tag{6}$$

In this way, we test if y^f is block exogenous in the VAR dynamics of the first differences of the series and also if it is weakly exogenous (the corresponding speed of adjustment is zero which implies that y^f is not affected by the disequilibrium in the long run relationship of the country's trade balance). For this purpose we will also use standard W tests. The Wald test for weak exogeneity will have a $\chi^2_{(1)}$ distribution while the test for both weak exogeneity and block-exogeneity will be contrasted with a $\chi^2_{(13)}$ distribution.

Our empirical work will proceed by performing standard unit root tests, followed by cointegration tests in a multivariate context. Next we will go on to test for GARCH effects in all equations of the system. Further, we will present the main results for the proposed VEC-GARCH specifications and the corresponding hypothesis testing. Finally, some robustness checks aimed to substantiate the validity of our approach and empirical findings will be conducted.

4 Results

4.1 Data and Definition of Variables

Our data set consists of monthly data from 1994 to 2014. The trade balance measure (x) is the logarithm of the ratio of total exports to total imports for Mexico. The country's trade data is expressed in U. S. dollars and is seasonally adjusted, as reported by the Instituto Nacional de Estadística y Geografía (INEGI). The RER variable (e) is the seasonally adjusted logarithm of the real exchange rate index of the Mexican peso, provided by Mexico's Central Bank (Banco de Mexico). The index reflects the value of the peso relative to the currencies of 111 countries and its increase represents a real depreciation of the peso.

Domestic real income (y^d) is approximated by the logarithm of the construction sector component of the seasonally adjusted series of the Industrial Activity Index of Mexico, elaborated by the (INEGI). Foreign income (y^f) is approximated by the logarithm of the joint total imports of the United

States, the Euro area, China, Japan and the United Kingdom. These countries' total imports are expressed in US dollars and are seasonally adjusted, as reported by the OECD. We employ the activity in the construction sector to measure Mexico's real income in order to avoid any possible correlation issue between the real exchange rate, world income and tradable domestic production. Correlation can arise due to the high contribution of Mexico's merchandise trade to its GDP.

4.2 Unit Root and Cointegration Tests

In order to establish the non-stationarity of the series, we applied unit root tests to the level of each series: The Dickey-Fuller GLS (DFGLS) test of Elliot, Rothenberg and Stock (1996) and the MZa, MZb, MSB and MPT tests suggested by Ng and Perron (2001). The tests are aimed to tackle the low power and distorted size problems –which can be severe in small samples– of the original unit root tests proposed by Dickey and Fuller (1979, 1981) and Phillips and Perron (1988).

In addition, we performed the stationarity test by Kwiatkowsky, Phillips, Schmidt y Shin (1992) known as the KPSS test. While the null hypothesis of the unit root tests is that the series has a unit root (i. e. the series is not stationary), the null hipothesis of the KPSS test is that the series is stationary (i. e. the series has no unit root). After looking at the findings of previous studies, we expect to observe the null hypothesis of unit root can not be rejected at conventional significance levels whereas the null hypothesis of the KPSS test is indeed rejected.

We also applied the unit root and the stationarity tests to the first difference of each series to discard the presence of multiple unit roots (Pantula and Dickey, 1987).[5] In these cases, we expect to observe the unit root test's null hypothesis is rejected at the conventional significance levels while the null hypothesis of the KPSS test can not be rejected. Overall, eight unit root tests were carried out.Their full results are shown in Table A1 in the Appendix.

In the level of the series, in logarithms, the results of the DFGLS and KPSS tests are both consistent with the presence of a unit root in e, y^d and y^f.[6] Regarding to x, the DFGLS and KPSS tests offer contradictory results but the Ng-Perron tests support the presence of a unit root as indicated by the DFGLS test. With respect to the first difference of the series, the results of both the DFGLS and KPSS tests confirm no unit roots in each of the

[5] The unit root and the stationarity tests were all implemented in Eviews 8.0.

[6] At the 5% significance level.

four series. Based on the these results, all the series of the trade balance equation can be characterized as I(1) processes. Consequently, we proceed to the cointegration testing before estimation.

The results of the Johansen procedure are presented in Table 1. Both the trace and maximum eigenvalue tests provide support for the existence of one cointegrating relationship between x, e, y^d, y^f in a benchmark model specification that allows for an intercept in the cointegrating relationship and no deterministic trends in the levels of the variables.[7] Therefore, the estimated cointegration vector normalized on x will provide the long run elasticities of the trade balance with respect to the real exchange rate as well as domestic and foreign income of the trade balance, as in equation (1). The number of lags selected for the Johansen procedure is 4. This is the order of a VEC representation of equation (1) which shows no residual correlation at 5% level of significance.[8] and is consistent with the Sequential Modified Likelihood Ratio (LR) and Akaike (AIC) selection criterion for a stationary VAR of the level of the series.[9]

[7]Although we are only presenting the results for this model, the finding of the existence of one cointegration relationship is robust across the five possible specifications of the VEC model.

[8]The results of the VEC residual serial correlation LM test are presented in Table A2 in the Appendix.

[9]No root of a VAR of the level of the series lies outside the unit circle. Both the LR and AIC criterion indicate 5 as the optimal order for VAR of the level of the series. The Final Prediction Error criterion (FPE) indicates 4 and the Schwarz (SC) as well as the Hannan-Quinn (HQ) criterion indicates 2. However, as suggested previously, the VECs of lower order exhibit high residual correlation.

Table 1. Johansen cointegration tests.			
Hypothesized No. of CE(s)	Eigenvalue	Statistic	Prob.
Unrestricted cointegration rank test (trace).			
None	0.15	74.24	0.000
At most 1	0.07	34.08	0.066
At most 2	0.04	14.90	0.232
At most 3	0.02	4.60	0.330
Unrestricted cointegration rank test (maximum eigenvalue).			
None	0.15	40.16	0.001
At most 1	0.075	19.19	0.129
At most 2	0.04	10.29	0.309
At most 3	0.018	4.60	0.330
Results obtained with Eviews 8.0. Number of lags: 4. Model with a constant in the cointegrating relationship and no deterministic trends in the levels of the variables. Probabilities based on MacKinnon-Haug-Michelis (1999). Number of observations: 247.			

4.3 Vector Error-Correction Model

The estimation results of the benchmark VEC model are shown in Table 2. The cointegration estimates of elasticities are the normalized Maximum Likelihood estimates of the cointegration vector, multiplied by -1 in order to show the correct signs of these coefficients. An increase of the domestic income has a negative and significant long-run effect on the trade balance, as expected, since it would stimulate consumption of imported goods. On the other hand, an increase of foreign income has a positive and significant effect on the trade balance, also expected, since it would encourage consumption of domestic products overseas.

A noteworthy result is that, in absolute value, the effect of the domestic income is greater than that of the foreign income implying that if both domestic and foreign income grow at the same rate, Mexico's trade balance will deteriorate.

Table 2. VEC estimation.				
Estimates				
	x	e	y^d	y^f
Cointegration estimates (β)	1.00	0.007 [0.053]	-0.50 [0.098]***	0.21 [0.039]***
Adjustment coefficients (α)	-0.19 [0.045]***	-0.27 [0.060]***	0.04 [0.045]	0.06 [0.046]
Error correction estimation statistics				
	D(x)	D(e)	D(y^d)	D(y^f)
R-squared	0.33	0.22	0.20	0.17
Adjusted R-squared	0.28	0.17	0.14	0.12
Sum squared residuals	0.13	0.24	0.14	0.14
S. E. equation	0.02	0.03	0.02	0.02
F-statistic	6.95	4.10	3.50	3.03
Log likelihood	579.97	505.99	576.72	573.56
Akaike (AIC)	-4.56	-3.96	-4.53	-4.51
Vector error correction estimation statistics				
Determinant residual covariance (d.o.f adjusted)				2.01E-13
Determinant residual covariance				1.51E-13
Log likelihood				2244.01
Akaike (AIC)				-17.58
Foreign income exogeneity tests				
$\chi^2_{(1)}$ (p-value)				0.64(0.42)
$\chi^2_{(13)}$(p-value)				13.5(0.41)
Results obtained with Eviews 8.0. Number of lags: 4. Model with a constant in the cointegrating relationship and no deterministic trends in the levels of the variables. Number of observations: 247. Standard errors in [ ]. *, ** & *** denote significance at 10%, 5% & 1% levels, respectively.				

As for the relative price effect, we find that the coefficient of the real exchange rate is positive but not statistically different from zero. This is corroborated by the Wald test of the MLC shown in Table 3 which evaluates the null hypothesis that the aforementioned coefficient is equal to zero. The result implies that the MLC does not hold in these data. Thus, according to this result, even if the depreciation of the mexican peso translates into a real one it would not improve its trade balance in the long run.

Table 3. Wald test on the Marshall-Lerner condition based on VEC $H_0 : \beta_{11} = 0$; $H_1 : \beta_{11} > 0$	
$\chi^2_{(1)}$ statistic	0.009
z-statistic	0.092
Probability	0.463

As mentioned in the cointegration analysis section, the residuals from the VEC model do not show correlation but they do present characteristics that justify including autoregressive conditional heteroskedasticity explicitly. If this is the case, the corresponding Wald test based on the VEC-GARCH estimates would yield a more reliable results regarding to the validity of the Marshall-Lerner condition.

Table 4. VEC residual normality and heteroskedasticity tests.		
Test	Statistic	Prob.
Skweness	149.07	0.000
Kurtosis	1279.51	0.000
Jarque-Bera	1428.57	0.000
White	1890.50	0.001
Number of observations: 247. The null hypothesis of the Jarque-Bera test is that residuals follow a multivariate normal distribution. Orthogonalization: Cholesky (Lutkepohl). The null hypothesis of the White test is that residuals are homoscedastic. The White test includes cross terms.		

As it can be seen in Table 4, according to the Jarque-Bera test, the residuals do not follow a multivariate normal distribution which might be indicative of the presence of heteroskedasticity. This is confirmed by the White test which rejects the hypothesis that the residuals are homoskedastic. Moreover, in Table 5 we show evidence that the variance error of the first difference of the series in a VAR context could be subject to ARCH effects of order greater than one. Consequently,given the previous evidence we consider a Vector Error-Correction Model with GARCH errors (VEC-GARCH) as a suitable specification for the trade balance equation.

Table 5. Heteroskedasticity tests based on the residuals of each equation of a VAR(4) of the first differences of the series.				
Equation	D(x)	D(e)	D(y^d)	D(y^f)
White heteroskedasticity test				
F-Statistic	1.59	7.50	4.18	1.96
Prob.	0.008	0.000	0.000	0.000
ARCH LM test				
F-Statistic	5.87	6.49	8.92	11.91
Prob.	0.003	0.002	0.000	0.000

Results obtained with Eviews 8.0. Number of observations: 247. The null hypothesis of the White test is that residuals are homoscedastic. The White test includes cross terms. The null hypothesis of the ARCH LM test is that there is no ARCH effects up to order 2 in the residuals.

4.4 Vector Error-Correction with GARCH errors

As in the previous section, we consider the benchmark VEC model that allows for an intercept in the cointegrating relationship and no deterministic trends in the levels of the variables. As mentioned in section 3, the conditional variance matrix $\boldsymbol{H}_t$ that is taken as our benchmark specification is the well-known Constant Conditional Correlation (CCC) model. The results are presented in Table 6.

As in the case of the VEC estimates, the domestic and foreign long-run income elasticities have the expected signs and are highly statistical significant, even though they are lower than those of the VEC estimates in absolute value. In the VEC-GARCH estimates, the long-run real exchange rate elasticty has a negative sign but it is not statistical significant at conventional significance levels. The GARCH(1,1) estimates for the conditional variances of the series are presented in Table A3 in the Appendix. Except for the real exchange rate, the conditional variances of the series exhibit significant ARCH(1) or GARCH(1) components in line with the VEC residual diagnosis.

Table 6. VEC-GARCH estimation. $\boldsymbol{H}_t$: Constant Conditional Correlation (CCC)				
Estimates				
	x	e	y^d	y^f
Cointegration estimates (β)	1.00	-0.008 [0.056]	-0.44 [0.088]***	0.18 [0.037]***
Adjustment coefficients (α)	-0.18 [0.046]***	-0.26 [0.107]**	0.05 [0.066]	0.05 [0.034]
Error correction estimation statistics				
	D(x)	D(e)	D(y^d)	D(y^f)
R-squared	0.32	0.23	0.20	0.17
Adjusted R-squared	0.26	0.16	0.13	0.10
Sum squared residuals	0.13	0.24	0.14	0.14
S. E. equation	0.02	0.03	0.02	0.02
Durbin-Watson statistic	1.99	2.01	2.02	2.02
VEC-GARCH estimation statistics				
Log likelihood				2233.71
Average log likelihood				2.26
Akaike (AIC)				-17.36
Foreign income exogeneity tests				
$\chi^2_{(1)}$ (p-value)				1.79(0.18)
$\chi^2_{(13)}$(p-value)				26.5(0.02)

Results obtained with Eviews 8.0. Estimation method: Maximum Likelihood. Number of lags: 4. Model with a constant in the cointegrating relationship and no deterministic trends in the levels of the variables. Number of observations: 247. Bollerslev-Wooldrige robust standard errors in [ ]. *, ** & *** denote significance at 10%, 5% & 1% levels, respectively.

Regarding the exogeneity tests, we do not find evidence against the weak-exogeneity hypothesis meaning absence of feedback from the disequilibrium in the Mexican long run relationship over foreign income. However, the joint hypothesis of weak-exogeneity and block-exogeneity is rejected at the 5%, indicating some feedback from Δx, Δe and Δy^d over Δy^f. Finally, concerning the MLC, the Wald test based on VEC-GARCH estimates does not support its validity. In Table 7 we report the testing results.

Table 7. Wald test on the Marshall-Lerner based on VEC-GARCH $H_0 : \beta_{11} = 0$; $H_1 : \beta_{11} > 0$	
$\chi^2_{(1)}$ statistic	0.021
z-statistic	-0.144
Probability	0.557

5 Some robustness checks

In this section we check if the results obtained so far are robust to other VEC and conditional covariance specifications. First, we evaluate the validity of the results shown in the previous section after relaxing the CCC (constant conditional correlation) assumption for the GARCH process. With this purpose, we consider two versions of the so called "Diagonal Vec(H)" model. The first specification (DVH1) considers that all variances and covariances follow a GARCH(1,1) process while the second specification (DVH2) considers that each variance follows a GARCH(1,1) and all covariances are restricted to zero. The results, presented in Table 8, show that qualitatively the alternative specifications of the variance-covariance process, produce similar results. In particular, the estimates of the income elasticities from the alternative specifications produce almost the same estimates than the CCC model already presented in Table 6. Similarly, the reported evidence does not support the validity of the MLC.

Further, we also consider two alternative specifications for the VEC model. The first one specifies no constant term in the cointegration vector and assumes no linear trends in the levels of the variables (model A) while the second one includes a constant term in the cointegration relationship together with the assumption of linear trends in the levels of the variables (model C).[10] Each of these models is then estimated without GARCH effects and with the three alternative specifications for the GARCH process defined before: CCC, DVH1 and DVH2.

In Tables 9 and 10 we present, respectively, the results for models A and B. The GARCH estimates, not reported due to space considerations, in general, are in line with those obtained for the benchmark model confirming that the explicit modelling of GARCH effects is worthwhile. As far as the weak-exogeneity tests, in the last panel of Tables 9 and 10 we can see that there is no compelling evidence against this hypothesis although the joint hypothesis of weak-exogeneity and block-exogeneity is rejected in all cases, indicating that Δy^f cannot be considered as block-exogenous. Finally, in the

[10]See Tables A4 and A5 in the Appendix for appropiate VEC diagnosis test for these alternative specifications

last panel of the aforementioned tables we report the tests on the MLC. In summary, when considering model A, we find support for the MLC under all variance specifications (See Table 9). However, in the case of model C, the MLC is supported only under the DVH1 specification of the GARCH process (See Table 10).

Although the results shown in Table 9 are quite appealing as far as the favourable outcome on the validity of the MLC, a major drawback of this specification is that none of the income elasticities are statistically significant at the 5% level, which contradicts economic theory and previous empirical findings and lead us to discard this model as a viable specification for Mexico's trade balance. Similarly, an important drawback of specification C (Table 10) is that under one covariance specification (DVH1) it shows evidence against weak exogeneity of foreign income, which is difficult to justify, casting some doubts on the robustness of this model.

Overall, taking into account the evidence reported in this section and in the previous section we can state, at this point, that the validity of the Marshall-Lerner condition is not supported with this data.

Table 8. Comparative of VEC estimates with alternative specifications of the conditional covariance matrix $\boldsymbol{H}_t$.

	CCC (Benchmark)	DVH1	DVH2
Cointegration estimates.			
x	1.00	1.00	1.00
e	-0.008 [0.056]	0.03 [0.043]	0.03 [0.045]
y^d	-0.44 [0.088]***	-0.44 [0.062]***	-0.44 [0.074]***
y^f	0.18 [0.037]***	0.16 [0.025]***	0.16 [0.031]***
Adjustment coefficients.			
D(x)	-0.18 [0.046]***	-0.25 [0.054]***	-0.27 [0.053]***
D(e)	-0.26 [0.107]**	-0.25 [0.056]***	-0.13 [0.045]***
D(y^d)	0.05 [0.066]	-0.14 [0.052]***	-0.07 [0.070]
D(y^f)	0.05 [0.034]	-0.04 [0.028]	-0.01 [0.025]
Foreign income exogeneity tests			
$\chi^2_{(1)}$ (p-value)	1.79 (0.18)	2.13 (0.14)	0.20 (0.65)
$\chi^2_{(13)}$(p-value)	26.5 (0.02)	20.6 (0.08)	37.7 (0.00)
Wald test on the Marshall-Lerner condition $H_0 : \beta_{11} = 0$; $H_1 : \beta_{11} > 0$			
$\chi^2_{(1)}$ statistic	0.021	0.388	0.516
z-statistic	-0.144	0.623	0.718
Probability	0.557	0.267	0.236

Results obtained with Eviews 8.0. Estimation method: Maximum Likelihood. Number of lags: 4. Model with a constant in the cointegrating relationship and no deterministic trends in the levels of the variables. Number of observations: 247. CCC: Constant Conditional Correlation. DVH1: Variances and covariances follow a GARCH(1,1). DVH2: Variances follow a GARCH(1,1), covariances are zero. Bollerslev-Wooldridge robust standard errors in [ ]. *, ** & *** denote significance at 10%, 5% & 1% levels, respectively.

Table 9. Comparative of VEC estimates with alternative especifications for the conditional covariance matrix $\boldsymbol{H}_t$.				
	No-GARCH	CCC	DVH1	DVH2
Cointegration estimates.				
x	1.00	1.00	1.00	1.00
e	0.15 [0.083]*	0.11 [0.059]*	0.25 [0.051]***	0.24 [0.039]***
y^d	-0.05 [0.049]	-0.05 [0.039]	-0.01 [0.034]	-0.05 [0.027]*
y^f	0.03 [0.036]	0.04 [0.029]	0.07 [0.025]	0.03 [0.020]*
Adjustment coefficients.				
D(x)	-0.14 [0.053]***	-0.13 [0.030]***	-0.16 [0.036]***	-0.21 [0.033]***
D(e)	-0.17 [0.066]**	-0.17 [0.066]**	0.02 [0.087]	-0.10 [0.048]**
D(y^d)	0.08 [0.050]	0.07 [0.052]	0.13 [0.030]***	0.12 [0.030]***
D(y^f)	-0.005 [0.029]	-0.007 [0.024]	0.02 [0.021]	-0.02 [0.023]
Foreign income exogeneity tests				
$\chi^2_{(1)}$ (p-value)	0.03 (0.87)	0.10 (0.75)	0.61 (0.44)	0.59 (0.44)
$\chi^2_{(13)}$(p-value)	28.1 (0.01)	26.1 (0.02)	40.7 (0.00)	30.4 (0.00)
Wald test on the Marshall-Lerner condition $H_0 : \beta_{11} = 0$; $H_1 : \beta_{11} > 0$				
$\chi^2_{(1)}$ statistic	3.059	3.361	24.451	36.25
z-statistic	1.749	1.833	4.945	6.02
Probability	0.040	0.033	0.000	0.000

Results obtained with Eviews 8.0. Estimation method: Full Information Maximum Likelihood (FIML). Number of lags: 4. Number of observations: 247. CCC: Constant Conditional Correlation. DVH1: Variances and covariances follow a GARCH(1,1). DVH2: Variances follow a GARCH(1,1), covariances are zero. Huber-White robust standard errors in [ ] for VEC and Bollerslev-Wooldridge robust standard errors for VEC-GARCH models. *, ** & *** denote significance at 10%, 5% & 1% levels, respectively.

Table 10. Comparative of VEC estimates with alternative especifications for conditional covariance matrix $\boldsymbol{H}_t$.

	No-GARCH	CCC	DVH1	DVH2
Cointegration estimates.				
x	1.00	1.00	1.00	1.00
e	0.01 [0.065]	-0.01 [0.057]	0.12 [0.046]***	0.04 [0.044]
y^d	-0.49 [0.162]***	-0.44 [0.088]***	-0.28 [0.082]***	-0.43 [0.072]***
y^f	0.20 [0.65]***	0.18 [0.037]***	0.11 [0.034]***	0.17 [0.030]***
Adjustment coefficients.				
D(x)	-0.18 [0.071]**	-0.17 [0.045]***	-0.25 [0.058]***	-0.28 [0.055]***
D(e)	-0.26 [0.086]***	-0.26 [0.106]**	-0.08 [0.075]	-0.12 [0.044]***
D(y^d)	0.07 [0.075]	0.07 [0.061]	0.14 [0.036]***	-0.07 [0.064]
D(y^f)	0.08 [0.060]	0.06 [0.036]	0.05 [0.023]**	-0.02 [0.024]
Foreign income exogeneity tests				
$\chi^2_{(1)}$ (p-value)	1.69 (0.19)	2.43 (0.12)	4.77 (0.03)	0.62 (0.43)
$\chi^2_{(13)}$(p-value)	28.4 (0.01)	26.6 (0.01)	52.1 (0.00)	37.7 (0.00)
Wald test on the Marshall-Lerner condition $H_0 : \beta_{11} = 0$; $H_1 : \beta_{11} > 0$				
$\chi^2_{(1)}$ statistic	0.030	0.025	6.835	0.715
z-statistic	0.173	-0.159	2.614	0.846
Probability	0.431	0.563	0.004	0.199

Results obtained with Eviews 8.0. Model includes a constant in the cointegrating relationship and allows for linear trends in the levels of the variables. Estimation method: Maximum Likelihood. Number of lags: 4. Number of observations: 247. CCC: Constant Conditional Correlation. DVH1: Variances and covariances follow a GARCH(1,1). DVH2: Variances follow a GARCH(1,1), covariances are zero. Huber-White robust standard errors in [ ] for VEC and Bollerslev-Wooldridge robust standard errors for VEC-GARCHs. *, ** & *** denote significance at 10%, 5% & 1% levels, respectively.

6 Conclusions

In this paper we have conducted an empirical investigation on Mexico's trade balance during the NAFTA era and evaluated the validity of the Marshall-Lerner condition. To this end, we have proposed a VEC-GARCH model as a viable specification and tested the MLC formally, thus contributing with novel results for the Mexican case.

In line with the related literature, we find evidence on unit roots and cointegration. In particular, we find robust evidence, through the Johansen's cointegration tests, that there is one cointegration relationship across all possible specifications of the VEC model. In addition, we also document using formal heteroskedasticity tests the presence of GARCH effects, which justifies the implementation of the VEC-GARCH approach.

After considering a variety of specifications we do not find convincing evidence on the validity of the Marshall-Lerner condition in the case of Mexico during the NAFTA era, using the described data. Thus, our study suggests that relative prices as measured by the real effective exchange rate do not seem to have important effects on Mexico's trade balance. Since September 2008, the 49% nominal depreciation of the Mexican peso has been accompanied by a real depreciation of 9% (Banco de Mexico, 2015). In an environment of low inflation rates, the normalization of monetary policy in U.S. could produce both greater nominal and real depreciation of the peso but it appears this would not improve significantly the country's trade balance in the long run. Therefore, there is no clear benefit from the current and foreseen depreciation of the Mexican peso on Mexico's external balance.

Moreover, the results obtained in this paper point to the importance of income effects, although the magnitudes of the corresponding elasticities indicate that, ceteris paribus, similar growth in both the Mexican and foreign income will deteriorate Mexico's trade balance, perhaps because not only Mexican consumption but also exports are highly dependent on imported goods.

Further evidence, using alternative measures of the fundamental variables as well as other model specifications together with an exploration of possible J-curve effects is certainly necessary.

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8 Appendix

Table A1. Unit root tests statistics					
Test	Deterministic component	x	e	y^d	y^f
DFGLS	t,c	-1.30	-2.05	-2.26	-2.35
MZa	t,c	-3.71	-10.11	-10.46	-17.10*
MZt	t,c	-1.33	-2.24	-2.28	-2.80*
MSB	t,c	0.36	0.22	0.22	0.16*
MPT	t,c	24.05	9.03	8.75	6.10*
KPSS	t,c	0.06	0.28***	0.21**	0.14*
DFGLS	c	-0.38	-1.70*	-0.02	0.86
MZa	c	-0.57	-6.84*	-0.04	0.83
MZt	c	-0.38	-1.83*	-0.02	1.00
MSB	c	0.66	0.27*	0.64	1.21
MPT	c	24.95	3.66*	26.67	95.16
KPSS	c	0.13	0.32	1.80***	2.00***
Test	Deterministic component	D(x)	D(e)	D(y^d)	D(y^f)
DFGLS	t,c	-4.19***	-3.22**	-14.98***	-5.15***
MZa	t,c	-14.90*	-8.21	-124.67***	-32.98***
MZt	t,c	-2.69*	-1.95	-7.89***	-4.06***
MSB	t,c	0.18*	0.24	0.06***	0.12***
MPT	t,c	6.35*	11.36	0.74***	2.77***
KPSS	t,c	0.09	0.08	0.06	0.05
DFGLS	c	-4.23***	-2.57**	-4.77***	-5.00***
MZa	c	-4.32	-5.06	-4.62	-31.66***
MZt	c	-1.41	-1.53	-1.52	-3.97***
MSB	c	0.33	0.30	0.33	0.13***
MPT	c	5.77	4.99	5.31	0.80***
KPSS	c	0.17	0.08	0.06	0.10

Results obtained with Eviews 8.0. The null hypothesis of the KPSS test is that the series is stationary. The null hypothesis of the rest of the unit root tests is that the series has a unit root. Lag length selection: Modified Akaike Information Criterion. Maximum lags = 15. The symbols *, ** & *** denote rejection of the null hypothesis at 10%, 5% & 1% levels, respectively.

Table A2. Bechmark VEC residual serial correlation LM test		
Lag	LM Statistic	Prob.
1	12.09487	0.7374
2	16.74940	0.4020
3	14.70044	0.5467
4	13.28963	0.6515
5	21.77145	0.1507
6	11.07980	0.8045
7	23.94536	0.0907
8	15.88414	0.4611
9	17.22871	0.3709
10	24.66171	0.0760
11	14.04107	0.5957
12	16.57735	0.4134
13	17.10207	0.3790
14	15.46368	0.4910
15	14.87323	0.5339
16	12.75678	0.6905
17	9.308796	0.9002
18	16.97128	0.3875
19	11.31057	0.7899
20	11.64685	0.7679
Number of observations: 247. Null Hypothesis: no serial correlation up to the corresponding lag		

Table A3. CCC conditional variance GARCH(1,1) estimates for benchmark VEC

	x	e	y^d	y^f
Constant	0.0004 [0.0001]***	0.0005 [0.0001]***	0.0000 [0.0000]	0.0001 [0.000]*
ARCH	0.357 [0.145]**	0.421 [0.279]	-0.0004 [0.018]	0.174 [0.085]**
GARCH	0.040 [0.155]	0.096 [0.171]	1.011 [0.013]***	0.577 [0.182]***

Results obtained with Eviews 8.0. Number of observations: 247. Bollerslev-Wooldridge robust standard errors in [ ]. *, ** & *** denote significance at 10%, 5% & 1% levels, respectively.

Table A4. Alternative VECs diagnosis tests				
	VEC A		VEC C	
Test	Statistic	Probability	Statistic	Probability
Unrestricted cointegration rank test (trace) Hypothesized No. of CE(s)				
None	50.58296	0.00330	66.15727	0.00040
At most 1	16.73684	0.32850	26.82356	0.10600
At most 2	6.16369	0.41630	7.933342	0.47260
At most 3	1.34636	0.28760	1.847965	0.17400
Unrestricted cointegration rank test (maximun eigenvalue) Hypothesized No. of CE(s)				
None	33.84612	0.00180	39.33371	0.00100
At most 1	10.57315	0.42660	18.89022	0.10010
At most 2	4.81733	0.50340	6.08538	0.60230
At most 3	1.34636	0.28760	1.84797	0.17400
VEC residual normality test)				
Skewness	167.92	0.000	148.71	0.000
Kurtosis	1388.89	0.000	1261.97	0.000
Jarque-Bera	1556.80	0.000	1410.68	0.000
VEC residual heteroskedasticity test				
White	1917.34	0.000	1891.55	0.001

Results obtained with Eviews 8.0. Number of observations: 247. Number of lags: 4. Probabilities for the cointegrations tests as in MacKinnon-Haug-Michelis (1999). VEC residual diagnosis results based on non-robust covariance matrix estimation. The null hypothesis of the Jarque-Bera test is that residuals follow a multivariate normal distribution. Orthogonalization: Cholesky (Lutkepohl). The null hypothesis of the White test is that residuals are homoscedastic. The White test includes cross terms.

Table A5. Alternative VECs residual serial correlation LM test				
	VEC A residual serial correlation LM test		VEC C residual serial correlation LM test	
Lag	LM Statistic	Probability	LM Statistic	Probability
1	14.57291	0.5561	12.52061	0.7074
2	18.80820	0.2787	16.08400	0.4471
3	16.41243	0.4246	14.50768	0.5609
4	15.72554	0.4723	12.75647	0.6905
5	22.11181	0.1396	19.26950	0.2549
6	9.270219	0.9019	10.16345	0.8580
7	22.84856	0.1178	23.10323	0.1110
8	15.95085	0.4564	15.03603	0.5220
9	20.08404	0.2165	15.92210	0.4584
10	26.11624	0.0524	23.25400	0.1071
11	13.91459	0.6051	13.01016	0.6720
12	17.19139	0.3733	15.39949	0.4956
13	15.96752	0.4552	16.05293	0.4493
14	14.92497	0.5301	14.14588	0.5878
15	14.46782	0.5639	13.55359	0.6319
16	12.33403	0.7207	11.49110	0.7782
17	9.158242	0.9068	8.112155	0.9455
18	17.80702	0.3353	15.28168	0.5041
19	12.29176	0.7237	10.18681	0.8567
20	12.46128	0.7117	10.06740	0.8631
Number of observations: 247. Null Hypothesis: no serial correlation up to the corresponding lag.				