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The Canadian-Mexico Commodity Trade and Exchange Rate Uncertainty: An Asymmetric Analysis

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A previous study assessed asymmetric effects of the real peso-dollar volatility on trade flows between Mexico and the U.S., two members of the former NAFTA. We now expand that analysis by considering the trade flows between Mexico and Canada. Estimating traditional linear models did not yield much significant effects of the real peso-Canadian dollar volatility on trade flows between the two countries. However, estimating a nonlinear model revealed that four out of 16 Canadian exporting industries to Mexico and 10 out of 21 Mexican industries to Canada were affected asymmetrically. While the export shares of four Canadian industries was 28.2%, that of 10 Mexican industries, with a non-linear model was 80%. Additionally, while increased volatility boosted exports of four Canadian industries, it had no significant effects on the exports of 10 Mexican industries. In contrast, decreased volatility had no significant effects on the Canadian exporting industries, but it had favorable impact on Mexican exporting industries

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1 Introduction

Floating exchange rates are said to introduce uncertainty to world markets by making exchange rates and commodity prices to be more volatile. Volatile exchange rate and prices introduce uncertainty to world trade and could eventually hurt trade among nations. Theoretical developments advanced by Hooper and Kohlhagen (1978), De Grauwe (1988), and Peree and Steinherr (1989), however, show that indeed, floating rates could boost the trade. Depending on the degree of risk tolerance by traders, they could trade less or more. Risk averse traders will

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trade less to avoid any loss due to uncertain prices. However, risk tolerant traders will trade more today to cover loss of revenue in the future. Review of empirical studies by Bahmani-Oskooee and Hagerty (2007) supports both views.

Previous studies that assessed the impact of exchange rate uncertainty or volatility on trade flows assumed that the effects are symmetric, meaning that if an x% increase in exchange rate volatility hurts exports of a country by y%, then an x% decrease in volatility will boost that country's exports by y%. However, recently Bahmani-Oskooee and Aftab (2017) argued and demonstrated asymmetric effects of exchange rate volatility on trade flows. Their arguments were mostly based on the downward rigidity of prices in international markets as well as asymmetric impact of exchange rate changes on trade flows.[1] Since asymmetric analysis requires using nonlinear models, it appears that introducing nonlinear adjustment of exchange rate volatility yields more significant outcomes than using linear adjustment or linear models. This point was recently demonstrated further by Bahmani-Oskooee and Harvey (2021) who considered trade flows of 95 U.S. exporting industries to Mexico and 89 U.S. importing industries from Mexico. They reported short-run asymmetric effects in 54 exporting and 46 importing industries. Short-run asymmetric effects lasted into long-run asymmetric effects in 44 exporting and 47 importing industries. As they argued, such asymmetric effects were masked by linear and symmetric models.

Our goal in this paper is to consider trade flows between two other members of the former NAFTA or current United States-Mexico-Canada Agreement (USMCA) which took effect on July 1, 2020. While the literature on Canadian trade flows is huge and reviewed by Bahmani-Oskooee and Harvey (2021), the literature on Mexican trade flows is very poor and includes only limited number of studies such as Arize et al. (2000) who found that exchange rate volatility has a significantly negative effect on Mexico's aggregate exports to the world. Sauer and Bohara (2001) using panel data from Latin America, which included Mexico also found adverse effect. Suspecting that both studies suffer from aggregation bias, De Vita and Abbott (2004b) considered the response of U.S. exports to its five major partners, one of which was Mexico, and found an adverse effect of peso-dollar volatility on U.S. exports to Mexico.

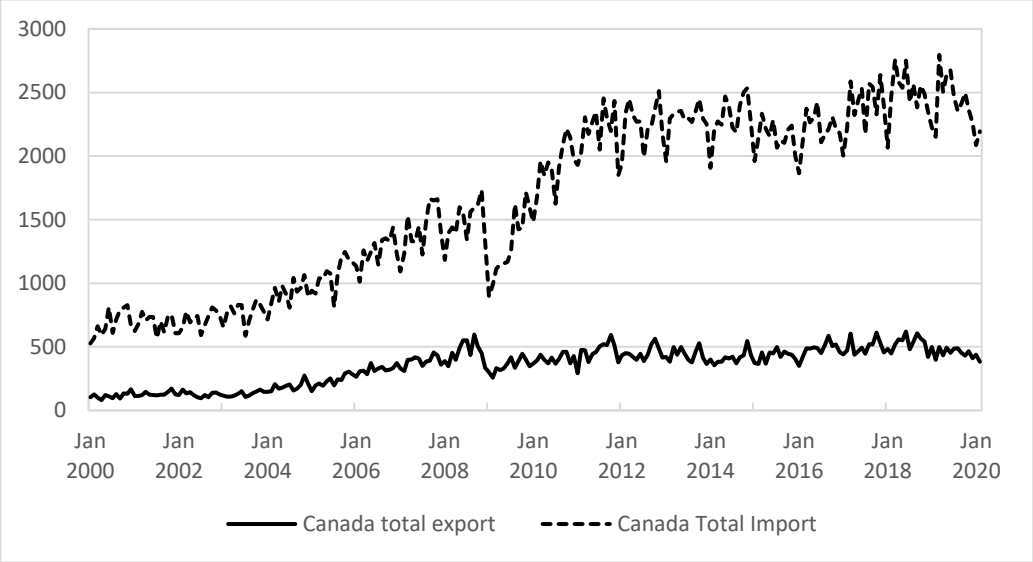
We not only try to add to the literature by assessing symmetric and asymmetric effects of exchange rate volatility on trade flows between Canada and Mexico, but also reduce aggregation bias by using trade flows at commodity or industry level. A total of 16 Canadian exporting industries to Mexico and 21 Canadian importing industries from Mexico are considered.[2] These industries in each group conduct close to 100% of the trade between the

[1] See Bahmani-Oskooee and Fariditavana (2016), Nusair (2016), and Arize et al. (2017) for the asymmetric impact of exchange rate changes on the trade flows or asymmetric J-curve.

[2] Klein (1990), Belanger et al. (1992), Fabiosa (2002), Pickard (2003), and Bahmani-Oskooee and Bolhassani (2012) are studies that have assessed only the symmetric effects of exchange rate volatility on commodity trade flows of Canada with the U.S. but not Mexico.

two countries. While the U.S. is the largest partner of Mexico with 80% trade share, Canada is the second largest with only 3% of trade share. In order to gain some insight about their trade relationship, we plot Canadian exports to and imports from Mexico in Figure 1 during our study period. As can be seen, while Canadian imports which is Mexican exports to Canada has trended upward over time, Canadian exports to Mexico has stayed stable.[3]

Figure 1: Canadian Export to and Imports from Mexico in millions USD



The rest of the paper is organized as follows: In Section II we outline the models and the methods that is followed by our empirical results in Section III. A summary is then provided in Section IV that is followed by an Appendix in which we define variables and provide sources of the data.

2 The Models and the Methods[4]

Bahmani-Oskooee and Harvey (2021) closely followed the literature and included a measure of economic activity, a measure of relative prices, and a measure of the real exchange rate volatility as three major determinants of trade flows. We modify their specifications so that the trade flows models conform to trade between Canada and Mexico as follows:

[3] For composition of trade between the two countries, see Tables 1 and 2 which also includes trade shares of each industry.

[4] The models and methods closely follow Bahmani-Oskooee and Harvey (2021).

$$ln\, X_{i,t}^{CAN} = a + b\, ln\, Y_t^{MEX} + c\, ln\, R\, EX_t + d\, ln\, V_t + \varepsilon_t \quad (1)$$

and

$$ln\, M_{i,t}^{CAN} = e + f\, ln\, Y_t^{CAN} + g\, ln\, R\, EX_t + h\, ln\, V_t + \xi \quad (2)$$

where $X_{i,t}^{CAN}$ is Canadian export of commodity i to Mexico which is assumed to depend on the level of economic activity in Mexico denoted by Y_t^{MEX}, the real bilateral exchange rate between Mexican peso and Canadian dollar, REX_t, and a GARCH-Based volatility of the REX_t, denoted by Vt. Similarly, in (2) $M_{i,t}^{CAN}$ is Canadian import of commodity ii from Mexico or Mexican export of commodity i to Canada which is assumed to depend on Canadian economic activity, Y_t^{CAN}, the same real exchange rate and its volatility.

As far as expected signs of coefficients are concerned, since increased economic activity leads to more trade, we expect estimates of b in (1) and f in (2) to be positive.[5] From the Appendix we gather that the real bilateral exchange rate is defined in a way that a decline reflects a real depreciation of Canadian dollar against Mexican peso. If a real depreciation of the Canadian dollar is to increase its exports and reduce its imports, we expect an estimate of c in (1) to be negative and an estimate of g in (2) to be positive. Finally, since exchange rate volatility could have negative or positive effects on trade flows, estimates of d and h could be negative or positive.

Coefficient estimates discussed above are all long-run estimates. To assess the short-run effects of all exogenous variables, (1) and (2) must be converted to error-correction models. Pesaran et al.'s (2001) ARDL bounds testing approach has some advantages over other approaches in that short-run and long-run effects are estimated in one step by estimating the following error-correction models that are associated with (1) and (2):

$$\Delta LnX_{i,t}^{CAN} = \alpha_0 + \sum_{j=1}^{n1} \alpha_{1j} \Delta LnX_{t-j}^{CAN} + \sum_{j=0}^{n2} \alpha_{2j} \Delta LnY_{t-j}^{MEX} + \sum_{j=0}^{n3} \alpha_{3j}\, \Delta LnREX_{t-j} + \sum_{j=0}^{n4} \alpha_{4j} \Delta LnV_{t-j}$$
$$+\lambda_1 LnX_{t,-j}^{CAN} + \lambda_2 LnY_{t-1}^{MEX} + \lambda_3 LnREX_{t-1} + \lambda_4 LnV_{t-1} + \mu_t \quad (3)$$

$$\Delta LnM_{i,t}^{CAN} = \beta + \sum_{j=1}^{n5} \beta_{1\,j} \Delta LnM_{t-j}^{CAN} + \sum_{j=0}^{n6} \beta_{2\,j} \Delta LnY_{t-j}^{CAN} + \sum_{j=0}^{n7} \beta_{3\,j}\, \Delta LnREX_{t-j} + \sum_{j=0}^{n8} \beta_{4\,j} \Delta LnV_{t-j}$$
$$+ \delta_1 LnM_{t-1}^{CAN} + \delta_2 LnY_{t-1}^{CAN} + \delta_3 LnREX_{t-1} + \delta_4 LnV_{t-1} + \psi_t \quad (4)$$

[5] These estimates could also be negative if increased economic activity or economic growth is due to an increase in production of import-substitute goods (Bahmani-Oskooee 1986).

Once (3) and (4) are estimated by the OLS method, coefficient estimated attached to first-differenced variables will reflect short-run effects and estimates of λ_2-λ_4 normalized on -λ_1 in (3) and δ_2-δ_4 normalized on -δ_1 in (4) will reflect the long-run effects. Pesaran et al. (2001) propose two cointegration tests to validate the long-run estimates. One is the F-test to establish joint significance of lagged level variables in both models and other one is the t-test to establish significance of λ_1 in (3) and δ_1 in (4).[6] Since the distribution of these tests are non-standard, Pesaran et al. (2001) tabulate new critical values for both tests which account for degree of integration of variables. Indeed, under this method variables could be combination of I(0) and I(1) and since almost all macro variables are either I(1) or I(0), this method becomes even more attractive.

Shin et al. (2014) have modified Pesaran et al.'s (2001) approach so that one could also assess the possibility of asymmetric effects of any of the variables. Following Bahmani-Oskooee and Harvey (2021), we concentrate on the variability of the real exchange rate V and try to decompose it into two unique time-series variables where one will reflect only increased volatility and the other one only the decreased volatility. To that end, we first form *ΔLnV* which includes positive and negative changes and using partial sum approach we generate the two variables as follows:

$$POS_t = \sum_{j=1}^{t} max\left(\Delta\, Ln\, V_j\,, 0\right), \text{ and } NEG_t = \sum_{j=1}^{t} min\left(\Delta\, Ln\, V_j\,, 0\,\right)$$

where the *POS* variable which is the partial sum of positive changes, reflects only increased volatility and the *NEG* variable, which is the partial sum of negative changes, reflects only the declines in volatility. We then move back to (3) and (4) and replace *LnV* with the two partial sum variables to arrive at:

$$\Delta LnX_{i,t}^{CAN} = \pi_1 + \sum_{j=1}^{n1} \pi_{2j} \Delta LnX_{t-j}^{CAN} + \sum_{j=0}^{n2} \pi_{3j} \Delta LnY_{t-j}^{MEX} + \sum_{j=0}^{n3} \pi_{4j}\, \Delta LnREX_{t-j} + \sum_{j=0}^{n4} \pi_{5j} \Delta POS_{t-j} + \sum_{j=0}^{n5} \pi_{6j} \Delta NEG_{t-j} + \theta_1 LnX_{t-1}^{CAN} + \theta_2 LnY_{t-1}^{MEX} + \theta_3 LnREX_{t-1} + \theta_4 POS_{t-1} + \theta_5 NEG_{t-1} + \gamma_t \qquad (6)$$

[6] Bahmani-Oskooee (2020) has demonstrated that the t-test in this context is exactly the same as the test of significance of lagged error-correction term in Engle and Granger (1987) specification.

$$\Delta LnM_{i,t}^{CAN} = \sigma_1 + \sum_{j=1}^{n6} \sigma_{2j} \Delta LnM_{t-j}^{CAN} + \sum_{j=0}^{n7} \sigma_{3j} \Delta LnY_{t-j}^{CAN} + \sum_{j=0}^{n8} \sigma_{4j} \Delta LnREX_{t-j} + \sum_{j=0}^{n9} \sigma_{5j} \Delta POS_{t-j} + \sum_{j=0}^{n10} \sigma_{6j} \Delta NEG_{t-j} + \chi_1 LnM_{t-1}^{CAN} + \chi_2 LnY_{t-1}^{CAN} + \chi_3 LnREX_{i,t-1} + \chi_4 POS_{t-1} + \chi_5 NEG_{t-1} + \phi_t \quad (7)$$

Error-correction models like (6) or (7) are commonly referred to nonlinear models even though they are linear when all variables are considered. Nonlinearity originates from the method of constructing the partial sum variables. In contrast, models like (3) or (4) are labeled linear ARDL models.

Shin *et al.* (2014) demonstrate that both the linear and nonlinear models are subject to the same OLS estimation method and the same diagnostic tests. Once we estimate the nonlinear models, we can test short-run and long-run asymmetric effects of exchange rate volatility on trade flows. If at a given lag order j, estimate of $\pi_{5j} \neq \pi_{6j}$ in (6) and estimate of $\sigma_{5j} \neq \sigma_{6j}$ in (7), short-run effects of exchange rate volatility will be asymmetric on trade flows. However, stronger evidence in favor of cumulative or impact short-run asymmetric effects will be confirmed if the Wald test rejected the null hypothesis of $\sum \pi_{5j} = \sum \pi_{6j}$ in (6) and $\sum \sigma_{5j} = \sum \sigma_{6j}$ in (7). As for the long-run asymmetric effects, the Wald test must reject the null of $\theta_4/_{-\theta_1} = \theta_5/_{-\theta 1}$ in (6) and $\chi_4/_{-\chi_1} = \chi_5/_{-\chi_1}$ in (7).[7],[8]

3 Estimation Results

The two linear models (3) and (4) and the two nonlinear models (6) and (7) are estimated using monthly data over the period January 2000 - Feb 2020 for each industry. A total of 16 Canadian exporting industries to Mexico and 21 Canadian importing industries from Mexico (or Mexican exporting industries to Canada) for which continuous monthly data were available are considered. These industries together engage in almost 100% of the trade between the two countries. Since data are monthly, we impose a maximum of 12 lags on each first-different variable in all models and use Akaike's Information Criterion (AIC) to select the optimum number of lags. Furthermore, the volatility of the real Canadian dollar-Mexican peso rate is generated through a GARCH (1,1) process explained in the data Appendix. Additionally, since

[7] For some other applications of these methods see Halicioglu (2007), Nusair (2012, 2016), Baghestani and Kherfi (2015), Durmaz (2015), Gogas and Pragidis (2015), Al-Shayeb and Hatemi-J. (2016), Lima et al. (2016), Aftab et al. (2017), Gregoriou (2017), and Hajilee and Niroomand (2019).

[8] Note that Shin et al. (2014, p. 291) argue that the critical values of the F test should stay at the same high level when we move from linear to nonlinear model.

different estimates and diagnostic statistics are subject to different critical values, we have collected all critical values in the notes to each table and used them to identify significant estimates. We begin with the estimate of the linear Canadian export model (3) first and report the results in Tables 1-3.

From Table 1, in which we report short-run coefficient estimates attached to the real exchange rate volatility, we gather that there are only six industries in which exchange rate volatility carries at least one significant coefficient, supporting short-run effects in these industries. In how many industries short-run effects last into long run? The answer is provided by Table 2 where we learn that the LnV variables carries a significant coefficient only in three industries, V, IX, and X. These estimates are valid because at least either the F test or the t test for cointegration (Table 3) is significant. The estimates also are positive, implying that exchange rate volatility boosts Canadian exports to Mexico in these industries. Total share of trade by three industries is 8.9%. Thus, not much Canadian exports to Mexico is affected by the real dollar-peso volatility.

In Table 3 we have also reported a few additional diagnostic statistics. To check for serial correlation, we have reported the Lagrange Multiplier test as LM. Since it is insignificant in all models, residuals in each model are autocorrelation free. We have also reported Ramey's RESET test to identify mis-specified models. This statistic is also insignificant in all models, rejecting misspecification. To establish stablish stability of all estimated coefficients in each model, following the literature we have applied the CUSUM and CUSUMSQ tests to the residuals of each model and indicated stable estimates by "S" and unstable ones by "US". As can be seen most estimates are stable. Finally, size of adjusted R^2 is reported to judge goodness of the fit. How would the results change if we introduce nonlinear adjustment of the exchange rate volatility and estimate the U.S. nonlinear export demand model (6) for the same industries? Estimates are provided in Tables 4-7.

Due to volume of the results, short-run coefficient estimates attached to ΔPOS variable (increased volatility) are reported in Table 4 and those attached to ΔNEG variable (decreased volatility) in Table 5. From these two tables we gather that either the ΔPOS or ΔNEG carry at least one lagged significant coefficient, 9 out of 16 industries (ΔNEG) and 8 out of 16 industries (ΔPOS). The increase in number of industries from six linear models indicating exchange rate volatility has significant short-run effects on Canadian exports to Mexico attributed to nonlinear adjustment of the volatility measure. Furthermore, since at any given lag j, estimate attached to ΔPOS_{t-j} is different than the estimate attached to ΔNEG_{t-j}, short-run effects are asymmetric. However, short-run cumulative asymmetric effects are evidenced only in industries XI, and XXI since the Wald test reported as Wald-S in diagnostic Table 7 is significant in these industries, rejecting equality of the sum of the coefficients attached to ΔPOS_{t-j} and ΔNEG_{t-j}. In which industry short-run asymmetric effects last into the long run?

Table 1: Short-run coefficient estimates of volatility in the linear Canadian export demand model.

Code	# Lags on $\Delta LnVt$											
	0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
Total merchandise trade #[b]	0.09	-0.16	0.19**[a]									
I - Live animals and animal products.	0.04											
II - Vegetable products	-0.11											
IV - Prepared foodstuffs; beverages, spirits and vinegar; tobacco and manufactures tobacco substitutes.	-0.14	0.34										
V - Mineral products	1.22*											
VI - Products of the chemical or allied industries.	-0.01											
VII - Plastics and articles thereof; rubber and articles thereof.	-0.05											
IX - Wood and articles of wood; wood charcoal; cork and articles of cork; manufactures of straw, of esparto or of other plaiting materials; basketware and wickerwork.	0.30*											
X - Pulp of wood or of other fibrous cellulosic material; recovered (waste and scrap) paper or paperboard.	0.19*											
XI - Textiles and Textile Articles	0.74*	-0.62*										
XIII - Articles of stone, plaster, cement, asbestos, mica or similar materials; ceramic products; glass and glassware.	-0.67											
XV - Base metals and articles of base metal	0.14											
XVI - Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles.	-0.19	0.15	-0.13	0.34**								
XVII - Vehicles, aircraft, vessels and associated transport equipment.	0.05											
XVIII - Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; clocks and watches; musical instruments; parts and accessories thereof.	-0.03											
XX - Miscellaneous manufactured articles	0.06											
XXI - Works of art, collectors' pieces and antiques.	-0.07											

Notes:
a)- * (**) indicates significance at the 5% (10%) level
b)- # indicates significance of the dummy for Global Financial Crisis of 2008.

Table 2: Long-Run Coefficient Estimates of the Linear Canadian Export Demand Model.

Industries		**Long-Run Coefficient Estimates**			
	Trade Share (%)	***Constant***	***Ln Y_t^{MEX}***	***Ln REX_t***	***LnV_t***
Total merchandise trade#[b]	100.0%	-2.93	4.19*[a]	-0.29	0.34*
I - Live animals and animal products.	6.5%	6.17	2.07**	-1.24*	0.19
II - Vegetable products	11.8%	2.11	1.99*	0.69**	-0.14
IV - Prepared foodstuffs; beverages, spirits and vinegar; tobacco and manufactures tobacco substitutes. #	2.7%	-3.79	2.32	4.71**	2.49
V - Mineral products	3.6%	-10.94	5.63**	0.96	2.62*
VI - Products of the chemical or allied industries. #	3.3%	1.21	1.98*	0.52*	-0.01
VII - Plastics and articles thereof; rubber and articles thereof.	5.2%	-31.23*	8.62*	1.26*	-0.15
IX - Wood and articles of wood; wood charcoal; cork and articles of cork; manufactures of straw, of esparto or of other plaiting materials; basketware and wickerwork.	0.6%	-21.72*	-2.18	1.44*	8.55*
X - Pulp of wood or of other fibrous cellulosic material; recovered (waste and scrap) paper or paperboard. #	4.7%	0.09	2.76*	0.01	0.42*
XI - Textiles and Textile Articles	1.6%	-17.85	10.00	-5.95	2.31
XIII - Articles of stone, plaster, cement, asbestos, mica or similar materials; ceramic products; glass and glassware. #	0.1%	6.41	0.31	0.26	0.51
XV - Base metals and articles of base metal#	19.8%	-12.67**	6.12*	-0.70	0.59
XVI - Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles. #	17.6%	-6.08	5.10*	-1.50*	0.49
XVII - Vehicles, aircraft, vessels and associated transport equipment.	17.2%	-15.59*	6.40*	0.06	0.23
XVIII - Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; clocks and watches; musical instruments; parts and accessories thereof.	1.0%	-27.57	7.30*	1.72*	-0.08
XX - Miscellaneous manufactured articles	1.1%	2.88	1.93*	-0.32	0.12
XXI - Works of art, collectors' pieces and antiques. #	1.1%	-17.37*	5.67*	0.74	-0.19

Notes:
a)- * (**) indicates significance at the 5% (10%) level.
b)- # indicates significance of the dummy for Global Financial Crisis of 2008

Table 3: Diagnostic Statistics Associated with Linear Canadian Export Demand Model.

Industries	Diagnostics						
	***F Stat*[b]**	$\hat{\lambda}_1$[c]	***LM*[d]**	***RESET*[e]**	***CUSUM***	***CUSUMSQ***	***Adj. R^2***
Total merchandise trade	11.41*[a]	-0.41*	0.003	0.02	S	US	0.87
I - Live animals and animal products.	7.06*	-0.24*	1.81	0.03	US	S	0.65
II - Vegetable products	3.70	-0.79*	0.19	0.58	S	S	0.38
IV - Prepared foodstuffs; beverages, spirits and vinegar; tobacco and manufactures tobacco substitutes.	3.27	-0.08*	1.83	4.29	S	S	0.87
V - Mineral products	5.41*	-0.46*	0.29	0.08	US	S	0.36
VI - Products of the chemical or allied industries.	16.05*	1.50*	0.88	0.34	S	S	0.45
VII - Plastics and articles thereof; rubber and articles thereof.	6.08*	-0.31*	0.29	0.01	US	S	0.93
IX - Wood and articles of wood; wood charcoal; cork and articles of cork; manufactures of straw, of esparto or of other plaiting materials; basketware and wickerwork.	8.18*	-0.21*	2.48	0.59	S	S	0.76
X - Pulp of wood or of other fibrous cellulosic material; recovered (waste and scrap) paper or paperboard.	7.42	-0.46*	1.14	1.17	S	S	0.39
XI - Textiles and Textile Articles	0.77	-0.05	0.12	0.08	US	US	0.89
XIII - Articles of stone, plaster, cement, asbestos, mica or similar materials; ceramic products; glass and glassware.	6.04*	-0.51*	0.05	0.003	US	US	0.55
XV - Base metals and articles of base metal	3.99**	-0.24*	2.47	2.98	S	US	0.84
XVI - Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles.	3.48	-0.32*	0.89	0.48	S	US	0.73
XVII - Vehicles, aircraft, vessels and associated transport equipment.	3.38	-0.21*	1.32	2.52	S	S	0.71
XVIII - Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; clocks and watches; musical instruments; parts and accessories thereof.	4.59*	-0.34*	2.17	0.002	S	US	0.71
XX - Miscellaneous manufactured articles	10.89*	-0.50*	0.09	1.87	S	US	0.33
XXI - Works of art, collectors' pieces and antiques.	4.70*	-0.39*	0.92	0.001	S	S	0.51

a. *, ** indicate significance at the 5% and 10% levels, respectively.

b. The upper bound critical value of the F-test for cointegration when there are three exogenous variables is 3.77 (4.35) at the 10% (5%) level of significance. These come from Pesaran *et al*. (2001, Table CI, Case III, p. 300).

c. The critical value of the t-test cointegration or significance of $\hat{\lambda}_1$ is -3.46 (-3.78) at the 10% (5%) level when k =3. These come from Pesaran *et al*. (2001, Table CII, Case III, p. 303).

d. LM is Lagrange Multiplier test of residual serial correlation. It is distributed as $\chi 2$ with one degree of freedom (first order). Its critical value at 5% (10%) significance level is 3.84(2.71).

e. RESET is Ramsey's test for misspecification. The critical value is 3.84 at the 5% level and 2.71 at the 10% level. *, ** indicate significance at the 5% and 10% levels, respectively.

Table 4: Short-run coefficient estimates attached to ΔPOS variable in the Canadian nonlinear export model.

Code	# Lags on *ΔPOS*											
	0	***1***	***2***	***3***	***4***	***5***	***6***	***7***	***8***	***9***	***10***	***11***
Total merchandise trade	0.10	-0.42	0.22	0.49								
I - Live animals and animal products.	-0.005											
II - Vegetable products	-1.84**	0.44	1.95									
IV - Prepared foodstuffs; beverages, spirits and vinegar; tobacco and manufactures tobacco substitutes.	-0.81	1.26**										
V - Mineral products	2.79*											
VI - Products of the chemical or allied industries.	-0.13											
VII - Plastics and articles thereof; rubber and articles thereof.	0.23	-0.04										
IX - Wood and articles of wood; wood charcoal; cork and articles of cork; manufactures of straw, of esparto or of other plaiting materials; basketware and wickerwork.	0.62*											
X - Pulp of wood or of other fibrous cellulosic material; recovered (waste and scrap) paper or paperboard.	0.39**											
XI - Textiles and Textile Articles	3.10*	-2.58*	-0.55									
XIII - Articles of stone, plaster, cement, asbestos, mica or similar materials; ceramic products; glass and glassware.	-3.88*	4.99*										
XV - Base metals and articles of base metal	0.56*											
XVI - Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles.	0.19											
XVII - Vehicles, aircraft, vessels and associated transport equipment.	0.15											
XVIII - Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; clocks and watches; musical instruments; parts and accessories thereof.	0.15											
XX - Miscellaneous manufactured articles	0.13											
XXI - Works of art, collectors' pieces and antiques.	-0.23											

Notes: a)- * (**) indicates significance at the 5% (10%) level.

Table 5: Short-run coefficient estimates attached to ΔNEG variable in the Canadian nonlinear export model.

Code	# Lags on ΔNEG											
	0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
Total merchandise trade	0.40*											
I - Live animals and animal products.	-0.10											
II - Vegetable products	5.77**	-2.65	-7.18**	3.19	2.78	-2.42	1.38	6.76**	-6.88*			
IV - Prepared foodstuffs; beverages, spirits and vinegar; tobacco and manufactures tobacco substitutes.	0.54**											
V - Mineral products	2.71*											
VI - Products of the chemical or allied industries.	-0.22											
VII - Plastics and articles thereof; rubber and articles thereof.	-0.26											
IX - Wood and articles of wood; wood charcoal; cork and articles of cork; manufactures of straw, of esparto or of other plaiting materials; basketware and wickerwork.	0.57**											
X - Pulp of wood or of other fibrous cellulosic material; recovered (waste and scrap) paper or paperboard.	0.34											
XI - Textiles and Textile Articles	-2.85	-1.83	4.42*									
XIII - Articles of stone, plaster, cement, asbestos, mica or similar materials; ceramic products; glass and glassware.	7.46**	-6.31										
XV - Base metals and articles of base metal	0.42											
XVI - Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles.	0.13											
XVII - Vehicles, aircraft, vessels and associated transport equipment.	2.03											
XVIII - Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; clocks and watches; musical instruments; parts and accessories thereof.	4.35**	-4.24**										
XX - Miscellaneous manufactured articles	-0.27	-2.63	5.99*	-1.35	5.83*	-4.72*						
XXI - Works of art, collectors' pieces and antiques.	-1.77	-3.27	4.86*									

Notes: a)- * (**) indicates significance at the 5% (10%) level.

Table 6: Long-Run Coefficient Estimates of the Canadian Nonlinear Export Demand Model.

Industries	***Constant***	***Ln Y_t^{MEX}***	***Ln REX_t***	***POS_t***	***NEG_t***
Total merchandise trade#[b]	-5.08	4.47*[a]	-0.33	0.99*	1.01*
I - Live animals and animal products.	16.14*	-0.30	-1.07*	-0.02	-0.35
II - Vegetable products#	-7.09	4.18*	0.54	0.73	1.03
IV - Prepared foodstuffs; beverages, spirits and vinegar; tobacco and manufactures tobacco substitutes.	-31.89	7.85	2.93**	3.55	4.19
V - Mineral products	-13.87	4.64	1.02	5.79*	5.65*
VI - Products of the chemical or allied industries. #	2.73	1.65*	0.53*	-0.09	-0.14
VII - Plastics and articles thereof; rubber and articles thereof.	-16.45*	5.24*	1.79*	-0.95	-1.21
IX - Wood and articles of wood; wood charcoal; cork and articles of cork; manufactures of straw, of esparto or of other plaiting materials; basketware and wickerwork.	-14.09	-1.86	2.85**	2.57	5.84
X - Pulp of wood or of other fibrous cellulosic material; recovered (waste and scrap) paper or paperboard. #	2.18	2.02**	0.07	0.83**	0.73
XI - Textiles and Textile Articles	29.69	-3.32	-2.69**	-0.25	-1.82
XIII - Articles of stone, plaster, cement, asbestos, mica or similar materials; ceramic products; glass and glassware. #	2.39	0.95	0.12	2.19*	2.24**
XV - Base metals and articles of base metal	-2.59	3.03*	0.27	1.19*	0.89
XVI - Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles.	4.74	2.13	-0.89	0.72	0.50
XVII - Vehicles, aircraft, vessels and associated transport equipment.	-16.89	6.54*	0.10	0.68	0.69
XVIII - Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; clocks and watches; musical instruments; parts and accessories thereof.	-19.42*	5.40*	1.99*	0.30	0.21
XX - Miscellaneous manufactured articles	-2.18	2.96*	-0.27	0.26	0.37
XXI - Works of art, collectors' pieces and antiques.	-19.63*	6.29*	0.68	-0.62	-0.49

Notes: a)- * (**) indicates significance at the 5% (10%) level.
b)- # indicates significance of the dummy for Global Financial Crisis of 2008.

Table 7: Diagnostic Statistics Associated with non-linear export demand ARDL Model.

Industries	F^b	$\widehat{\theta}_1{}^c$	LM^d	$RESET^e$	*CSM(SQ)*	*Adj.* R^2	Wald-S[f]	Wald-L
Total merchandise trade	9.89*[a]	-0.39*	0.01	0.05	S(US)	0.87	2.12	7.78*
I - Live animals and animal products.	6.97*	-0.29*	0.85	0.03	US(S)	0.65	0.27	0.18
II - Vegetable products	4.99*	-0.73*	0.01	0.28	S(US)	0.41	2.41	0.23
IV - Prepared foodstuffs; beverages, spirits and vinegar; tobacco and manufactures tobacco substitutes.	2.88	-0.13*	1.06	0.23	US(S)	0.87	0.02	1.32
V - Mineral products	4.50*	-0.48*	0.41	0.04	S(US)	0.36	0.29	0.14
VI - Products of the chemical or allied industries.	13.51*	-1.54*	1.19	0.005	S(S)	0.45	1.15	8.14*
VII - Plastics and articles thereof; rubber and articles thereof.	3.50	-0.22*	0.25	0.10	S(S)	0.93	0.001	5.82*
IX - Wood and articles of wood; wood charcoal; cork and articles of cork; manufactures of straw, of esparto or of other plaiting materials; basketware and wickerwork.	6.44*	-0.22*	1.35	0.93	US(US)	0.77	0.42	3.81*
X - Pulp of wood or of other fibrous cellulosic material; recovered (waste and scrap) paper or paperboard.	6.31*	-0.47*	1.14	1.28	US(S)	0.39	1.09	1.28
XI - Textiles and Textile Articles	2.91	-0.15*	0.99	1.29	S(S)	0.88	3.96*	14.61*
XIII - Articles of stone, plaster, cement, asbestos, mica or similar materials; ceramic products; glass and glassware.	5.93*	-0.51*	0.0002	0.01	S(US)	0.56	2.38	1.57
XV - Base metals and articles of base metal	7.30	-0.48*	0.14	1.65	US(US)	0.78	0.55	22.66*
XVI - Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles.	3.28	-0.27*	0.56	2.25	US(US)	0.72	1.52	5.77*
XVII - Vehicles, aircraft, vessels and associated transport equipment.	3.17	-0.21*	0.86	2.39	US(S)	0.71	2.37	1.79
XVIII - Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; clocks and watches; musical instruments; parts and accessories thereof.	8.52*	-0.51*	1.29	1.06	US(US)	0.73	0.87	7.35*
XX - Miscellaneous manufactured articles	9.18*	-0.52*	0.14	0.81	S(US)	0.34	0.21	0.13
XXI - Works of art, collectors' pieces and antiques.	3.65	-0.36*	0.69	0.01	S(S)	0.52	3.48*	0.01

a. *, ** indicate significance at the 5% and 10% levels, respectively.

b. The upper bound critical value of the F-test for cointegration when there are three exogenous variables is 3.77 (4.35) at the 10% (5%) level of significance. These come from Pesaran *et al*. (2001, Table CI, Case III, p. 300).

c. The critical value of the t-test for cointegration or significance of $\widehat{\boldsymbol{\theta}}_{\mathbf{1}}$ is -3.67 (-4.03) at the 10% (5%) level when k =4. These come from Pesaran *et al*. (2001, Table CII, Case III, p. 303).

d. LM is Lagrange Multiplier test of residual serial correlation. It is distributed as $\chi 2$ with one degree of freedom (first order). Its critical value at 5% (10%) significance level is 3.84(2.71).

e. RESET is Ramsey's test for misspecification. The critical value is 3.84 at the 5% level and 2.71 at the 10% level. *, ** indicate significance at the 5% and 10% levels, respectively.

f. Wald test are distributed as χ^2 with 1 degree of freedom. Critical value is 2.71(3.84) at 10% (5%) significant level.

Long-run estimates reported in Table 6 reveal that either the POS or the NEG variable carry a significant coefficient that is validated at least by one of the cointegrations tests in Table 7 in industries V, X, XIII and XV. In line with linear model, all estimates are positive, implying that increased volatility will boost Canadian exports to Mexico of these four industries and decreased volatility will reduce exports of V and XIII but will have no long-run effect on the exports of X and XV. The two largest industries that were affected in the short run, i.e., II (Vegetable Products with 11.8% export share) and XV (Base metals and articles of base metal with 19.8% exports share), only industry XV is affected in the long run. Furthermore, in this industry since increased volatility boosts exports but decreased volatility has no effect, the effects are asymmetric which is supported by the Wald test reported as Wald-L in Table 7. Indeed, long-run asymmetric effects is supported in a total of seven industries. Given that, the total share of exports by industries whose exports are boosted by exchange rate volatility is 28.2%. The nonlinear models add additional discoveries to export-volatility nexus that is absent from estimates of the linear models.[9]

Next, we consider estimate of the Canadian linear import demand models or Mexican exports to Canada. The results are reported in Tables 8-10. From the short-run estimates in Table 8 we gather that the exchange rate volatility carries at least one lagged significant coefficient in a total of 10 out of 21 industries. However, short-run effects last into significant and meaningful effects only in industries classified as I, V, XIX, and XXI.[10] From trade shares reported in Table 9 we learn that the total shares of these industries add up to 2.811%, a negligible amount. Thus, we are safe to conclude that Mexican exports to Canada has minimal affect from real peso-Canadian dollar volatility in the long run. Other diagnostics in Table 10 support autocorrelation free residuals, correctly specified models, and stable estimates.

Finally, we consider estimates of the Canadian nonlinear import demand models (or Mexican exports to Canada) that are reported in Tables 11-14. From short-run estimates attached to ΔPOS in Table 11 and ΔNEG in Table 12 we gather that at least one of them carry a lagged significant coefficient in 11 out of 21 industries. Again, increase from 10 linear models to 11 nonlinear models in which exchange rate volatility has short-run effects on Mexican exports to Canada must be attributed to nonlinear adjustment of exchange rate volatility. While short-run effects are asymmetric in most instances, cumulative short-run asymmetric effects are established by the Wald-S test (reported in Table 14) only in two industries classified as II, and VII. Short-run asymmetric effects translate into long-run significant effects in 10 industries classified as I, IV, V, VI, X, XIII, XV, XV1, XVII, and XX1.

[9] Other diagnostics in Table 7 are similar to those in Table 3 and need no repeat.

[10] By meaningful we mean the long-run estimates are supported by either the F or the t test for cointegration that are reported in diagnostics Table 10.

Table 8: Short-run coefficient estimates of volatility variable in the Canadian linear import demand (or Mexican export) model.

Code	# Lags on ΔV_t											
	0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
Total merchandise trade	0.05*											
I - Live animals and animal products.	0.41*											
II - Vegetable products	-0.20	0.48*	-0.25									
III - Animal or vegetable fats and oils and their cleavage products; prepared edible fats; animal or vegetable waxes.	0.37											
IV - Prepared foodstuffs; beverages, spirits and vinegar; tobacco and manufactures tobacco substitutes.	0.27	-0.47**	0.27									
V - Mineral products	0.64	-1.68	2.11	-2.19*								
VI - Products of the chemical or allied industries.	0.04											
VII - Plastics and articles thereof; rubber and articles thereof.	0.03	0.14	-0.18*									
VIII - Raw hides and skins, leather, furskins and articles thereof; saddlery and harness; travel goods, handbags and similar containers; articles of animal gut (other than silk-worm gut).	-0.06											
IX - Wood and articles of wood; wood charcoal; cork and articles of cork; manufactures of straw, of esparto or of other plaiting materials; basketware and wickerwork.	0.21	-0.29**										
X - Pulp of wood or of other fibrous cellulosic material; recovered (waste and scrap) paper or paperboard.	-0.19	0.39*										
XI - Textiles and Textile Articles	0.02											
XII - Footwear, headgear, umbrellas, sun umbrellas, walking-sticks, seat-sticks, whips, riding-crops and parts thereof; prepared feathers and articles made therewith; artificial flowers; articles of human hair.	-0.15											
XIII - Articles of stone, plaster, cement, asbestos, mica or similar materials; ceramic products; glass and glassware.	0.05											
XIV - Natural or cultured pearls, precious or semi-precious stones, precious metals, metals clad with precious metal and articles thereof; imitation jewellery; coin.	0.23	0.09	-1.61**	0.76	-0.55	1.39*						
XV - Base metals and articles of base metal	-0.03											
XVI - Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles.	0.01											
XVII - Vehicles, aircraft, vessels and associated transport equipment.	0.07											
XVIII - Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; clocks and watches; musical instruments; parts and accessories thereof.	0.02											
XIX - Arms and ammunition; parts and accessories thereof.	-0.70	1.67	-0.17	2.83*	-2.64*							
XX - Miscellaneous manufactured articles	0.01											
XXI - Works of art, collectors' pieces and antiques.	0.21	0.71*										

Notes: a)- * (**) indicates significance at the 5% (10%) level.

Table 9: Long-Run Coefficient Estimates of the Nonlinear Canadian Demand Model (or Mexican Exports).

Industries		**Long-Run Coefficient Estimates**			
	Trade Share (%)	***Constant***	***Ln Y_t^{CAN}***	***Ln REX_t***	***LnV_t***
Total merchandise trade#[b]	100.00%	-1051.72	226.89	-33.45	-26.93
I - Live animals and animal products. #	0.25%	-24.74*[a]	7.38*	0.28	1.06*
II - Vegetable products#	7.85%	-4.58	3.08*	1.33*	0.12
III - Animal or vegetable fats and oils and their cleavage products; prepared edible fats; animal or vegetable waxes. #	0.14%	-20.38**	6.56*	-0.66	1.18
IV - Prepared foodstuffs; beverages, spirits and vinegar; tobacco and manufactures tobacco substitutes. #	1.47%	18.64	-2.09	6.01	3.13
V - Mineral products#	1.36%	28.61*	-5.31*	2.93*	-1.18*
VI - Products of the chemical or allied industries. #	2.57%	-1.45	2.65*	0.65	0.16
VII - Plastics and articles thereof; rubber and articles thereof.	1.81%	10.04	0.66	-0.27	-0.08
VIII - Raw hides and skins, leather, furskins and articles thereof; saddlery and harness; travel goods, handbags and similar containers; articles of animal gut (other than silk-worm gut).	0.07%	-10.13	2.90	2.29	-0.49
IX - Wood and articles of wood; wood charcoal; cork and articles of cork; manufactures of straw, of esparto or of other plaiting materials; basketware and wickerwork.	0.09%	-16.84	1.95	5.59	-2.01
X - Pulp of wood or of other fibrous cellulosic material; recovered (waste and scrap) paper or paperboard. #	0.34%	7.86	0.98	-0.94	-0.13
XI - Textiles and Textile Articles#	1.05%	17.31*	-1.00*	0.20	0.07
XII - Footwear, headgear, umbrellas, sun umbrellas, walking-sticks, seat-sticks, whips, riding-crops and parts thereof; prepared feathers and articles made therewith; artificial flowers; articles of human hair. #	0.11%	-4.48	1.88	1.26	-0.81
XIII - Articles of stone, plaster, cement, asbestos, mica or similar materials; ceramic products; glass and glassware. #	0.66%	10.23*	0.75	-0.77*	0.23
XIV - Natural or cultured pearls, precious or semi-precious stones, precious metals, metals clad with precious metal and articles thereof; imitation jewellery; coin. #	0.07%	67.07	-20.22	22.67	4.31
XV - Base metals and articles of base metal	2.75%	1.78	1.62*	1.36*	-0.14
XVI - Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles. #	37.23%	24.59**	-3.05	2.72	0.23
XVII - Vehicles, aircraft, vessels and associated transport equipment.	32.86%	42.04	-5.15	0.08	1.26
XVIII - Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; clocks and watches; musical instruments; parts and accessories thereof.	3.90%	10.92	0.34	0.69	0.32
XIX - Arms and ammunition; parts and accessories thereof.	0.001%	12.72*	0.62	-3.47*	1.12*
XX - Miscellaneous manufactured articles	4.25%	28.61	-1.98	-1.95	0.55
XXI - Works of art, collectors' pieces and antiques. #	1.20%	-6.16	2.69*	2.86*	1.37*

Notes: a)- * (**) indicates significance at the 5% (10%) level.
b)- # indicates significance of the dummy for Global Financial Crisis of 2008.

Table 10: Diagnostic Statistics Associated with the Canadian Linear Import Demand Model (or Mexican Exports).

Industries	Diagnostics						
	F^b	$\widehat{\delta}_1{}^c$	LM^d	$RESET^e$	*CUSUM*	*CUSUMSQ*	*Adj.* R^2
Total merchandise trade	8.64*[a]	-0.002*	0.81	0.59	S	S	0.96
I - Live animals and animal products.	7.80*	-0.39*	0.07	1.32	US	US	0.81
II - Vegetable products	9.66*	-0.29*	0.21	0.98	S	S	0.95
III - Animal or vegetable fats and oils and their cleavage products; prepared edible fats; animal or vegetable waxes.	3.50	-0.31*	0.09	0.04	US	US	0.79
IV - Prepared foodstuffs; beverages, spirits and vinegar; tobacco and manufactures tobacco substitutes.	2.21	-0.02	2.43	0.99	US	S	0.83
V - Mineral products	38.15*	-0.94*	0.004	2.07	US	US	0.17
VI - Products of the chemical or allied industries.	6.53	-0.27*	2.62	1.23	US	US	0..85
VII - Plastics and articles thereof; rubber and articles thereof.	2.64	-0.03**	2.05	0.78	S	US	0.97
VIII - Raw hides and skins, leather, furskins and articles thereof; saddlery and harness; travel goods, handbags and similar containers; articles of animal gut (other than silk-worm gut).	2.27	-0.12	1.11	1.04	S	US	0.79
IX - Wood and articles of wood; wood charcoal; cork and articles of cork; manufactures of straw, of esparto or of other plaiting materials; basketware and wickerwork.	1.40	-0.04	0.07	0.09	S	US	0.92
X - Pulp of wood or of other fibrous cellulosic material; recovered (waste and scrap) paper or paperboard.	2.03	-0.14	1.24	0.40	US	S	0.77
XI - Textiles and Textile Articles	10.17*	-0.31*	0.49	0.57	S	S	0.75
XII - Footwear, headgear, umbrellas, sun umbrellas, walking-sticks, seat-sticks, whips, riding-crops and parts thereof; prepared feathers and articles made therewith; artificial flowers; articles of human hair.	2.61	-0.18**	0.72	0.42	S	S	0.73
XIII - Articles of stone, plaster, cement, asbestos, mica or similar materials; ceramic products; glass and glassware.	3.72	-0.21*	0.34	0.002	US	S	0.83
XIV - Natural or cultured pearls, precious or semi-precious stones, precious metals, metals clad with precious metal and articles thereof; imitation jewellery; coin.	3.97**	-0.07*	0.34	0.12	S	US	0.83
XV - Base metals and articles of base metal	4.58*	-0.27*	0.58	0.54	S	S	0.84
XVI - Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles.	6.34*	-0.07*	1.55	0.82	S	US	0.94
XVII - Vehicles, aircraft, vessels and associated transport equipment.	1.73	-0.06	0.99	0.04	US	US	0.91
XVIII - Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; clocks and watches; musical instruments; parts and accessories thereof.	3.91**	-0.07*	1.40	2.13	S	US	0.96
XIX - Arms and ammunition; parts and accessories thereof.	36.26*	-0.87*	2.01	0.37	S	US	0.25
XX - Miscellaneous manufactured articles	1.01	-0.03	0.03	0.06	US	US	0.93
XXI - Works of art, collectors' pieces and antiques.	7.57*	-0.36*	0.28	0.63	US	US	0.96

Notes:

a. *, ** indicate significance at the 5% and 10% levels, respectively.

b. The upper bound critical value of the F-test for cointegration when there are three exogenous variables is 3.77 (4.35) at the 10% (5%) level of significance. These come from Pesaran *et al.* (2001, Table CI, Case III, p. 300).

c. The critical value of the t-test cointegration or significance of $\widehat{\boldsymbol{\delta}}_{\mathbf{1}}$ is -3.46 (-3.78) at the 10% (5%) level when k =3. These come from Pesaran *et al.* (2001, Table CII, Case III, p. 303).

d. LM is Lagrange Multiplier test of residual serial correlation. It is distributed as $\chi 2$ with one degree of freedom (first order). Its critical value at 5% (10%) significance level is 3.84(2.71).

e. RESET is Ramsey's test for misspecification. The critical value is 3.84 at the 5% level and 2.71 at the 10% level. *, ** indicate significance at the 5% and 10% levels, respectively.

Table 11: Short-run coefficient estimates attached to ΔPOS variable in the Canadian nonlinear import model (Mexican exports).

Code	# Lags on ΔPOS											
	0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
Total merchandise trade	0.25	-0.28										
I - Live animals and animal products.	1.15*[a]											
II - Vegetable products	-0.66	1.51*	-0.81**									
III - Animal or vegetable fats and oils and their cleavage products; prepared edible fats; animal or vegetable waxes.	0.92											
IV - Prepared foodstuffs; beverages, spirits and vinegar; tobacco and manufactures tobacco substitutes.	1.54*	-1.79*	1.20	-1.07**								
V - Mineral products	2.27	-5.93	6.52	-6.02*								
VI - Products of the chemical or allied industries.	-0.05											
VII - Plastics and articles thereof; rubber and articles thereof.	0.18	0.32	-0.56*									
VIII - Raw hides and skins, leather, furskins and articles thereof; saddlery and harness; travel goods, handbags and similar containers; articles of animal gut (other than silk-worm gut).	-0.13											
IX - Wood and articles of wood; wood charcoal; cork and articles of cork; manufactures of straw, of esparto or of other plaiting materials; basketware and wickerwork.	0.68	-0.95**										
X - Pulp of wood or of other fibrous cellulosic material; recovered (waste and scrap) paper or paperboard.	-0.31											
XI - Textiles and Textile Articles	0.04											
XII - Footwear, headgear, umbrellas, sun umbrellas, walking-sticks, seat-sticks, whips, riding-crops and parts thereof; prepared feathers and articles made therewith; artificial flowers; articles of human hair.	-0.34											
XIII - Articles of stone, plaster, cement, asbestos, mica or similar materials; ceramic products; glass and glassware.	0.14*											
XIV - Natural or cultured pearls, precious or semi-precious stones, precious metals, metals clad with precious metal and articles thereof; imitation jewellery; coin.	1.19	2.24	-8.23*	2.76	-2.41	3.30	-0.05	-0.67	-1.83	4.14	-3.88	-2.31
XV - Base metals and articles of base metal	-0.15											
XVI - Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles.	-0.06											
XVII - Vehicles, aircraft, vessels and associated transport equipment.	0.58**	-0.52										
XVIII - Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; clocks and watches; musical instruments; parts and accessories thereof.	0.005											
XIX - Arms and ammunition; parts and accessories thereof.	-4.74	6.07	-1.09	12.37*	-3.17	-4.44	-4.34					
XX - Miscellaneous manufactured articles	0.002											
XXI - Works of art, collectors' pieces and antiques.	1.06*											

Notes: a)- * (**) indicates significance at the 5% (10%) level.

Table 12: Short-run coefficient estimates attached to ΔNEG variable in the Canadian nonlinear import model (Mexican exports).

Code	# Lags on ΔNEG											
	0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
Total merchandise trade	-0.17**[a]											
I - Live animals and animal products.	0.13											
II - Vegetable products	-0.03											
III - Animal or vegetable fats and oils and their cleavage products; prepared edible fats; animal or vegetable waxes.	-0.33											
IV - Prepared foodstuffs; beverages, spirits and vinegar; tobacco and manufactures tobacco substitutes.	-0.52*											
V - Mineral products	-3.43*											
VI - Products of the chemical or allied industries.	-0.33**											
VII - Plastics and articles thereof; rubber and articles thereof.	-0.13											
VIII - Raw hides and skins, leather, furskins and articles thereof; saddlery and harness; travel goods, handbags and similar containers; articles of animal gut (other than silk-worm gut).	-0.12											
IX - Wood and articles of wood; wood charcoal; cork and articles of cork; manufactures of straw, of esparto or of other plaiting materials; basketware and wickerwork.	-0.39**											
X - Pulp of wood or of other fibrous cellulosic material; recovered (waste and scrap) paper or paperboard.	-0.43*											
XI - Textiles and Textile Articles	0.03											
XII - Footwear, headgear, umbrellas, sun umbrellas, walking-sticks, seat-sticks, whips, riding-crops and parts thereof; prepared feathers and articles made therewith; artificial flowers; articles of human hair.	-0.32											
XIII - Articles of stone, plaster, cement, asbestos, mica or similar materials; ceramic products; glass and glassware.	-0.01											
XIV - Natural or cultured pearls, precious or semi-precious stones, precious metals, metals clad with precious metal and articles thereof; imitation jewellery; coin.	-6.52	-0.49	-8.37	8.49	9.03	-5.95	-5.41	17.93*	-5.20	-8.87	11.48	10.19
XV - Base metals and articles of base metal	-0.27**											
XVI - Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles.	0.61	-0.10	0.06	-0.76**								
XVII - Vehicles, aircraft, vessels and associated transport equipment.	-0.29**											
XVIII - Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; clocks and watches; musical instruments; parts and accessories thereof.	-0.06											
XIX - Arms and ammunition; parts and accessories thereof.	12.92	-6.22	10.09	-14.34	-18.89	-4.32	21.46*					
XX - Miscellaneous manufactured articles	-0.12											
XXI - Works of art, collectors' pieces and antiques.	0.85*											

Notes: a)- * (**) indicates significance at the 5% (10%) level.

Table 13: Long-Run Coefficient Estimates of the Canadian Nonlinear Import Demand Model (Mexican exports).

Industries	*Constant*	*Ln* Y_t^{CAN}	*Ln* REX_t	POS_t	NEG_t
Total merchandise trade#b	32.26*[a]	-3.69*	0.55*	-0.05	-0.67*
I - Live animals and animal products.	11.76*	-0.11	-1.79*	1.58*	0.18
II - Vegetable products#	1.35	1.86	1.05*	0.14	-0.08
III - Animal or vegetable fats and oils and their cleavage products; prepared edible fats; animal or vegetable waxes.	18.81*	-2.21	-1.37**	1.29	-0.47
IV - Prepared foodstuffs; beverages, spirits and vinegar; tobacco and manufactures tobacco substitutes. #	29.71*	-4.21*	0.79	-0.32	-1.49*
V - Mineral products	37.36*	-6.35*	2.66*	-3.45*	-3.75*
VI - Products of the chemical or allied industries. #	19.87*	-1.68*	-0.05	-0.13	-0.83*
VII - Plastics and articles thereof; rubber and articles thereof.	16.75*	-1.09	0.18	-0.59	-1.11
VIII - Raw hides and skins, leather, furskins and articles thereof; saddlery and harness; travel goods, handbags and similar containers; articles of animal gut (other than silk-worm gut).	-11.08	3.35	2.39	-1.08	-0.98
IX - Wood and articles of wood; wood charcoal; cork and articles of cork; manufactures of straw, of esparto or of other plaiting materials; basketware and wickerwork.	23.06	-3.78	1.64	2.71	-3.91
X - Pulp of wood or of other fibrous cellulosic material; recovered (waste and scrap) paper or paperboard.	19.33*	-1.26	-1.18**	-1.53**	-2.13*
XI - Textiles and Textile Articles#	17.97*	-1.17*	0.17	0.14	0.11
XII - Footwear, headgear, umbrellas, sun umbrellas, walking-sticks, seat-sticks, whips, riding-crops and parts thereof; prepared feathers and articles made therewith; artificial flowers; articles of human hair. #	-5.61	2.46	1.59	-2.04	-1.91
XIII - Articles of stone, plaster, cement, asbestos, mica or similar materials; ceramic products; glass and glassware.	16.13	-0.67**	-0.70*	0.28*	-0.02
XIV - Natural or cultured pearls, precious or semi-precious stones, precious metals, metals clad with precious metal and articles thereof; imitation jewellery; coin.	-39.37	1.92	17.61	22.05	25.12
XV - Base metals and articles of base metal	11.23*	-0.10	0.88*	-0.46	-0.82**
XVI - Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles. #	19.43*	-1.27*	0.89*	-0.15	-0.44*
XVII - Vehicles, aircraft, vessels and associated transport equipment.	29.21*	-2.72*	-0.84*	0.14	-0.66*
XVIII - Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; clocks and watches; musical instruments; parts and accessories thereof. #	22.27*	-2.25	0.54	0.04	-0.55
XIX - Arms and ammunition; parts and accessories thereof.	8.11	1.01	-3.61*	1.01	1.07
XX - Miscellaneous manufactured articles#	51.38*	-7.28*	-1.84**	0.02	-1.17
XXI - Works of art, collectors' pieces and antiques. #	2.53	0.18	2.48*	2.63*	2.12*

Notes: a)- * (**) indicates significance at the 5% (10%) level.
b)- # indicates significance of the dummy for Global Financial Crisis of 2008.

Table 14: Diagnostic Statistics Associated with the Canadian Nonlinear Import Demand Model (Mexican Exports).

Industries	F^b	$\widehat{\chi}_1{}^c$	LM^d	$RESET^e$	*CSM(SQ)*	*Adj.* R^2	Wald-S[f]	Wald-L
Total merchandise trade	10.53*[a]	-0.25*	0.54	1.86	S(US)	0.97	0.02	0.67
I - Live animals and animal products.	22.73*	-0.73*	0.002	0.0001	S(US)	0.82	0.01	195.39*
II - Vegetable products	8.31*	-0.31*	0.02	1.48	S(S)	0.95	4.66*	42.90*
III - Animal or vegetable fats and oils and their cleavage products; prepared edible fats; animal or vegetable waxes.	22.56*	-0.71*	0.89	2.52	S(US)	0.81	0.05	105.87*
IV - Prepared foodstuffs; beverages, spirits and vinegar; tobacco and manufactures tobacco substitutes.	9.66*	-0.35*	0.21	0.004	US(S)	0.83	1.78	0.82
V - Mineral products	31.84	-0.91*	0.26	1.54	S(US)	0.16	0.08	12.33*
VI - Products of the chemical or allied industries.	4.78*	-0.40*	1.86	0.84	S(US)	0.86	0.21	0.77
VII - Plastics and articles thereof; rubber and articles thereof.	2.15	-0.12**	1.48	0.006	S(US)	0.97	2.83*	0.10
VIII - Raw hides and skins, leather, furskins and articles thereof; saddlery and harness; travel goods, handbags and similar containers; articles of animal gut (other than silk-worm gut).	1.89	-0.12	1.11	1.02	S(US)	0.79	0.08	0.001
IX - Wood and articles of wood; wood charcoal; cork and articles of cork; manufactures of straw, of esparto or of other plaiting materials; basketware and wickerwork.	1.42	-0.10	0.21	1.62	S(US)	0.92	0.002	2.72*
X - Pulp of wood or of other fibrous cellulosic material; recovered (waste and scrap) paper or paperboard.	2.43	-0.21**	0.51	2.19	S(S)	0.77	0.37	0.85
XI - Textiles and Textile Articles	8.46*	-0.31*	0.49	0.56	S(S)	0.75	0.48	15.68*
XII - Footwear, headgear, umbrellas, sun umbrellas, walking-sticks, seat-sticks, whips, riding-crops and parts thereof; prepared feathers and articles made therewith; artificial flowers; articles of human hair.	2.17	-0.17**	0.73	0.37	US(S)	0.73	0.64	1.25
XIII - Articles of stone, plaster, cement, asbestos, mica or similar materials; ceramic products; glass and glassware.	16.32*	-0.50*	0.03	2.35	S(S)	0.83	0.25	0.01
XIV - Natural or cultured pearls, precious or semi-precious stones, precious metals, metals clad with precious metal and articles thereof; imitation jewellery; coin.	1.96	-0.08	0.32	0.73	S(S)	0.84	0.75	3.37*
XV - Base metals and articles of base metal	4.79*	-0.33*	0.77	0.01	S(S)	0.84	0.26	0.38
XVI - Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles.	9.85*	-0.42*	1.47	1.05	S(S)	0.93	2.34	2.52
XVII - Vehicles, aircraft, vessels and associated transport equipment.	5.22*	-0.44*	0.93	2.29	S(US)	0.91	0.0001	0.74
XVIII - Optical, photographic, cinematographic, measuring, checking, precision, medical or surgical instruments and apparatus; clocks and watches; musical instruments; parts and accessories thereof.	4.11*	-0.12*	1.00	2.29	S(S)	0.96	0.88	-0.03
XIX - Arms and ammunition; parts and accessories thereof.	6.57	-0.65*	1.89	0.98	S(US)	0.28	0.61	0.78
XX - Miscellaneous manufactured articles	3.68	-0.11*	0.21	0.02	S(US)	0.94	0.19	0.005
XXI - Works of art, collectors' pieces and antiques.	6.78*	-0.40*	0.49	0.003	US(US)	0.95	0.11	1.32

Notes:

a. *, ** indicate significance at the 5% and 10% levels, respectively.

b. The upper bound critical value of the F-test for cointegration when there are three exogenous variables is 3.77 (4.35) at the 10% (5%) level of significance. These come from Pesaran *et al*. (2001, Table CI, Case III, p. 300).

c. The critical value of the t-test for cointegration or significance of $\widehat{\chi}_1$ is -3.67 (-4.03) at the 10% (5%) level when k =4. These come from Pesaran *et al*. (2001, Table CII, Case III, p. 303).

d. LM is Lagrange Multiplier test of residual serial correlation. It is distributed as $\chi 2$ with one degree of freedom (first order). Its critical value at 5% (10%) significance level is 3.84(2.71).

e. RESET is Ramsey's test for misspecification. The critical value is 3.84 at the 5% level and 2.71 at the 10% level. *, ** indicate significance at the 5% and 10% levels, respectively.

f. Wald test are distributed as χ^2 with 1 degree of freedom. Critical value is 2.71(3.84) at 10% (5%) significant level.

In these industries either the POS or the NEG variable carry a significant coefficient in Table 12 that are supported by one of the cointegration tests reported in the diagnostics Table 14. Again, the increase in number of industries from four linear models to 10 nonlinear models must be attributed to nonlinear adjustment of the exchange rate variability. Furthermore, while total trade share of the four industries in the linear models were no more than 28%, aggregate share of 10 affected industries associated with nonlinear models is almost 80%. Included among the 10 industries are the two largest Mexican exporting industries XV1 (Machinery and mechanical appliances; electrical equipment; parts thereof; sound recorders and reproducers, television image and sound recorders and reproducers, and parts and accessories of such articles with 37.23% export share) and XVII (Vehicles, aircraft, vessels and associated transport equipment with 32.86% export share) in which while increased volatility has no long-run effects, decreased volatility has stimulative effects on the exports of these two industries. Indeed, the NEG variable carries a negative coefficient in seven of the 10 industries, implying that decreased volatility leads to increase in exports of seven industries (IV, V, VI, X, XV, XVI, and XVII) which all together have 78.58% trade share. Clearly, these new discoveries by using nonlinear model were masked if we only relied upon estimates of the linear models.

4 Summary and Conclusion

Research on the impact of exchange rate volatility or uncertainty on the trade flows has now entered a new direction of asymmetric effects. Since assessing the asymmetric effects of exchange rate volatility on trade flows requires estimating nonlinear models, their estimates yield more significant outcomes compared to estimates of the linear models that were estimated before. In this paper we add to this new literature by considering trade flows between Canada and Mexico, two members of the former North American Free Trade Area (NAFTA) or current United States-Mexico-Canada Agreement (USMCA). Since both countries are subject to different fiscal and monetary policies, their prices move at different rates, making the real peso-Canadian dollar exchange rate change over time and at times become more volatile.

To avoid aggregation bias, we use monthly data at commodity level. A total of 16 Canadian exporting industries to Mexico and 21 Mexican industries to Canada are included in the study. Using monthly data over the January 2000 - February 2020 for each industry we first estimate a traditional linear ARDL model by applying Pesaran et al.'s (2001) approach for cointegration and error-correction modeling. Next, in the hope of discovering new results we estimate a nonlinear ARDL model for each industry by applying Shin et al.'s (2014) approach for asymmetric cointegration and asymmetric error-correction modeling.

Our findings could be best summarized by saying that when a linear model was estimated, we found short-run effects of exchange rate volatility on six Canadian exporting industries to Mexico. However, short-run effects lasted into the long run only in three industries. Total export share of the three industries was a negligible amount of 8.9%. Similar results were also found

for Mexican exports to Canada. Ten industries were affected in the short run but only four in the long run. The four industries had no more than 2.8% exports share, again, a negligible amount. Thus, we are safe to conclude that estimate of linear models predict an outcome in which trade flows between Canada and Mexico are not significantly affected.

However, the picture is somewhat different when we estimate the nonlinear models. Eleven out of 16 Canadian exporting industries are affected in the short run, mostly in an asymmetric manner. Short-run asymmetric effects translate to long run in four industries which all together have 28.2% export share. More importantly, in these four industries we found that increased volatility boosts exports of Canada to Mexico in these industries. As for Mexican exports to Canada, 11 out of 21 industries were affected by exchange rate volatility in the short run asymmetrically. However, short-run asymmetric effects lasted to long run in 10 industries which all together had almost 80% export share. Furthermore, in almost all of these industries our asymmetric analysis revealed that while increased volatility has no long-run effects on their exports, decreased volatility stimulated their exports. The nonlinear model yields more noteworthy results on the link between exchange rate volatility and trade flows compared to the estimate of the linear model, an outcome consistent with the findings of Bahmani-Oskooee and Harvey (2021) associated with the trade flows between Mexico and the U.S.

Appendix

Data Definitions and Sources

Monthly data over the period January 2000 - Feb 2020 are used to carry out the empirical analysis. Data come from the following sources:

a. International Financial Statistics (IFS)
b. Canadian International Merchandise Trade Database
c. International merchandise trade, by commodity, price, and volume indexes, monthly

Variables:

$\boldsymbol{X^{CAN}}$ = Volume of exports of commodity *i* by Canada to Mexico. Export value data in dollars for each commodity come from **source b**. In the absence of export price at commodity level, following Bahmani-Oskooee and Hagerty (2009) and Bahmani-Oskooee and Harvey (2021) we use aggregate export price index of Canada to deflate the nominal exports of each commodity. The aggregate export price index comes from **source c.**

$\boldsymbol{M^{CAN}}$ = Volume of imports of commodity *i* by the U.S. from Mexico. Import value data for each commodity comes from **source b.** Again, we use aggregate import price index of Canada and deflate the nominal imports. The aggregate import price index comes from **source c.**

$\boldsymbol{Y^{CAN}}$ = Measure of economic activity in Canada. Since data are monthly, the only measure at monthly frequency is Industrial Production Index. We follow the literature and use this index. The data come from **source a.**

$\boldsymbol{Y^{MEX}}$ = Industrial Production Index of Mexico. The data come from **source a.**

REX = Real bilateral exchange rate between Canadian dollar (CAD) and Mexican Peso (MXN). It is defined as REX = (P_{CAN} * NEX/ P_{MEX}), where NEX is the nominal exchange rate defined as number of units of MEX per CAD, P_{CAN} is the price level in Canada (measured by CPI) and P_{MEX} is the price level in Mexico (also measured by CPI). Thus, a decline in REX reflects a real depreciation of the Canadian dollar. All data come from **source a.**

V_t = Volatility measure of REX_t. Following Bahmani-Oskooee and Harvey (2021) we use Generalized Autoregressive Conditional Heteroskedasticity (GARCH 1, 1) method and generate the volatility measure. GARCH assumes that our variable REX is random, and it follows a first order auto-regressive process, i.e., $REX_t = \sigma_0 + \sigma_1 REX_{t-1} + \varepsilon_t$, where ε_t is white noise with $E(\varepsilon) = 0$ and $V(\varepsilon) = h^2$. To forecast the variance of REX, the conditional variance of ε_t which is a time varying variable needs to be estimated from the following specifications:

$$REX_t = \sigma_\circ + \sigma_1 REX_{1,t-1} + \delta_t \qquad \text{(A1)}$$

$$h_t^2 = \alpha_0 + \alpha_1 \delta_{t-1}^2 + \alpha_2 \delta_{t-2}^2 + \ldots + \alpha_q \delta_{t-q}^2 + \chi_1 h_{t-1}^2 + \chi_2 h_{t-2}^2 + \chi_3 h_{t-3}^2 + \ldots + \chi_p h_{t-p}^2 \qquad \text{(A2)}$$

where h_t^2 is the conditional variance. The GARCH (p,q) model outlined by Eq. (A2) is used to generate the predicted value of h_t^2 as a measure of the volatility of real exchange rate. Equation (A1) and (A2) are estimated simultaneously after setting up an ARCH effect.

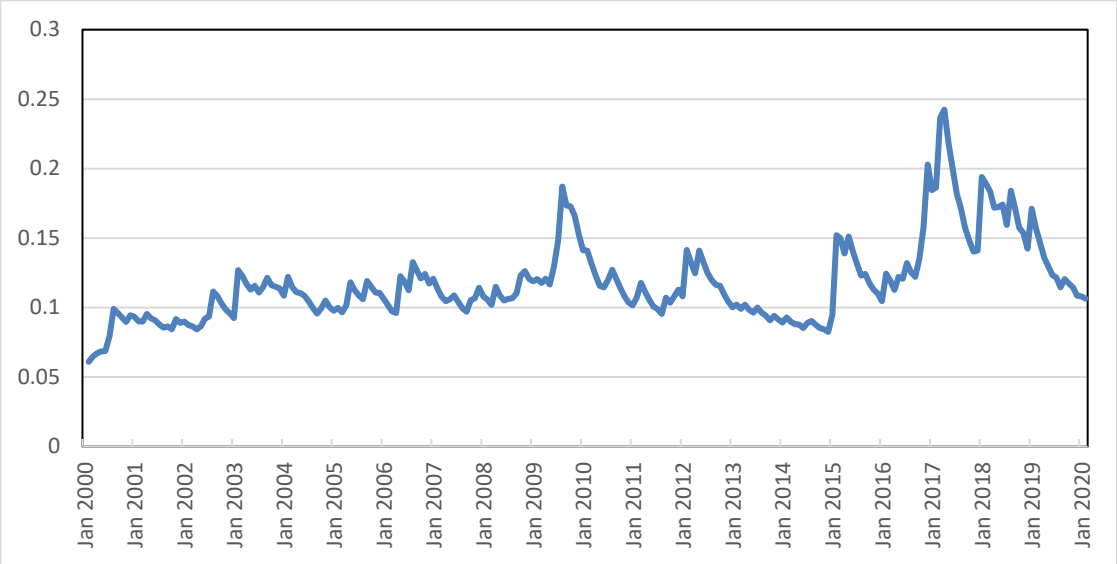
The order of GARCH is decided by significance of α's and χ's in (A2). In our case, GARCH (1,1) specification was sufficient.

The exact results (output below) with the t-ratios inside the parentheses are as follows:

$$\underset{\qquad\quad (1.44)\qquad (82.21)}{REX_t = 0.191189 + 0.9826735 REX_{t-1}} \qquad \text{(A3)}$$

$$\underset{\qquad\quad (1.12)\qquad\quad (1.28)\qquad\quad (8.00)}{\hat{h}_t^2 = 0.009871 + 0.058428 \hat{\varepsilon}_{t-1}^2 + 0.859111 \hat{h}_{t-1}^2} \qquad \text{(A4)}$$

Figure 2: Volatility Measure of the Real Exchange Rate (REX).



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