ASYMMETRIC EFFECTS OF EXCHANGE RATE CHANGES ON CROSS-BORDER TRADE: EVIDENCE FROM CANADA-US BILATERAL FREIGHT FLOWS BY TRANSPORT MODE[1]

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Introduction

Exchange rate plays a key role in international trade and its effect on trade flows has long been the object of a policy debate. A large body of literature has investigated the relationship between international trade and exchange rate (e.g.,Bahmani-Oskooee and Wang, 2007; Marquez and Schindler, 2007; Chi, 2014 and 2016; Hooy et al., 2015). For example, Bahmani-Oskooee and Wafng (2007) analyzed the effect of exchange rate on the trade balance between the United States (US) and China. The results revealed that the real exchange rate is significantly associated with the trade balance. Chi (2014) employed the fully modified ordinary least squares (FM-OLS) technique to explore the exchange rate sensitivities of cross-border freight flows between the US and Canada. His paper found that the US dollar depreciation against Canadian dollar increases freight flows from the US to Canada and reduces freight flows from Canada to the US. Hooy et al. (2015) investigated the effect of exchange rate on Association of Southeast Asian Nations (ASEAN) exports to China and showed that ASEAN total exports to China are significantly associated with the exchange rate, but the exchange rate effects are found to vary at a disaggregate level.

A group of studies have used volatility measures to take into account exchange rate uncertainty and risk. The empirical evidence that rising exchange rate volatility has an adverse effect on international trade flows is relatively widespread in literature (e.g.,Koray and Lastrapes, 1989; McKenzie, 1999; Chowdhury, 2005; Byrne et al., 2008; Chi and Cheng, 2016; Vieira and MacDonald, 2016; Kim, 2017; Aftab et al., 2017; Bahmani-Oskooee and Gelan, 2018). For example, Koray and Lastrapes (1989) used a vector autoregression (VAR) approach to examine the effect of real exchange rate volatility on US bilateral imports from its trade partners. The results showed a negative impact of permanent shock to volatility, implying that firms are risk-averse and exchange rate uncertainty reduces the benefits of international trade. Byrne et al. (2008) used disaggregate sectoral data of US exports and imports and found that an adverse effect of exchange rate volatility is robust across sectors. Kim (2017) investigated the effects of dollar-won exchange rate volatility on seaborne import volume in South Korea and found that a rise in exchange rate volatility has a negative impact on Korea's seaborne import volume.

Despite previous studies having improved understanding of the effects of exchange rate changes on international trade flows, several unresolved issues remain in existing literature. First, relatively little attention has been paid to the asymmetric effects of exchange rate changes on the bilateral trade flows. Most previous studies assumed the symmetric effects of exchange rate, implying that the impact of a currency appreciation (rising exchange rate volatility) is of the same magnitude and move in the opposite direction of the effect of a currency depreciation (falling exchange rate volatility). This may be too restrictive since risk-averse traders may be more sensitive to their losses than their gains from currency value changes. For example, exporters and importers can respond differently when exchange rates are more volatile as compared to when they are less volatile. Recent empirical literature also supported that the effect of exchange rate volatility is in a nonlinear fashion (Aye et al., 2015; Bahmani-Oskooee and Aftab, 2017; Sharma and Pal, 2018).

Second, there is a lack of information on exchange rate asymmetries by transport mode. It is possible that the asymmetric effects of exchange rate fluctuations can vary by transport mode,such as rail, water,

[1] 54th Annual Meetings of the *Canadian Transportation Research Forum*, May 26 - 29, 2019 at Vancouver, British Columbia

truck and air, due to the characteristics of trading commodities. For instance,US vehicles and electrical machinery are transported by truck, while US crude oil and petroleum products are mostly transported by pipeline. The exchange rate elasticities of demand for these imported commodities can differ in Canada, which may lead to a different magnitude of asymmetric effects of exchange rate on the trade flows for these two transport modes. Bahmani-Oskooee and Ratha (2007) found that exchange rate elasticities vary by commodity groups between US and its major trading partners. Chi (2014) also supported that exchange rate elasticities of demand for US-Canada bilateral trade flows vary among transportation modes. It is necessary to further investigate exchange rate asymmetries to help policymakers and shippers advance understanding of the bilateral trade flows associated with exchange risks and develop a strategic plan for transportation infrastructure investment and service expansion.

This study aims to investigate the possible asymmetric effects of exchange rate changes on the cross-border freight flows between the US and Canada. In this paper, we examine the long-run effects of currency value, exchange rate volatility, and the gross domestic product on bilateral freight flows by air, pipeline, rail, truck, and vessel. To our knowledge, this study is the first to investigate possible asymmetric impacts of 1) the currency appreciation and depreciation and 2) exchange rate volatility changes on cross-border freight flows by transport mode. To test for the existence of asymmetries, this paper employs both the linear and nonlinear autoregressive distributed lag (ARDL) models. Nonlinear ARDL model, developed by Shin et al. (2014), allows modeling asymmetry in the long-run cointegrating relationship and short-run error-correction mechanism. The main advantage of the ARDL approach is that it can be applied regardless of whether underlying variables are entirely *I*(0), entirely *I*(1) or a combination of both. Therefore, pre-testing for unit roots is not necessary unlike other cointegration techniques (e.g., Johansen's procedure), which require that regressors to be integrated are in the same order. Moreover, the ARDL procedure allows for uneven lag lengths and appropriate modification of the orders of ARDL can simultaneously correct for the problems of serial correlation and endogeneity (Pesaran and Shin, 1999).

The rest of the paper is organized as follows. Section 2 outlines the linear and nonlinear ARDL models and discusses data and variables. Empirical findings of freight flow models are provided in Section 3. The long-run determinants of bilateral freight flows between the US and Canada are presented by mode of transportation. Finally, concluding remarks and policy implications are discussed in Section 4.

Method

Linear and nonlinear ARDL models

To investigate adynamic relationship among cross-border freight flows, currency value, exchange rate volatility, and the gross domestic product, this paper follows the general forms of export and import models proposed by Bahmani-Oskooee and Ardalani (2006). The reduced-form equations for exports ($lnEXP_t^i$) and imports ($lnIMP_t^i$) are specified as follows:

$$lnEXP_t^i = a_0 + a_1 lnER_t + a_2 lnV_t + a_3 lnGDP_t^{CA} + \varepsilon_t (1)$$

$$lnIMP_t^i = b_0 + b_1 lnER_t + b_2 lnV_t + b_3 lnGDP_t^{US} + \mu_t (2)$$

where $lnEXP_t^i$ ($lnIMP_t^i$) is the total exports from the US to Canada (total imports from Canada to the US) by transport mode *i* at time *t*;$ER_t$is the real exchange rate between the US and Canada; $V_t$is a volatility measure of the real exchange rate; and GDP_t^{CA} (GDP_t^{US}) is the real gross domestic production in Canada (the US). The transport mode *i*includes air, pipeline, rail, truck, and vessel (*i = a, p, r, t, and v*). The bilateral real exchange rate is computed by multiplying the nominal exchange rate of Canadian dollar against US dollar by the ratio of the consumer price indices of the US to Canada (base year = 2010). It is expressed as Canadian dollar per US dollar and therefore, a rise in the exchange rate indicates an appreciation of US dollar against Canadian dollar (or a depreciation of Canadian dollar against US dollar).

Regarding the signs of the coefficients, it is expected that $a_1 < 0$, since an appreciation of US dollar against Canadian dollar increases the price of imported US goods in Canada, which reduces the US exports to Canada. Similarly, a depreciation of Canadian dollar against US dollar reduces the price of imported Canadian goods in the US, which increases the imports from Canada ($b_1 > 0$). An increase in exchange rate uncertainty can have a negative effect on cross-border freight flows and therefore, a negative sign can be expected ($a_2 < 0$ and $b_2 < 0$). Finally, we expect a positive sign of the GDP variables as economic growth in Canada (the US) can increase demand for imported US (Canadian) commodities ($a_3 > 0$ and $b_3 > 0$).

Following the ARDL bounds testing approach (Pesaran et al., 2001), the conditional error-correction model (ECM) is specified as follows:

$$\Delta lnEXP_{it}^{i} = \alpha_0 + \sum_{k=1}^{p1} \pi_k \Delta lnEXP_{t-k}^{i} + \sum_{k=0}^{p2} \tau_k \Delta \ln ER_{t-k} + \sum_{k=0}^{p3} \chi_k \Delta lnV_{t-k} + \sum_{k=0}^{p4} \delta_k \Delta lnGDP_{t-k}^{CA}$$
$$+\alpha_1 lnEXP_{t-1}^{i} + \alpha_2 \ln ER_{t\text{-}1} + \alpha_3 lnV_{t\text{-}1} + \alpha_4 lnGDP_{t-1}^{CA} + \xi_t \quad (3)$$

$$\Delta lnIMP_{t}^{i} = \beta_0 + \sum_{k=1}^{p1} \tau_k \Delta lnIMP_{t-k}^{i} + \sum_{k=0}^{p2} \rho_k \Delta \ln ER_{t-k} + \sum_{k=0}^{p3} \varsigma_k \Delta lnV_{t-k} + \sum_{k=0}^{p4} \phi_k \Delta lnGDP_{t-k}^{US}$$
$$+\beta_1 lnIMP_{t-1}^{i} + \beta_2 \ln ER_{t\text{-}1} + \beta_3 lnV_{t\text{-}1} + \beta_4 lnGDP_{t-1}^{US} + \upsilon_t (4)$$

where Δ is the difference operator; *p1*, *p2*, *p3*, and *p4* are lag lengths; and ξ_t and υ_t are error terms. In Equation (3), α_i are the long-run parameters and the coefficients following the summation signs (i.e., $\pi_k, \tau_k, \chi_k, \text{ and } \delta_k$) are the short-run parameters. Similarly, β_i show the long-run relationships while the coefficients following the summation signs represent the short-run relationship among the variables in Equation (4).

The primary focus of this study is on the asymmetric effects of currency value and exchange rate volatility. Following the nonlinear ARDL approach by Shin et al. (2014), we decompose the series of exchange rate variables into two partial sums: a partial sum process of positive changes and a partial sum process of negative changes. Exchange rate variables ($\ln ER_t$ and $\ln V_t$) are decomposed as follows:

$$lnER_t^{+} = \sum_{j=1}^{t} \Delta lnER_j^{+} = \sum_{j=1}^{t} \max\left(\Delta lnER_j\ , 0\right), lnER_t^{-} = \sum_{j=1}^{t} \Delta lnER_j^{-} = \sum_{j=1}^{t} \min\left(\Delta lnER_j\ , 0\right) (5)$$

$$lnV_t^{+} = \sum_{j=1}^{t} \Delta lnV_j^{+} = \sum_{j=1}^{t} \max\left(\Delta lnV_j\ , 0\right), lnV_t^{-} = \sum_{j=1}^{t} \Delta lnV_j^{-} = \sum_{j=1}^{t} \min\left(\Delta lnV_j\ , 0\right) (6)$$

The error correction model is re-specified by replacing $lnEX_t$ by $lnEX_t^{+}$ and $lnEX_t^{-}$ (lnV_t by lnV_t^{+} and lnV_t^{-}). Equations (3) and (4) are rewritten as follows:

$$\Delta lnEXP_{t}^{i} = \alpha_0 + \sum_{k=1}^{p1} o_k \Delta lnEXP_{t-k}^{i} + \sum_{k=0}^{p2} \theta_k^{+} \Delta \ln ER_{t-k}^{+} + \sum_{k=0}^{p3} \theta_k^{-} \Delta lnER_{t-k}^{-} + \sum_{k=0}^{p4} \varphi_k^{+} \Delta \ln V_{t-k}^{+}$$
$$+ \sum_{k=0}^{p5} \varphi_k^{-} \Delta \ln V_{t-k}^{-} + \sum_{k=0}^{p6} \delta_k \Delta lnGDP_{t-k}^{CA} + \alpha_1 lnEXP_{t-1}^{i} + \alpha_2 \ln ER_{t\text{-}1}^{+} + \alpha_3 lnER_{t\text{-}1}^{-}$$
$$+ \alpha_4 lnV_{t\text{-}1}^{+} + \alpha_5 lnV_{t\text{-}1}^{-} + \alpha_6 lnGDP_{t-1}^{CA} + \xi_t (7)$$

$$\Delta lnIMP_t^i = \beta_0 + \sum_{k=1}^{p1} \epsilon_k \Delta lnIMP_{t-k}^i + \sum_{k=0}^{p2} u_k^+ \Delta \ln ER_{t-k}^+ + \sum_{k=0}^{p3} u_k^- \Delta lnER_{t-k}^- + \sum_{k=0}^{p4} \omega_k^+ \Delta \ln V_{t-k}^+ + \sum_{k=0}^{p5} \omega_k^- \Delta \ln V_{t-k}^- + \sum_{k=0}^{p6} \delta_k \Delta lnGDP_{t-k}^{US} + \beta_1 lnIMP_{t-1}^i + \beta_2 \ln ER_{t\text{-}1}^+ + \beta_3 lnER_{t\text{-}1}^- + \beta_4 lnV_{t-1}^+ + \beta_5 lnV_{t-1}^- + \beta_6 lnGDP_{t-1}^{US} + v_t \quad (8)$$

To test for the existence of cointegration, this study uses the *F*-statistic (H_0:$\alpha_1 = \alpha_2 = \cdots = \alpha_6 = 0$ in Equation (7) and H_0: $\beta_1 = \beta_2 = \cdots = \beta_6 = 0$ in Equation (8)). In this paper, we use the Wald test to test the null hypothesis of long-run symmetriesassociated with currency value and volatility changes. If currency appreciation and depreciation have symmetric effects, normalized coefficients for the exchange rate changes must be the same in sign and size (H_0:$\alpha_2 = \alpha_3$ in Equation (7) and H_0: $\beta_2 = \beta_3$in Equation (8)).Otherwise, their effects are asymmetric. If positive and negative changes in exchange rate volatility have symmetric effects, normalized coefficients for the volatility variables must be the same in sign and size (H_0:$\alpha_4 = \alpha_5$ in Equation (7) and H_0: $\beta_4 = \beta_5$in Equation (8)).Otherwise, exchange rate volatility changes affect trade flows in an asymmetric manner.

Data

The period of this study covers from January 2006 to December 2017. Monthly US-Canada trade data are collected from the North American TransBorder Freight Data published by the Bureau of Transportation Statistics (2019). To obtain the real exchange rate, the nominal exchange rate is multiplied by the ratio of the consumer price indices (CPI) of the US and Canada. The real exchange rate data are taken from the Economic Research Service (ERS), the United States Department of Agriculture (ERS, 2019). The gross domestic product (GDP) is used as a proxy for economic growth in the country. Since monthly GDP data are not available, we transform annual GDP data into monthly GDP by using monthly Industrial Production Index (IPI). The GDP data are collected from the World Bank national accounts data published by the World Bank (2019) and IPI data are collected from the FRED Economic Data published by Federal Reserve Bank (2019). This paper uses 2010 as the base year for the exchange rate and GDP variables. To measure exchange rate volatility, this paper uses the Generalised Autoregressive Conditional Heteroscedasticity model (GARCH) developed by Bollerslev (1986). The GARCH-based measure captures the time-varying conditional variance from a time-series model and it is widely used in the literature on international trade.

Empirical Results

For comparison purposes, we estimate both linear and nonlinear ARDL models. This approach helps us determine if exchange rate asymmetries exist in US-Canada cross-border trade flows. Table 1 shows the long-run coefficient estimates from aggregate bilateral data. With regards to long-run coefficients, exchange rate ($lnER_t$) has a significant long-run effect on the bilateral trade flows between the US and Canada. The variable carries a negative coefficient in the US export model, while it has a positive coefficient in the US import model. These findings suggest that an appreciation of US dollar against Canadian dollar has a negative effect on the US exports to Canada and a positive impact on the US imports from Canada. In contrast, the effect of exchange rate volatility (lnV_t) is found to be insignificant even at the 10% significance level in both export and import models. As expected, the real GDP is found to be significantly associated with the bilateral trade flows. The coefficient of $lnGDP_t^{CA}$ ($lnGDP_t^{US}$) is 2.25 (2.52) in the US export model (import model). This suggests that real GDP is a key driving force of rising cross-border freight flows between the two nations.

Table 1. Results of the linear ARDL models.

Panel A: Long-Run Coefficients for the Export Model (US Exports to Canada)				
Constant	$lnER_t$	lnV_t	$lnGDP_t^{CA}$	
-34.22** (-7.89)	-1.11** (-8.48)	-0.01* (-1.74)	2.25** (13.29)	
Diagnostic Statistics				
Adj. R^2	*F*	ECM_{t-1}	*LM*	*ARCH*
0.84	11.19**	-0.58** (-7.60)	0.41 [0.66]	0.63 [0.53]
Panel B: Long-Run Coefficients for the Import Model (US Imports from Canada)				
Constant	$lnER_t$	lnV_t	$lnGDP_t^{US}$	
-46.52** (2.96)	1.43** (3.34)	-0.02 (-0.47)	2.52** (4.44)	
Diagnostic Statistics				
Adj. R^2	*F*	ECM_{t-1}	*LM*	*ARCH*
0.85	6.40**	-0.24** (-5.55)	0.25 [0.77]	0.75 [0.46]

Notes:
a. Numbers in the parentheses are *t*-values. *P*-values are given in brackets.
b. The upper bound critical values of the *F*-statistic at the 5% and 10% significance levels are 4.35 and 3.77, respectively. These values come from Pesaran et al. (2001), Table CI-Case III.
c. LM and ARCH are the Lagrange multiplier test of serial correlation and heteroskedasticity, respectively. The ARCH test is based on the regression of squared residuals on squared fitted values. All tests are based on the *F*-statistic with two degree of freedom.
d. ** and * denote significance at the 5% and 10% levels, respectively.

We now turn our attention to the results of the nonlinear models to investigate possible asymmetric effects of currency value and exchange rate volatility. Table 2 reports the long-run coefficients of the nonlinear ARDL models. The results indicate that the exchange rate variables ($lnER_t^+$ and $lnER_t^-$) have significant effects on the bilateral trade flows. This suggests that exchange rate is an important factor affecting trade flows between the US and Canada. Regarding exchange rate uncertainty, lnV_t^+ and lnV_t^- have significant effects on the bilateral trade flows in 3 out of 4 cases. The coefficients differ in size, suggesting that positive and negative changes in volatility affect the cross-border trade flows in an asymmetric manner. These findings contradict those of the linear models in which exchange rate volatility is found to be insignificant even at the 10% significance level. These findings imply that using the conventional linear specification may mislead the asymmetric effects of exchange rate uncertainty on trade flows.

Table 2. Results of the nonlinear ARDL models.

Panel A: Long-Run Coefficients for the Export Model (US Exports to Canada)					
Constant	$lnER_t^+$	$lnER_t^-$	lnV_t^+	lnV_t^-	$lnGDP_t^{CA}$
-36.32** (-4.66)	-1.11** (-5.81)	-0.58** (-2.49)	-0.02** (-2.30)	-0.01 (0.72)	2.34** (7.70)
Diagnostic Statistics					
Adj. R^2	*F*	ECM_{t-1}	*LM*	*ARCH*	
0.86	10.43**	-0.71**	0.45	0.73	

		(-8.75)	[0.63]	[0.48]	
Panel B: Long-Run Coefficients for the Import Model (US Imports from Canada)					
Constant	$lnER_t^+$	$lnER_t^-$	lnV_t^+	lnV_t^-	$lnGDP_t^{US}$
-70.65**	0.78**	0.80**	-0.06**	-0.04**	2.40**
(-7.82)	(3.54)	(3.13)	(-3.84)	(-4.59)	(10.48)
Diagnostic Statistics					
Adj. R^2	*F*	ECM_{t-1}	*LM*	*ARCH*	
0.88	10.70**	-0.57**	1.15	1.55	
		(-8.95)	[0.31]	[0.21]	

Notes:
a. Numbers in the parentheses are *t*-values. *P*-values are given in brackets.
b. The upper bound critical values of the *F*-statistic at the 5% and 10% significance levels are 3.79 and 3.35, respectively. These values come from Pesaran et al. (2001), Table CI-Case III.
c. LM and ARCH are the Lagrange multiplier test of serial correlation and heteroskedasticity, respectively. The ARCH test is based on the regression of squared residuals on squared fitted values. All tests are based on the *F*-statistic with two degree of freedom.
d. ** and * denote significance at the 5% and 10% levels, respectively.

To test if the effects of exchange rate changes vary by transport mode, this paper analyzes export and import flows by transport mode. Table 3 provides the estimated long-run coefficients of the linear ARDL models. The results show that exchange rate is a crucial factor affecting the bilateral trade flows in most cases. For the US exports, $lnER_t$ is found to be statistically significant for air, rail, truck, and vessel. Similarly, it carries a significant coefficient for air, pipeline, truck and vessel in the US import models. In contrast, exchange rate volatility (lnV_t) appears to be insignificant even at the 10% significance level in the majority of cases. Only two modes (truck and vessel) reveal a significant effect of exchange rate volatility on trade flows from the US to Canada, while only air transportation exhibits a significant impact of exchange rate volatility on trade flows from Canada to the US. In addition, the real GDP is found to be significantly associated with the bilateral trade flows in 9 out of 10 cases. Among transportation modes, the US exports by air and pipeline are highly sensitive to a change in Canadian GDP, compared to US exports by rail.

Table 3. Results of the linear ARDL models by transport mode.

Variable	US Exports to Canada				
	$lnEXP_t^a$	$lnEXP_t^p$	$lnEXP_t^r$	$lnEXP_t^t$	$lnEXP_t^v$
Constant	12.31**	-201.02**	-53.67**	-22.24**	-166.84**
	(3.36)	(-9.67)	(-7.06)	(-4.81)	(-4.91)
$lnER_t$	-0.84**	-1.48	-1.26**	-0.86**	-2.39**
	(-7.50)	(-0.45)	(-5.47)	(-5.50)	(-2.51)
lnV_t	0.01	-0.04	-0.01	-0.03**	-0.18**
	(0.97)	(-0.81)	(-0.27)	(-2.46)	(-2.34)
$lnGDP_t^{CA}$	2.93**	2.59**	0.34**	1.77**	1.24**
	(9.85)	(10.54)	(2.62)	(9.72)	(5.45)
	US Imports from Canada				
	$lnIMP_t^a$	$lnIMP_t^p$	$lnIMP_t^r$	$lnIMP_t^t$	$lnIMP_t^v$
Constant	-50.54**	-16.29**	-64.57**	-72.42**	-17.33
	(-4.23)	(-0.68)	(-3.71)	(-2.22)	(-1.24)
$lnER_t$	2.10**	-0.82**	-1.12	1.44**	0.77**
	(7.94)	(-3.21)	(-1.54)	(3.12)	(2.68)

lnV_t	-0.09**	-0.01	-0.05	-0.03	-0.04
	(-2.27)	(0.50)	(-1.37)	(-0.68)	(-1.60)
$lnGDP_t^{US}$	2.54**	2.42**	1.10**	1.36	1.37**
	(5.93)	(2.91)	(4.93)	(1.60)	(2.75)

Finally, Table 4 presents the long-run coefficients of the nonlinear ARDL models. The results indicate that the real GDP is a crucial long-run determinant of US freight exports for all transport modes. Regarding the effects of exchange rate, the results show that exchange rate plays an important role in the cross-border trade flows. At least one of exchange rate variables ($lnER_t^+$ and $lnER_t^-$) is statistically significant in all cases except rail freight flows from Canada to the US. We also find that the coefficients differ in size for all transport modes, implying that currency appreciation and depreciation influence trade flows in an asymmetric fashion. While exchange rate volatility is found to be insignificant in the linear models, the results of nonlinear models reveal that positive and negative changes in exchange rate volatility (lnV_t^+ and lnV_t^-) tend to be significantly associated with the bilateral trade flows. At least one of exchange rate volatility variables is statistically significant in 4 cases (air, pipeline, truck, and vessel) in the US export models and 3 cases (air, truck, and vessel) in the US import models.

Table 4. Results of the nonlinear ARDL models by transport mode.

Variable	US Exports to Canada				
	$lnEXP_t^a$	$lnEXP_t^p$	$lnEXP_t^r$	$lnEXP_t^t$	$lnEXP_t^v$
Constant	4.81	-138.67**	-74.24**	-38.57**	-200.83**
	(0.71)	(-4.37)	(-4.83)	(-7.02)	(-3.18)
$lnER_t^+$	-0.69**	-2.05**	-1.16**	-1.16**	-4.36**
	(-4.17)	(-2.44)	(-3.05)	(-8.32)	(-2.92)
$lnER_t^-$	-0.93**	-1.60	-1.25**	-0.65**	0.12
	(-5.13)	(-1.63)	(-2.62)	(-4.19)	(0.06)
lnV_t^+	-0.02**	-0.01**	-0.01	-0.08**	-0.17**
	(-2.40)	(-2.79)	(-0.26)	(-2.04)	(-2.68)
lnV_t^-	0.01	-0.05	0.01	-0.01	-0.06
	(1.32)	(-1.02)	(0.10)	(-0.97)	(-0.70)
$lnGDP_t^{CA}$	2.62**	2.16**	1.73**	2.41**	0.63**
	(3.49)	(4.97)	(6.22)	(11.25)	(2.43)
	US Imports from Canada				
	$lnIMP_t^a$	$lnIMP_t^p$	$lnIMP_t^r$	$lnIMP_t^t$	$lnIMP_t^v$
Constant	-22.05**	-64.74	-73.50**	-76.82**	-26.68
	(-2.06)	(-1.41)	(-5.20)	(-5.80)	(-1.28)
$lnER_t^+$	0.66**	0.37	-0.21	0.57	1.50**
	(2.40)	(0.31)	(-0.63)	(1.45)	(2.16)
$lnER_t^-$	0.09	3.52**	-0.44	0.82*	1.14**
	(0.30)	(2.12)	(-1.17)	(1.90)	(4.37)
lnV_t^+	-0.17**	0.01	-0.07	-0.03*	0.18*
	(-2.14)	(0.51)	(-0.25)	(-1.75)	(1.88)
lnV_t^-	-0.07*	-0.01	-0.06	-0.01	0.24
	(-1.72)	(0.39)	(-0.21)	(-1.21)	(0.60)
$lnGDP_t^{US}$	1.52**	2.13*	2.59**	0.44**	1.74**
	(3.97)	(1.91)	(7.57)	(6.80)	(2.34)

4. Conclusion

This study tackles the issue of the asymmetric effects of exchange rate changes on the cross-border freight flows. The main contribution of this paper is to provide empirical evidence of asymmetric effects of 1) the

currency appreciation and depreciation and 2) exchange rate volatility increase and decrease on cross-border freight flows between the US and Canada. The findings of this study provide important policy or managerial implications. First, using trade flow data by transport mode, the results show that the asymmetric effects of exchange rate changes vary by transport mode. These findings support the importance of using disaggregate data by transport mode to avoid the aggregation bias. The information derived from a disaggregate trade model would be useful for traders and shippers to develop a long-term strategic plan for infrastructure investment and service expansion for their exporting and importing commodities.Second, in the nonlinear models, exchange rate volatility appears to be significantly associated with trade flows. This conclusion differs from the findings from the linear ARDL models in which exchange rate volatility is insignificant in most cases. Without considering the nonlinear model, we would have concluded that exchange rate uncertainty has a no significant effect on the bilateral trade flows between the US and Canada. This suggests that using the conventional linear specification may mislead the true effects of exchange rate volatility and result in the problem of omitted-variable bias. Thus, the nonlinear exchange rate elasticities of demand should be considered to develop trade and exchange rate policies in improving the country's trade balance.

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