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Exchange Rate Effects on the U.S.–Canada Forest Product Trade: Are the Effects Asymmetric?

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Up until now, relatively little attention has been given to the asymmetric effects of exchange rates on global trade flows of forest products. Thus, the primary thrust of this article is to probe the asymmetric influences exchange rate fluctuations have on bilateral trade flows of various forest products between the United States and Canada. We use the nonlinear autoregressive distributed lag (NARDL) method and discover strong evidence that the ups and downs of exchange rates appear to have asymmetric impacts on U.S. exports and imports of forest products in the long run. However, there is little evidence that the exchange rate asymmetry is present in the short run.

Key words: forest products trade, NARDL, North America

Introduction

Since exchange rates have long been recognized as the most important macroeconomic variable influencing global trade flows of forest products, extensive attention has been given in forest economics to the study of their impact. The vast majority of this research uses time series methods (e.g., Adams, McCarl, and Homayounfarrokh, 1986; Buongiorno, Chavas, and Uusivuori, 1988; Uusivuori and Buongiorno, 1990; Jennings, Adamowicz, and Constantino, 1991; Sarker, 1993; Baek, 2007; Wang, Yin, and Gan, 2017), but these studies provide mixed evidence on the impact of exchange rates on trade flows of forest commodities. For example, Buongiorno, Chavas, and Uusivuori (1988) and Baek (2007) detect a weak link between exchange rate fluctuations and the U.S.–Canada lumber trade. Adams, McCarl, and Homayounfarrokh (1986) and Sarker (1993), by contrast, find that exchange rate movements significantly affect softwood lumber trade between the United States and Canada. More recently, Wang, Yin, and Gan (2017) find a sizeable impact of the Chinese yuan on China's panel exports to its major trade partners.

A crucial point that studies have frequently overlooked and rarely investigated is that they typically assume that changes in exchange rates symmetrically affect forest product trade. This means that currency appreciation is thought of as having equally opposite effects as currency depreciation (and vice versa). Since international forest product traders tend to react differently to depreciation and appreciation of currencies, however, nothing guarantees that such an assumption holds true. In fact, if exchange rates turn out to have asymmetric effects on forest products, prior empirical analyses are likely to be misspecified, casting doubts on the findings of previous analyses. In other words, the conflicting evidence found in previous research could be due to the failure to identify the possibility of asymmetric responses of forest product trade to exchange rate fluctuations. Thus, only by incorporating an assumption of asymmetry when exploring the nexus between a country's forest product trade and exchange rates can we provide more robust evidence of these effects.

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Table 1. U.S.–Canada Forest Product Trade, 2018

Harmonized System Code	Product	Value ($thousands)	Share of Total Exports (%)
Exports			
4401	Fuelwood	123,728	3.5
4403	Wood in the rough	326,182	9.2
4406	Railway ties	136,388	3.9
4407	Wood sawn, chipped	458,326	13.0
4408	Veneers and sheets	118,282	3.4
4409	Shaped wood	70,340	2.0
4410	Particle board	94,611	2.7
4411	Fiberboard of wood	147,994	4.2
4412	Plywood	106,320	3.0
4415	Wooden cases	51,954	1.5
4418	Builders' joinery	265,896	7.5
4421	Articles of wood	74,911	2.1
4703	Chem pulp sulfate	131,621	3.7
4707	Waste or scrap paper	165,555	4.7
4804	Uncoated kraft paper	493,861	14.0
4805	Uncoated paper	336,774	9.5
4810	Paper, board, clay	58,966	1.7
Imports			
4407	Wood sawn, chipped	5,643,489	39.3
4408	Veneers and sheets	312,989	2.2
4410	Particle board	1,870,929	13.0
4411	Fiberboard of wood	318,441	2.2
4412	Plywood	340,377	2.4
4418	Builders' joinery	1,123,596	7.8
4421	Articles of wood	140,793	1.0
4703	Chem pulp sulfate	1,812,129	12.6
4801	Newsprint	863,551	6.0
4804	Uncoated kraft paper	375,051	2.6
4805	Uncoated paper	448,146	3.1
4810	Paper, board, clay	221,319	1.5

In this article, therefore, our central interest is to evaluate the asymmetric influences that exchange rate fluctuations have on trade flows of various forest products (identified using the four-digit Harmonized System Code, HS-4) between the United States and Canada. We allow for asymmetric responses to changes in the bilateral exchange rate by splitting U.S. dollar appreciation and U.S. dollar depreciation into separate variables and applying Shin et al.'s (2014) approach, known as the nonlinear autoregressive distributed lag (NARDL) method to test (i) whether each of the two variables is statistically significant and (ii) whether an asymmetric response is present.[1] In 2018, Canada was the top supplier for the U.S. forest product import market; U.S. imports totaled

[1] NARDL has been widely utilized to make rigorous nonlinear (asymmetric) analyses in the literature on international economics (e.g., Bahmani-Oskooee and Fariditavana, 2016).

$10 billion, comprising nearly 50% of the value of U.S. forest product imports. Canada also was the second-largest export market for the United States (after China) in 2018, U.S. exports totaled $2.1 billion, accounting for approximately 22% of the value of U.S. forest product exports. The top three U.S. export products to Canada include sawn wood (HS 4407), uncoated kraft paper (HS 4804), and uncoated paper (HS 4805) (Table 1). The U.S. top three import products from Canada are sawn wood (HS 4407), particle board (HS 4410), and chemical pulp sulfate (HS 4703).

Model and Methods

The recent literature on international trade (e.g., Baek, 2013; Aftab, Syed, and Katper, 2017) illustrates that trade models considering exports and imports separately within the framework of bilateral trade flows by product/commodity would not only be able to avoid the aggregation bias problem but also be able to directly capture how and the extent to which exchange rates influence exports and/or imports. In studying how the bilateral exchange rate influences North America's trade in various forest products, therefore, we also rely on the bilateral export and import demand equations:[2]

$$\log\left(EX_{i,t}^{US}\right) = \alpha_o + \alpha_1 \log\left(Y_t^{CA}\right) + \alpha_2 \log\left(REX_t\right) + \varepsilon_t; \quad (1)$$

$$\log\left(IM_{i,t}^{US}\right) = \beta_o + \beta_1 \log\left(Y_t^{US}\right) + \beta_2 \log\left(REX_t\right) + u_t; \quad (2)$$

where $EX_{i,t}^{US}$ ($IM_{i,t}^{US}$) is the value of U.S. exports (imports) to (from) Canada for forest product i;[3] Y_t^{CA} and Y_t^{US} represent the real income of Canada and the United States, respectively; and REX_t is the real CAD/USD exchange rate. In equations (1) and (2), we expect that $\alpha_1 > 0$ and $\beta_1 > 0$ if increasing real income in Canada and the United States causes trade in forest commodities to increase. We expect that $\alpha_2 < 0$ and $\beta_2 > 0$ if the depreciation of USD (i.e., a decrease in REX_t, see the data section) increases (decreases) U.S. exports (U.S. imports) via a reduction (upsurge) in export (import) prices.

The method of specifying the export and import functions as equations (1) and (2) implicitly assumes that exchange rate changes symmetrically affect trade flows. As discussed in the introduction, nothing guarantees that such an assumption is true. Thus, the asymmetry of exchange rate changes would be a more relevant assumption. To properly incorporate this hypothesis in our models, we first split the bilateral exchange rate into two new variables, REX_t^+ (the appreciation of the U.S. dollar) and REX_t^- (the depreciation of the U.S. dollar), as in Bahmani-Oskooee and Fariditavana (2016). These variables are conveniently gauged by the partial sum processes of positive and negative $\log(REX_t)$ changes:

$$REX_t^+ = \sum_{j=1}^{t} \Delta\log\left(REX_j^+\right) = \sum_{j=1}^{t} \max\left[\Delta\log\left(REX_j, 0\right)\right]; \quad (3)$$

$$REX_t^- = \sum_{j=1}^{t} \Delta\log\left(REX_j^-\right) = \sum_{j=1}^{t} \min\left[\Delta\log\left(REX_j, 0\right)\right]. \quad (4)$$

If we then replace REX_t^+ and REX_t^- with $\log(REX_t)$ in equations (1) and (2), the resulting models are

$$\log\left(EX_{i,t}^{US}\right) = \alpha_o + \alpha_1 \log\left(Y_t^{CA}\right) + \alpha_2 REX_t^+ + \alpha_3 REX_t^- + \varepsilon_t; \quad (5)$$

$$\log\left(IM_{i,t}^{US}\right) = \beta_o + \beta_1 \log\left(Y_t^{US}\right) + \beta_2 REX_t^+ + \beta_3 REX_t^- + u_t. \quad (6)$$

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[2] For more details, refer to Baek (2013).

[3] Forest product designations in this article are based on four-digit Harmonized System Code (HS-4): U.S. exports (imports) are divided into 17 (12) forest commodities.

It should be remembered that equations (5) and (6) represent only the potential long-run determinants of U.S. exports/imports of forest product i to/from Canada. When performing the NARDL method properly, Shin, Yu, and Greenwood-Nimmo (2014) recommend that equations (5) and (6) be written as error-correction models after incorporating the short-run dynamics:

$$\begin{aligned}\Delta\log(EX_{i,t}^{US}) = \alpha_0 &+ \sum_{k=1}^{p}\alpha_{i1,t-k}\Delta\log(EX_{i,t-k}^{US}) + \sum_{k=0}^{p}\alpha_{i2,t-k}\Delta\log(Y_{t-k}^{CA}) \\ &+ \sum_{k=0}^{p}\alpha_{i3,t-k}\Delta RER_{t-k}^{+} + \sum_{k=0}^{p}\alpha_{i4,t-k}\Delta RER_{t-k}^{-} + \delta_0\log(EX_{i,t-1}^{US}) \\ &+ \delta_1\log(Y_{t-1}^{CA}) + \delta_2 RER_{t-1}^{+} + \delta_3 RER_{t-1}^{-} + \psi_t\end{aligned} \tag{7}$$

$$\begin{aligned}\Delta\log(IM_{i,t}^{US}) = \beta_0 &+ \sum_{k=1}^{p}\beta_{i1,t-k}\Delta\log(IM_{i,t-k}^{US}) + \sum_{k=0}^{p}\beta_{i2,t-k}\Delta\log(Y_{t-k}^{US}) \\ &+ \sum_{k=0}^{p}\beta_{i3,t-k}\Delta RER_{t-k}^{+} + \sum_{k=0}^{p}\beta_{i4,t-k}\Delta RER_{t-k}^{-} + \lambda_0\log(IM_{i,t-1}^{US}) \\ &+ \lambda_1\log(Y_{t-1}^{US}) + \lambda_2 RER_{t-1}^{+} + \lambda_3 RER_{t-1}^{-} + \zeta_t.\end{aligned} \tag{8}$$

How do we estimate the parameters in equations (7) and (8)? First, cointegration must be established among the variables. For this purpose, Pesaran, Shin, and Smith (2001) recommend applying the conventional F-test to establish the joint significance of all lagged-level variables as a sign of cointegration.[4] We take the null hypothesis to be that no cointegration exists (i.e., $H_0 : \delta_0 = \delta_1 = \delta_2 = \delta_3 = 0$ in equation 7 and $H_0 : \lambda_0 = \lambda_1 = \lambda_2 = \lambda_3 = 0$ in equation 8). However, the distribution of the F-tests is nonstandard, so that Pesaran, Shin, and Smith tabulate new two sets of critical values depending on different significance levels. Since these critical values provide critical value bounds (lower and upper) covering all possible classifications of variables into $I(0)$ and $I(1)$, it is unnecessary to determine the order of integration of the selected variables prior to testing for cointegration. Thus, there is no need for pretesting for unit roots. This is one of the main advantages of this method over typical cointegration methods (e.g., Engle and Granger, 1987; Johansen, 1988), which requires all variables in a model to be $I(1)$. Once the F-value is larger than the critical value, H_0 would be rejected, thereby confirming cointegration. Second, once we have obtained cointegration, we then can estimate the long- and short-run relationships in equations (7) and (8) using a one-step procedure.[5] The dynamic short-run impacts are obtained from the coefficients next to the summation (Σ). The long-run effects are captured by coefficients of δ_1, δ_2, and δ_3 divided by $-\delta_0$ in equation (7) and by coefficients of λ_1, λ_2, and λ_3 divided by $-\lambda_0$ in equation (8). Finally, we employ the Wald statistic to test the asymmetric hypothesis in equations (7) and (8). In equation (7), for example, the null hypothesis is stated as $H_0 : {}^{\delta_2}\!/_{-\delta_0} = {}^{\delta_3}\!/_{-\delta_0}$ ($H_0 : \sum\alpha_{i3} = \sum\alpha_{i4}$), meaning no long-run (short-run) asymmetry. Under H_0, the Wald statistic is distributed as a χ^2 random variable with q degrees of freedom (df). Once the critical value (c) is obtained, we reject H_0 if $> c$, providing evidence of asymmetry.

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[4] Since NARDL is an extension of Pesaran, Shin, and Smith's (2001) autoregressive distributed lag (ARDL) approach, the ARDL testing procedures are equally applicable to NARDL.

[5] This is another advantage of this method over the Engler–Granger and Johansen tests, which require two steps in applying cointegration and error-correction models to derive the long- and short-run impacts. Finally, NARDL/ARDL performs well for finite sample sizes compared to standard cointegration techniques.

Data

The dataset contains 121 quarterly observations for the period from 1989:Q1 to 2019:Q1. The nominal values of exports and imports of forest products (four-digit Harmonized System Code, HS-4) between the United States and Canada are collected from the U.S. Department of Agriculture's Foreign Agricultural Service (FAS). The U.S. aggregated export and import price indices from the International Monetary Fund's International Financial Statistics (IFS) are used to derive the real values of forest products exports and imports.[6] The incomes of the United States and Canada are measured as an index of real gross domestic product (GDP) (2010 = 100) and are taken from the IFS. The nominal U.S.–Canada bilateral exchange rate is also collected from the IFS. The consumer price indices (CPIs, 2010 = 100) in both countries, obtained from the IFS, are then used to derive the real bilateral exchange rate. Since the exchange rate is defined as the Canadian dollar per USD, a decline in the exchange rate indicates a depreciation of USD. Finally, the data are converted to natural logarithms and used throughout.

Results

The bilateral export and import equations outlined by equations (7) and (8) are estimated to probe whether the bilateral exchange rate asymmetrically influences North America's forest product trade.

Prerequisite Issues in NARDL

Before turning to the empirical results, one of the prerequisite issues to be solved is determining the order of integration of the time series. More specifically, since NARDL is an extension of Pesaran, Shin, and Smith's (2001) approach—known as a (linear) autoregressive distributed lag (ARDL) method, which is applicable irrespective of whether series are $I(0)$ or $I(1)$—it basically rules out preunit root testing. When NARDL is applied to $I(2)$ series, however, then the spurious regression problem can arise with time series data. For this reason, a stationary test of the variables is certainly a safe course to follow. Thus, we carry out the Dickey–Fuller generalized least squares (GLS) test (Table 2). The results show that the null of nonstationarity can be rejected only for HS 4703 in both equations and HS 4810 in the export equation, indicating that they are stationary $I(0)$ series. For all of the other variables, the null cannot be rejected in levels but can be rejected after first differencing, providing evidence of $I(1)$ series. Thus, there is strong evidence that all variables are either $I(0)$ or $I(1)$ in equations (7) and (8).

Because we are now confident that no variables are $I(2)$, the second prerequisite issue to be tackled is carrying out the F-test to establish cointegration (Table 3). For the U.S. export (import) equation, we obtain that the computed F-statistics exceed at least 3.90 (4.53) in 14 of the 17 cases (all 12 cases). The 10% critical value is 3.77 so that the null is soundly rejected, confirming cointegration among the variables. It is worth pointing out, however, that (since the computed F-statistics are very sensitive to the lag order p) we also use a significantly negative error-correction term as another criterion of establishing cointegration. We find that the error-correction terms are negative and very significant for 15 cases (all 12 cases) in the export (import) equation. Taken together, we conclude that all variables in the export (import) equation are cointegrated in 15 out of the 17 cases (all 12 cases). For the remaining two cases—railway ties (HS 4406) and uncoated paper (HS 4805)—in the export equation, however, the values of the F-statistics and t-statistics on the error-correction terms turn out to be insignificant at the 10% level, providing an indication of no cointegration; therefore, these two products are eliminated from further analysis.

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[6] Since product-level export and import price indices are not available, aggregate export and import price indices are employed, as is done in Bahmani-Oskooee, Harvey, and Hegerty (2013).

Table 2. Test Results for a Unit Root Using DF-GLS

Harmonized System Code	Level	First Difference
Exports		
4401 Fuelwood	−1.21 (0)	−3.67 (6)**
4403 Wood in the rough	−0.88 (8)	−10.39 (0)**
4406 Railway ties	−1.77 (4)	−5.62 (3)**
4407 Wood sawn, chipped	−0.79 (6)	−2.89 (6)*
4408 Veneers and sheets	−0.79 (4)	−4.27 (3)**
4409 Shaped wood	−0.79 (4)	−3.14 (3)**
4410 Particle board	−1.19 (4)	−2.72 (4)*
4411 Fiberboard of wood	−1.19 (2)	−5.37 (2)**
4412 Plywood	−1.78 (4)	−6.61 (4)**
4415 Wooden cases	−1.56 (2)	−12.47 (0)**
4418 Builders' joinery	−0.84 (8)	−5.96 (0)**
4421 Articles of wood	−2.65 (0)	−10.16 (0)**
4703 Chem pulp sulfate	−3.98 (0)**	
4707 Waste or scrap paper	−0.79 (6)	−3.55 (4)**
4804 Uncoated kraft paper	−1.17 (0)	−7.47 (0)**
4805 Uncoated paper	−1.96 (0)	−3.17 (0)**
4810 Paper, board, clay	−3.52 (0)**	
Imports		
4407 Wood sawn, chipped	−1.28 (2)	−11.34 (1)**
4408 Veneers and sheets	−2.33 (9)	−3.26 (4)**
4410 Particle board	−1.44 (3)	−4.78 (2)**
4411 Fiberboard of wood	−0.98 (4)	−3.71 (3)**
4412 Plywood	−1.50 (4)	−3.48 (3)**
4418 Builders' joinery	−1.61 (4)	−3.37 (3)**
4421 Articles of wood	−1.13 (4)	−10.51 (0)**
4703 Chem pulp sulfate	−3.05 (0)**	
4801 Newsprint	−2.10 (1)	−8.40 (0)**
4804 Uncoated kraft paper	−0.96 (1)	−3.46 (1)**
4805 Uncoated paper	−1.45 (2)	−3.21 (2)**
4810 Paper, board, clay	−1.57 (0)	−6.11 (5)**
Income		
United States	−1.29 (2)	−4.97 (1)**
Canada	−1.17 (1)	−8.52 (0)**
Exchange rate		
RER_t^+	−1.34 (0)	−9.19 (0)**
RER_t^-	−1.05 (1)	−8.11 (0)**

Notes: The null is that each variable has a unit root. Single and double asterisks (*, **) indicate rejection of the null at 10% and 5% significance level, respectively. The Schwert information criterion is employed to determine lag lengths, reported in parentheses. The critical values for the DF-GLS test of nonstationary at significance levels of 5% and 10% are −3.02 and −2.73, respectively.

Table 3. Results of the Cointegration Tests

Harmonized System Code	*F*-Statistic	Error-Correction Term	SC
Exports			
4401 Fuelwood	6.14**	−0.24 (5.03)**	1.69
4403 Wood in the rough	6.77**	−0.46 (5.28)**	0.41
4406 Railway ties	2.65	−0.40 (3.30)	3.39
4407 Wood sawn, chipped	6.80**	−0.42 (5.30)**	0.69
4408 Veneers and sheets	4.22**	−0.12 (4.17)**	0.96
4409 Shaped wood	7.81**	−0.43 (5.68)**	0.37
4410 Particle board	11.42**	−0.54 (6.85)**	0.73
4411 Fiberboard of wood	3.59	−0.21 (3.85)**	0.39
4412 Plywood	3.90*	−0.32 (4.01)**	0.19
4415 Wooden cases	7.79**	−0.58 (5.66)**	0.44
4418 Builders' joinery	5.18**	−0.27 (4.61)**	0.09
4421 Articles of wood	7.92**	−0.46 (5.71)**	0.30
4703 Chem pulp sulfate	4.62**	−0.30 (4.36)**	0.44
4707 Waste or scrap paper	6.02**	−0.20 (4.98)**	6.88
4804 Uncoated kraft paper	4.49**	−0.22 (4.30)**	2.81
4805 Uncoated paper	1.65	−0.09 (2.61)	0.18
4810 Paper, board, clay	8.28**	−0.37 (5.84)**	0.61
Imports			
4407 Wood sawn, chipped	4.91**	−0.21 (4.50)**	0.9
4408 Veneers and sheets	5.65**	−0.23 (4.82)**	0.81
4410 Particle board	4.53**	−0.21 (4.31)**	0.95
4411 Fiberboard of wood	6.76**	−0.23 (5.27)**	0.55
4412 Plywood	5.80**	−0.19 (4.88)**	0.03
4418 Builders' joinery	5.32**	−0.25 (4.68)**	0.00
4421 Articles of wood	7.92**	−0.40 (5.71)**	0.08
4703 Chem pulp sulfate	5.64**	−0.42 (4.82)**	0.03
4801 Newsprint	9.18**	−0.36 (6.15)**	0.66
4804 Uncoated kraft paper	7.63**	−0.65 (5.60)**	0.08
4805 Uncoated paper	5.26**	−0.27 (4.65)**	0.47
4810 Paper, board, clay	21.40**	−0.41 (9.38)**	1.22

Notes: Single and double asterisks (*, **) indicate significance at the 10% and 5% level, respectively. Numbers in parentheses are absolute t-statistics. The upper critical value for the F-test at 5% (10%) is 4.35 (3.77). The critical value for t-statistics of the error-correction term at the 5% (10%) is −3.78 (−3.46). SC refers to the ÏĞ statistic to test for no serial correlation.

Do Exchange Rate Changes Asymmetrically Influence U.S. Forest Product Exports to Canada?

We are now in a position to estimate equation (7) to detect whether exchange rate changes have asymmetric effects on U.S. exports of forest products to Canada.[7] Let us first discuss the long-run results. Of the 15 cases showing the variables are cointegrated, 11 cases—fuelwood (HS 4401), wood in the rough (HS 4403), sawn wood (HS 4407), veneers and sheets (HS 4408), shaped wood (HS 4409), particle board (HS 4410), plywood (HS 4412), builders' joinery (HS 4418), articles of

[7] One thing to emphasize here is that, since the NARDL assumes that the errors should not be serially correlated, we need to select the integer p (lag length) to account for the serial correlation in equations (7) and (8). When choosing $p = 6$, the Lagrange multiplier (LM) statistics generally exhibit that the null of homoskedasticity in the models cannot be rejected (Table 3). By imposing $p = 6$ as the maximum lag on each first-differenced variable in equations (7) and (8), therefore, the Akaike information criterion (AIC) is applied in identifying the optimal model specifications.

Table 4. Long-Run Effects of Exchange Rates on U.S. Exports to Canada

Harmonized System Code	RER_t^+	RER_t^-	$\log\left(Y_t^{CA}\right)$	Constant	Wald Statistic
4401 Fuelwood	−1.20 (1.86)*	−0.49 (0.87)	2.32 (3.17)**	0.04 (1.72)*	2.87*
4403 Wood in the rough	0.51 (1.89)*	1.49 (7.31)**	1.51 (4.52)**	2.36 (5.29)**	23.12**
4407 Wood sawn, chipped	−0.10 (0.58)**	0.56 (4.41)**	0.93 (4.54)**	3.36 (5.29)**	24.67**
4408 Veneers and sheets	1.46 (1.27)	2.36 (3.80)**	2.20 (1.46)	0.09 (3.98)**	1.55
4409 Shaped wood	−1.55 (5.31)**	−0.27 (1.28)	1.66 (5.32)**	1.68 (5.74)**	35.45**
4410 Particle board	−0.20 (0.82)	0.44 (2.12)**	2.03 (6.84)**	0.62 (6.85)**	11.82**
4411 Fiberboard of wood	−0.60 (1.15)	−0.39 (1.05)	0.97 (1.54)	1.24 (3.84)**	0.22
4412 Plywood	−1.51 (2.17)**	−1.64 (3.24)**	0.30 (0.42)	2.90 (4.04)**	0.20
4415 Wooden cases	−0.04 (0.20)	0.09 (0.57)	2.33 (9.57)**	−0.81 (5.56)**	0.46
4418 Builders' joinery	−1.04 (2.40)**	−0.58 (1.66)*	2.08 (4.61)**	0.50 (4.62)**	2.05
4421 Articles of wood	−1.17 (4.29)**	−0.46 (2.24)**	2.03 (6.35)**	0.55 (5.94)**	13.21**
4703 Chem pulp sulfate	0.19 (0.39)	−0.24 (0.60)	−0.43 (0.74)	3.48 (4.32)**	2.13
4707 Waste or scrap paper	0.77 (1.10)	1.60 (3.02)**	0.56 (0.64)	1.64 (4.85)**	5.23**
4804 Uncoated kraft paper	−0.44 (0.95)	0.39 (1.12)	2.73 (4.86)**	−0.06 (2.63)**	0.58
4810 Paper, board, clay	−0.46 (0.83)	−1.65 (3.24)**	−1.86 (2.93)**	6.17 (5.82)**	8.86**

Notes: Single and double asterisks (*, **) indicate significance at the 10% and 5% level, respectively. Numbers in parentheses are absolute *t*-statistics. Based on the χ^2, the critical value for the Wald test at 5% (10%) is 3.84 (2.71).

wood (HS 4421), waste or scrap paper (HS 4707), and paper, board, clay (HS 4810)—reveal that at least one of the coefficients on RER_t^+ and RER_t^- is significant at the 10% level (Table 4). These 11 cases account for nearly 70% of total U.S. forest product exports. In the long run, therefore, exchange rate fluctuations generally seem to play an important role in fluctuations in U.S. forest products exported to Canada. We also observe that the signs on the coefficients of RER_t^+ are divided between negative and positive, and the negative coefficients are mostly significant. This means that an appreciation of USD tends to drive down U.S. exports via a rise in the prices of exported forest products. When looking at RER_t^-, the signs are also mixed, and the positive coefficients now turn out to be mostly significant. This indicates that the U.S. dollar's depreciation has a significant detrimental impact on U.S. exports.

Recall that we are interested in whether the asymmetry of the exchange rate is present in equation (7). We can detect that all the slope coefficients on RER_t^+ are different from those on RER_t^- in terms of magnitudes, oftentimes together with statistically significant differences. Thus, the long-run asymmetry of exchange rates appears to exist. To corroborate our statement, however, we should calculate the Wald statistic. Based on χ_1^2, long-run asymmetry impacts are confirmed in 8 cases (out of the 15 cointegrated cases)—fuelwood (HS 4401), wood in the rough (HS 4403), sawn wood (HS 4407), shaped wood (HS 4409), particle board (HS 4410), articles of wood (HS 4421), waste or scrap paper (HS 4707), and paper, board, clay (HS 4810). In the long run, therefore, there is evidence that exchange rate changes asymmetrically influence almost 40% of total U.S. forest products exported to Canada.

Pertaining to the Canadian income, we discover that the estimated coefficients on Y_t^{CA} are highly significant in 10 cases. The significant estimates are positive for 9 cases. By and large, therefore, growth in the real Canadian income enhances the purchasing power of Canadian consumers and hence their demand for U.S. forest products in the long run.

Next, we turn to the short-run effects (Table 5). We notice that either ΔRER_t^+ or ΔRER_t^- has at least one significant estimate for all cases except chem pulp sulfate (HS 4703), indicating significant short-run impacts of the exchange rate on the U.S. exports. However, the short-run asymmetry impacts endorsed by the Wald test turn out to be significant only in four cases—sawn wood (HS 4407), fiberboard of wood (HS 4411), chem pulp sulfate (HS 4703), and waste or scrap paper

Table 5. Short-Run Effects of Exchange Rates on U.S. Exports to Canada

	Lag Order					
Variable	**0**	**1**	**2**	**3**	**4**	**Wald Statistic**
4401 Fuelwood						
ΔRER_t^+	−0.29 (1.95)*					0.26
ΔRER_t^-	−0.12 (0.92)					
$\Delta\log(Y_t^{CA})$	0.25 (0.18)	3.61 (2.75)**	−1.78 (1.32)	0.18 (0.13)		
4403 Wood in the rough						
ΔRER_t^+	0.23 (1.95)**					0.43
ΔRER_t^-	0.68 (4.28)**					
$\Delta\log(Y_t^{CA})$	0.69 (2.88)**					
4407 Wood sawn, chipped						
ΔRER_t^+	−1.15 (3.50)**	−0.40 (1.62)*	−0.75 (2.18)**	−0.04 (0.12)	0.63 (1.86)*	4.09**
ΔRER_t^-	0.23 (2.92)**					
$\Delta\log(Y_t^{CA})$	1.53 (2.65)**	0.98 (1.68)*				
4408 Veneers and sheets						
ΔRER_t^+	−1.09 (2.69)**					2.20
ΔRER_t^-	0.28 (2.33)**					
$\Delta\log(Y_t^{CA})$	0.98 (1.43)	1.69 (2.47)**				
4409 Shaped wood						
ΔRER_t^+	−0.75 (1.34)	−0.08 (0.14)	0.29 (0.49)	1.54 (2.62)**	0.87 (1.49)	1.94
ΔRER_t^-	−0.12 (1.35)					
$\Delta\log(Y_t^{CA})$	0.71 (3.63)**					
4410 Particle board						
ΔRER_t^+	−1.28 (1.85)*					0.92
ΔRER_t^-	0.24 (1.92)*					
$\Delta\log(Y_t^{CA})$	3.52 (2.93)**	1.26 (1.04)	2.74 (2.27)**			
4411 Fiberboard of wood						
ΔRER_t^+	−0.76 (1.44)	0.91 (1.69)*	0.93 (1.70)*			4.61**
ΔRER_t^-	−0.23 (0.41)	0.52 (0.90)	−1.04 (1.79)*	−1.53 (2.83)**		
$\Delta\log(Y_t^{CA})$	0.20 (1.28)					
4412 Plywood						
ΔRER_t^+	−2.04 (2.14)**	−2.55 (2.77)**	−1.64 (1.65)	1.31 (1.43)	1.31 (1.44)	0.05
ΔRER_t^-	−2.73 (2.67)**					
$\Delta\log(Y_t^{CA})$	0.10 (0.41)					
4415 Wooden cases						
ΔRER_t^+	−0.02 (0.20)					1.64
ΔRER_t^-	−1.98 (3.22)**					
$\Delta\log(Y_t^{CA})$	1.34 (4.22)**					

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Table 5. – continued from previous page

	Lag Order					
Variable	**0**	**1**	**2**	**3**	**4**	**Wald Statistic**
4418 Builders' joinery						
ΔRER_t^+	−0.28 (2.71)**					1.21
ΔRER_t^-	−0.16 (1.87)*					
$\Delta \log(Y_t^{CA})$	2.02 (2.14)**	2.10 (2.25)**				
4421 Articles of wood						
ΔRER_t^+	−1.08 (1.75)*	0.98 (1.58)	1.09 (1.75)*	−0.98 (1.56)		0.01
ΔRER_t^-	−0.21 (2.14)**					
$\Delta \log(Y_t^{CA})$	0.94 (4.02)**					
4703 Chem pulp sulfate						
ΔRER_t^+	1.18 (1.60)					3.85**
ΔRER_t^-	−0.07 (0.59)					
$\Delta \log(Y_t^{CA})$	−1.88 (1.45)	−2.11 (1.63)	2.35 (1.81)*			
4707 Waste or scrap paper						
ΔRER_t^+	0.15 (1.11)					3.80**
ΔRER_t^-	−1.45 (2.10)**	−0.92 (1.28)	−0.64 (0.89)	−1.30 (1.79)*		
$\Delta \log(Y_t^{CA})$	2.76 (2.54)**	−0.83 (0.73)	3.01 (2.72)**			
4804 Uncoated kraft paper						
ΔRER_t^+	−0.10 (0.91)					0.10
ΔRER_t^-	0.12 (0.24)	0.16 (0.31)	0.67 (1.28)	−1.42 (2.82)**		
$\Delta \log(Y_t^{CA})$	0.59 (2.99)**					
4810 Paper, board, clay						
ΔRER_t^+	−0.17 (0.87)					0.60
ΔRER_t^-	−0.60 (3.40)**					
$\Delta \log(Y_t^{CA})$	2.43 (1.42)	−0.50 (0.28)	4.89 (2.80)**	2.31 (1.30)	3.01 (1.68)*	

Notes: Single and double asterisks (*, **) indicate significance at the 10% and 5% level, respectively. Numbers in parentheses are absolute *t*-statistics. Based on the χ^2, the critical value for the Wald test at 5% (10%) is 3.84 (2.71).

(HS 4707). With regard to the Canadian income, the short-run estimates are statistically significant for all cases except the fiberboard of wood (HS 4411) and plywood (HS 4412). Combined with the long-run outcomes, this finding would seem to imply that the bilateral exchange rate and income are rather more pronounced in the short run than in the long run.

Do Exchange Rate Changes Asymmetrically Influence U.S. Forest Product Imports from Canada?

We now move on to the outcomes of the U.S. import equation underlying equation (8). Again, our primary interest continues to be the coefficients on RER_t^+ and RER_t^-. When first looking into the long-run outcomes (Table 6), we detect that at least one of the coefficients on RER_t^+ and RER_t^- becomes significant at the 10% level for all cases. Evidently, the bilateral exchange rate is a significant determinant of U.S. imports of forest products from Canada in the long run. In addition, the coefficients turn out to be positive for all cases except RER_t^+ in the models belong to newsprint (HS 4801) and paper, board, clay (HS 4810). This means that an appreciation (depreciation)

Table 6. Long-Run Effects of Exchange Rates on U.S. Imports from Canada

Harmonized System Code	RER_t^+	RER_t^-	$\log\left(Y_t^{CA}\right)$	Constant	Wald Statistic
4407 Wood sawn, chipped	1.49 (2.33)**	1.75 (3.53)**	0.01 (0.01)	2.92 (4.42)**	0.25
4408 Veneers and sheets	0.84 (1.84)*	1.82 (6.81)**	2.18 (2.93)**	0.36 (4.35)**	7.44**
4410 Particleboard	1.33 (1.49)	2.97 (5.19)**	4.61 (3.28)**	−1.63 (4.43)**	5.64**
4411 Fiberboard of wood	0.57 (0.84)	3.23 (7.44)**	7.36 (8.45)**	−4.79 (5.26)**	49.38**
4412 Plywood	1.17 (1.64)	3.41 (7.70)**	5.79 (6.10)**	−2.66 (4.91)**	21.90**
4418 Builders' joinery	0.12 (0.28)	2.36 (8.75)**	5.56 (8.78)**	−2.92 (4.71)**	51.66**
4421 Articles of wood	0.24 (0.47)	3.40 (10.62)**	5.18 (7.78)**	−4.22 (5.67)**	83.60**
4703 Chem pulp sulfate	−0.11 (0.43)	0.51 (3.15)**	0.72 (2.07)**	4.32 (4.83)**	12.41**
4801 Newsprint	−0.51 (2.51)**	1.39 (10.26)**	0.73 (2.26)**	4.06 (6.10)**	132.81**
4804 Uncoated kraft paper	0.08 (0.54)	1.27 (12.04)**	2.81 (12.66)**	−0.28 (5.13)**	113.28**
4805 Uncoated paper	1.41 (4.02)**	1.43 (5.75)**	1.02 (1.87)*	1.68 (4.58)**	0.02
4810 Paper, board, clay	−0.66 (2.91)**	0.07 (0.39)	2.15 (6.16)**	0.72 (9.55)**	15.08**

Notes: Single and double asterisks (*, **) indicate significance at the 10% and 5% level, respectively. Numbers in parentheses are absolute *t*-statistics. Based on the χ^2, the critical value for the Wald test at 5% (10%) is 3.84 (2.71).

of USD tends to drive up (down) U.S. imports via a decline (rise) in the prices of imported (exported) forest products. Further, given the magnitudes of the estimated coefficients along with statistical significance, we observe that U.S. imports seem to be more responsive to the dollar's depreciation than to its appreciation, showing the possibility of the long-run asymmetry. To validate this observation, we conduct the Wald test, which strongly rejects the null hypothesis for 10 of the 12 cases. In the long run, therefore, there is convincing evidence that exchange rate changes asymmetrically impact most of U.S. imports of forest products from Canada. It is important to note, however, that the hypothesis for the long-run asymmetry does not seem to hold true for sawn wood (HS 4407), which comprises more than one-third of U.S. forest products imports from Canada.

Concerning U.S. income, we detect that the estimated coefficients on $Y_t^{US}$are statistically significant for almost all cases (11 cases). The significant coefficients are always positive. Thus, increasing real income in the U.S. causes imports of Canadian forest products to increase in the long run. It is worth highlighting that the estimated coefficients of the real U.S. income in equation (8) are generally larger than those of the real Canadian income in equation (7). This means that, *ceteris paribus*, the same changes in U.S. income have a larger effect than Canadian income on the U.S. trade balance with Canada in forest products. In the case of sawn wood (HS 4407), however, the coefficient becomes insignificant even at the 10% level: At best, the U.S. income seems to have no connection with the top U.S. imports from Canada.

When turning to the short-run outcomes, we notice that either or has at least one significant estimate for all cases except builders' joinery (HS 4418), indicating a significant short-run impact of the bilateral exchange rate on U.S. imports (Table 7). However, the Wald tests reveal that the short-run asymmetry impacts turn out to be significant only for two cases—article of wood (HS 4421) and chem pulp sulfate (HS 4703). Compared with the long-run outcomes, therefore, this finding would seem to imply that the asymmetry impacts could be viewed as a long-run phenomenon. With regard to U.S. income, the short-run coefficients are highly significant for all cases except uncoated kraft paper (HS 4804).

Finally, the regressions in equations (7) and (8) successfully pass the diagnostic tests such as serial correlation, functional form misspecification, and stability tests.[8] Thus, the U.S. export and import demand equations seem well justified.

[8] The results of diagnostic tests are not reported here for brevity but can be obtained from the authors on request.

Table 7. Short-Run Effects of Exchange Rates on U.S. Imports from Canada

	Lag Order					
Variable	0	1	2	3	4	Wald Statistic
4407 Wood sawn, chipped						
ΔRER_t^+	0.32 (2.10)**					0.02
ΔRER_t^-	0.37 (2.07)**					
$\Delta \log(Y_t^{CA})$	11.02 (4.91)**					
4408 Veneers and sheets						
ΔRER_t^+	0.20 (2.13)**					0.01
ΔRER_t^-	0.43 (3.18)**					
$\Delta \log(Y_t^{CA})$	3.76 (2.54)**	5.30 (3.49)**				
4410 Particleboard						
ΔRER_t^+	0.28 (1.61)					0.72
ΔRER_t^-	0.63 (3.00)**					
$\Delta \log(Y_t^{CA})$	13.17 (4.55)**					
4411 Fiberboard of wood						
ΔRER_t^+	0.13 (0.97)					0.01
ΔRER_t^-	0.75 (4.35)**					
$\Delta \log(Y_t^{CA})$	1.71 (2.78)**					
4412 Plywood						
ΔRER_t^+	0.22 (1.94)**					0.08
ΔRER_t^-	0.65 (4.04)**					
$\Delta \log(Y_t^{CA})$	5.59 (3.37)**					
4418 Builders' joinery						
ΔRER_t^+	0.03 (0.29)					0.17
ΔRER_t^-	−0.09 (0.20)					
$\Delta \log(Y_t^{CA})$	6.23 (4.00)**					
4421 Articles of wood						
ΔRER_t^+	0.09 (0.49)					8.99**
ΔRER_t^-	−0.59 (0.86)	−0.67 (0.86)	−1.93 (2.55)**	−1.23 (1.60)	−1.48 (1.97)*	
$\Delta \log(Y_t^{CA})$	2.05 (3.51)**					
4703 Chem pulp sulfate						
ΔRER_t^+	0.23 (0.52)	−1.23 (2.75)**	−1.16 (2.53)**	0.76 (1.63)		4.82**
ΔRER_t^-	0.21 (2.81)**					
$\Delta \log(Y_t^{CA})$	0.30 (1.83)*					
4801 Newsprint						
ΔRER_t^+	0.50 (1.46)	−0.19 (0.59)	−0.85 (2.68)**	−0.80 (2.56)**		1.84
ΔRER_t^-	−0.35 (0.99)					
$\Delta \log(Y_t^{CA})$	−2.86 (2.50)**	0.76 (0.65)	1.58 (1.29)	1.23 (1.01)	2.52 (2.26)**	

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Table 7. – continued from previous page

	Lag Order					
Variable	**0**	**1**	**2**	**3**	**4**	**Wald Statistic**
4804 Uncoated kraft paper						
ΔRER_t^+	−0.09 (0.19)	−0.90 (2.05)**				2.41
ΔRER_t^-	0.83 (4.99)**					
$\Delta \log(Y_t^{CA})$	−0.09 (0.06)					
4805 Uncoated paper						
ΔRER_t^+	0.38 (3.25)**					0.32
ΔRER_t^-	0.39 (3.08)**					
$\Delta \log(Y_t^{CA})$	2.29 (1.49)	5.57 (3.55)**				
4810 Paper, board, clay						
ΔRER_t^+	−0.27 (2.77)**					0.05
ΔRER_t^-	0.03 (0.39)					
$\Delta \log(Y_t^{CA})$	0.88 (4.48)**					

Notes: Single and double asterisks (*, **) indicate significance at the 10% and 5% level, respectively. Numbers in parentheses are absolute *t*-statistics. Based on the χ^2, the critical value for the Wald test at 5% (10%) is 3.84 (2.71).

Concluding Remarks

Current research on the exchange rate impacts on forest product trade typically assumes that exchange rate changes symmetrically influence forest product trade. In this article, therefore, we contribute to the literature by applying the method of the nonlinear autoregressive distributed lag (ARDL) to investigate whether exchange rate fluctuations have *asymmetric* impacts on exports and imports within the context of bilateral trade flows of various forest products (i.e., four-digit Harmonized System Code, HS-4) between the U.S. and Canada. From a methodological perspective, the NARDL can separate currency appreciation from currency depreciation and provide insightful results that had been veiled in previous research, which typically relies on the symmetry assumption.

We unveil that exchange rate changes asymmetrically impact on U.S. trade in forest products with Canada in the long run. However, our examination provides little evidence of the exchange rate asymmetry in the short run. Thus, we conclude that the asymmetry impacts would be viewed as a long-run phenomenon for North America's forest product trade. A related finding is that the asymmetric impacts could also be viewed as a product-specific phenomenon. In the case of U.S. forest products exports to Canada, for example, an appreciation of USD leads to a decrease in U.S. exports of articles of wood (HS 4421) to Canada declines, while a depreciation of USD results in an increase of U.S. exports of articles of wood. For sawn wood (HS 4407), on the other hand, both appreciation and depreciation of USD decrease U.S. exports to Canada. Or else, the U.S. dollar's depreciation decreases U.S. exports of particle board (HS 4410), while the U.S. dollar's appreciation has no effects. As far as we are aware, this is a finding that has not been previously reported in the literature. This outcome further explains why disaggregated trade data are needed for analyzing the asymmetric exchange rate impacts on U.S. trade in forest products with Canada.

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