

Do Protectionist Trade Policies Integrate Domestic Markets? Evidence from the Canada-U.S. Softwood Lumber Dispute

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Acknowledgements

We are grateful for comments and suggestions from Ben Tomlin, Willy Chetwin, and Kun Mo. The research leading to this paper was supported in part by joint venture agreements between the University of Wisconsin and the United States Department of Agriculture Forest Service Southern Research Station (16-JV-11330143-039 and 17-JV-11330143-087). All errors are our own. The views presented in this paper are those of the authors and do not represent the Bank of Canada's position.

Abstract

We consider the effects of protectionist trade policies on international and domestic market integration, using evidence from the long-standing softwood lumber trade dispute between Canada and the United States. The benefits of trade liberalization are widely acknowledged, including better home-to-foreign price transmission due to reduced tariffs and lower trade costs between countries. Yet in recent years we see efforts to protect specific domestic groups, including producers, through a revival of protectionist trade policies. Such policies could improve the home-to-home price transmission across domestic markets as consumers may seek lower-cost alternatives domestically. We investigate these ideas using a bi-variate three-regime threshold vector error-correction model (TVECM) to examine the spatial price transmission between Canadian and U.S. markets and within U.S. domestic markets. We do that by introducing a structural break at the start of an effective free trade period within our sample. The results suggest that duty-free treatment for imported Canadian softwood lumber substantially lowers the transaction costs between the two nations. Prices are more easily transmitted from the Canadian market to the U.S. at a higher speed, but the speed of price transmission in the reverse direction is not statistically significant. The U.S. domestic market experienced a higher speed of price adjustment across domestic regions prior to the free trade period, which provides evidence that protectionist policies lead to better domestic market integration.

Topics: International topics; Market structure and pricing; Trade integration

JEL codes: F1, F13, Q17

Résumé

En nous fondant sur des données relatives au différend sur le bois d'œuvre résineux qui oppose depuis de nombreuses années le Canada et les États-Unis, nous examinons les effets de politiques commerciales protectionnistes sur l'intégration des marchés nationaux et internationaux. Les avantages de la libéralisation des échanges sont largement reconnus et comprennent une meilleure transmission des prix du marché intérieur aux marchés étrangers en raison de la réduction des droits de douane et des coûts des échanges commerciaux entre les pays. Nous constatons toutefois ces dernières années une relance des politiques commerciales protectionnistes ayant pour but de protéger certains groupes à l'échelle nationale, comme les producteurs. De telles politiques pourraient améliorer la transmission des prix sur les marchés intérieurs, les consommateurs étant susceptibles de chercher des solutions moins coûteuses au pays plutôt qu'à l'étranger. Nous analysons ces idées à l'aide d'un modèle vectoriel à correction d'erreurs à seuil, bivarié et comportant trois régimes afin d'examiner la transmission spatiale des prix entre les marchés canadien et américain et sur les marchés intérieurs aux États-Unis. Pour ce faire, nous introduisons un point de rupture structurel au début d'une période de libre-échange donnée comprise dans notre échantillon. Les résultats donnent à penser que l'importation en franchise de droits de douane de bois d'œuvre résineux

canadien réduit considérablement les coûts de transaction entre les deux pays. Les prix se transmettent ainsi plus facilement et plus rapidement du marché canadien au marché américain, mais dans le sens opposé, la rapidité de transmission n'est pas statistiquement significative. Sur le marché intérieur des États-Unis, la vitesse d'ajustement des prix entre les régions était plus grande avant la période de libre-échange, ce qui tend à indiquer que les politiques protectionnistes permettent une meilleure intégration du marché intérieur.

Sujets : Questions internationales; Structure de marché et fixation des prix; Intégration des échanges

Codes JEL : F1, F13, Q17

Non-technical summary

An important theme of international policy has been the dismantling of protectionist policies in favor of free trade, aimed at better integrating foreign markets in order to promote economic growth. A removal of barriers to international exchange encourages consumers to seek lower-cost alternatives in foreign markets. This may place less pressure on intraregional trade to meet domestic demand and thus deteriorate domestic market integration and price transmission, making it more difficult for producers to efficiently respond to market signals. This may partially explain the re-emergence of protectionist sentiment in favor of promoting the interests of domestic producers.

The U.S.-Canada lumber market offers a nice case study. First, there has been a movement back and forth between free trade and protectionist policies between these two nations in recent decades. Second, the U.S. softwood lumber industry is composed of three distinct producing regions, enabling an investigation into domestic market integration. Third, domestic production within the U.S. is insufficient to meet U.S. demand. Canada has been the largest source of softwood lumber imports to the U.S. market for decades, with 96 percent of U.S. softwood lumber imports originating from Canada in 2016 (32 percent U.S. market share).

In this paper we investigate the dynamics of trade policy on both foreign and domestic market integration. A unique dataset of monthly U.S. and Canadian softwood lumber prices covering the trade restriction and liberalization episodes further allows us to investigate what impact trade agreements have on transaction costs, and their implications for the integration across softwood lumber markets.

Three major conclusions can be drawn from this study. First, trade liberalization leads to a decline in home-to-foreign transaction costs and a rise in home-to-home transaction costs, confirming that free trade better integrates foreign markets at the expense of domestic market integration. Second, this is also confirmed using regional data. All U.S. regional domestic lumber markets are more integrated with the Canadian lumber market during the import duty exemption period than when duties are in place. Finally, results indicate that protectionist policies help to integrate domestic markets. The U.S. domestic market experienced a quicker speed of price adjustment across domestic regions prior to the free trade period.

1 Introduction

Trade liberalization has been a major economic phenomenon of the past few decades. The removal of trade barriers leads to reduced transaction costs and results in a more complete cross-border price pass-through. As home markets integrate into the global market, the volume of cross-border trade is likely to grow, which may reduce a country's reliance on trade across home markets and cause price inequality within the country. This may partially explain a growing trend in the application of protectionist policies to agricultural markets, stock markets, and energy markets to standardize domestic prices (e.g., Porteous, 2017; Baylis et al., 2014). Thus, we are motivated to ask whether there is a connection between trade liberalization, home-to-foreign market integration and home-to-home market segmentation. The U.S.-Canada lumber market offers a good case for exploration.

The U.S. softwood lumber industry is composed of three distinct regions, yet domestic production is insufficient to meet demand within the U.S. The U.S. has consequently relied heavily on imports from Canada to fill this gap. Canada has been the largest source of softwood lumber imports to the U.S. market for decades, with 96 percent of U.S. softwood lumber imports originating from Canada in 2016—equivalent to 32 percent U.S. market share. There has been a movement between free trade and protectionist policies in recent decades, while recurring price spikes in U.S. lumber markets have helped to rekindle the debate over market integration and the optimal policy response.

Spatial market integration, broadly defined as the extent to which demand and supply shocks arising in one market are transmitted to other markets for homogeneous goods (Fackler, 1996; Fackler and Goodwin, 2001; Barrett, 2001), has been the subject of numerous studies over the past 50 years. Examples include Giuliadori and Rodriguez (2015) for the stainless-steel market, Bachmeier and Griffin (2006) for the energy market, Götz et al. (2015) for the wheat market, and Menezes et al. (2015) for the stock market. Although the examples are spread over a wide range of markets, much of this research aims at simply identifying the degree of integration between international markets but does little to unveil the driving factors behind integration.

Only a handful of studies have explicitly addressed the impact of trade agreements on market integration (e.g., Listorti, 2009; Stephens et al., 2012; Valdes, 2017), generally concluding that trade liberalization better integrates markets and results in more efficient resource allocation across countries. Lim and Breuer (2019) were among the few who attempted to address the role of free trade agreements on market integration from a transaction cost perspective.

Nearly all the existing studies restrict their attention to tests of home-to-foreign integration, while the two that look at home-to-home integration do so from the net exporters' perspective, with mixed results. In one, Porteous (2017) observed that export restrictions could increase the cost of domestic trade, which further exacerbates home-to-home price differentials of maize markets in East and Southern Africa. In the other, Svanidze and Götz (2017) found that the application of a wheat export ban strengthened regional wheat market integration within Russia by stimulating interregional trade. Both studies focus on price transmission when one market goes from free trade to a trade-restricted period in exporting countries.

Studies focusing on Canada-U.S. softwood lumber markets have primarily analyzed the role of protectionist policies on cross-border trade while ignoring the effects on market integration (e.g., Parajuli et al. 2015), or analyzed price transmission while holding bilateral trade agreements constant (e.g., Sun and Zhuo 2014).

The question remains: is there a connection among trade liberalization, home-to-foreign and home-to-home market integration? A removal of barriers to international exchange encourages consumers to seek lower-cost alternatives in foreign markets. This may place less pressure on intraregional trade to meet domestic demand and thus deteriorate domestic market integration and price transmission, making it more difficult for producers to efficiently respond to market signals. In the remainder of this paper, we will therefore try to answer two questions: First, do trade liberalization policies lower transaction costs and promote home-to-foreign market integration? And second, does the level of domestic trade affect the degree of home-to-home market integration? To our knowledge, no one to date has examined the impact of free trade agreements on market integration from the perspective of the net importing country. Our paper fills the gap.

The vector error-correction model (VECM) is a commonly used method to estimate market integration in the literature but is criticized for failing to account for transaction costs (e.g., Caner and Hansen, 2001; Meyer, 2004). In most cases, it is the transaction costs that make the price adjustment exhibit a nonlinear transmission fashion, whereby a “band of inaction” occurs where price differences are smaller than transaction costs, rendering arbitrage unprofitable. Once the price deviation exceeds this threshold, arbitrage will take place and bring the relative price back in line. The threshold vector error-correction model (TVECM) is a powerful tool to handle the discontinuous price adjustment process as described above. TVECM handles well the assumption that price transmission across markets is regime-dependent. To capture the interaction among transaction costs, market integration and trade regimes, a three-regime TVECM model developed by Greb et al. (2013) is used in our analysis. The TVECM has the advantage of identifying unobservable transaction costs by endogenously choosing optimal threshold values based only on price data. A more detailed description of the TVECM model is presented in section 3. To our knowledge, this is the first attempt to examine the impact of a free trade agreement on home-to-foreign and home-to-home market integration using a three-regime TVECM model. In addition, this paper also contributes to the literature by comparing two threshold cointegration tests (which will be detailed later).

The rest of the paper proceeds as follows. Before moving to model and data descriptions in section 3, we provide a conceptual framework to explain how the U.S. lumber price will respond before and after the introduction of free trade agreements. Section 4 describes the results. The paper ends with a discussion of the main conclusions in section 5.

2 Conceptual framework

The conceptual framework for exploring the potential impact on market integration of free trade is a variation of the model of Mundlak and Larson (1992), who measured market integration as the elasticity of the domestic price with respect to the world price. We expand their work by

allowing for asymmetry of inaction bands. In their work, the price relationships can be depicted as follows:

$$P_{d,t} = P_{w,t}(1 + T_c), \quad (1)$$

where $P_{d,t}$ and $P_{w,t}$ denotes prices of a good in the domestic and world market respectively, with transaction costs, T_c . This equation implies that the price of a good in one country is equal to its price in the foreign country net of transaction costs. Here we simply assume the exchange rate is equal to unity. T_c encompasses observable transport costs, T_r , and unobservable trade costs, T_p (e.g., trade barriers, asymmetric information flow, etc.). For simplicity, both costs are expressed as a percentage of foreign prices:

$$P_{d,t} = P_{w,t}(1 + T_r + T_p). \quad (2)$$

The domestic country tends to import goods from the world market when foreign goods are cheaper net of transport costs:

$$P_{d,t} > P_{w,t}(1 + T_{r,1} + T_{p,1}) \text{ or } \frac{P_{d,t}}{P_{w,t}} > (1 + T_{r,1} + T_{p,1}), \quad (3)$$

where $T_{r,1}$ is the cost of transporting the good from the world market to the domestic market and $T_{p,1}$ reflects barriers to exporting to the domestic market. The domestic country tends to export to the world market when:

$$(1 + T_{r,2} + T_{p,2})P_{d,t} > P_{w,t} \text{ or } \frac{P_{d,t}}{P_{w,t}} < 1/(1 + T_{r,2} + T_{p,2}), \quad (4)$$

where $T_{r,2}$ is the cost of transporting the good from the domestic market to the world market and $T_{p,2}$ reflects barriers to exporting to the world market. It's worth noting that $T_{p,1}$ and $T_{p,2}$ or $T_{r,1}$ and $T_{r,2}$ do not need to be identical.

When the price ratio $\frac{P_{d,t}}{P_{w,t}}$ falls within two thresholds shown below in equation (5), price differences are smaller than transport costs and so are insufficient to trigger arbitrage, and price adjustment is characterized by a random walk process.

$$1/(1 + T_{r,2} + T_{p,2}) < \frac{P_{d,t}}{P_{w,t}} < (1 + T_{r,1} + T_{p,1}). \quad (5)$$

And in logarithmic form, (5) becomes:

$$-\log(1 + T_{r,2} + T_{p,2}) < \log(P_{d,t}) - \log(P_{w,t}) < \log(1 + T_{r,1} + T_{p,1}). \quad (6)$$

The price adjustment tends to be faster in both outer regimes—i.e., the further we go outside the thresholds. Price deviations from the long-term equilibrium will be quickly pushed back to the middle regime. In contrast, small deviations are not adjusted because transaction costs wipe out all the arbitrage profits in the inner regime or no-arbitrage regime.

When the trade barrier is larger, the difference between the two prices needs to be larger to create profitable arbitrage opportunities and trigger the price adjustment mechanism. It is more likely that price differentials lie within the band of the no-arbitrage regime and lower the degree

of market integration for cointegrated prices. Porteous (2012) modeled the export ban as an increase in trade cost. The introduction of a free trade agreement will, on the other hand, lower the costs of trade and further narrow the band of non-adjustment (Lim and Breuer, 2019). That is,

$$-\log(1 + T_{r,2} + T_{p,2}^*) < \log(P_{d,t}) - \log(P_{w,t}) < \log(1 + T_{r,1} + T_{p,1}^*), \quad (7)$$

where $T_{p,1}^*$ and $T_{p,2}^*$ denote the reduced but still positive trade costs compared with their counterparts, $T_{p,1}$ and $T_{p,2}$. In the extreme case with no trade barriers and transport costs, namely, $T_{r,2} + T_{p,2}^* = T_{r,1} + T_{p,1}^* = 0$, the band of inaction does not exist and all the deviations from long-run equilibrium are corrected.

The conceptual framework indicates that the spatial price adjustment exhibits a three-regime process, in which it contains a band of inaction, while a pull back to the equilibrium is operational from each outer regime. This conceptual framework implies that a three-regime TVECM model is well suited to modeling price transmission in markets with frictions and unobservable transaction costs.

3 Method

The application of standard VECMs and cointegration in the market integration literature have been stagnant due to their inability to account for nonlinear price transmission and transaction costs. Balke and Fomby (1997) first introduced the concept of threshold integration, stating that the error correction towards long-run equilibrium can be discontinuous as a result of adjustment costs. Goodwin and Piggott (2001) made the first attempt to apply threshold cointegration to examine this discontinuity of the spatial price transmission and market integration. This has gained wide acceptance in studies of the integration of spatially separated markets. Among the threshold integration models, TVECM has been found sufficient to account for the regime-dependent price adjustment (e.g., Goodwin and Piggott, 2001; Balcombe et al., 2007). Another advantage of TVECM is its ability to estimate the band of inaction—transaction costs—a key factor influencing the market integration (but rarely available), exclusively based on price data. The empirical analysis in this paper is based on a bi-variate three-regime threshold VECM model given that it is closely tied to spatial equilibrium theory, as discussed above (Meyer, 2004). The general form can be formulated as follows:

$$\begin{aligned} \begin{bmatrix} \Delta P_t^a \\ \Delta P_t^b \end{bmatrix} &= \begin{bmatrix} \mu_t^a \\ \mu_t^b \end{bmatrix} + \sum_{i=1}^k \begin{bmatrix} \Gamma_i^{a,a} & \Gamma_i^{a,b} \\ \Gamma_i^{b,a} & \Gamma_i^{b,b} \end{bmatrix} \begin{bmatrix} \Delta P_{t-i}^a \\ \Delta P_{t-i}^b \end{bmatrix} + \begin{bmatrix} \rho_a \\ \rho_b \end{bmatrix} \varepsilon_{t-1} & \text{if } \varepsilon_{t-1} > \psi_U \\ \begin{bmatrix} \Delta P_t^a \\ \Delta P_t^b \end{bmatrix} &= \begin{bmatrix} \mu_t^a \\ \mu_t^b \end{bmatrix} + \sum_{i=1}^k \begin{bmatrix} \Gamma_i^{a,a} & \Gamma_i^{a,b} \\ \Gamma_i^{b,a} & \Gamma_i^{b,b} \end{bmatrix} \begin{bmatrix} \Delta P_{t-i}^a \\ \Delta P_{t-i}^b \end{bmatrix} + \begin{bmatrix} \rho_a \\ \rho_b \end{bmatrix} \varepsilon_{t-1} & \text{if } \psi_L < \varepsilon_{t-1} < \psi_U \\ \begin{bmatrix} \Delta P_t^a \\ \Delta P_t^b \end{bmatrix} &= \begin{bmatrix} \mu_t^a \\ \mu_t^b \end{bmatrix} + \sum_{i=1}^k \begin{bmatrix} \Gamma_i^{a,a} & \Gamma_i^{a,b} \\ \Gamma_i^{b,a} & \Gamma_i^{b,b} \end{bmatrix} \begin{bmatrix} \Delta P_{t-i}^a \\ \Delta P_{t-i}^b \end{bmatrix} + \begin{bmatrix} \rho_a \\ \rho_b \end{bmatrix} \varepsilon_{t-1} & \text{if } \varepsilon_{t-1} < \psi_L, \end{aligned} \quad (8)$$

where $\Delta P_t = (\Delta P_t^a, \Delta P_t^b)$ is a vector of price series a and b of a homogenous good, specified as the first difference of a natural logarithm between periods t and $t-1$. ε_{t-N} is the error-correction term

lagged by N period, obtained from the long-run cointegration relationship, $P_t^a = \alpha + \beta P_t^b + \varepsilon_t$. It denotes the price deviation from the long-run equilibrium. The estimated error-correction term (ε_{t-1}) is included in one lag period (Ters and Urban, 2019). Γ is the (2x2) regime-specific matrix of short-run coefficients with lag i .

Two types of parameters are worth our attention. The first is the coefficient vector of the error-correction term, ρ , also interpreted as a speed of the adjustment parameter. It characterizes to what extent prices return to the long-term equilibrium at the next period after a deviation. The price adjustment can vary across regimes, and we expect it to be faster and statistically significant in the outer regimes. One can expect ρ_a to be negative, ranging between -1 and 0, and ρ_b to be positive between 0 and 1. The sum of their absolute values should lie between 0 and 1 to rule out explosive behavior. The second is the vector of threshold parameters, $\psi = (\psi_L, \psi_U)$, denoting the degree of transaction costs. Subscripts U and L correspond to the upper and the lower thresholds. ψ delineates the three different regimes. The coefficients Γ , ρ , and μ differ based on regimes, whether ε_{t-1} is above the ψ_U threshold (upper regime), between the two thresholds (middle regime), or below the ψ_L threshold (lower regime). Clearly, the threshold parameters hinge on ε_{t-1} from the model, that is, $\min(\varepsilon_{t-1}) < \psi_L < \psi_U < \max(\varepsilon_{t-1})$.

There are several challenges in estimating the threshold parameters, making some methods unsuitable for our purposes. For example, the profile likelihood estimator is a commonly used method to estimate the threshold parameters (Hansen and Seo, 2002) that maximize the likelihood function. However, this method suffers from biased estimates (e.g., Lo and Zivot, 2001). The Bayesian estimator is an alternative method to analyze the threshold model (Chen and So, 2006). The Bayesian estimator has its own shortcomings. It requires that prior distributions for each parameter need to be specified to estimate the threshold values. Limited prior knowledge of probability distributions renders the results less accurate.

To generate more reliable results than these other methods, we use the regularized Bayesian (RB) technique introduced by Greb et al. (2013) to estimate threshold parameters. The RB method is not dependent on trimming parameters that require a certain number of observations to fall within each regime, which places less restriction on the size of observation. The thresholds are determined using integral calculus, which provides a way to account for inherent variability of estimates and generates more theoretically consistent results with spatial price equilibrium. To estimate the optimal threshold parameters over the grid of error-correction terms, we use the posterior median, which can be constructed as:

$$\int_{\min(\varepsilon_{t-1})}^{\overline{\psi}_M} P_{RB}(\psi_i | \Delta P, X) d\psi_i = 0.5, \quad M = L, U, \quad (9)$$

where the threshold parameter vector, $\overline{\psi}_M = (\overline{\psi}_L, \overline{\psi}_U)$, is computed as posterior median. $P_{RB}(\psi_i | \Delta P, X)$ is the upper or lower threshold's marginal posterior density. A median of posterior distribution is selected as the estimate of the threshold parameter. The rest of the coefficients are estimated using the restricted maximum likelihood method. For a detailed description of the model, see Greb et al. (2013).

As noted above, the TVECM extends the standard VECM by adding a switching regime specification. Thus, besides the unit-root test and cointegration test, a nonlinearity test is also needed to determine whether there exist threshold effects, prior to using a threshold cointegration model. Hansen and Seo (2002) developed a Sup-LM (Supremum Lagrange Multiplier) test to check a linear cointegration model against a two-regime threshold cointegration model. Larsen (2012) extended the nonlinearity test, allowing it to test for a three-regime threshold cointegration. Seo (2006) developed a Sup-Wald (Supremum Wald statistic) test based on a three-regime TVECM. Table 3 summarizes all the linearity/nonlinearity tests used in these papers.

Table 1. Summary of Cointegration Tests

Test	Method	Null hypothesis	Alternative hypothesis
Enders and Granger (1998)	ADF	Non-cointegration	Linear cointegration
Hansen and Seo (2002)	Sup-LM	Linear cointegration	Threshold cointegration (1 threshold 2-regime)
Seo (2006)	Sup-Wald	Non-cointegration	Threshold cointegration (2 threshold 3-regime)
Larsen (2012)	Sup-LM	Linear cointegration	Threshold cointegration (2 threshold 3-regime)

Following the estimation of the TVECM, impulse response analysis is conducted to capture how rapidly the price shock in one market is transmitted to the other. In our paper, we choose to use the nonlinear impulse response function (NIRF) developed by Pesaran and Shin (1998). The NIRF allows us to assess the responses of U.S. domestic prices to shocks in foreign and home market prices under different trading environments. Differing from generalized impulse response functions (GIRF) developed by Koop et al. (1996), the NIRF adopts a conditional expectation instead of a standard linear predictor. The NIRF is defined as the difference between the forecasted paths of variables with an exogenous shock and the unconditional baseline forecast, which can be formed as:

$$\text{NIRF} = E[P_{t+n} | \varepsilon_t, \Psi_{t-1}] - E[P_{t+n} | \Psi_{t-1}], \quad (10)$$

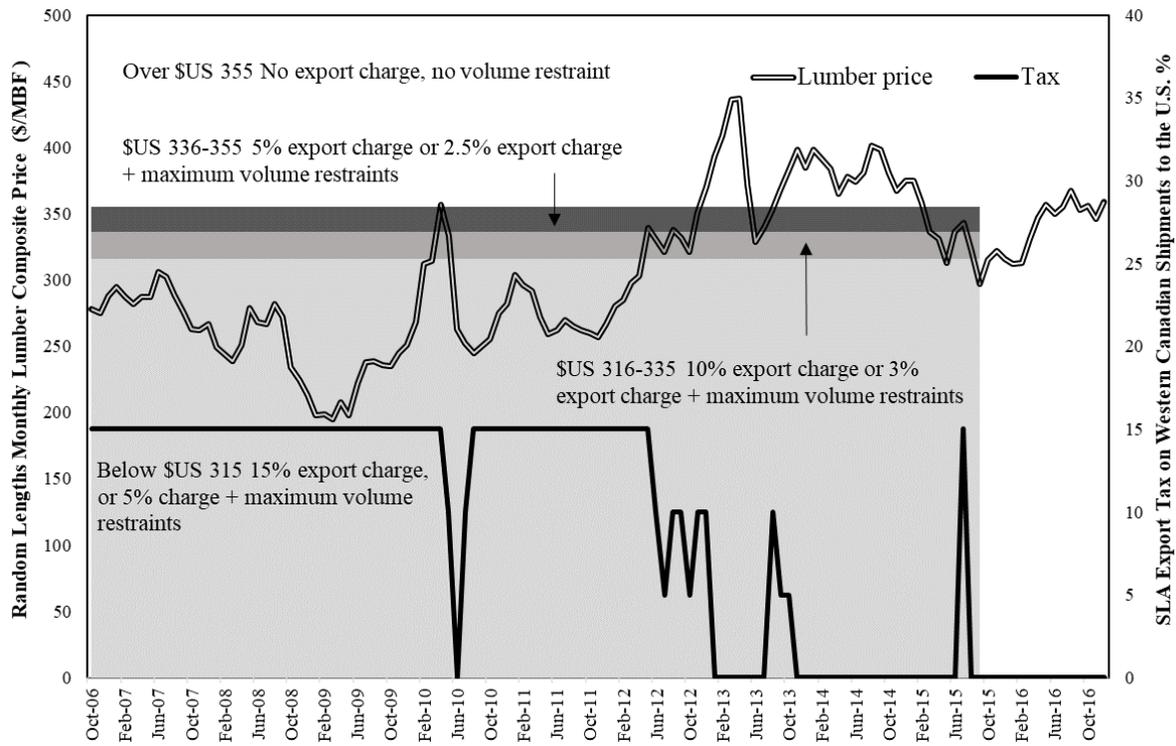
where ε_t is an exogenous shock of a specific size, Ψ_{t-1} is the information available at time $t-1$, and n is the forecasting horizon.

4 Data

To ensure data consistency, all the domestic price information is derived from the Random Lengths database, a widely circulated source of information for North American wood product markets. The U.S. domestic lumber markets can be divided into three sub-region markets: North, South, and West (Howard, 2007; Ince et al., 2010). Random Lengths, however, only reported the price of lumber and panel items by grades and dimensions. We follow Sun and Zhuo (2014), who related the specific prices of kiln-dried Stud 2X4 8' PET to different sub-region markets as a proxy. The Southern Yellow Pine (westside) is selected to represent the South market and the Coast Douglas Fir to represent the West market. In addition to following their specification, we choose the Inland Hem-Fir to represent the North market, which is missing in their analysis. For the Canadian

softwood lumber price, a country-level price is not available. Here we follow the method used in Sun (2017) to derive the price information by dividing the total value of the imports by quantity of imported softwood lumber from Canada to get unit values. The U.S.-Canada exchange rate is then used to convert the Canadian dollar unit values into U.S. dollars. Parajuli and Zhang (2016) and Parajuli et al. (2018) also adopted such unit values (ratio of value over quantity) as a representation of the Canadian lumber price. The monthly data on Canadian lumber exports to the U.S. are sourced from a custom extract from Statistics Canada’s International Trade Statistics, and the Canada/U.S. Foreign Exchange Rate is collected from the database of U.S. Federal Reserve Economic Data (FRED). To assess the impact of the reference Canada lumber price on the final results, a robustness analysis using different price series is performed at the end. This recognizes the fact that different Canadian lumber prices might affect the estimated transaction costs between the two nations; for example, Sun and Zhuo (2014) consider the Eastern Spruce-Pine-Fir (SPF) Great Lakes price as a measure of the Canadian domestic lumber price.

Figure 1. Effective export tax and lumber price under SLA 2006



Sources: Random Lengths website and Government of Canada, Foreign Affairs, Trade, and Development, prevailing monthly price reports on softwood lumber prices and consumption

Under the Softwood Lumber Agreement (SLA), Canadian softwood lumber shipped to the United States was subject to export charges and quota limitations when the prevailing monthly price of U.S. softwood products fell below \$355 per thousand board feet (US\$355/MBF). Figure 1 shows that since 2013, due to the higher lumber price, the Canadian softwood lumber imported into the U.S. is not subject to any export charges. This created a de facto free trade environment

between the two nations. To analyze the impact of de facto free trade on market integration, we split the dataset into two sub-periods: October 2006 to December 2012 for the binding period, and January 2013 to December 2016 for the free trade period. We further construct six price pairs by linking each market to all other domestic or Canadian markets under both the binding period and the free trade period. The prices reported by Random Lengths are nominal terms. To obtain the real terms, the U.S. lumber price series and the Canadian lumber price series were deflated by U.S. CPI (2015=100) and Canadian CPI (2015=100), respectively. The price series in levels are utilized for the threshold cointegration analysis, which allows the threshold parameters to be measured in US\$/MBF.

Table 2 provides the statistical summary of the price series for each region and period. The descriptive statistics show differences among the price series in the binding and free trade period. First of all, as expected, the mean of all lumber prices in the free trade period is higher than those in the binding period. The mean, minimum, and maximum Canadian lumber prices are all higher than their U.S. domestic counterparts. Secondly, the standard deviation of U.S. domestic lumber prices is greater than the Canadian lumber price in both periods, and all price series exhibit lower monthly price fluctuations during the free trade period, except for the U.S. South market. The descriptive evidence indicates that trade liberalization may have a heterogeneous impact on domestic lumber markets.

Table 2. Descriptive statistics of U.S. and Canadian softwood lumber prices

		Observation	Minimum	Maximum	Mean	Median	Stdev
Binding period	U.S. South	75.0	169.9	365.1	234.1	222.4	45.8
	U.S. West	75.0	129.1	320.4	222.8	222.4	46.3
	U.S. North	75.0	153.3	336.6	239.1	239.1	43.3
	Canada	75.0	205.8	375.4	284.3	284.3	39.5
Free trade period	U.S. South	48.0	263.5	479.2	357.9	362.7	49.7
	U.S. West	48.0	262.1	441.1	332.0	328.0	39.5
	U.S. North	48.0	278.6	458.7	339.5	341.9	35.3
	Canada	48.0	321.9	435.4	388.9	395.6	27.3

5 Results

5.1 Testing for unit roots and cointegration

We first examine the stationarity of the price series for both sub-periods in the levels and first differences using the Augmented Dickey-Fuller (ADF) test, the Phillips and Peron (PP) test, and the Kwiatkowski-Phillips Schmidt-Shin (KPPS) test. The lag length is selected based on the Akaike Information Criterion (AIC). The ADF test and PP test fail to reject the null hypotheses of unit roots for the price series in levels at the 10 percent (or less) level of significance but reject the null hypotheses for all price series in first differences at the 1 percent level of significance. The

KPSS test with its null hypothesis of stationarity strongly confirms the conclusion that all prices are integrated of order one.¹

Table 3. Unit root test

		Binding period <i>Oct. 2006 to Dec. 2012</i>			Free trade period <i>Jan. 2013 to Dec. 2016</i>		
		ADF	PP	KPSS	ADF	PP	KPSS
Level	Canada	0.906	0.984	0.742***	0.309	-0.291	0.282
	U.S. North	0.370	0.383	0.439*	-0.219	-0.199	0.350*
	U.S. South	0.207	-0.146	0.482**	-0.648	-0.073	0.088
	U.S. West	0.388	0.234	0.419*	-0.456	-0.119	0.319
	U.S. National	0.573	0.646	0.578**	-0.306	-0.321	0.428*
First difference	Canada	-4.908***	-5.285***	0.113	-2.317**	-5.336***	0.129
	U.S. North	-5.431***	-5.979***	0.097	-3.068**	-5.108***	0.087
	U.S. South	-5.765***	-4.940***	0.027	-5.960***	-4.880***	0.070
	U.S. West	-7.102***	-7.097***	0.103	-4.766***	-4.658***	0.089
	U.S. National	-6.620***	-6.632***	0.153	-5.211***	-5.491***	0.153

Note: Binding period from October 2006 to December 2012. Free trade period from January 2013 to December 2016. The null hypothesis of ADF test and PP test is that the price series is non-stationary. The null hypothesis of KPSS test is stationarity. *, **, and *** indicate rejection of the null hypothesis at the 10%, 5%, and 1% level, respectively.

Source: authors' own calculation

An Engle-Granger test is utilized to determine the cointegration relationship among all six price pairs in both the binding period and the free trade period. The results (Table 4) show that the non-stationarity of the residual in all is rejected by the ADF test at the 1 percent significance level, suggesting that there exists a linear cointegrating relationship for each price pair. The results provide sufficient evidence that all the markets are integrated.

5.2 Non-linearity test

Before we proceed to estimate the threshold vector error-correction model, we must check whether the non-linear model is appropriate as compared to a linear model. Three non-linear threshold tests are conducted without and with an intercept. The results indicate that at least one of the alternative hypotheses of cointegration with a three-regime TVECM has been accepted for each price pair at the 90 percent significance level, suggesting clear evidence of threshold effects. The results justify our use of a threshold vector error-correction model.

¹ The inclusion of a constant in the tests provides some mixed evidence. For the U.S. South price in levels, the null hypothesis of non-stationarity is rejected by the ADF test and KPSS test at the 5 percent level but accepted by the PP test at the same significance level. For the rest of the price series, the results are in line with previous unit root tests. Therefore, we broadly conclude that all the price series are non-stationary in levels but are stationary in their first differences, I(1).

Table 4. Co-integration test

	Binding period			Free trade period		
	<i>Oct. 2006 to Dec. 2012</i>			<i>Jan. 2013 to Dec. 2016</i>		
	Price pairs	E-G Test	Residual	Price pairs	E-G Test	Residual
Canada-North	CaNB	cointegration	-3.011***	CaNA	cointegration	-2.424***
Canada-South	CaSB	cointegration	-2.714***	caSA	cointegration	-1.642*
Canada-West	CaWB	cointegration	-2.726***	CaWA	cointegration	-2.641***
North-South	NSB	cointegration	-2.122**	NSA	cointegration	-2.076**
North-West	NWB	cointegration	-5.609***	NWA	cointegration	-3.394***
South-West	SWB	cointegration	-4.101***	SWA	cointegration	-4.890***

Note: The ending letter B in price pairs denotes the period between October 2006 and December 2012, used interchangeably with the term “Binding period,” while A denotes the period between January 2013 and December 2016, used interchangeably with the term “Free trade period.”

Table 5. Nonlinearity test

		H-S Test Larsen (2012) Seo (2006)			H-S Test (I) Larsen (2012) (I) Seo (2006) (I)		
Canada-U.S. North	B	0.48	0.06	0.41	0.07	0.04	0.45
	A	0.16	0.02	0.02	0.18	0.02	0.02
Canada-U.S. South	B	0.71	0.59	0.00	0.81	0.56	0.02
	A	0.60	0.65	0.00	0.23	0.66	0.00
C2-U.S. West	B	0.03	0.00	0.94	0.00	0.01	0.95
	A	0.09	0.00	0.44	0.18	0.00	0.49
North-South	B	0.40	0.31	0.00	0.42	0.32	0.00
	A	0.00	0.06	0.00	0.06	0.04	0.00
North-West	B	0.11	0.08	0.00	0.52	0.09	0.00
	A	0.20	0.15	0.00	0.19	0.17	0.00
South-West	B	0.27	0.28	0.05	0.21	0.28	0.09
	A	0.08	0.08	0.00	0.34	0.07	0.00

Note: C2 refers to an alternative Canadian price series. Please see section 5.5 *Sensitivity analysis: Canadian price series*.

The results of the TVECM model are sensitive to the choice of lag length. The lag length is determined by the minimization of information criteria AIC(n), HQ(n), SC(n) and FPE(n) using VARselect in R. Ten out of the 12 price pairs are suggested choosing 2 as the optimal lag length. Thus, we continue to estimate our three-regime TVECM with a lag length of 1 for each price pair.²

5.3 Estimate of TVECM

The speed of price adjustment is a key parameter to measure the degree of market integration, reflecting the correction of price deviations between two pairs by a market mechanism. We find

² Optimal lag length of VECM = optimal lag length of VAR - 1; or one can estimate the TVECM for lags 1 to 10 using the package tsDyn in R and choose the one that can minimize the AIC and BIC selection criteria.

strong evidence of increased market integration in the price pairs for Canada and the U.S. when the trading environment becomes liberalized (Table 6).

For example, the Canada and U.S. North price pair has estimated price adjustment parameters of 0.143, 0.136, and 0.136 for the lower, middle, and upper regimes, respectively, when the export tax is levied on lumber imported from Canada prior to 2013. The imported Canadian softwood lumber after 2013 is treated as duty-free, and the price adjustment parameters increase to 0.233, 0.262, and 0.217, respectively. The U.S. North price adjustment parameter increases from 0.239 to 0.276 in the lower regime, from 0.226 to 0.285 in the middle regime, and from 0.226 to 0.295 in the upper regime. This implies that both price series move to the long-run equilibrium at a faster speed when the trading environment becomes liberalized, and that the U.S. North price adjusts faster than the Canadian lumber price. These findings largely apply to the remaining Canada-U.S. South and Canada-U.S. West price pairs. The increased speed of the adjustment parameter between Canada and the U.S. indicates that the exemption of the export tax will enhance market integration.

It needs to be noted that in the case of Canada-U.S. West, we can find the highest total speed of adjustment³ between of any Canada-U.S. price pair. This suggests that the U.S. West market is better connected to the Canadian market than any other U.S. domestic lumber market. The results are not surprising given that most lumber exported to the U.S. is made in Western Canada, meaning the geographic distance to market is shortest.

When shifting our focus to home-home adjustment across the U.S. domestic markets, we find a trend that the speed of the adjustment parameter decreased after 2013 when the restriction stopped binding.⁴ The U.S. North adjustment parameter decreased from 0.762 to 0.283 in the lower regime, from 0.556 to 0.475 in the middle regime, and from 0.762 to 0.345 in the upper regime. The U.S. South adjustment parameter followed the same trend. The decreased speed of adjustment parameter among the U.S. domestic price pairs indicates that the exemption from the export tax will lower home-home market integration.

The statistical significance gives us confidence that the parameter estimates contain useful information about the disequilibrium behavior of the Canadian and U.S. domestic lumber prices. For each regime in the three Canada-U.S. price pairs, the parameters for adjustment of Canadian prices towards U.S. prices are statistically insignificant. Conversely, the U.S. North, U.S. South, and U.S. West price adjustment parameters exhibit a high statistical significance. This combination of results indicates that there exists a unidirectional influence from the Canadian price to the U.S. domestic price. These price patterns are highly consistent in both the pre-free trade period and the post-free trade period and confirm the role of the Canadian softwood lumber market as a price leader. These results are in line with the fact that Canada is a dominant supplier of softwood lumber to the U.S.

³ Total speed of adjustment is calculated as the sum of the absolute value of the two speeds of price adjustment parameters within the same regime.

⁴ Here we only pay attention to the parameters that are statistically significant, that is, the U.S. North adjustment parameter in the North and West price pair and the U.S. South adjustment parameter in the South and West price pair.

Regionally, when we look at the TVECM estimations for the U.S. South and U.S. West price pair, we do not observe significant price adjustment from U.S. West prices towards U.S. South prices. The U.S. South market shows a significant adjustment towards U.S. West prices of about 65 percent in all the regimes. Similarly, the U.S. North prices also adjust towards U.S. West lumber prices to correct deviations from the long-term equilibrium. However, U.S. West prices do not exhibit statistically significant error-correction behavior to either of the other two U.S. prices, suggesting that the U.S. West price plays a leadership role in the U.S. domestic markets.

The band of inaction between the upper and lower thresholds is another parameter we are interested in. As pointed out by Goodwin and Piggott (2001), a wider band of inaction in the middle regime can be interpreted as a reflection of poorer market integration. The bands of inaction for each price pair, before and after the start of the effective free trade period, are summarized in Table 6.

Most of the estimated coefficients have the expected sign and exhibit highly regime-specific characteristics, which confirms the existence of threshold effects in our dataset. Half of the adjustment parameters are significant at the 10 percent level (or less) in the lower regimes and upper regimes, while only one-third of all parameters are significantly different from zero at the 10 percent significance level in the middle regimes.

The average band of inaction between the two nations is lower than among the domestic markets, which suggests that the domestic markets face large transaction costs. One explanation lies in the means of transportation, as shipping internationally by ocean is always cheaper than shipping domestically by rail, especially for lumber products.⁵ Consistent with this, Svanidze and Götz (2017) concluded that an export ban could strengthen the domestic market integration due to the increased interregional trade. In contrast, an open lumber trading environment encourages the import of lumber from Canada and thus reduces the volume of interregional trade among the U.S. domestic markets. One can therefore expect an increased domestic band of inaction in a free trade period.

This pattern shows up in Table 6, where elimination of the export tax between the U.S. and Canada lowers the band of inaction by 1 percent to 12 percent among all Canada-U.S. pairs. The reverse can be found among the domestic lumber price pairs.

Equally, the results are consistent with the theory of spatial price equilibrium, that the price pairs are not supposed to be highly cointegrated in the middle regimes. Price deviations with the two thresholds are not able to trigger arbitrage and thus two lumber markets only partially respond to the price changes.

⁵ The U.S. International Trade Commission reported that in 2015 softwood lumber transportation costs shipped from Canada to the U.S. averaged 2.2 percent of the total delivered cost, while the U.S inland transportation costs are usually well over 5 percent.

Table 6. Estimated parameters of TVECM for U.S. and Canadian softwood lumber prices

	ρ_L	φ_L	ρ_M	φ_U	ρ_U	Band of inaction
Canada and U.S. North						
CA to N (<i>Binding</i>)	-0.14		-0.14	18.57	-0.14	35.03
N to CA (<i>Binding</i>)	0.24*	-16.47	0.23*		0.23*	
CA to N (<i>Free trade</i>)	-0.23		-0.26		-0.22	
N to CA (<i>Free trade</i>)	0.28**	-17.52	0.28	13.21	0.29**	30.73
Canada to U.S. South						
CA to S (<i>Binding</i>)	-0.02		-0.02		-0.02	
S to CA (<i>Binding</i>)	0.22**	-28.07	0.22**	19.78	0.22**	47.85
CA to S (<i>Free trade</i>)	-0.18		-0.16	12.67	-0.18	42.43
S to CA (<i>Free trade</i>)	0.29**	-29.76	0.26*		0.29**	
Canada to U.S. West						
CA to W (<i>Binding</i>)	-0.26		-0.23		-0.08	
W to CA (<i>Binding</i>)	0.23	-28.99	-0.05	13.62	0.42***	42.61
CA to W (<i>Free trade</i>)	-0.29**		-0.29**		-0.29**	
W to CA (<i>Free trade</i>)	0.47***	-29.76	0.47***	12.58	0.47***	42.35
U.S. North to U.S. South						
N to S (<i>Binding</i>)	-0.09		-0.09		-0.09	
S to N (<i>Binding</i>)	0.21*	-28.31	0.13	24.03	0.13	52.35
N to S (<i>Free trade</i>)	-0.15		-0.17		-0.15	
S to N (<i>Free trade</i>)	0.59***	-63.92	0.10	22.79	0.59***	86.70
U.S. North to U.S. West						
N to W (<i>Binding</i>)	-0.76***		-0.56**		-0.76***	
W to N (<i>Binding</i>)	-0.35	-9.63	-0.13	14.39	-0.35	24.01
N to W (<i>Free trade</i>)	-0.28		-0.48		-0.28	
W to N (<i>Free trade</i>)	0.44	-16.69	0.01	9.50	0.44	26.16
U.S. South to U.S. West						
S to W (<i>Binding</i>)	-0.68***		-0.34***		-0.68***	
W to S (<i>Binding</i>)	-0.01	-26.61	-0.05	58.93	-0.01	85.54
S to W (<i>Free trade</i>)	-0.36***		-0.32***		-0.36***	
W to S (<i>Free trade</i>)	0.07	-47.74	0.10	44.43	0.07	92.17

Note: Vectors ρ_L , ρ_M , ρ_U all include a regime-specific speed of adjustment parameter, ρ_a and ρ_b . *Binding* covers the period from October 2006 to December 2012; *Free trade* covers January 2013 to December 2016.

5.4 Impulse response analysis

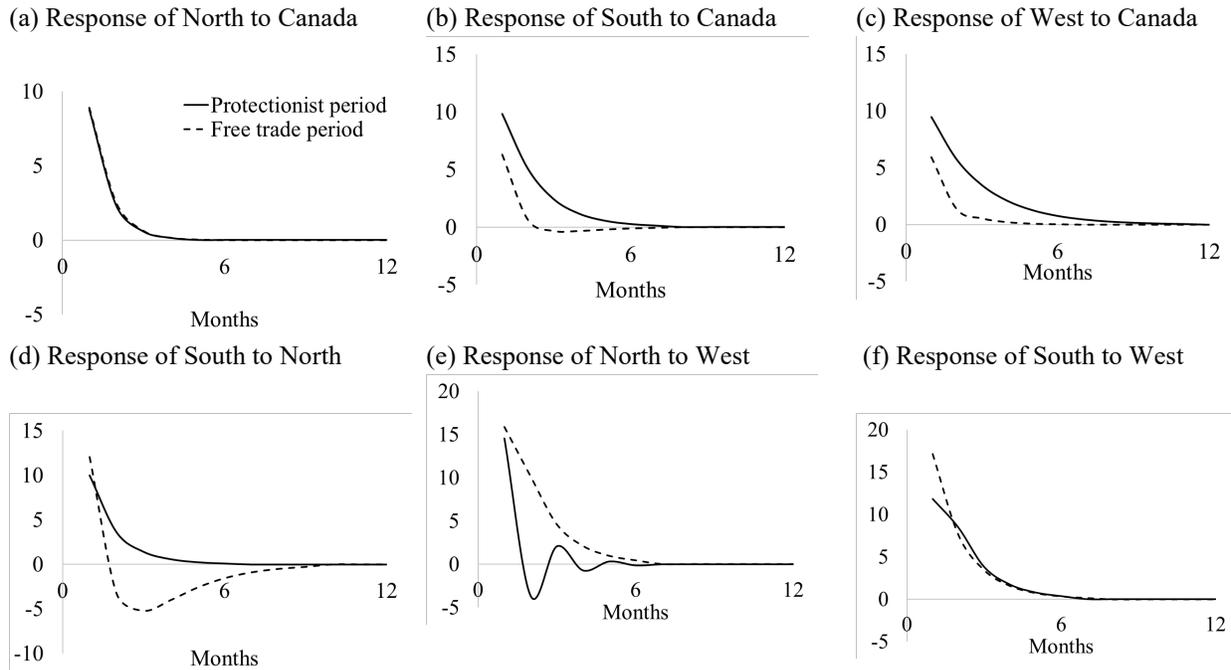
Figure 2 shows impulse response analysis to trace the response over time of U.S. domestic lumber prices to home and foreign market shocks.⁶ The dashed line represents the pre-free trade impulse response, and the solid line the post-free trade response.

⁶ Six market pairs are chosen based on the statistical significance of the speed of adjustment terms in the upper regime. Price response in the middle and lower regimes is not performed.

Panels (a)-(c) of Figure 2 show the impulse response of the three U.S. domestic lumber prices given a positive Canadian lumber price shock. Compared to the binding period, a positive Canadian price shock during the initial trade-restricted period would lead to a relatively smaller increase in the U.S. domestic price, and the effect of the shock would die out within a shorter period than in the free trade period.

Panels (d)-(f) of Figure 2 show how the U.S. domestic price responds to price shocks from their domestic counterparts. Panel (d) depicts how a 1 percent positive shock in the U.S. North price produces a 12 percent response in the U.S. South during the free trade period. Additionally, due to changes in market integration, the magnitude of the U.S. South price response is larger and takes more time to fall to zero during the free trade period than during the protectionist period. Similar findings are shown for the response of the U.S. South and the U.S. North to a positive one standard deviation in U.S. West price shocks. In conclusion, the price responses confirm the results of our previous analysis.

Figure 2. Monthly diesel and gasoline prices: October 2006-December 2016



5.5 Sensitivity analysis: Canadian price series

In the regime-switching cointegration model, the error-correction term is the variable that causes the regime switch. Thus, one might be concerned that the estimated band of inaction relies heavily on the imputed price series.⁷ To deal with this concern, an extra price pair, Canada-U.S. national, is tested to check whether the U.S. regional price transmission patterns are robust for the whole country. The Random Lengths Framing Lumber Composite Price is selected to represent the U.S.

⁷ The Canadian price series is calculated as the total value of the imports divided by the total quantity of imported softwood lumber from Canada.

national lumber price, a reference price for the 2006 softwood lumber agreement. The Eastern Spruce-Pine-Fir 2x4 #2 is chosen as an alternative proxy for the Canadian domestic lumber price (Statistics Canada; Sun and Zhuo, 2014).

Table 7. Estimated parameters of TVECM for alternative price pairs

	ρ_L	φ_L	ρ_M	φ_U	ρ_U	Band of inaction
<i>Panel 1: National price series</i>						
Canada and U.S. National						
CA to U.S. (<i>Binding</i>)	-0.09		-0.05	12.83	-0.05	
U.S. to CA (<i>Binding</i>)	0.22	-15.63	0.38***		0.38***	28.45
CA to U.S. (<i>Free trade</i>)	-0.38**		-0.42**	6.41	-0.38**	
U.S. to CA (<i>Free trade</i>)	0.11	-7.72	-0.08		0.11	14.13
<i>Panel 2: Alternative Canadian price series</i>						
Canada to U.S. North						
CA to N (<i>Binding</i>)	0.13		0.13	10.04	0.15	
N to CA (<i>Binding</i>)	0.43*	-15.00	0.43*		0.43**	25.04
CA to N (<i>Free trade</i>)	-0.06		-0.06	7.27	-0.06	
N to CA (<i>Free trade</i>)	0.20	-15.36	0.20		0.20	22.63
Canada to U.S. South						
CA to S (<i>Binding</i>)	-0.02		-0.11	25.11	-0.11	
S to CA (<i>Binding</i>)	0.24**	-33.35	0.13		0.13	58.46
CA to S (<i>Free trade</i>)	-0.15		-0.15	29.14	-0.15	
S to CA (<i>Free trade</i>)	0.11	-51.87	0.11		0.11	81.01
Canada to U.S. West						
CA to W (<i>Binding</i>)	-0.14		-0.14	14.89	-0.11	
W to CA (<i>Binding</i>)	0.47*	-17.75	0.47*		0.27	32.63
CA to W (<i>Free trade</i>)	-0.04		0.65	13.78	-0.04	
W to CA (<i>Free trade</i>)	0.28*	-7.30	1.17***		0.28*	21.08

Note: The alternative Canadian price is the price of Kiln-Dried Dimension Eastern Spruce-Pine-Fir (delivered, Great Lakes). Vectors ρ_L , ρ_M , ρ_U all include regime-specific speed of adjustment parameters, ρ_a and ρ_b .

Binding covers the period from October 2006 to December 2012; *Free trade* covers January 2013 to December 2016.

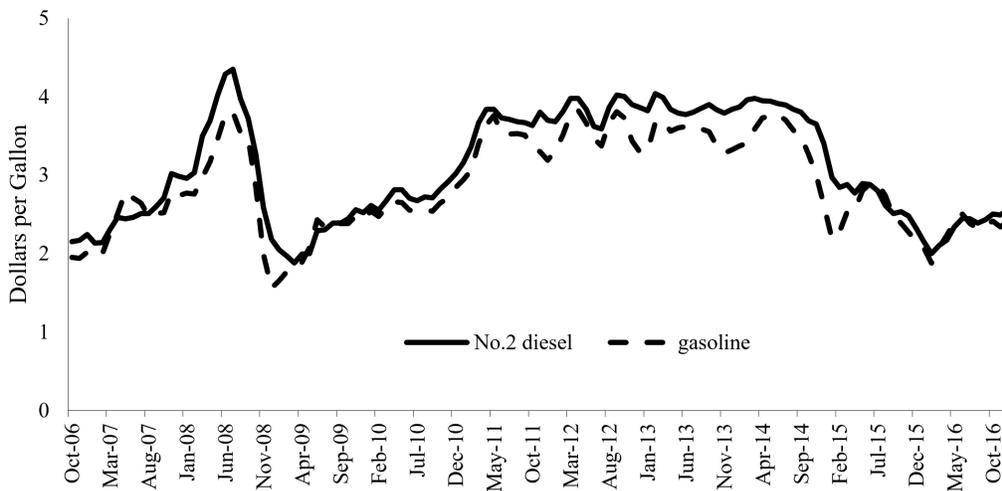
In the following sensitivity analysis, we replace our calculated Canadian lumber price with the price of Kiln-Dried Dimension Eastern Spruce-Pine-Fir (delivered, Great Lakes) # 2 collected from the Random Lengths database. Some of the key results are listed in Table 7. Panel 1 indicates that the framing lumber composite price is capable of representing the price movement in the U.S. domestic lumber market. Price transmission between Canada and the U.S. at the country level and at the regional level shows a similar pattern in terms of reduced transaction costs and faster response to price deviations after 2013. Panel 2 informs us that the major results are insensitive to

the reference Canadian lumber price in all cases (except for Canada-U.S. South). To avoid repetition, we skip further analysis.

5.6 Sensitivity analysis: fuel prices

Using a similar framework, Jamora and von Cramon-Taubadel (2016) analyzed the transaction cost thresholds in world rice markets between January 2000 and December 2012 and concluded that the transaction costs increased substantially after 2008. They argued that surging fuel prices led to higher transport costs and offset the reduced trade barrier brought by trade liberalization. One may therefore suspect that the changing domestic transaction costs found in our analysis may partly result from increased costs of inputs in transportation, like diesel and gasoline prices. However, diesel and gasoline prices over the past 15 years (constant 2015 US\$) do not appear to be significantly higher after 2013. In fact, there are some years when the average price is even lower in the free trade period than that in binding period (Figure 3). This implies that the increased domestic transaction costs identified within this study can be reasonably attributed to the occurrence of free trade. The use of real prices for the TVECM estimate further increases confidence about the robustness of our findings. Since our focus is on the U.S.-Canada lumber market, other country-country price pairs are not included in our sensitivity analysis.

Figure 3. Monthly diesel and gasoline prices: October 2006-December 2016



Source: U.S. Department of Energy, Energy Information Agency, available at www.eia.doe.gov as of March 2019

Conclusion

An important theme of international policy has been the dismantling of protectionist policies in favor of free trade, aimed at better integrating foreign markets in order to promote economic growth. A removal of barriers to international exchange may encourage consumers to seek lower cost alternatives in foreign markets. As a result, this may place less pressure on intraregional trade to meet domestic demand and therefore deteriorate domestic market integration.

Previous studies investigating the effect of trade liberalization policies on market integration have usually ignored the role of transaction costs. In this paper a TVECM is utilized to capture the dynamics of trade policy on both foreign and domestic market integration. A unique dataset of monthly U.S. and Canadian softwood lumber prices covering trade restriction and liberalization episodes further allows us to investigate what impact trade agreements have on transaction costs and their implications for integration across softwood lumber markets.

Two major conclusions can be drawn from this study. We find that trade liberalization leads to a decline in home-foreign transaction costs and a rise in home-home transaction costs. Correspondingly, all U.S. regional domestic lumber markets are more integrated with the Canadian lumber market during the import duty exemption period than when duties are in place. However, duty-free access to the Canadian lumber market reduces U.S. intraregional trade opportunities, meaning the home-home market price pairs become less integrated.

We also find that the estimated speed of adjustment parameters for the ECM (i.e., the coefficient on the error-correction term) is statistically significant in the upper and lower regimes in Canada-U.S. equations but not vice versa. So, in the long-run, there exists a unidirectional causality from the Canadian market to U.S. domestic markets. Within the U.S. domestic markets, we find evidence of unidirectional causality from U.S. West to U.S. South and to U.S. North. Therefore, we conclude that the Canadian lumber market acts as a price leader and can affect U.S. domestic lumber prices either directly or indirectly via the U.S. West market. The sensitivity analysis of different price series confirms the robustness of our main analysis.

The 2006 U.S.-Canada Softwood Lumber Agreement (SLA) aims to secure domestic lumber supply and stabilize the U.S. lumber market, and our results imply that the 2006 SLA achieved its expected outcomes for markets from the domestic price transmission angle. Our results indicate that previous lumber import restrictions may have enhanced the level of domestic market integration in softwood lumber markets. Currently the 2006 SLA has expired, and there is no further discussion about the new SLA.

Our paper could be extended along two major directions. First, it would be interesting to identify other factors that have contributed to the surge in U.S. domestic lumber prices besides Canadian imported lumber prices. Second, our results reveal that transaction costs are highly tied to trade policies, which may have important implications for welfare analysis. A commonly used method to analyze market welfare is a partial equilibrium model. To our knowledge, no one has accounted for the changing transaction costs when performing welfare analysis. The welfare effects of market integration warrant further examination.

References

- Bachmeier, L.J., Griffin, J.M., 2006. Testing for market integration crude oil, coal, and natural gas. *The Energy Journal*, 27(2), 55-71.
- Balcombe, K., Bailey, A., Brooks, J., 2007. Threshold effects in price transmission: the case of Brazilian wheat, maize, and soya prices. *American Journal of Agricultural Economics*, 89(2), 308-323.
- Balke, N.S., Fomby, T.B., 1997. Threshold cointegration. *International Economic Review*, 38, 627-645.
- Barrett, C.B., 2001. Measuring integration and efficiency in international agricultural markets. *Review of Agricultural Economics*, 23(1), 19-32.
- Baylis, K., Jolejole-Foreman, M.C., Mallory, M., 2014. Effects of export restrictions on domestic market efficiency: The case of India's rice and wheat export ban. Available at: http://works.bepress.com/kathy_baylis/54/ (accessed January 10, 2019)
- Caner, M., Hansen, B.E., 2001. Threshold autoregression with a unit root. *Econometrica*, 69(6), 1555-1596.
- Chen, C.W., So, M.K., 2006. On a threshold heteroscedastic model. *International Journal of Forecasting*, 22(1), 73-89.
- Giuliodori, D., Rodriguez, A., 2015. Analysis of the stainless steel market in the EU, China and US using co-integration and VECM. *Resources Policy*, 44, 12-24.
- Goodwin, B.K., Piggott, N.E., 2001. Spatial market integration in the presence of threshold effects. *American Journal of Agricultural Economics*, 83(2), 302-317.
- Götz, L., Glauben, T., Brümmer, B., 2013. Wheat export restrictions and domestic market effects in Russia and Ukraine during the food crisis. *Food Policy*, 38(1).214-226.
- Greb, F., von Cramon-Taubadel, S., Krivobokova, T., Munk, A., 2013. The estimation of threshold models in price transmission analysis. *American Journal of Agricultural Economics*, 95(4), 900-916.
- Hansen, B.E., Seo, B., 2002. Testing for two-regime threshold cointegration in vector error-correction models. *Journal of Econometrics*, 110(2), 293-318.
- Howard, J.L., 2007. U.S. Timber Production, Trade, Consumption, and Price Statistics 1965–2005. Madison, WI: U.S. Department of Agriculture, Forest Service.
- Ince, P.J., Kramp, A.D., Skog, K.E., Yoo, D.I., Sample, V.A., 2011. Modeling future U.S. forest sector market and trade impacts of expansion in wood energy consumption. *Journal of Forest Economics*, 17(2), 142-156.
- Jamora, N., von Cramon-Taubadel, S., 2016. Transaction cost thresholds in international rice markets. *Journal of Agricultural Economics*, 67(2), 292-307.
- Koop, G., Pesaran, M.H., Potter, S.M., 1996. Impulse response analysis in nonlinear multivariate models. *Journal of econometrics*, 74(1), 119-147.
- Larsen, B., 2012. A threshold cointegration analysis of Norwegian interest rates. Master Thesis, University of Tromsø, Oslo.

- Lim, E.S., Breuer, J.B., 2019. Free trade agreements and market integration: Evidence from South Korea. *Journal of International Money and Finance*, 90, 241-256.
- Listorti, G., 2009. Testing international price transmission under policy intervention. An application to the soft wheat market. PhD Studies Series Vol. 6, Università Politecnica delle Marche, Department of Economics, Italy.
- Lo, M.C., Zivot, E., 2001. Threshold cointegration and nonlinear adjustment to the law of one price. *Macroeconomic Dynamics*, 5(4), 533-576.
- Menezes, R., Dionísio, A., Hassani, H., 2012. On the globalization of stock markets: an application of vector error correction model, mutual information and singular spectrum analysis to the G7 countries. *The Quarterly Review of Economics and Finance*, 52(4), 369-384.
- Meyer, J., 2004. Measuring market integration in the presence of transaction costs—a threshold vector error correction approach. *Agricultural Economics*, 31(2-3), 327-334.
- Mundlak, Y., Larson, D.F., 1992. On the transmission of world agricultural prices. *The World bank economic review*, 6(3), 399-422.
- Pesaran, M.H., Shin, Y., 1998. An autoregressive distributed-lag modelling approach to cointegration analysis. *Econometric Society Monographs*, 31, 371-413.
- Porteous, O., 2017. Empirical effects of short-term export bans: The case of African maize. *Food Policy*, 71, 17-26.
- Seo, M., 2006. Bootstrap testing for the null of no cointegration in a threshold vector error correction model. *Journal of Econometrics*, 134(1), 129-150.
- Stephens, E.C., Mabaya, E., Cramon-Taubadel, S.V., Barrett, C.B., 2012. Spatial price adjustment with and without trade. *Oxford Bulletin of Economics and Statistics*, 74(3), 453-469.
- Sun, C., Zhuo, N., 2014. Timber restrictions, financial crisis, and price transmission in North American softwood lumber markets. *Land Economics*, 90(2), 306-323.
- Sun, C., 2017. Competition of wood products with different fiber transformation and import sources. *Forest Policy and Economics*, 74, 30-39.
- Svanidze, M., Götz, L., 2017. How well is the Russian wheat market functioning? A comparison with the corn market in the USA. Paper presented at the annual meeting of the Applied and Agricultural Economics Association, Chicago, Illinois.
- Ters, K., Urban, J., 2019. Estimating unknown arbitrage costs: Evidence from a 3-regime threshold vector error correction model. *Journal of Financial Markets* (in press)
- Valdes, R., 2017. What drives the regional integration of agribusiness stocks? Evidence in worldwide perspective. Paper presented at the annual meeting of the Applied and Agricultural Economics Association, Chicago, Illinois.