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Vertical Price Transmission in the Canadian Beef Industry: Does the Canada-US Exchange Rate Matter?

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Abstract

Cross-border trade with the United States is a crucial factor in the performance of the Canadian beef industry. While many studies have analyzed vertical price transmission in agricultural markets, studies that consider exogenous and trade-related information in the analysis of domestic vertical price relationships are missing. This study fills this gap by estimating regime-switching farm-to-wholesale price transmission in the Canadian beef industry using the Canadian-U.S. dollar exchange rate as the regime-inducing variable in a threshold vector error-correction model. We find that the exchange rate acts as a regime-inducing factor in the coordination between Canadian cattle producers and their packer buyers.

Keywords: Canadian beef supply chain, CAD/USD exchange rate, price transmission, regime-switching, threshold ECM, BSE.

1. Introduction

The recent re-negotiation of the North American Free Trade Agreement (NAFTA) and media attention given to agricultural markets during the current COVID-19 pandemic highlight the importance of functioning cross-border supply chains and the interdependencies in major Canadian and U.S. agricultural product markets in particular (Ker and Cardwell 2020; Martinez, Maples and Benavidez 2020).[1] A prime example of this kind of integrated industry is the Canadian beef sector, whose domestic economic performance and vertical market structure perpetually hinge on external market conditions in its largest export market. Prominent and often volatile factors—including the Canadian dollar/U.S. dollar (CAD/USD) exchange rate, feed grain prices (Zhen, Rude and Qiu, 2018), bovine spongiform encephalopathy (BSE) (Saha and Mitura, 2008), and policy shocks such as mandatory U.S. country-of-origin labeling (Twine, Rude and Unterschultz, 2016)—have been shown to affect Canadian export flows of beef and cattle to the U.S. market.

The industry's dependence on exports to the United States has been a topic of ongoing debate, especially in the aftermath of the 2003–2005 BSE-induced border closure (Grier, 2005; Miljkovic 2009; Schulz, Schroeder and Ward 2011). Saha and Mitura (2008) and Twine (2014) have previously argued that the BSE-induced market shock has resulted in a lasting structural transformation of the Canadian beef supply chain, with implications for market integration and price relationships. The literature has not yet investigated whether Canada's continued reliance on U.S. imports leaves its cattle and beef producers vulnerable to trade-related market shocks. Nor have previous studies quantified the extent to which Canadian exports to the U.S. affect the price-coordination mechanisms between cattle producers and beef packers in the Canadian market.

This paper fills the gap in the literature by estimating the long-run equilibrium and short-run dynamics of vertical price transmission in the Canadian beef supply chain. Our specific focus is on testing whether and how fluctuations in the CAD/USD exchange rate have affected the vertical farm-to-wholesale price-transmission mechanism in the Canadian market. Our empirical approach implements advances in modelling non-linear price dynamics by estimating a threshold vector error correction model (TVECM) that allows us to test whether the Canadian beef supply chain exhibited regime-switching type adjustment behaviour in response to exogenous CAD/USD exchange-rate shocks. The empirical analysis takes advantage of the 2003 Canadian BSE crisis as an exogenous market shock-inducing a structural break that identifies potential shifts in the price transmission regimes before (May 2003) and after

(July 2005) the U.S. border was closed to Canadian cattle and beef exports. We thus introduce the CAD/USD exchange rate as a regime-switching variable into the price transmission model as a potential trigger of asymmetric price adjustment in the presence of market power and adjustment costs that may lead to regime-switching behaviour by the underlying market agents.

The analysis in this paper does not strive to fully characterize the Canadian beef supply chain. Instead, we draw attention to the critical role of the bilateral exchange rate as an exogenous and trade-related variable plays in the estimation of co-movements along integrated agricultural supply chains that stretch across an international border. The added flexibility in transmission modelling we introduce produces estimates of short-run price adjustment patterns for the Canadian beef sector and contributes to a better understanding of how exchange-rate movements induce regime-switching behaviour among domestic supply-chain agents. Moreover, the empirical evidence we present below has important implications for how policymakers and industry stakeholders evaluate the competitiveness and resilience of the Canadian beef-cattle sector; especially when considering current disruptions to Canadian agri-food supply chains during the Covid crisis.

2. Literature

Analyses of price linkages along vertical agri-food supply chains (Goodwin and Holt, 1999; Fousekis, Katrakilidis and Trachanas, 2016) and in international commodity and beef trade (Goodwin and Piggott, 2001; An, Qiu and Zheng, 2016) have long traditions in agricultural economics. Central to the development of this field are progressive time-series econometric techniques using various types of regime-switching error-correction models (ECM), which provide robust evidence of asymmetric and non-linear processes in price adjustments in response to exogenous market or policy shocks (Meyer and Cramon-Taubadel, 2004).

An improved understanding of the mechanism by which currency fluctuations could influence cross-border commodity supply chains and their effects on the welfare of economic agents is of particular interest to trade-risk managers and policymakers alike. Past research (e.g., Bahmani-Oskooee and Hegerty, 2007; Anders and Fedoseeva, 2017) provide evidence of asymmetric and non-linear pass-through of exchange rates into domestic goods markets. Savoie-Chabot and Khan (2015) and Forbes, Hjortsoe and Nenovac (2018) report that movements in the CAD/USD exchange rate can have indirect yet material impacts on domestic (consumer) prices and thus the balance between domestic and U.S. import demand for traded goods.

However, despite recent levels of high commodity price volatility (Ganneval, 2016) and exchange-rate interdependence (Hatzenbuehler, Abbott and Foster, 2016) that challenge the standard assumption of linear and symmetric market reactions, the literature on exchange-rate pass-through for agricultural commodity markets is still limited. Existing studies have analyzed exporter or importer pricing behaviour in response to exchange-rate shocks (e.g., Mutuc, Pan and Hudson, 2011), potential regime-switching behaviour of price transmission in response to trade policies (Götz et al., 2016), and the role of exchange rates and market power in asymmetric price co-movement across regions (Luckstead, 2018). This paper contributes to the literature by investigating whether and the extent to which the CAD/USD exchange rate as an exogenous, trade-related variable influences the vertical farm-to-wholesale price-transmission mechanism along the domestic Canadian beef supply chain, one of the country's most important agricultural commodity sectors.

Schulz, Schroeder, and Ward (2011) and Grier (2005) have argued that exchange rates—through their effect on relative prices for cattle and beef—will directly affect the relative competitiveness of domestic and imported substitutes in the North American beef market. Under perfectly competitive market conditions, shifts in the CAD/USD exchange rate should be passed through perfectly into domestic prices and cause uniform price adjustments across domestic market levels. However, in the absence of perfect competition, co-movements in the domestic market might differ in their response to changes in the exchange rate. For instance, depending on their relative bargaining power along the supply chain (Rude, Harrison and Carlberg, 2011; Zhen, Rude and Qiu, 2018), heterogeneous impacts may be amplified during periods of excess Canadian supply and/or a high degree of dependence on U.S. trade. According to Grier (2005), the excess supply of fed cattle in Canada, for instance due to unfavourable U.S. exchange-rate situations, may hand Canadian beef packers additional bargaining power, resulting in depressed prices for domestic fed cattle, an indicator of asymmetric price adjustment (Goodwin and Holt, 1999; Awokuse and Wang, 2009). As cattle producers and packers on both sides of the border closely monitor prices to determine relative market opportunities, Canadian fed-cattle producers' choice of market will critically depend on the CAD/USD exchange rate.

3. Econometric Approach

We apply a two-step procedure to capture non-linear dynamics in the Canadian beef-cattle supply chain. First, we investigate the cointegration relationship between Canadian farm- and wholesale-level (packer) prices. Second, we identify and estimate the threshold error correction models. Specifically, we utilize a threshold autoregressive

(TAR) model to identify the threshold effects of the CAD/USD exchange rate. Then, we estimate a two-regime TVECM to investigate the direction and speed of adjustments to price deviations from the long-run relationship depending on the identified threshold values of the exchange rate.

3.1 Long-run Price Relationships

Following Engle and Granger (1987), we test and estimate the long-run price relationships between farm and wholesale prices. Existing studies confirm the structural change in the Canadian beef industry in the aftermath of the BSE crisis (e.g., Twine, Rude and Unterschultz 2016). The resulting adjustment is likely to have an impact on the long-run relationship between the two prices. To differentiate the Canadian–U.S. border closure and open periods, we estimate and test the long-run relationship in three periods: 1) before BSE (January 05, 2001-May 20, 2003), 2) during the U.S. border closure (May 20, 2003-July 18, 2005) and 3) after BSE (July 19, 2005 - February 2018). In each period, the long-run relationship between farm and wholesale prices is specified as:

$$p_t^w = \alpha + \beta\, p_t^f + e_t \tag{1}$$

where p_t^j is the market price at level *j,* α is a constant, and β can be interpreted as the transmission elasticity since all prices are transformed into logarithmic form. The transformation of price series into logarithms is common practice in market co-movement analyses to stabilize the variance of the data and to translate absolute changes to percentage changes (e.g., Gervais, 2011; Saghaian, Nemati, Walters and Chen, 2018). The saved residuals from the equilibrium regression, $\hat{e}_{t-1} = p_{t-1}^w - \beta\, p_{t-1}^f$, yield the error-correction term used to estimate the ECM in the subsequent stage.

3.2 Threshold vector error-correction models

Next, in order to investigate potential regime-switching behaviour in the error-correction procedure in response to changes in the CAD/USD exchange rate, we first test for non-linearity and identify the threshold value of the exchange rate. In the price transmission literature, two-threshold and three-regime TVECMs are popular. The rationale for having two threshold values is that existing studies usually use the (relative) price returns or deviations from the long-run relationship as the forcing variable (also known as the threshold-indicating variable). Deviations and price returns/changes can be positive or negative. Therefore, studies usually search for two

threshold values, one positive and one negative, before investigating regime-specific behaviors. In our case, we use the CAD/USD exchange rate as the forcing variable, which allows only positive values. Therefore, we adopt a one-threshold and two-regime TVECM for empirical investigation. Under the two-regime TVECM, price adjustment depends on whether the exchange rate is low or high. To determine the threshold value, combining the TAR model and Chan's (1993) approach, we first run the regression of TAR model (see Eq. (2) below) repetitively, using each exchange-rate value as the potential threshold value.[2] We then compare the sum of squared residuals (SSR) of these TAR models. The final threshold value (τ) of the exchange rate is determined by the TAR results with the smallest SSR value.

The exchange rate has the potential to induce asymmetric price adjustments to any deviation from the equilibrium. The prime reason is that high and low exchange rates represent two different trade environments, one of which is favourable and another that is unfavourable to domestic producers. Depending on where the exchange rate falls relative to the threshold, the price series adjusts to any deviation from the last period differently.

The two-regime TAR model we adopted to identify the threshold value can be specified as:

$$e_t = I_t(\alpha_0 + \alpha_1 e_{t-1} + \alpha_2 e_{t-2} + \alpha_3 e_{t-3}) + (1 - I_t)(\beta_0 + \beta_1 e_{t-1} + \beta_2 e_{t-2} + \beta_3 e_{t-3}) + \varepsilon_t \quad (2)$$

In Equation (2), I_t is the Heaviside indicator function represented by:

$$I_t = \begin{cases} 1, & if\ E_{t-1} \geq \tau \\ 0, & if\ E_{t-1} < \tau \end{cases} \quad (3)$$

where e_t is the deviation from the long-run relationship in period t; I_t is the Heaviside indicator function (based on the exchange rate level, E^1_{t-1}); τ is the threshold value; α_1, α_2 and α_3 measure the effect of the price deviation from the long-run relationship in periods $t-1$, $t-2$ and $t-3$ when $E^1_{t-1} \geq \tau$; β_1, β_2 and β_3 measure the effect of the price deviation from the long-run relationship from the last three periods when $E^1_{t-1} < \tau$.

After finding the threshold value with the smallest SSR, we run the linear version of Equation (2) without incorporating the Heaviside indicator function and obtain the SSR. If the SSR of the TAR model is smaller than the SSR of the linear equation, we conclude that the true model should be a threshold model instead of a one-regime linear model.

Estimate the threshold vector error-correction models

Given the identification of the threshold value, we can proceed to estimate the short-run price adjustment using regime-switching TVECM specified below:

$$\begin{aligned}\Delta p_t^w = I_t \Bigg(\alpha_{10} + \alpha_{11} E_{t-1} + \alpha_{12} ECT_{t-1} + \sum_{i=1} \delta_{11}^{(1)}(i)\, \Delta p_{t-i}^w \\ + \sum_{i=1} \delta_{12}^{(1)}(i) \Delta p_{t-i}^f \Bigg) + \\ (1 - I_t) * \Bigg(\beta_{10} + \beta_{11} E_{t-1} + \beta_{12} ECT_{t-1} + \sum_{i=1} \delta_{11}^{(2)}(i)\, \Delta p_{t-i}^w \\ + \sum_{i=1} \delta_{12}^{(2)}(i) \Delta p_{t-i}^f \Bigg) + v_{wt}\end{aligned} \tag{4}$$

$$\begin{aligned}\Delta p_t^f = I_t \Bigg(\alpha_{20} + \alpha_{21} E_{t-1} + \alpha_{22} ECT_{t-1} + \sum_{i=1} \delta_{21}^{(1)}(i)\, \Delta p_{t-i}^w \\ + \sum_{i=1} \delta_{22}^{(1)}(i) \Delta p_{t-i}^f \Bigg) + \\ (1 - I_t) * \Bigg(\beta_{20} + \beta_{21} E_{t-1} + \beta_{22} ECT_{t-1} + \sum_{i=1} \delta_{21}^{(2)}(i)\, \Delta p_{t-i}^w \\ + \sum_{i=1} \delta_{22}^{(2)}(i) \Delta p_{t-i}^f \Bigg) + v_{ft}\end{aligned} \tag{5}$$

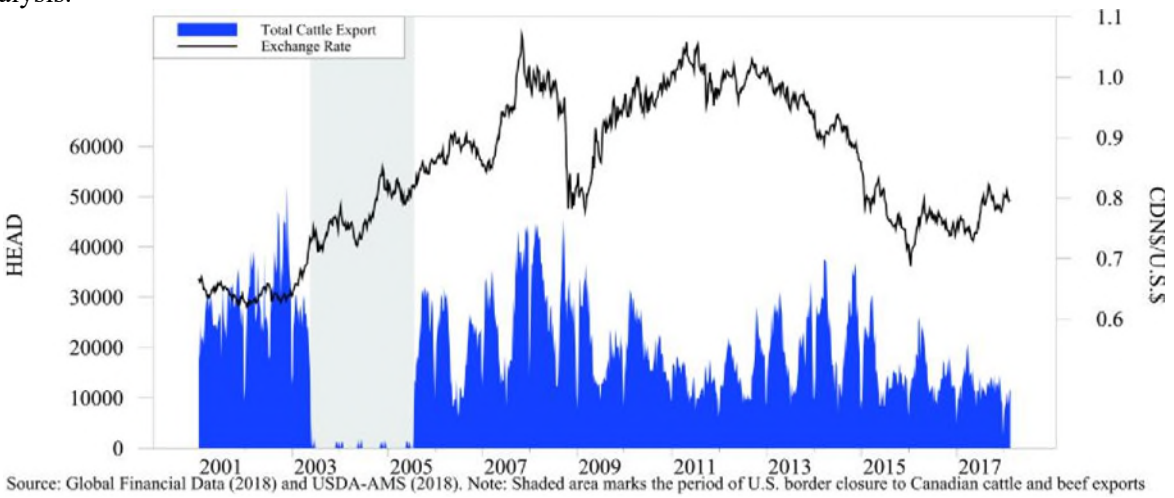
Where,

$$TAR: I_t = \begin{cases} 1, & if\ E_{t-1} \geq \tau \\ 0, & if\ E_{t-1} < \tau \end{cases} \tag{6}$$

In Equation (4) and (5), p_t^w and p_t^f are prices at the wholesale- and farm-levels, respectively; E_{t-1} is the exchange rate in period *t-1*; α and β are the speed-of-adjustment coefficients; and $ECT_{t-1} = \hat{e}_{t-1}$ is the error-correction term (i.e., the estimated deviation from the equilibrium relationship) at time $t-1$. The absolute value of the error-correction term represents a deviation from the long-run equilibrium in period $t-1$, and the speed-of-adjustment coefficients indicate the direction and speed at which prices adjust (%) when there is a deviation from the long-run relationship. In Equation (5), depending on the exchange rate above or below τ, farm and wholesale prices will respond to the deviation, the exchange rate, and lagged price adjustments differently in two regimes.

4. Data

The empirical analysis of price transmission dynamics along the Canadian beef-cattle supply chain employs three weekly data series: 1) farm-level prices for fed cattle, 2) wholesale beef prices and 3) CAD/USD exchange rates for January 2001 to February 2018 (897 weekly observations). Total weekly exports of Canadian cattle (USDA-AMS 2018) to the U.S. market and weekly bilateral CAD/USD exchange rates (Global Financial Data 2018) are depicted in Figure 1. Table 1 presents summary statistics of farm prices, wholesale prices and exchange rates for the three periods considered in the analysis.



Source: Global Financial Data (2018) and USDA-AMS (2018). Note: Shaded area marks the period of U.S. border closure to Canadian cattle and beef exports

Figure 1. Weekly Cattle Exports to the U.S. and CAD/USD Exchange Rate, 2001-2018

We use available weekly data reports for Alberta fed-steer prices from Canfax (2018) to represent Canadian live cattle farm-gate prices. We compute Canadian

wholesale level beef prices as weighted averages across the wholesale boxed-beef prices of A, AA, and AAA carcass grades using their respective grade market shares and composite cut-out values (Canfax 2018), which represent roughly 97% of all graded beef in Canada (BCRC, 2012). Cattle and beef prices are in dollars per hundredweight ($/cwt). We deflate all price series using CPI data obtained from Statistics Canada (2018).

Table 1. Descriptive Statistics for the Canadian Beef-cattle Supply Chain, 2001-2018

Variable	Mean	Std. Dev.	Skew	Min	Max
Pre-BSE period (January 05, 2001 - May 20, 2003), N=125					
Wholesale price (CAD$ /cwt)	187.33	18.63	3.00	161.74	317.31
Farm price (CAD$ /cwt)	103.38	9.95	1.49	82.72	159.10
Exchange rate (CDN$/ U.S.$)	0.65	0.02	1.85	0.62	0.73
Cattle exports to U.S. (head)	28390.86	7676.91	0.19	6194	51746
BSE border closure (May 20, 2003 - July 18, 2005), N=114					
Wholesale price (CAD$ /cwt)	174.19	13.45	-0.15	140.20	213.15
Farm price (CAD$ /cwt)	73.33	12.23	-2.05	34.07	90.45
Exchange rate (CDN$/ U.S.$)	0.77	0.04	0.24	0.71	0.85
Cattle exports to U.S. (head)	304.40	771.16	4.57	0.00	6194
Post-BSE period (July 18, 2005 - February 17, 2018), N=658					
Wholesale price (CAD$ /cwt)	180.34	35.35	0.88	132.22	271.95
Farm price (CAD$ /cwt)	97.84	23.51	0.90	64.46	160.37
Exchange rate (CDN$/U.S.$)	0.90	0.09	-0.29	0.69	1.07
Cattle exports to U.S. (head)	19333.59	8473.07	0.79	2248	45469

Figure 2 plots Canadian farm- and wholesale-level beef prices. Farm- and wholesale-level beef price series exhibit a visible degree of co-movement, except for

the year 2003, where the sharp decrease in farm prices is only partially mirrored by wholesale prices. Between 2004 to 2010, both price series and margin appear relatively stable, despite evident volatility in the CAD/USD exchange rate. Finally, between 2010 and 2015, both farm and wholesale price series exhibit upward trends, reaching highs of $160.37/cwt and $271.95/cwt, respectively, in 2015. After 2015, both price series experience more pronounced fluctuations. However, the mean values of farm and wholesale prices between January 2014 and February 2018 remain above 2005–2014 levels, while the exchange rate continues its retreat from parity.

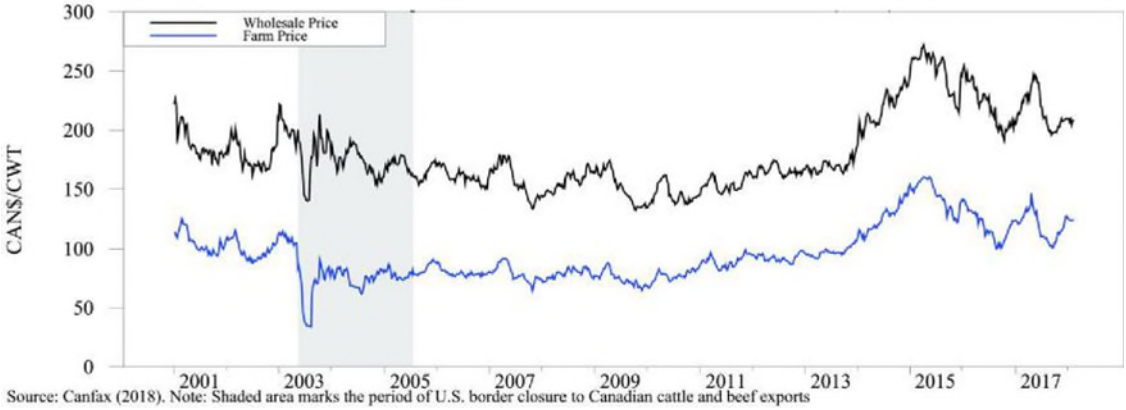


Figure 2. Weekly Canadian Farm and Wholesale Beef Prices (Real), 2001-2018

5. Results

5.1 Long-run Price Equilibrium

We discuss our empirical results for each step of the three-step estimation procedure. As a prerequisite for the cointegration analysis, we conducted the standard ADF test (Dickey and Fuller, 1979) and the Kwiatkowski-Phillips-Schmidt-Shin (KPSS) test (Kwiatkowski et al., 1992) to assess the time series properties of the price series (see Table 2). For both time periods under analysis, before and after the U.S. border closure, the ADF tests fail to reject the unit root hypothesis and the KPSS tests reject the stationarity null for both farm and wholesale prices. Meanwhile, the test results reject the unit root hypothesis and are not able to reject stationarity for the first difference of price series. Therefore, the price series can be considered as *I(1)* for both pre- and post-BSE periods.

Table 2. Unit root test of farm and wholesale prices

Prices series		Farm	Δ Farm	Wholesale	Δ Wholesale
Pre BSE (Jan.05,	ADF (lag=3)	-1.82	-6.36**	-2.48	-8.92**
2001- May 20, 2003)	KPSS (lag=3)	0.67*	0.18	0.52*	0.45
Post BSE (July 18,	ADF (lag=3)	-1.25	-21.18**	-1.28	-23.18**
2005- Feb. 17, 2018)	KPSS (lag=3)	12.54**	0.06	10.87**	0.08

Note: ** and * denote 1% and 5% levels of significance, respectively. For the ADF test, the critical values at 1% and 5% levels of significance are -3.48 and -2.89, respectively; and for the KPSS test, critical values at the 1% and 5% levels of significance are 0.74 and 0.46, respectively. Lags in the unit root tests are based on the Akaike information criterion (AIC).

Using the Engle and Granger's (1987) two-step approach, we find equilibrium relationships between the co-integrated farm and wholesale prices in both pre- and post-border-closure periods, when Canadian cattle and beef exports flow freely. Table 3 presents the results of Engle-Granger cointegration test of farm and wholesale prices. Test results confirm the cointegration relationship between farm-level and wholesale prices during pre- and post-border closure periods.

TABLE 3 Engle-Granger Cointegration test of farm and wholesale prices

H0: No cointegration	
Pre BSE (Jan.05, 2001- May 20, 2003)	-3.83*
During Border Closure (May 20, 2003 - July 18, 2005)	-2.51
Post BSE (July 18, 2005- Feb. 17, 2018)	-4.96**

Note: ** and * denote 1% and 5% levels of significance, respectively. The critical values at 1% and 5% levels of significance are -3.99 and -3.38, respectively.

The estimated corresponding long-run equilibrium relationships are shown in table 4. Coefficient estimates are significant at the 1% level, with transmission elasticities of 0.84 and 0.78 during pre- and post-border-closure periods, respectively. Thus, a 10% change in the Canadian farm-level fed-cattle price translates to an 8.4% adjustment in the wholesale price of beef before the border closure, falling to 7.8% in the post-BSE period. Although the cointegration regression results do not imply any causal

relationship, the (Granger) causality inference regarding price responses can be drawn from the results of error-correction model in the next subsection.

Table 4. Estimated Equilibrium Price Relationships

Dependent Variable：Wholesale Price		
Parameter	**Coefficient**	**Standard Error**
Pre-BSE period		
Constant	1.36***	0.43
Farm Prices	0.84***	0.09
Post-BSE period		
Constant	1.61***	0.03
Farm Prices	0.78***	0.01

Note. ***, ** and * denote 1%, 5% and 10% levels of significance, respectively.

The main reason for the lack of a long-run equilibrium relationship between farm and wholesale prices during the U.S. border closure is that the cessation of exports to the United States significantly altered the vertical relationship in the Canadian supply chain and undermined the long-established equilibrium. Separation from its most important export market rendered the domestic market more volatile and unpredictable and contributed to a temporary lack of equilibrium.

The exchange-rate threshold values that produced the lowest SSRs for pre- and post-BSE periods are 0.66 and 0.94, respectively. Comparing the lowest SSRs of the TAR models with their linear model counterparts (no threshold variable) supports our decision to adopt a TAR model. In other words, the CAD/USD exchange rate does impose a threshold effect on domestic price transmission between fed-cattle and Canadian beef-packer prices.

5.2 Threshold Vector Error-correction Models

Table 4 presents coefficient estimates of a two-regime threshold TVECM between farm and wholesale markets for the pre- and post-border-closure periods, respectively, using

the identified exchange-rate threshold values. Lag selection is based on the Akaike information criterion (AIC) values.

First, our results indicate that Canadian fed-cattle farm prices did not respond to price deviations from long-run equilibrium during either the pre- or the post-BSE period. In contrast, the wholesale side of the supply chain adjusted toward the market equilibrium in three of the four cases. This finding implies that cattle producers possess some degree of bargaining power over packers in the domestic fed-cattle market when exports to the United States are viable, a result that contrasts with the U.S. market situation. Our interpretation is consistent with prior evidence reported by Rude, Harrison and Carlberg (2011) in that Canadian beef packers do not appear to have exercised any degree of market power in the Canadian beef supply chain.

Second, we find significant differences in the speed of adjustment by which wholesale prices revert to equilibrium in the two periods. Before 2003, wholesale prices responded to deviation only when the exchange rate was below a critical threshold. In this market scenario, 23.6% of the deviation (ECT_{t-1}) could be corrected in the following week. After 2005, however, although Canadian wholesale prices adjusted to deviations from equilibrium in both regimes, the magnitudes of adjustment were only 5.8% in the above-threshold regime and 16% in the below-threshold regime. Overall, the wholesale adjustment was reduced compared to the pre-BSE period.

Third, we find evidence of faster wholesale-price adjustment when the CAD/USD exchange rate is below the threshold. A possible explanation for this result lies in the critical role the exchange rate plays in determining the competitiveness of Canadian cattle exports in the U.S. market. In a high(er) exchange-rate regime, Canadian fed cattle lose price competitiveness to their U.S. peers in the U.S. wholesale market. Canadian fed-cattle producers may thus be more likely to sell their animals to domestic beef packers, which in turn strengthens Canadian packers' market (bargaining) position; as a result, packers adjust more slowly to price deviations. In comparison, during periods of below-threshold exchange rates, Canadian cattle are relatively more competitive in the U.S. wholesale market. In this scenario, Canadian fed-cattle producers increase their exports to the United States, which improves their bargaining position against Canadian packers and in turn leads packers to respond more quickly to market signals. Overall, our results suggest that even though both Canadian producers and beef packers and processors have access to the U.S. market, fed-cattle producers have a choice to direct a critical input to either U.S. or Canadian beef-packing plants, which explains why Canadian cattle producers do not respond to price departures from long-run relationships in the Canadian supply chain.

Table 5. Two-regime Error-correction Model Short-run Price Adjustment Results

	Δp_t^w		Δp_t^f		Δp_t^w		Δp_t^f	
	Pre-BSE period				**Post-BSE period**			
	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error	Coefficient	Std. error
Regime 1: Exchange rate > Threshold Value								
Constant	-0.163	0.221	1.436***	0.258	-0.001	0.037	0.007	0.045
E_{t-1}	0.247	0.326	-2.141***	0.380	-0.001	0.038	-0.006	0.046
ECT_{t-1}	-0.395	0.459	0.662	0.534	-0.058**	0.024	-0.007	0.030
Δp_{t-1}^w	0.023	0.275	-0.642**	0.321	0.053	0.069	0.221***	0.084
Δp_{t-2}^w	-0.325	0.239	-0.164	0.279	0.071	0.067	0.068	0.081
Δp_{t-3}^w	-0.096	0.186	0.258	0.217	-0.004	0.067	-0.021	0.081
Δp_{t-1}^f	0.055	0.500	0.479	0.583	0.147**	0.059	0.223***	0.071
Δp_{t-2}^f	0.444	0.436	0.483	0.508	0.087	0.058	-0.214***	0.070
Δp_{t-3}^f	0.383	0.228	0.024	0.265	0.006	0.058	-0.093	0.070
Regime 2: Exchange rate < Threshold Value								
Constant	-0.056	0.166	0.334*	0.194	0.020*	0.011	-0.002	0.014
E_{t-1}	0.085	0.259	-0.520*	0.301	-0.018	0.013	0.004	0.016
ECT_{t-1}	-0.236***	0.094	0.135	0.109	-0.160***	0.025	-0.043	0.030
Δp_{t-1}^w	-0.021	0.124	-0.157	0.145	-0.004	0.049	0.118**	0.059
Δp_{t-2}^w	-0.017	0.118	-0.115	0.138	-0.016	0.048	-0.104*	0.058
Δp_{t-3}^w	0.189*	0.109	0.009	0.127	-0.043	0.046	0.070	0.055
Δp_{t-1}^f	0.373***	0.123	0.366***	0.143	0.139***	0.046	0.113**	0.055
Δp_{t-2}^f	-0.043	0.127	-0.171	0.148	0.065	0.046	0.043	0.056
Δp_{t-3}^f	-0.192	0.128	0.092	0.149	0.017	0.046	-0.018	0.056

Note ***, ** and * denote 1%, 5% and 10% significance. The term E_{t-1} in the error correction model results controls for short-run exchange rate effects on price.

6. Conclusion

We investigated whether and the extent to which an exogenous, trade-related variable—the CAD/USD exchange rate—influences the price transmission along the Canadian beef supply chain, one of the country's most important agricultural commodity sectors. To empirically test for threshold effects of exchange-rate regimes on the domestic vertical price-transmission mechanism between fed-cattle producers and Canadian beef packers, we employed a two-regime threshold autoregression model. We used the Canadian 2003–2005 BSE border closure to the U.S. market as a potential structural shock in the estimation of pre and post shock long-run equilibrium and short-run price adjustment processes within the Canadian beef-cattle supply chain. Our results indicate that the long-run relationships are relatively stable; however, the short-run price dynamics changed substantially after BSE.

Our results confirm that the CAN/USD exchange rate does play an important role in explaining the domestic commodity market price relationship. This evidence suggests that changes in commodity producer's export conditions in the U.S. market, driven by fluctuations in the bilateral exchange rate, not only affect export decisions but may also lead to significant adjustments in the coordination along the domestic supply chain; as we show in terms of price transmission elasticities that differ significantly across periods and exchange-rate regimes. Our estimates from a two-regime threshold ECM model show that Canadian beef wholesale prices adjusted more rapidly to price deviations during periods of below-threshold exchange rates. This result suggests that Canadian beef packers are more willing to negotiate cattle prices during periods when Canadian cattle are more price competitive in the U.S. market, adding further evidence in support of the Canadian industry's dependence on U.S. markets previously discussed by Rude, Harrison, and Carlberg (2011) and in Twine, Rude, and Unterschultz (2016). We therefore conclude that both the performance and the degree of coordination between producers and processors along the Canadian beef supply chain is determined to a considerable degree by the price competitiveness of Canadian cattle in the U.S. packer market, namely, the exchange-rate effect on the trade relationship between Canadian and U.S. markets for beef cattle (Schulz, Schroeder and Ward 2011).

Our analysis provides two contributions to the literature. First, our novel application of a threshold vector ECM approach to investigating the regime-inducing behaviour of an exogenous trade-related variable on price adjustments in a domestic supply-chain setting provides new possibilities for the analysis of integrated cross-border supply chains. Future work on vertical price transmission shall find it helpful to incorporate other exogenous forcing variables that represent broader trade, economic, and policy

environments. Second, our study has implications for risk-manager along the Canadian beef-cattle supply chain should therefore be of particular interest to those tasked with mitigating trade-related risks through hedging and contract management. On top of the fact that pricing in the Canadian beef-cattle market is dependent on U.S. market conditions, our results indicate that the relative bargaining position along the Canadian supply chain is, to some degree, also determined by the United States, providing further evidence of close cross-border integration in the North American beef industry.

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Endnotes

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[2] Following common practice, the highest and lowest 15% of the exchange-rate values are excluded from the search in order to ensure adequate observations in each regime.