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Article

Vertical and spatial price transmission in the Mexican and international cattle and beef market

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Abstract:

From 2000 to 2019, the Mexican beef subsector has undergone significant structural changes; the most important was the concentration of both production and marketing stages. In 2019, the Mexican Federal Commission of Competence revealed that, Mexican households' income diminished between 16 and 31 % due to a lack of market efficiency. In the case of meat, the reduction may be up to 98 %. In this context, the objective of this study was to examine the degree of spatial price transmission between national and international live cattle prices and the vertical transmission between live cattle prices and carcass meat prices to evaluate market efficiency. The econometric approach consists of the estimation of a vector error correction model, using monthly beef real prices, for the period 1990-2019. Findings from this research provide information for decision-makers and stakeholders in this industry: these comprehend unidirectional transmission of international beef prices to domestic beef prices and from farm price to processor price. Also point to the existence of asymmetric price transmission, which is related to whether cattle and beef prices are increasing or decreasing. Results indicate that a long-run single cointegration relationship exists between international and farmer prices, and between processor and farm price. The direction of price transmission tends to go from producers to processors and from international price to farmer price. When the international price increases, the speed of adjustment tends to be significantly slower, in contrast to when the international price decreases, resulting in a significantly faster rate of adjustment.

Key words: Asymmetric price transmission, Beef prices, Vector error, Correction model.

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Introduction

The livestock and beef industry in Mexico

The Mexican beef cattle sub-sector has substantial economic and social relevance. Production of beef represents almost half the value of Mexican gross animal product[1]. Mexico occupies the eighth position in the world ranking for beef production, with 1.91 million t, 3.35 % of world beef production[2]. The growth average rate (GAR) of cattle production in Mexico was 1.92 % in 2000-2018 (SIAP[3]). From a social perspective, it is the main economic activity carried out by small family farms, accounting for 1.06 million cattle production units in 2018 that generated 1.2 million direct jobs, and three million related jobs[4].

In Mexico, from 1990 to 2019, the beef cattle and beef industry have undergone significant consolidation, as since 2000, both cattle and beef packing have rapidly reorganized into fewer and larger plants. The outcome of these processes is a highly concentrated cattle and beef industry. Thus, Sukarne® is the largest beef processing company in Mexico and has dominated beef export growth from 2010 to 2019. SuKarne® ranks as the sixth-largest beef packing company in North America, it accounts for 74 % of total Mexican beef exports[5]. However, the Mexican Federal Commission of Competence[6] revealed that Mexican households lose between 16 and 31 % of their income. The rapid concentration of beef and cattle industry generates pressure on small processing firms, government, and consumers because retail beef prices grew at a GAR of 4.99 % from 2009 to 2018. However, farmer prices increased at a GAR of 2.43 %, calculated with data from USDA[2] and INEGI[7]. Market concentration in the beef cattle industry is associated with non-competitive behavior that may result in economic inefficiency and a decline in consumer welfare[8]. Some research[9] pointed out that market concentration is among the major causes of asymmetric price transmission in agricultural market chains. Nonetheless, in Mexico, up to now, there are few studies about beef cattle and beef price transmission and then, no consensus exist on this issue.

Spatial price transmission

Spatial price transmission refers to the transmission of price shocks across different areas and commodities[10]. The critical underlying theoretical explanation of spatial price transmission is revealed in the spatial arbitrage relationship, known as the Law of One Price (LOP). It implies that the difference between prices at different market locations will never exceed transaction costs; otherwise, arbitrageurs would exploit these profit opportunities[10].

Suppose that P_A and P_B represent the prices for a homogeneous commodity in two spatially separated markets in *t*, and r_{AB} represents transfer costs to move one unity of merchandise from B to A, the LOP asserts that: $P_B - P_A \leq r_{AB}$. The price difference in *t* for a commodity at two spatially separated markets should not differ by more than transfer costs. If the spatial price difference exceeds that of transfer costs, economic agents make spatial arbitrages. Following the adjustment process, a new equilibrium is reached, and the LOP is once again maintained. As literature[11] asserted, trade between two markets implies they are integrated.

Vertical price transmission

Vertical price transmission analysis is useful for assessing the efficiency of integrating different economic actors into a market. The extent and speed at which price changes are transmitted from one level to another in the market have important policy implications for welfare distribution and competitiveness. In a competitive market, price shocks at one level of the market chain should be reflected by similar changes at other levels, as market efficiency hypothesize a relationship of mutual price equilibrium[12].

From 1990 to 2010, extensive studies examined market links between farm, processor, and retail markets[13]. The extent of adjustment and speed with which shocks transmit between farmer, processor and retailer market prices is an essential factor that reflects market participants' actions at varying market levels. The nature, speed and extent of adjustment to market shocks may also have important implications for marketing margins, spreads, and mark-up pricing practices[9,12].

The objective of this study was to estimate the speed of price transmission between the price of the Mexican beef cattle processor (carcass) and cattle farmer (calf) (vertical transmission) and between the price of Mexican and international cattle price (calf) (spatial price transmission) in order to know on possible asymmetric price transmission and related economic consequences on producer and consumers. The hypothesis was that domestic and international beef price transmission is asymmetric.

Material and methods

The study method consisted of econometric tests using time series of monthly spot real price data, deflated using the consumer price index, from 1990 to 2019. Farmer price was represented by calf prices, intermediate (processor) price was represented by carcass price, and international and import price by calf prices. The last one in dollars, but converted to Mexican real pesos using the bilateral exchange rate. International beef price (calf) comes from the U.S. Department of Agriculture (USDA). Additional information on other indicators originates from official statistical sites in Mexico, among which are the Sistema de Información Agropecuaria y Pesquera (SIAP), the National Institute of Statistics, Geography and Informatics (INEGI by its acronym in Spanish), the National Confederation of Livestock Organizations (CNG by its acronym in Spanish), and from the ANETIF (National Association of Federal Inspection Type) Foundation.

Verification of each series´ integration order was conducted, using the Augmented Dickey-Fuller and Phillips-Perron (PP) tests[14,15]. These tests were followed by an estimation of the long-run relationship, using the Engle-Granger two-step cointegration and the Johansen test[16]. Finally, asymmetric Vector Error Correction Model (VECM) was performed; a test to select the lag order for an asymmetric VECM and a F-test on the coefficient of ECT^+ and ECT^- (positive and negative changes in the error term respectively) in order to test the null hypothesis of symmetry: H_0: $B^+_i = B^-_i$.

Test for cointegration; long-run relationship

Once a unit´s root existence is proved, cointegration between variables in the series is necessary for a long-term equilibrium relationship. A variable vector with a unit root is co-integrated if a linear combination of these variables is stationary[17]. The Engle-Granger two-step cointegration test[17] and the Johansen test[16] were applied to test for a long-run relationship. The first approach consists of estimating the cointegration regression, equation (1), by Ordinary Least Squares (OLS) method:

$$p_t^{out} = a + b_1 p_t^{\text{in}} + m_t \quad (1)$$

where p_t^{out} is a firm output price in period t, p_t^{in} is the input price in t and U_t is the error term. The estimation of equation (1) generated the residual $\hat{u}_t$, to which was applied a unit root test for $\hat{u}_t$. As the coefficient of U_{t-1} was less than unity, a cointegration relationship exists. Subsequently, a regression of equation (2) was performed.

$$\Delta \mu_t = \alpha + \beta_1 \mu_{t-1} + \beta_2 \Delta \mu_{t-1} \tag{2}$$

A negative coefficient of the error term (between -2 and zero) confirms a long run relationship between prices. In contrast, the Johansen test derived the distribution of two test statistics for the null of no cointegration; the Trace and Eigenvalue test(16). Once cointegration between prices was verified, a two-step Error Correction Model (ECM) was applied to capture the short- and long-term effects of p_t^{in} on p_t^{out}, and the speed of adjustment at which p_t^{out} restores equilibrium after a change in p_t^{in}. Two econometric models were estimated: the spatial asymmetric model and the vertical asymmetric model.

Spatial asymmetric price transmission

Considering that farm and international prices have a unit root and were cointegrated, symmetric and asymmetric VECM were estimated to investigate possible price interdependence. Following an econometric approach(18), the ECM for spatial price transmission is depicted in equation (3).

$$\Delta p_t^{farm} = \alpha + \beta_1 \Delta p_t^{int} + \beta_2 ECT_{t-1} + \beta_3(L) \Delta p_{t-1}^{farm} + \beta_4(L) \Delta p_{t-1}^{int} \tag{3}$$

In equation 3, the contemporaneous response term was also segmented(18). It leads to equation (4), in which contemporaneous and short run response to departures from the cointegrating relationship are asymmetric if $\beta_1^+ \neq \beta_1^-$ and $\beta_2^+ \neq \beta_2^-$, respectively.

$$\Delta p_t^{farm} = \alpha + \beta_1^+ \Delta p_t^{int} + \beta_1^- \Delta p_t^{int} + \beta_2^+ ECT_{t-1}^+ + \beta_2^- ECT_{t-1}^- + \beta_3(L) \Delta p_{t-1}^{farm} + \beta_4(L) \Delta p_{t-1}^{int} \tag{4}$$

An F-test was used to test for the null hypothesis of symmetry.

Vertical asymmetric price transmission

In the literature, an approach based on cointegration theory was proposed[17] to test for possible asymmetries in the beef value chain. It indicates that two non-stationary time series may be long-term co-integrated if both series, from the same order, are integrated. In contrast, using an asymmetric VECM, Cramon-Taubadel[19] tested for Asymmetric Price Transmission (APT) in the presence of non-stationary series, by applying the two-step Engel and Granger approach. For this approach, the authors proposed splitting the error-correction-term into positive and negative components to identify whether prices are transmitted differently, depending on whether they increase or decrease. Following the approach for testing vertical asymmetric price transmission[19], it was estimated equation (5):

$$\Delta P_t^{ret} = \beta_0 + \beta_1 \Delta P_t^{farm} + \beta_2 ECT_{t-1} + B_3(L)\Delta P_{t-1}^{ret} + B_4(L)P_{t-1}^{farm} + \varepsilon_t \qquad (5)$$

where: $ECT_{t-1} = P_{t-1}^{ret} - \alpha_0 - \alpha_1 P_{t-1}^{farm}$ is the error correction term, and $\beta_3(L), \beta_4(L)$ are polynomial lags. Furthermore, splitting the ECT into positive and negative components (i.e. positive and negative deviations from the long-term equilibrium – ECT^+ and ECT^-) reveals whether the speed of prices´ transmission differs, depending on it increases or decreases. Furthermore, it enables testing for Asymmetric Price Transmission (APT)[20]. Then, we estimated equation (6):

$$\Delta P_t^{ret} = \beta_0 + \beta_1 \Delta P_t^{farm} + \beta_2^+ ECT_{t-1}^+ + \beta_2^- ECT_{t-1}^- + B_3(L)\Delta P_{t-1}^{ret} + B_4(L)P_{t-1}^{farm} + \varepsilon_t \quad . \qquad (6)$$

To test for asymmetry, an F-test was used to test the null hypothesis of symmetry, whether an asymmetric price response exists, $\beta_2^+ \neq \beta_2^-$.

Results and discussion

Results from the ADF and PP[14,15] unit root tests cannot negate the null of non-stationarity of price series; T-statistic values do not corroborate rejection of the null hypothesis of a unit root with 95% confidence (Table 1).

Table 1: Results of the ADF and PP test on beef price series

Price series	**ADF test**	**5% critical value**	**PP test**	**5% critical value**
International price	-2.456	-3.426	-11.886	-21.378
Farm price	-2.096	-3.426	-13.455	-21.378
Processor price	-3.489	-3.426	-22.733	-21.378
Import price	-7.396	-3.426	-86.416	-21.378

Source: own calculations.

These results enabled to use the cointegration technique to calculate the relationship between international and domestic Mexican beef prices and between a processor and farm beef prices. These results concur with previous studies concerning the non-stationarity of beef prices[21,22,23].

Long run cointegration

The estimation of equation (1), for the spatial model (equation 4), shows an R^2 of 0.78, a t-statistic of 34.78 and an F statistic of 1209.7, which indicate long-run cointegration. The ADF test on the error term shows a test statistic of -2.57 *vs* a 5 % critical value of -2.87, which indicates a failure to reject the null of non-stationarity. Different authors[21,22,23] reported similar results for beef prices. For the vertical model (equation 6), it was found an R^2 of 0.68, a t-statistic of 27.47, and an F statistic of 742.4. On the error-term, the ADF shows a test statistic of -2.696 *vs* a 5 % critical value of -2.87, indicating that cannot reject the null of non-stationarity. For the two models, it was estimated equation (2). The results showed a negative coefficient of the error term, which confirms the long run relationship between beef prices (Table 2).

Table 2: Engle-Granger two-step cointegration test

Farmer-Int. price	Coefficient	Standard error	t-value
m_{t-1}	-.148	.032	-4.53*
Dm_{t-1}	-.240	.052	-4.59*
Constant	.000	.004	0.020
F-test	30.280		
R-squared	0.1501		
Farmer-processor			
m_{t-1}	-.014	.016	-1.291
Dm_{t-1}	-.234	.053	-4.461*
Constant	.002	.002	
F-test	11.65		
R-squared	0.164		

Source; own estimation. *denote 95% significance.

Results from Johansen's test (Table 3) provided strong evidence to reject the null hypothesis of non-cointegration between domestic farmer price and international price and between farmer price and processor beef prices, suggesting the existence of a long run single cointegration relationship.

Table 3: Johansen cointegration test for price cointegration

Farmer-International price	Rank	Eigenvalue	Trace statistic	5% critical value
	0	.	30.208	15.411
	1	0.035	1.744*	3.761
	2	0.004		
Variable	**Coeff.**		**SE**	**Z**
Farmer price	1	--	--	--
International price	-.826		.083	-9.902
Constant	.528	--	--	--
Farmer-processor	**Rank**	**Eigenvalue**	**Trace statistic**	**5% critical value**
	0	.	14.182*	15.41
	1	0.035	1.537	3.761
	2	0.004		
Variable	**Coeff.**		**SE**	**Z**
Farmer price	1			
Processor Price	-0.678		0.1697	-3.998*
Constant	5.375			

Source: Own estimation. Coeff.= Coefficient; SE= standard error.
*denote 95% significance.

Studies on beef and cattle prices, applying the Johansen test, reported cointegration between domestic farm prices and international prices. Long-run cointegration between farmers and processors/retail beef prices was also reported(24).

The results suggest that their historical innovations profoundly influence prices in the international beef market. The international beef price has a consistently strong impact on Mexican price movements in the long-run. Given a unit change in the international price, farmer price of live cattle changes by 82 %, which implies a large effect, but different from unity. The remaining of the explanation given by other market fundamentals. For the case of farm-processor relationship, an increase of 1 % of the processor price, induces a 0.68 % increase in farm price. Since the above results confirmed the cointegration of international and domestic farm prices and between farmer and processor beef prices, it was estimated a symmetric and an asymmetric VECM.

Spatial vector error correction model

For the spatial model, it was estimated a VECM to investigate the possible interdependence of domestic and international beef prices considering that farm and international prices have a unit root, and are co-integrated. Results from the VECM show that both farm and international beef prices respond to disequilibria because coefficients are significant at the 5 % level. There is limited correction of price disequilibria, and coefficients are of the correct sign. In a similar study conducted in Europe(25), using the asymmetric VECM, it was found that price movement in global beef markets transmitted to domestic markets, but a lesser extent.

Table 4 shows that contemporaneous change coefficients are significantly less than one in both equations. It means that within a single month, farm prices do not react entirely to global price changes. This fact shows that monthly data is adequate for revealing the process of beef price transmission(18).

Table 4: Results of the VECM; symmetric and asymmetric spatial model

Independent variable	Symmetric spatial model				Asymmetric spatial model			
	Coef.	**Std. Err.**	**t-value**	***P*-value**	**Coef.**	**Std. Err.**	**t-value**	***P*-value**
$Pprod_{t-1}$	0.27	0.054	4.99*	0.000	0.273	0.061	4.49*	0.000
$Pprod_{t-2}$	0.017	0.056	0.31	0.768	0.017	0.056	0.31	0.768
$Pprod_{t-3}$	0.043	0.056	0.77	0.441	0.042	0.056	0.75	0.453
$Pprod_{t-4}$	0.04	0.055	0.65	0.514	0.034	0.055	0.62	0.535
$Pint_{t-1}$	-.028	0.022	-1.26	0.210	-0.059	0.024	-2.44*	0.015
$Pint_{t-2}$	-0.048	0.022	-2.14*	0.033	-0.025	0.023	-2.09*	0.037
$Pint_{t-3}$	-0.008	0.022	-0.37	0.715	-0.005	0.022	-0.23	0.820
$Pint_{t-4}$	0.022	0.019	1.17	0.243	0.023	0.018	1.27	0.215
ECT_{t-1}	-0.049	0.015	-3.26*	0.000	---	---	---	
ECT^{+}_{t-1}	---	---	---		-0.049	0.021	-2.38*	0.018
ECT^{-}_{t-1}	---	---	---		-0.059	0.029	-2.05*	0.042
Constant	0.0011	0.002	0.62	0.552	0.001	0.002	0.58	0.556
Norm. test	(Prob>z)=0.000				(Prob>z)=0.000			
LM test	(Prob>chi2)=0.291				(Prob>chi2)=0.524			
DW test	0.299				0.532			
R-squared	0.320				0.353			
$H_0 : b_1^+ = b_1^-$	---				F(1,330)= 0.822			
$H_0 : b_2^+ = b_2^-$	---				F(1,330)= 12.084			

Source: Own estimation.*denote 95% significance.

The t- statistics for ECT+ and ECT- indicate that farm prices respond strongly to negative shocks, but positive shocks in the margin are allowed to persist. The induces a significantly greater change in farm price than the ECT+. A similar result, reported in economic literature[26], showed that VECM indicated that most of the market´s disequilibrium was corrected within a month. Prices correct a small percentage of disequilibria in the markets, mostly by external forces. An F-test of the null hypothesis of symmetry ($b_2^+ = b_2^-$) leads to rejection at the 5 % level of significance (F= 12.08). This result implies that when price fall, the transmission is faster than when price rise. Price increases reach producers with a delay, with respect to a fall in international prices, which are transmitted faster. This result is consistent with the fact that international prices react more rapidly when the margin is squeezed than when it is stretched[27]. A possible explanation for the price asymmetry is the insufficient access by livestock producers to price information and infrastructure[9].

The spatial market integration of livestock and beef prices between international and

Mexican market is an issue of major importance because is deficit country, and therefore efficient trade has important food security policy implications. From the policy point of view, this should help in the design of agricultural support programs, and risk management tools for the beef industry. The finding of strong transmission effects between international and Mexican prices corroborates the view that participants in the Mexican supply chain need to consider the highly volatile nature of international prices in their decision-making process.

Vertical vector error correction model

Because cointegration exists between processor and farm beef prices, a VECM was estimated, following Cramon-Taubadel's approach (equation 5). The output of the symmetric and asymmetric VECM in Table 5 indicates that both the coefficient for ECT and the short-term parameter are significant at the 5 % level.

Table 5: Results of VECM; vertical symmetric and asymmetric model

Independent variable	**Symmetric vertical model**				**Asymmetric vertical model**			
	Coef.	**Std. Err.**	**t-value**	***P*-value**	**Coef.**	**Std. Err.**	**t-value**	***P*-value**
$Pprod_{t-1}$	0.077	0.036	2.120*	0.035	0.094	0.031	2.944*	0.004
$Pprod_{t-2}$	-0.079	0.056	-1.411	0.158	-0.075	0.056	-1.321	0.187
$Pprod_{t-3}$	0.026	0.056	0.47	0.645	0.023	0.056	0.41	0.675
$Pprod_{t-4}$	0.067	0.053	1.242	0.214	0.068	0.054	1.263	0.21
$Pint_{t-1}$	0.111	0.032	3.440*	0.001	0.104	0.033	3.090*	0.002
$Pint_{t-2}$	0.065	0.032	2.000*	0.046	0.063	0.032	1.93	0.054
$Pint_{t-3}$	0.002	0.032	0.075	0.948	0.003	0.032	0.121	0.908
$Pint_{t-4}$	-0.04	0.031	-1.28	0.202	-0.042	0.031	-1.33	0.184
ECT_{t-1}	-0.029	0.008	-3.690*	0.000	---	---	---	
ECT^{+}_{t-1}	---	---	---		-0.033	0.0118	-2.811*	0.006
ECT^{-}_{t-1}	---	---	---		-0.042	0.0117	-3.560*	0.000
Constant	0.001	0.002	0.88	0.375	0.001	0.0015	0.89	0.375
Normality test	(Prob>z)=0.000				(Prob>z)=0.000			
LM test	(Prob>chi2)=0.336				(Prob>chi2)=0.605			
DW test	0.344				0.612			
R-squared	0.341				0.391			
Test: $b_2^{+} \neq b_2^{-}$	---				F(1,330)= 14.371			

Source: Own estimation. *denote 95% significance

This result suggests that processor and farmer's prices share a relationship of long-term equilibrium. A change in farmer's prices has a significant effect on processor prices during the subsequent period. The ECT^{-} induces a significantly greater change in the processor price than ECT^{+}. These results corroborate the hypothesis that price changes are not transmitted efficiently from one level to another[28]. It also supports the hypothesis[9] that beef processors may have some market power.

The asymmetric VECM results reveal that the transmission of beef prices is asymmetrical for the speed of adjustment. The *t*- statistics for ECT^{+} and indicate that retail prices respond strongly to negative shocks, indicating that when producer prices decrease, the speed of adjustment tends to be significantly faster. Moreover, when prices increase, there are statistically significant changes in the speed of adjustment. An F-test of the null hypothesis of symmetry ($b_2^{+} = b_2^{-}$) leads to rejection at the 5 % level of significance (F= 14.37). It suggests that farm prices react more rapidly when the margin is squeezed than when it is stretched. In a study of the US beef market[29], it was pointed out a price transmission asymmetry that is much more critical for wholesale-retail than for farm-wholesale. Likewise, positive price shocks are transmitted with higher intensity than negative ones.

Focusing on adjustments of retail prices to restore equilibrium, estimates of the adjustment coefficients indicate that, within a month, retail prices adjust so as to eliminate approximately 4.2 % of a unit negative change in the deviation from the equilibrium relationship created by changes in producer prices. On the other hand, retail prices adjust by 3 % of a positive change in deviation from the equilibrium created by changes in producer prices.

Because beef and carcasses are nonstorable commodities subject to production lags with inelastic supply in the short run, producers are unable to adjust production in response to transitory price changes. By contrast, beef processor can immediately respond to changes in producer prices by adjusting their prices. Furthermore, processor, unlike feedlots, face significant fixed costs. In the short run, margins may thus be reduced in an attempt to keep a plant operating near full capacity. Therefore, as a result of competition between different processor, farm prices may be bid down more quickly than they are bid up. Given that asymmetric price transmission implies a certain degree of market power and / or market inefficiency, more research is needed to delve into the possible causes of asymmetric price transmission of livestock and beef, not only at the national level but also regional.

Conclusions and implications

This research provides for Mexico that the transmission of beef prices is asymmetric in the domestic and international markets. A long-run cointegration relationship exists between international and Mexican beef farm prices and between farm and domestic processor price. For the spatial analysis, both farm and international prices show a significant response to price disequilibria and asymmetric price transmission. Price movements in international markets are transmitted asymmetrically to the Mexican market, indicating that a decrease in international prices tends to be transmitted faster to farmers than an increase in international prices. Considering the vertical price transmission model during the following period, a change in producer prices has a significant effect on processor prices. The speed at which prices tend to converge to entirely correct for deviation is moderately slow, but when producer prices decrease, the speed of adjustment tends to be significantly faster. Asymmetric price transmission in the Mexican beef market have policy implications. The role of government intervention in the market via various price support programs may have welfare and income redistribution effects. For example, bovine livestock support programs in Mexico may be benefiting more to processors than farmers (feedlots). Findings from this research can provide valuable contributions to the policy debate, revealing a unidirectional transmission of beef prices from producers to processors, and that the transmission of beef prices is asymmetrical, depending on whether prices are increasing or decreasing.

Acknowledgments and conflict of interest

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