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Article

Vertical and spatial price transmission in the Mexican and international milk market

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Abstract:
During the last two decades, the Mexican dairy sector experienced important structural changes, especially after the implementation of the NAFTA agreement. In 2016, the Bank of Mexico observed that in milk market, the final prices tend to rise when input prices increase, however; they do not decrease when input prices decrease. In this context, this study examines the degree of spatial and vertical price transmission between farm milk prices and international milk prices as well as between farm milk prices and retail milk prices, in order to assess the efficiency level of the Mexican and international dairy market. The findings of this research provide contributions to decision makers and industry stake-holders: a unidirectional transmission of international milk prices to domestic milk prices and from farm price to retail price along with the existence of asymmetric price transmission which depends on whether milk prices are increasing or decreasing. The results have shown that a long-run single co-integration relationship exists between international and farmer's prices and between retail and farm price; that the direction of price transmission tends to go from producers to retailers and from international to farmer price and that when international price increase the speed of adjustment tend to be significantly slower, and that when international

price decrease, the speed of adjustment tend to be significantly faster.

Key words: Asymmetric price transmission, Milk prices, Vector error correction model.

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Introduction

In the last two decades, the dairy sub-sector in Mexico had undergone a significant change. The dairy industry experienced domestic price liberalization; the distribution of milk production among 32 states in México, measured by the Gini index, shows an increase in concentration, from a value of 0.55 in 1990 to 0.63 in 2016. In 1990, six states concentrated 58.71 % of total milk production; in 2008, they contributed with 61.7 %, and in 2016, with 63.5 % (own estimation using data from SIAP-SAGARPA[1].

The Bank of Mexico[2] observed that in the Mexican milk market, price to consumers tend to rise when input prices increase; however, they do not decrease when input prices decrease. The concern about the competitiveness of the Mexican dairy market involve several issues; (i) there is a high degree of concentration in the processing stage of milk (a few processing firms) which contrasts with the low concentration in the dairy farmers sector (A large number of farms); (ii) dairy farmers have expressed concerns about the competitiveness of the dairy supply chain, due to the entrance to Mexico of imported milk, at prices below US consumer paid for and even below international prices.

The importance of the analysis of price transmission rests on the role of prices as instruments, by which, different levels of the supply chain are linked. Thus, ensuring adequate price signals at the farm gate is fundamental to agricultural productivity[3]. A better understanding of the extent to which retailers' and wholesalers' prices are efficiently transmitted down to producers at the farm gate level is an important issue for the design of policy, that seek not only to reduce the possible causes of market failure to improve competitiveness, but also to increase farm net income.

In economic terms, the Mexican agricultural sector accounts for 3.1 % of the total national GDP and contributes with 14.4 % of the employment in the agricultural sector. Cattle production is one of the most important activities of the agricultural sector in Mexico. It accounts for 28.18 % of the total agricultural GDP and 30 % of employment in the agricultural sector. The cattle inventory in Mexico has grown at an average rate of 2.04 in the last 20 yr, while milk production has an average growth rate of 2.56 % in the same period (own estimation with data from SIAP-SAGARPA[1]. Over the last decade, México observed a 6 % increase in the size of its herd, passing from 30.3 million heads in 1996 to 32.2 million in 2016. However, the increase in milk herd was remarkable because it raised 52 % from 1.67 to 2.58 million heads (own estimation with data from SIAP-SAGARPA[1].

The number of cattle farms in Mexico fell from 1,129,217 in 2007 to 499,250 in 2016[4,5] with an inventory of 32.2 million heads. There are three main cattle production systems in México: one specialized in milk, a second specialized in beef, and a third that consists of a dual-purpose system producing both milk and beef. The largest part of the cattle production system in Mexico is concentrated in the north of the country and along the Gulf of Mexico.
Milk production is an economic activity of social and economic importance in Mexico. This is evidenced by the financial, natural and human resources involved in the production-consumption supply chain of fluid milk and dairy products, as well as by the income and employment generated by this activity; in Mexico, there are 197 million hectares, of which, livestock in its different modalities occupies 58 %[6]; the national population of dairy cattle amounted to 2.5 million heads, producing a total of 11.8 million liters of fluid milk in 2016[1]; in value, the milk industry amounts to 106 billion dollars; primary milk production contributed with 46.4 % to milk industry, preparation of milk powder with 22 % and production of dairy products with 31.6 %[7].

Six large firms dominate Mexican dairy market (Production, distribution, and processing). These companies, in 2016, traded 60 % of total milk in the country; Liconsa, a state-owned enterprise, contributes with 10.3 %, Grupo LaLa with 21.4 %, Alpura with 10.2 %, Nestle with 7.70 %, Grupo Sigma alimentos with 6.20 % and Grupo Lactalis with 4.10 %[8].

Historically, México has been a net importer of milk, however, since 1992, the production deficit began to grow significantly. This fact is explained mainly by the effects of pricing policies on production, which until 1997, were not linked to production costs, because it discouraged investments in technology and genetic material to improve productivity[9]. With the adhesion of Mexico to NAFTA, Mexico's dairy industry entered into competition, in prices and quality, with milk industries of United States and Canada. The Annual Average Growth Rate (AAGR) of the national milk production for the period of 1990-2016 was 2.5 % while AAGR of consumption was 2.8 %. The gap between national production and consumption is expected to become wider, and, as a consequence, US milk would play a major role within the Mexican milk market.

Several authors agree that commercial liberalization of the dairy sector in 1993, the end of the domestic protected market policy and change to a market defined by demand-supply balance, determined a negative impact on the commercial viability of small to medium dairy farms and also affected negatively production of milk, mainly among small to medium farms[4,10]. An explanation of the fall of milk production in Mexico is that domestic milk prices were determined by the international price and for internal asymmetries in the Mexican industry, which mean an unbalanced development among types of milk cattle farms, and also an unequitable governmental support among dairy milk farmers.

Domestic and international milk prices behavior, in 1995, a year after Mexico entered NAFTA, the producer price follows the international price, and to a lesser extent, the consumer price. The consumer-producer price relationship (Pc/Pp) showed a growing trend, which could imply an asymmetric transmission of prices between different levels of the market.

Transmission of market shocks, through stages of the supply chain or through horizontally related markets, is a topic with long tradition in economics. Vertical price transmission analysis can be used to assess how efficiently different actors are integrated in a market. The extent and speed with which price changes are transmitted from one level to the other in the market have important policy implications; for welfare distribution, competitiveness, and sustainability. In a competitive market, price shocks at one level of the market chain should be reflected by similar changes at the other levels, as market efficiency suggests a price equilibrium relationship between them[11].

Over the past two decades, extensive studies have been developed to examine market linkages among farm, wholesale, and retail markets[12-15]. The main focus of these studies is oriented to assess the nature, extent of adjustment, and speed with which shocks transmit along the different market levels. In these studies, the rate of price response is generally measured through the lag relationship between upstream and downstream price, while the asymmetry of price response is measured as the relative response of downstream prices as upstream prices rise or fall[15].

The factors that constrain the complete and symmetric transmission of agricultural commodity prices from one market level to another are classified into: 1) Market power concentration at levels beyond the farm gate; 2) Different adjustment costs when firms change the quantities and/or price of inputs and/or outputs; 3) Government intervention in the pricing of agricultural products; 4) Imperfect information; 5) Different price elasticity at different levels of the market chain; 6) The presence of rapidly perishable goods[12,14,16].

Spatial price transmission refers to the process based through which markets for a homogeneous commodity, at spatially separated locations, share long-run information[17]. Spatial price transmission has been widely analyzed in the context of the "Law of One Price," which hypothesizes that if two markets are linked by trade and they are efficient, the price differential between them is equal to transaction costs[17]. Prices are consequently thought of as being connected by a stable long-run equilibrium, with attraction forces of this equilibrium, which result in the correction of temporal deviations that occur due to supply or demand shocks. Therefore, a proportional increase in the international price of an agricultural commodity will lead to an equally proportional increase of its price in domestic markets, at all points in time, assuming markets are integrated[18]. In this context, Price transmission analysis measures the extent and speed to which price shocks are transmitted between spatially separated locations[19].

On the other hand, price asymmetry refers to the process in which transmission differs according to whether the prices are increasing or decreasing[16]. The literature on spatial price transmission dealt with various factors that constrain the transmission of prices from one market to another. It identifies three groups: transaction costs, trade policies, and market power[20].

The objective was to estimate the degree of price transmission between Mexican milk retail price and farm milk price (vertical transmission) and between Mexican farm milk price and the international one (spatial price transmission) to shed light on the possible asymmetric price transmission and the related consequences for market inefficiency.

Material and methods

An econometric analysis was carried out using monthly time series of milk prices from 1990:01 to 2016:12. The Mexican data was downloaded from the website of official statistics from the Agro-Food and Fisheries Information Service[1] of the Ministry of Agriculture, Livestock, Fisheries and Food Service (SAGARPA), The Bank of Mexico (BM), and LACTODATA. The international milk Price was obtained from USDA-AMS[21]. Milk prices are monthly spot price. The data was transformed into natural logarithms because the coefficients (βs) of the econometric model are understood as transmission elasticities.

Verification of the integration order of each series, using the Augmented Dickey-Fuller and Phillips-Perron (PP) tests were performed[22,23]. It was followed by estimation of ~~l~~ong-run relationship, using the Engle-Granger two-step cointegration and the Johansen tests[24]. Finally, Asymmetric Vector Error Correction Model (AVECM) was performed; a test to select the lag order for a AVECM and a F-test on the coefficient of ECT^+ and ECT^- (positive and negative changes in the error term respectively) to test the null hypothesis of symmetry: $H_o : \beta_2^+ = \beta_2^-$.

Test for cointegration; long-run relationship

The cointegration between variables -once the unit root existence has been proved- is a necessary condition for the existence of a long-term equilibrium relationship in the series. A variable vector with unit root is cointegrated if a linear combination of these variables is stationary[25].

To test for long-run relationship, both, the Engle-Granger two-step cointegration test[25] and the Johansen test[24] were used. The first approach consists of estimating the cointegration regression, equation (1), by OLS, obtaining the residual $\hat{u}_t$ and applying a unit root test for $\hat{u}_t$. Again, ADF and PP test were used. Since the coefficient of U_{t-1} is less than unity, a cointegration relationship exists.

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

Where, p_t^{out} is a firm output price in period t, p_t^{in} is the input price in t.

The Johansen test derived the distribution of two test statistics for the null of no cointegration; the Trace and Eigen value tests[24]. 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} returns to equilibrium after a change in p_t^{in}. Two econometric models were estimated; Spatial asymmetric model and Vertical Asymmetric model.

Spatial Asymmetric Price Transmission

Taking into account that farm and international prices have a unit root and were cointegrated, an Asymmetric Vector Error Correction Model is estimated (AVECM) in order to investigate possible interdependence of prices. Following the approach of Cramon-Taubadel and Loy[26], the ECM for spatial price transmission, takes the following form:

$$\Delta p_t^{farm} = \alpha + \beta_1 \Delta p_t^{\text{int}} + \beta_2 ECT_{t-1} + \beta_3(L)\Delta p_{t-1}^{farm} + \beta_4(L)\Delta p_{t-1}^{\text{int}} \qquad (2)$$

Cramon-Taubadel and Fahlbusch also segment the contemporaneous response term[27]. This leads to Equation (3), in which contemporaneous and short run response to departures from the cointegrating relation are asymmetric if $\beta_1^+ \neq \beta_1^-$ and $\beta_2^+ \neq \beta_2^-$ respectively.

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

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

Vertical Asymmetric Price Transmission

Economic model to analyze vertical price transmission use variations of a model introduced by Wolffram in 1971[28]. This model was criticized for being unreliable, since most of the evidence presented to support the assumption that commodity prices were cointegrated was affected by spurious regressions or non-stationary series[29]. In order to deal with these econometric shortcomings, Engle and Granger proposed an alternative approach based on cointegration theory, which indicates that two non-stationary time series could be long-term cointegrated if both series are integrated of the same order[25].

An initial attempt to use cointegration techniques in testing for asymmetric price transmission was applied by Cramon-Taubadel[30]. He used the two-step method approach, based on Engel and Granger, to test for Asymmetric Price Transmission (APT) in the presence of non-stationary series, using an Asymmetric Error Correction Model (AECM).

In this approach, the authors proposed splitting the error correction term into positive and negative components in order to identify if prices are transmitted differently depending on whether they increase or decrease. Following the approach proposed by Cramon-Taubadel[30] to test for vertical asymmetric price transmission, we estimated equation (4).

$$\Delta P_t^{ret} = \beta_0 + \beta_1 \Delta P_t^{farm} + \beta_2 ECT_{t-1} + B_3(L)\Delta P_{t-1}^{ret} + B_4(L)P_{t-1}^{farm} + \varepsilon_t \qquad (4)$$

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 polinomial lags. Furthermore, splitting the ECT into positive and negative components (i.e. positive and negative deviations from the long-term equilibrium – ECT^+ and ECT^-) allows one to identify if the speed at which prices are transmitted differs depending on whether prices are increasing or decreasing. Furthermore, it makes possible to test for Asymmetric Price Transmission (APT)[31]. Then, we estimated equation (5):

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

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

Results and discussion

According to the results of the ADF and PP unit root tests, they cannot reject the null of non-stationarity of price series; T-statistic values do not allow to reject the null hypothesis of a unit root with a 95% confidence interval (Table 1). This result upheld the use of the cointegration technique to calculate the relationship between the international and domestic Mexican milk prices. The above result is in line with previous studies on non-stationarity of milk prices[32].

Table 1: Results of the ADF and PP test on domestic and international milk price series

Price series	ADF test	5% critical value	PP test	5% critical value
International price	-1.864	-3.427	-13.992	-21.358
Retail Price	-1.632	-3.427	-11.84	-21.358
Farm Price	-3.149	-3.427	-18.69	-21.358

Cointegration of spatial model

The estimation of equation (1), show a R^2 of 0.59, a t-statistic of 21.84 and a F statistic of 476.94, which indicated a long run cointegration. The ADF test on the error term shows a test statistic of -2.575 *vs* a 5% critical values of -2.877, which indicates failure of rejection of the null of non-stationarity, then, the following regression was performed:

$$D\eta_t = a + b_1\eta_{t-1} + b_2 D\eta_{t-1} \qquad (6)$$

A negative coefficient of the error term (between -2 and zero) confirmed a long run relationship between milk farm price and international milk price (Table 2). The results of the Johansen's test (Table 3) indicated a strong evidence to reject the null hypothesis of non-cointegration between prices, suggesting the existence of a long run single cointegration relationship. Previous studies on milk prices reported cointegration between domestic farm price and imported milk price(32). Results suggest that price in the international milk market is highly influenced by their own historical innovations, while international milk price has a consistently strong impact on price movements in Mexican milk prices in the long- run. Since the above results confirmed cointegration of international and domestic farm milk price, a VECM was estimated(32,33).

Cramon-Taubadel & Fahlbusch suggested that in the case of cointegration between non-stationary series, an error correction model (ECM), extended by the incorporation of asymmetric adjustment terms, provides appropriate specification for testing APT[33].

An ECM, that relates changes in P_t^{int} to changes in P_t^{farm} for the case of spatial model, as well as the so-called error correction term (ECT), the lagged residuals from the cointegrating equation were estimated. The ECT measures deviations from the long run equilibrium; so, including it in the ECM allows the dependent variable not only to respond to changes in independent variable, but also to 'correct' any deviations from the long run equilibrium that may be left over from previous periods[28,34,35].

Table 2: Engle-Granger two step cointegration test

Variable	**Coefficient**	**Std. Err.**	**t-value**
η_{t-1}	-0.1016	0.0186	-5.450
$\Delta\eta_{t-1}$	0.4585	0.0492	9.32
Constant	0.0002	0.0023	0.09
F-test	50.8		
R-squared	0.3416		

Table 3: Results of the Johansen test for price cointegration

P^{farm} - P^{int}	Maximun rank	eigenvalue	Trace statistic	5% critical value
	0	.	33.9609	15.41
	1	0.09116	3.1814*	3.76
	2	0.00983		
Cointegrating Equation	Coefficient	Std. Err.	*P*-value	
LnP^{farm}	1			
LnP^{int}	-0.398	0.0488	-8.14	
Constant	0.741			

Spatial Vector Error Correction Model

or the spatial model, taking into account that farm and international prices have a unit root and were cointegrated, there was estimated an Asymmetric Vector Error Correction Model (AVECM) in order to investigate possible interdependence of domestic and international milk prices. Following the approach of Cramon-Taubadel and Loy(26), the ECM for spatial price transmission was estimated as in equation (2). The Cramon-Taubadel and Loy approach is the most frequent model to analyze asymmetric price transmission based on an econometric specification that is shown to be inconsistent with cointegration(28).

Cramon-Taubadel and Fahlbusch(27), also segmented the contemporaneous response term. Then, we estimated equation (3), in which contemporaneous and short run response to departures from the cointegrating relation are asymmetric if $b_1^{+}\ 1\ b_1^{-}$ and $b_2^{+}\ 1\ b_2^{-}$ respectively. An F-test was used to test the null hypothesis of symmetry.

The results of the AECM show that both farm and international milk price respond to disequilibria because coefficients are significant at the 5% level. The correction of price disequilibria is of a small magnitude and coefficients are of the correct sign. In similar studies, using the AECM, several authors found that price swings in global markets are transmitted to domestic markets, but with lower magnitude(35).

Table 4 shows that contemporaneous change coefficients are significantly less than one in both equations. This means that farm prices do not react completely within one month to international price changes and that monthly data is frequent enough to expose the process of price transmission[26].

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

Independent	Symmetric Spatial Model			Asymmetric Spatial Model		
Variable	**Coef.**	**Std. Err.**	**t**	**Coef.**	**Std. Err.**	**t**
$P\text{int}$	0.1173	0.0396	2.96	---	---	---
$P\text{int}_t^-$	---	---	---	0.3219	0.1159	2.78
$P\text{int}_t^+$	---	---	---	0.3237	0.1217	2.66
$Pfarm_{t-1}$	0.5337	0.0555	9.61	0.5186	0.0629	8.24
$Pfarm_{t-2}$	0.0362	0.0621	0.58	-0.1743	0.0631	-2.76
$Pfarm_{t-3}$	-0.1796	0.0629	-2.85	0.0386	0.0502	0.77
$Pfarm_{t-4}$	-0.0106	0.0554	-0.19	0.0246	0.0424	0.58
$P\text{int}_{t-1}$	0.0389	0.0426	0.91	0.0329	0.0622	0.53
$P\text{int}_{t-2}$	-0.0612	0.0421	-1.45	-0.0153	0.0555	-0.28
$P\text{int}_{t-3}$	0.0253	0.0423	0.60	-0.0589	0.0423	-1.39
$P\text{int}_{t-4}$	0.0796	0.0411	1.94	0.0789	0.0412	1.92
ECT_{t-1}	-0.1680	0.0205	-8.19	---	---	---
ECT_{t-1}^+	---	---	---	-0.0694	0.0262	-2.65
ECT_{t-1}^-	---	---	---	-0.1977	0.0329	-2.97
Constant	0.0003	0.0020	0.13	0.0002	0.0021	0.10
Normality test (Prob>z)	0.903			0.808		
LM test (Prob>chi2)	0.5758			0.3989		
DW test	1.97			1.98		
R-squared	0.4352			0.4378		
Test: $H_0 : b_1^+ = b_1^-$	---			F(1,306) = 0.85		
Test: $H_0 : b_2^+ = b_2^-$	---			F(1, 307) = 10.03		

Source: Own estimation

The ECT^- induces a significantly greater change in the farm price than the ECT^+. Similar results were reported by several studies for spatial price transmission of international milk prices to domestic milk prices[35,36,37].

An F-test of the null hypothesis of symmetry ($b_2^+ = b_2^-$) leads to rejection at the 5% percent level of significance (F = 10.03). Since ECT^- indicates that farm milk price is low with respect to the international price, this suggests that milk farm prices react more rapidly when the margin is squeezed than when it is stretched. Therefore, the analysis provides robust statistical evidence for asymmetry in price responses[35].

From the policy point of view, this should help in the design of agricultural support programs, as well as risk management tools for the dairy industry. The finding of strong transmission effects between international and Mexican prices supports the view that trade liberalization in Mexico in the 1990s resulted in greater market orientation. It also shows that participants along the Mexican supply chain need to consider the highly volatile nature of international milk prices in their decision-making process.

Long-run cointegration in the vertical model

In the following, P_t^{farm} is a milk farmer's price in period t and P_t^{ret} is the milk retail price. Hypothesis is that retail price is caused by farm price. Assuming symmetric and linear price transmission, it was estimated equation (1).

The results from the cointegrating regression show a R^2 of 0.435, a t-statistic on milk farm price of 15.75, and a F statistic of 247.92. The ADF test on error term shows a test statistic of -2.696 *vs* a 5% critical value of -2.877, which indicates that we cannot reject the null of non-stationarity. Then, it was estimated equation (6). The results show a negative coefficient of the error term, which confirm the long run relationship between prices (cointegration) (Table 5).

Table 5: Results of the Engle-Granger two step cointegration test

Variable	Coefficient	Std. Err.	t-value
η_{t-1}	-0.0523	0.0134	-3.890
$D\eta_{t-1}$	0.3975	0.0510	7.79
Constant	0.0007	0.0031	0.21
F-test	35.35		
R-squared	0.2814		

Source: Own estimation.

Using Johansen test[24], the null of cointegration cannot be rejected. Because it found that there exists one cointegration relationship between price series (Table 6).

Table 6: Johansen test (1991) for cointegration of P^{ret} and P^{farm}

P^{retail}- P^{farm}	Maximun rank	eigenvalue	Trace statistic	5% critical value
	0	.	46.0998	15.41
	1	0.1016	3.3528*	3.76
	2	0.01343		
Cointegrating equation	Coefficient	Std. Err.	z	
LnP^{ret}	1			
LnP^{farm}	-2.175	0.2878	-7.56	
Constant	-2.292			

Source: Own estimation.

Vertical Vector Error Correction Model

Since cointegration of retail and farm milk prices exist, and following the approach proposed by Cramon-Taubadel(31), it was estimated a VECM (Equation 4). Splitting the ECT into positive and negative components (i.e. positive and negative deviations from the long-term equilibrium – ECT^+ and ECT^-) makes it possible to test for Asymmetric Price Transmission (APT)(36). Then, was estimated equation (5). To test for asymmetry, if b_2^{+} 1 b_2^{-} asymmetric price response is present, an F-test was used to test the null hypothesis of symmetry.

The output of the symmetric VECM in Table 7, indicates that both, the coefficient of the ECT and the short-term parameter are significant at the 5% level. This result suggests that retail's and producer's prices share a long-term equilibrium relationship, and that a change in farmer's prices does have a significant effect on retailer's prices in the next period. The ECT^- induces a significantly greater change in the retail price than ECT^+. The results support the assumption that price changes are not transmitted efficiently from one level to another(38,39). It also supports the view that Mexican retailers and wholesalers of milk have more market power than milk farmers.

Table 7: Results of the VECM; symmetric and asymmetric vertical model

Independent variable	Symmetric Model Coef.	Std. Err.	t	Asymmetric Model Coef.	Std. Err.	t
$Pfarm_t$	0.327	0.0533	6.13	0.358	0.0536	6.67
$Pret_{t-1}$	0.1273	0.0565	2.25	0.1068	0.0661	1.62
$Pret_{t-2}$	0.0557	0.0570	0.98	0.0575	0.0571	1.01
$Pret_{t-3}$	0.0058	0.0569	0.10	0.0037	0.0570	0.07
$Pret_{t-4}$	-0.0848	0.0571	-1.49	-0.0808	0.0576	-1.40
$Pfarm_{t-1}$	-0.0593	0.0610	-0.97	-0.0457	0.0652	-0.70
$Pfarm_{t-2}$	0.0919	0.0601	1.53	-0.0457	0.0604	1.57
$Pfarm_{t-3}$	-0.1000	0.0615	-1.62	-0.1003	0.0616	-1.63
$Pfarm_{t-4}$	0.0335	0.0531	0.63	0.0340	0.0532	0.64
ECT_{t-1}	-0.1958	0.0938	-2.09	---	---	---

ECT_{t-1}^{+}	---	---	---	-0.0519	0.0219	-2.37
ECT_{t-1}^{-}	---	---	---	-0.2026	0.0546	-3.71
Constant	0.0018	0.0020	0.89	0.0117	0.0020	0.83
Normality test (Prob>z)	0.922			0.882		
LM test (Prob>chi2)	0.5904			0.5878		
Durbin-Watson (DW)	2.0163			2.0171		
R-squared	0.515			0.526		
Test $H_o:\beta_2^{+}=\beta_2^{-}$	---			F(1,307) =10.36		

Source: Own estimation.

This output reveals that the transmission of milk prices is asymmetric with respect to the speed of adjustment, indicating that when producers' prices decrease, the speed of adjustment tends to be significantly faster, and 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 = 10.36). This suggests that farm prices react more rapidly when the margin is squeezed than when it is stretched. The analysis therefore provides robust statistical evidence for asymmetry in price responses(31). Previous studies(11,40) found, for the US and the Spanish dairy markets, asymmetric price changes between producer and retail stages of the marketing chain.

These results suggesting the presence of asymmetric price transmission in the Mexican milk market has important policy implications. First, the role of government intervention in the market via various price support programs could have notable welfare and income redistribution effects. Policy makers have to be very careful in balancing the potential impact of income support programs on producers and its implications for consumer prices in a market where asymmetric price transmission prevails. Also, the existence of imperfect price transmission may also be a warning to policy makers that efforts to further reform and liberalize agricultural markets may not be as beneficial to consumers as expected. Given the limitations of existing models that are primarily price-based, future research that better quantify the impacts of asymmetric price adjustments on producers and consumers are still needed(41).

Conclusions and implications

Long-run cointegration relationship exists between international and Mexican farm milk prices and between farm and domestic retail milk price. For the spatial analysis, both, farm and international prices show significant responses to price disequilibria and asymmetric price transmission. Price movements in international markets are being transmitted asymmetrically to Mexican milk market, indicating that a decrease in international milk prices tend to be transmitted faster to farmers than an increase in international milk prices. For the vertical price transmission model, a change in the producer's prices do have a significant effect on retailer's prices in the next period; the speed at which prices tend to converge to fully correct for deviation is moderately slow; and when producers' prices decrease the speed of adjustment tends to be significantly faster. In this regard, policy makers trying to design mechanisms other than traditional technology transfer approaches to increase small dairy producers' competitiveness, should pay close attention to measures aimed at increasing the level of price transmission from wholesalers to producers in the marketing chain. The findings of this research provide for the first time important contributions to the policy debate uncovering a couple of issues; a unidirectional transmission of milk prices from producers to retailers, and that the transmission of milk prices is asymmetric depending on whether prices are increasing or decreasing.

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