Combining market structure and econometric methods for price transmission analysis

Alejandro Acosta*
Animal Production and Health Division, Food and Agriculture Organization of the United Nations, Rome, Italy

Rico Ihle
Department of Economics, Wageningen, Wageningen University, Wageningen, The Netherlands

Stephan von Cramon-Taubadel
Department of Agricultural Economics and Rural Development, University of Göttingen, Göttingen, Germany

*Corresponding author

Abstract

Much attention has been devoted in the literature to the analysis of price transmission along food supply chains. Price transmission analysis has traditionally focused on applying econometric methods to assess price dynamics and interrelationships. However, the exclusive application of econometric methods without considering the market's institutional context has limited potential to support evidence-based policy-making. In recent years, studies have thus attempted to combine the use of quantitative and qualitative methods to better understand the level of performance of food value chains. This study contributes to broadening these empirical toolkits by suggesting a structured analytical framework that benefits from the simultaneous application of econometric and market-structure methods in price transmission analysis. To illustrate the application of the framework, we analyze the milk market of Panama.

Keywords: Price Transmission; Market Structure; Food Price Formation; Food Policy Design.

JEL code: Q13, C59, D40

1. Introduction

The structure, performance and degree of price transmission (PT) in agrifood value chains has important welfare effects on consumers and producers (Sexton and Lavoie 2001; McCorriston 2013). Recent research (Dawe and Maltsoglou 2014; Luckmann et al. 2015; Usman and Haile 2017) highlights the relevance of understanding the dynamics of food prices for analyzing the effects of policy measures on food security. In particular the magnitude, speed, and symmetry with which price changes in one market are transmitted to another can have direct and indirect effects on all four dimensions of food security in both the short and the long term (FAO, 2012).

In the short-term, direct effects of this transmission on prices and the resulting incentives for supply and demand can affect food availability, access, price stability, and shift food use preferences. In the long term, domestic factors of production such as land, labour and capital can move towards new equilibria due to factor price adjustment, causing indirect dynamic effects on land use, production structures, dietary patterns, employment, and income (FAO, 2012). These issues have focused attention on PT analysis not only from researchers but also policy makers (OECD, 2015).

Since the early 1990s most PT analyses have used different specifications of the (vector) error-correction model (VECM/ECM) introduced by Granger (1981) and Engel and Granger (1987). In these models, the relationship between price series are influence by the magnitude of deviations from their long-run equilibrium relationship (Enders, 1998). In recent years, more flexible non-linear models have been suggested by several authors (e.g., by Serra and Goodwin 2002; Hassouneh et al. 2010; Busse et al. 2012; Würriehausen et al. 2015). Comprehensive reviews of PT analytical methods are provided, for example, by Fackler and Goodwin (2001), Meyer and von Cramon-Taubadel (2004), Frey and Manera (2007), Bakucs et al. (2014), von Cramon-Taubadel (2017), and Lloyd (2017).

Although the variability and flexibility of the modeling toolset has greatly evolved, less attention has been devoted to improving the integration of insights and the understanding of market structure into PT analyses. In their review of the empirical literature addressing vertical and spatial PT, Goodwin and Vavra (2009) emphasize that the evaluations of price transmission are

not likely to be very informative without a wider understanding of the market structure and institutions underlying the price data. Miller and Hayenga (2001) note that insights from econometric methods are often limited because plausible explanations of price behavior cannot be discovered based on price data alone. Lloyd (2017) stresses that while PT parameters are valuable descriptive determinants of price adjustments, one should be wary of inferring too much about the competitive setting of the market analyzed based on these parameters alone.

Acknowledgment of these issues has stimulated various authors (Kim and Cotterill 2008; Brümmer et al. 2009; Ihle et al. 2012; Fabinger and Weyl 2013; Hovhannisyan and Bozic 2014) to incorporate information about market structure into PT analyses. This study aims to advance this literature by examining how to combine market structure and time-series methods systematically in PT analysis. The analytical framework is composed of three steps: 1) Step 1 uses market-structure analysis to obtain detailed insight into the organization of the market of interest. 2) Step 2 employs time-series econometric methods to evaluate the price dynamics between actors along the supply chain. 3) Step 3 triangulates the results obtained from both analyses to increase the understanding of the factors that influence price transmission.

The presented framework provides a constructive approach for complementing quantitative price analysis with information on the institutional structure of the market of interest. Thus, with this paper, we contribute to a growing literature that includes, for example, Davenport and Funk (2015) and König et al. (2017), and that combines quantitative and qualitative methods to assess the performance of food value chains. To illustrate the application of this framework, we analyze the milk market in Panama.

2. Market Structure as a Key Ingredient of Price Transmission Analysis

Many studies emphasize the central role that market structure plays in analyzing the degree of PT in food markets (McCorriston et al. 1998; Peltzman 2000; Carlton and Perloff 2004; Armstrong and Porter 2007; Bakucs et al. 2014; Lloyd 2017). Some publications highlight that it is imperative to understand the institutional setting in which PT takes place, if findings from PT analyses are to be interpreted and understood appropriately (e.g., Goodwin and Vavra 2009). Market-structure analyses have extensively applied the use of structure-conduct-performance (SCP) approaches

to analyze causal relationships that run between industry concentration, the pricing behavior of firms, and profitability (Sutton 1991). Many economists criticize the SCP approach for being descriptive rather than analytic, arguing that market-structure studies should employ price-theory models of the new empirical indusrial organisation (NEIO) literature based on the explicit, maximizing behavior of firms (Carlton and Perloff 2004).

One of the first studies to use NEIO methods in PT analysis is Gardner (1975), who analyzes the farm-retail price spread in the food industry. Based on a structural model of demand and supply for two inputs and one output under perfect competition, the author derives several elasticities to investigate how PT changes when food demand, farm product supply, or marketing input supply shifts occur. His analysis shows that the PT elasticity depends on whether the exogenous shock that generates the change in the market comes from the demand or the supply side. McCorriston et al. (1998) and Weldegebriel (2004) build on this model but account as well for market power in the food chain.

Bulow and Pfleiderer (1983) show that PT is affected not only by elasticities of demand and supply but also by the shape of the demand and supply curves. However, Fabinger and Weyl (2013) demonstrate that while PT is determined by the elasticity of supply and demand and the curvature of the demand curve under imperfect competition, under constant returns to scale, only the curvature of demand plays a role. Kim and Cotterill (2008) point out that in differentiated product markets the curvature of the demand curve depends on the empirical distribution of consumer characteristics. Hovhannisyan and Bozic (2014) show that prices may respond only partially to shocks when demand becomes increasingly more elastic at higher price levels.

Recent studies have highlighted the interaction between vertical and horizontal structures in determining PT. Bonnet and Requillart (2013) assess the PT of a cost change considering horizontal and vertical interactions between manufacturers and retailers. Hong and Li (2017) develop a model to assess simultaneous interaction between horizontal and vertical market structure and the resulting effects on PT from commodity to wholesale prices and from wholesale to retail prices. Their results highlight the ambiguous effects derived from these interactions, showing that greater vertical integration raises PT but simultaneous increases in market share lower it. In summary, there is increasing recognition in the literature that market structure has

manifold implications for the nature of price transmission, and that a particular type of observed PT behavior can result from different underlying market structures.

3. Methodology

We propose an analytical framework composed of three steps, each of which has several tasks (Figure 1). Step 1 consists of analyzing the structure of the market of interest to obtain detailed insights into its organization. The first task of Step 1 (1.1) is to develop propositions to guide the data collection process, inform the design of the econometric model, and allow the study to link the empirical results with theory. The second task (1.2) is to map the supply chain to assess the structure of the market and to identify the interlinkages between firms and the flow of products. The third task (1.3) is to define the specific actors of interest; for example, in our empirical application below we focus on interactions between small producers and wholesalers. The fourth task (1.4) is to collect evidence using various qualitative sources of information including documentation, newspaper articles, semi-structured interviews, and focus group discussions, as in Yin (2013).

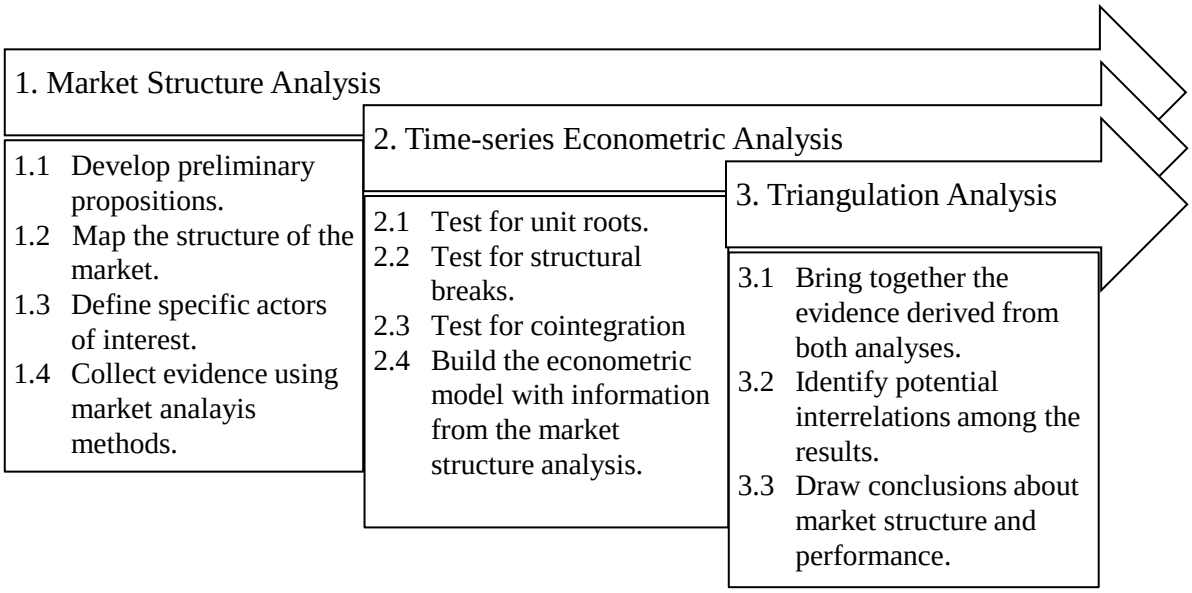

Figure 1. PT analytical framework.

In Step 2, time-series econometric methods are used to analyze the price dynamics among the actors of interest. The first task of Step 2 (2.1) is to determine whether the series are stationary or nonstationary and, therefore, to test for unit roots. A standard Augmented Dickey Fuller (ADF)

test can be used to test for unit roots, while also considering the potential presence of structural breaks in the series (Perron 1989; Saikkonen and Lütkepohl 2002; Wang and Tomek 2007). The second task (2.2) is to test for structural stability, as a fundamental assumption of most PT models is that the parameters remain constant throughout the sample period. If both series are integrated of order one, the third task (2.3) is to test for cointegration, for example using the methods proposed by Johansen (1991). If no evidence against cointegration is found, the fourth task (2.4) is to build the time-series econometric model to assess the price dynamics between the series, ideally ensuring that crucial characteristics of the market are reflected.

Finally, in Step 3, the different sources of information are combined to improve our understanding of the factors that influence PT. The first task (3.1) of Step 3 is to bring together the evidence derived from both analyses. The second task (3.2) is to identify potential interrelations among the results of the market structure and econometric analysis. The third task (3.3) is to link the evidence of both analyses with the propositions formulated in Step 1 and draw conclusions about the market structure and performance. We follow Yin (2013) in triangulating the results of these steps.

4. Application to the Case Study

To illustrate the application of the framework, we analyze the milk market in Panama. In Panama, newspaper articles that started appearing in 2006 highlighted the lack of transparency in dairy market and suggested that processors were colluding on the farm-gate prices paid to milk producers. This motivated the national antitrust authority to launch an investigation against a group of industrial processors over the alleged abuse of market power. The investigation found that four major milk processors had shared information that ultimately led them to collude on setting the purchase price of milk paid to producers.

The market-structure analysis was conducted using various sources of information, including a competitiveness analysis of the dairy sector, value chain studies, official government reports, and two major national newspapers (*La Prensa* and *Panamá América*). We carried out semi-structured interviews with key public and private actors active in the dairy chain, including two retailers, three industrial milk processors, five traditional milk processors, and ten milk

producers. Two focus group discussions were organized with key stakeholders involved in the milk supply chain, including the Panamanian Livestock Dairy Institute, and the Livestock National Producers Association.

The time-series analysis was conducted using 252 monthly observations of fresh whole milk prices at the producer and wholesale levels between January 1991 and December 2013. These data were provided by the Agricultural Information System of the Contraloría General de la República de Panamá (CGRP). In this application, the assessment of the effects of changes in market structure on the price relationship between producers and wholesalers is of interest. Thus, following Esposti and Listorti (2013), and based on the results of the qualitative analysis described above, we specify a VECM in which a structural change dummy variable influences the constant term of the cointegration relationship. The VECM is specified according to equation (1).

$$\Delta p_t = \alpha\left[\beta p_{t-1} + \mu + \delta D_{ct-1}\right] + \sum_{i=1}^{n} \Gamma_i \Delta p_{t-i} + \varepsilon_t \qquad (1)$$

The variable p is a vector containing the producer and wholesaler prices in logarithms, α is the loading matrix that reflects the speeds at which the prices adjust to correct deviations from long-run equilibrium. The parameter β represents the cointegrating vector quantifying the prices' long-term equilibrium relationship, and μ is the intercept term that captures all the elements that contribute to the magnitude of the price spread between producers and wholesalers. D_c is a structural change dummy variable that takes the value of zero from January 1991 to December 2005, and one from January 2006 to December 2013. The parameters Γ_i, $i = 1,\ldots,n$ contain the autoregressive short-term parameters.

5. Results

5.1 Market-Structure Analysis

The first task of our analysis was to develop a set of specific propositions. The literature review yielded the propositions described in Table 1. These propositions serve to guide the direction and scope of the market-structure analysis in the form of interviews and focus group discussions, and thus inform the design of the econometric model and the corresponding data collection.

Table 1. Propositions.

Proposition	Description
Proposition 1	The market structure is characterized by oligopsonistic competition.
Proposition 2	Oligopsonistic market power dampens price transmission.
Proposition 3	The price spread narrows when the market becomes more competitive.

Source: Authors.

As illustrated in the mapping of the milk market structure in Figure 2, Panama produces approximately 206 million kg of fluid milk equivalent (FME), imports 112 million FME, and exports 22 million FME. Thus, the total milk availability is approximately 296 million FME, and the import dependency ratio is 38%. Average consumption per capita is 77 liters per year. In 2013, total FME imports amounted US $104 million, of which cheese accounted for 53%, milk powder for 26%, butter for 8%, whey for 6%, yogurt for 5% and fluid milk and cream for 3%. The export of dairy products in Panama has been relatively low. In 2013 the country's FME exports amounted US $11.5 million, 73% of this total value was milk powder, and 27% was cheese. Due to tariff preferences obtained under the free trade agreement with other Central American countries, dairy exports went mainly to Costa Rica, El Salvador, Guatemala, Honduras, and Nicaragua.

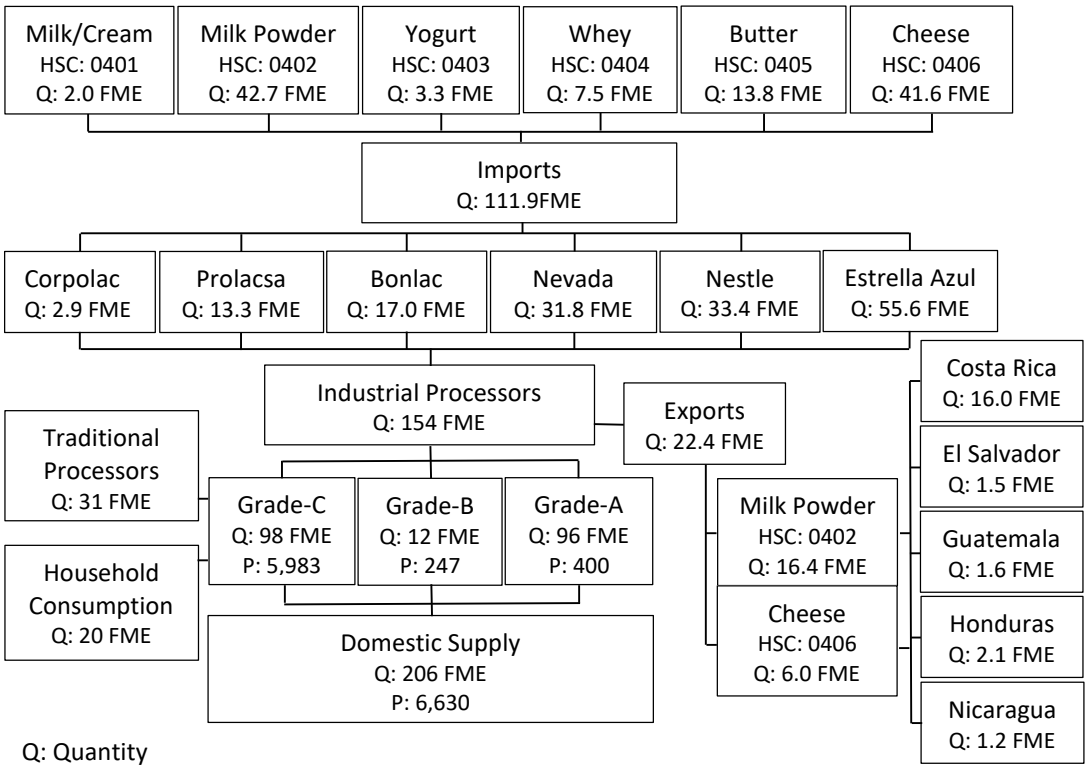

Figure 2. Structure of the milk market in Panama (data for 2013).

Source: Authors based on data from MIDA, 2011; CGRP, 2011; and INEC, 2014.

As shown in Figure 2, there are approximately 6,630 dairy farmers in Panama. Of these, 6% produce milk of grade A, 4% produce milk of grade B, and 90% produce grade C milk. Of the 206 million kg of milk the country produced in 2013, 46% was grade A, 6% was grade B and 48% was grade C. Grades A and B are used to supply the domestic market with fresh milk, whereas grade C is used mainly for industrial purposes, the manufacturing of traditional cheese, and self-consumption at the farm level. Of the total domestic supply, 75% goes to industrial processors, 15% to traditional processors, and the remaining 10% is directly consumed by households.

There are six major milk processing companies in Panama. Figure 2 shows that in 2013, the concentration ratio (CR_4) of the four largest processors (Estrella Azul, Nestle, Nevada, and Bonlac) was 90%. In the last ten years, the Panamanian dairy processing sector has experienced several consolidations. For example, Coca-Cola Fomento Económico Mexicano S.A (FEMSA) acquired Estrella Azul, the cooperative Dos Pinos from Costa Rica acquired Nevada, and the

company Castillo Hermanos from Guatemala acquired Bonlac. These recent developments have led to changes in the structure of the market, not only due to the increase in the size of operations but also because of the type and quality of raw products they demand.

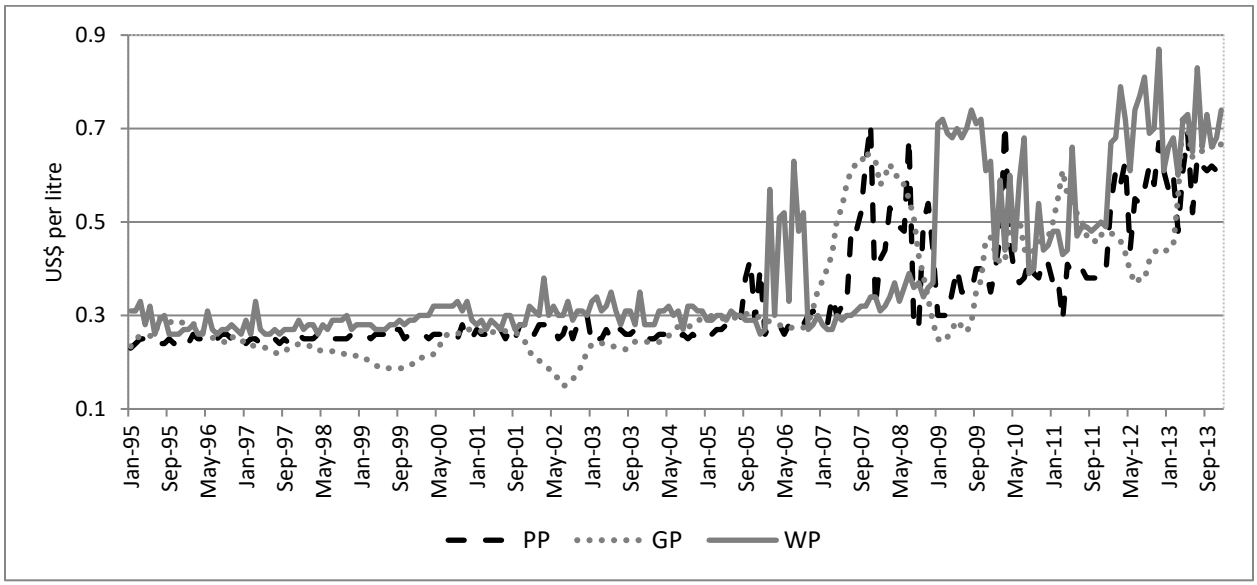

Figure 3. Producer, wholesale, and global milk prices.

Source: Authors based on price data from CGRP (2014).

Visual inspection of the price series in Figure 3 shows that producer (PP), wholesale (WP), and global (GP) milk prices were relatively stable between 1995 and 2005, moving constantly around approximately US$ 25 cents per liter[1]. The graph also reveals that milk prices increased and became more volatile after 2006. The increase in PP in 2007 can be partially explained by the 2006-08 world food crisis. Acosta et al. (2014) show that the global price fluctuations during this period were transmitted to the domestic milk market in Panama. However, Figure 3 also reveals three episodes in which WP and PP appeared to be moving independently. In some periods PP was higher than WP, which is unexpected. In 2006 WP increased while PP remained below 0,3 US$/litre, but in 2007 PP increased strongly while WP remained comparatively stable. In 2009 WP again increased much more strongly than PP. This behavior suggests that major changes in the structure of the market might have been taking place.

[1] US$ represent American dollar

Table 2. Media search timeline results.

Timeline	News headlines	Newspaper
12 Jan. 2006	While major dairy processors in Panama increase milk prices at consumer level, producer prices remain constant.	La Prensa
12 Oct. 2006	Milk producers request that industrial processors adjust the prices paid for raw milk at the farm gate level.	La Prensa
22 Nov. 2006	Producers accuse industrial processors of oligopoly behaviour, fixing the price per liter of raw milk paid to producers.	La Prensa
22 May 2007	Producers threaten industrial processors with strike action if raw milk prices are not adjusted.	La Prensa
7 Jun. 2007	Producers accept a price increase offered by industrial processors, but point out that they will explore other actions to ensure more competitive prices.	La Prensa
8 Mar. 2008	Four major dairy processors are sued for the alleged abuse of market power. A fine of US $100,000 is imposed on each of the companies involved and an audit process established.	Panamá América

Source: Authors.

The results of the media search (Table 2) reveal that milk producers and industrial processors of milk confronted each other regarding the oligopsonistic practices that industrial processors were suspected of using. An article published in January 2006 (Berrocal 2006) highlights that one of the biggest multinational dairy companies in Panama raised the price of dairy products to consumers. The article indicates that a price list was sent by this multinational company to all supermarkets informing about the increase in prices. Other dairy companies also considered increasing their prices. Milk producers complained that the farm-gate prices that they received for milk remained constant at 0,20 US$/litre although processors increased dairy prices for consumers by between 0,01 and 0,10 US$/litre. Producers demanded that industrial processors increase the farm-gate price of raw milk, accusing them of using market power practices (Guerra 2006a), and asked the National Authority for Consumer Protection (ACODECO) to look into possible price agreements among the few large-scale industrial dairy processors (Guerra 2006b).

In 2007 milk producers warned of an impending increase in consumer's milk prices, but claimed that they were not responsible for this increase (Tapia 2007a). Producers threatened processors

with strike actions if milk prices were not increased by 0,09 US$/ litre (Torres 2007). The companies did not meet this demand (Tapia 2007b), offering a price rise of 0,03 US$/litre instead. Producers accepted the offer but indicated that they were exploring other actions to ensure more competitive prices (Tapia 2007c). In March 2008, ACODECO sued four major industrial processors for the presumed use of market power practices to reduce prices paid to milk producers (De Gracia 2008).

The semi-structured interviews highlighted that the articles that appeared in various newspapers in 2007 motivated ACODECO to open an investigation against four industrial dairy processors due to presumed collusion. The investigated processors were found guilty of having abused their market power. The evidence gathered revealed that they had exchanged information that ultimately led to them setting lower farm-gate prices for raw milk. As a result, a fine of US$ 100,000 was imposed on each of the companies involved and an audit process was established. The interviews also revealed that while the fear of being sued for collusion has discouraged the manipulation of prices, the lack of antitrust legislation to address violations of competitive market behavior has resulted in the use of other practices, such as the establishment of exclusivity agreements or the use of boycotts to limit market entrance by potential competitors. Both types of practices are more challenging to investigate and monitor.

Milk producers noted during the focus group discussions that milk prices regularly increase in Panama during the dry season between January and May and decrease during the rainy season between June and December. Milk producers also expressed their worries about the asymmetric change in fluid milk prices between consumers and producers. Producers stated that some of the following factors might be affecting PT in the milk supply chain:

- the presence of many poorly organized milk producers facing a small number of industrial processors, leading to low bargaining power of milk producers;
- the high perishability of milk, which restricts the geographic movement of raw milk and forces producers to sell their output to local milk collectors, even if more distant collectors offer higher prices;

- the fear of potential substitution by an alternative supplier if producers reduce their deliveries below a certain level;
- a large proportion of fixed and specific inputs that prevent a low-cost reallocation of capital resources in the short run, leading to a low price elasticity of supply.

During the semi-structured interviews, traditional milk processors reported that they purchase raw milk to process it into different types of cheese for local markets, especially mozzarella. The prices they pay milk producers are often two cents above the prices paid by the large industrial processors. However the volume that the traditional processors can absorb is limited and determined by the size of the cheese market. When milk prices fall, the retail price of mozzarella follows suit, which increases the demand for mozzarella and, by extension, the traditional processors' demand for raw milk. Thus, when milk prices decrease below a certain threshold, small milk producers partially shift the supply of raw milk from wholesalers to traditional factories (Figure 4). This scheme has become a buffer mechanism to smooth milk price reductions.

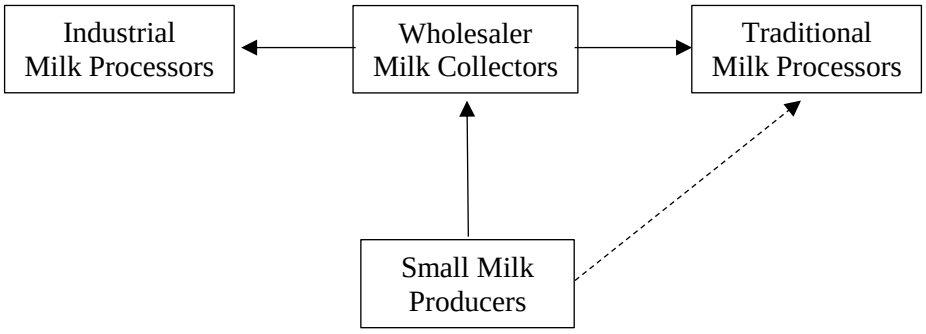

Figure 4. Small milk producers supply network in Panama

Finally, the semi-structured interviews with industrial processors revealed that industrial milk processors in Panama demand fluid milk of grade C as input to produce ice cream and butter. The price paid to milk producers considers the quality grade of the product (whether milk is of grade A, B, or C), the international price of milk powder, and whether the dry or rainy season is currently prevailing. Most processors hold between two and three months of milk powder stocks, which enables them to smooth the prices that they pay milk producers and charge retailers. Stocks are usually lower during the dry season and higher during the rainy season, and processors therefore claim that they pay slightly higher prices to milk producers during the dry season,

confirming what was reported by the milk producers above. In an initial specification of our empirical model we included seasonal effects to account for this, but these effects were not statistically significant. Hence, we do not include seasonal effects in the results presented below.

5.2 Time-series Econometric Analysis

A standard ADF is used to test for unit roots in both price series. However, considering the potential presence of structural breaks in the series, the unit root test with structural breaks (URSB) proposed by Saikkonen and Lütkepohl (2002) is also employed. Two specifications are considered for the ADF test. One includes only an intercept, and the other includes a trend and intercept. For the URSB test, the specification includes a shift or a shift and a trend. The optimal number of lags is selected using the Schwarz criterion. As reported in Table 3, the results of the ADF and the URSB test indicate that there is insufficient evidence to reject the null hypothesis of nonstationarity at the 5% level, confirming the presence of unit roots in both the producer and wholesaler price series.

Table 3. Results of the unit root tests.

Test	Variable	Break	Lags	$Ho: \gamma \approx I(0)$	$Ho: \Delta\gamma \approx I(0)$	Critical Values at 5%
ADF	WP	-	2	-1.26	-9.27	-2.86
	PP	-	3	-0.91	-6.38	-2.86
ADF Intercept/trend	WP	-	2	-2.54	-8.62	-3.41
	PP	-	3	-3.10	-4.72	-3.41
URSB shift	WP	2006 M2	2	-2.54	-10.21	-2.88
	PP	2006 M1	3	-0.16	-6.93	-2.88
URSB shift/trend	WP	2006 M2	2	-2.68	-10.22	-3.03
	PP	2007 M12	3	-2.33	-7.00	-3.03

Source: Authors.

Note: All prices in natural logarithms.

Considering the results of the ADF and URSB tests presented in Table 3, which indicate that both WP and PP are nonstationary, a Johansen cointegration test is employed to test whether they are cointegrated (Johansen 1988, 1995). However, since we suspect the presence of a structural break in the relationship between these prices in January 2006, a modified test proposed by

Johansen (2000) for cointegration in the presence of structural breaks is also conducted. The results of both tests, which are presented in Table 4, suggest that there is a long-run cointegrating relationship between the WP and PP.

Table 4. Johansen trace tests of cointegration between WP and PP with and without a break in January 2006

Test without a break			Test with a break in January 2006		
Null hypothesis	Trace statistic	p-value	Null hypothesis	Trace statistic	p-value
r = 0	22.71	0.020	r = 0	29.32	0.008
r = 1	1.26	0.900	r = 1	8.66	0.220

Notes: Tests carried out with prices in natural logarithms and with three lags according to the Schwarz criterion.

To assess the dynamic interactions between the producer and wholesale prices we first estimated a VECM using the full sample. Since the media search presented above suggests that structural changes took place at the beginning of 2006, which is corroborated by the results of the cointegration test with structural break in January 2006, we performed break point and sample split Chow tests (Candelon and Lütkepohl 2001) on the residuals of this VECM. The test statistics and corresponding bootstrap p-values are reported in Table 5. The results add to the evidence that the price behavior in the Panamanian milk market changed fundamentally in early 2006.

Table 5. Results of Chow tests for structural breaks in the VECM model residuals

Break Date	Test	Test Statistic	Bootstrapped *p*-value	Asymptotic Chi^2 *p*-value
2006 M1	Break Point Chow test (BP)	311	0.00	0.00
	Sample Split Chow test (SS)	13	0.09	0.09

Source: Authors.

Note: Bootstrap *p*-values based on 100 replications; sample period 1991 M3 to 2013 M12.

Based on the results of the market structure analysis and the empirical tests above, we estimate then the VECM described in equation (1) above, which includes a structural break in January 2006. This VECM includes an intercept shift in the constant term of the cointegration vector to capture a shift in the price spread between producer and wholesale prices.

Table 6. VECM parameter estimates.

Long-run PT elasticity	$\hat{b}_2$	-0.45^{***}
		(0.13)
PP speed of adjustment	$\hat{\alpha}_1$	-0.23^{***}
		(0.04)
WP speed of adjustment	$\hat{\alpha}_2$	0.16^{***}
		(0.05)
Price spread	$\hat{\mu}$	-1.71^{***}
		(0.44)
Structural change dummy	$\hat{\delta}$	-0.30^{***}
		(0.08)

Source: Authors.

Note: Numbers in parentheses are standard errors. *** denotes statistical significance at the 1% level; ** denotes statistical significance at the 5% level; * denotes statistical significance at the 10% level.

The results of the VECM model in Table 6 indicate that in the long run a change of 1% in the wholesaler price leads to a change of 0.45% in the producer price. The loading coefficients show that both producer and wholesale prices adjust to correct deviations from this long run equilibrium at average rates of 23% and 16% per month, respectively. As the intercept and the intercept shift are in logs, we take their anti-logs to interpret them. The exponential value of the intercept $\hat{\mu} =$ -1.71 indicates that the marketing margin between wholesale and producer prices is equivalent to a mark-up of approximately 18% on the latter. Furthermore, the exponential value of the market-structure change dummy $\hat{\delta}$= -0.30 indicates that this mark-up dropped to 13% after 2006. These results complement previous analysis of PT on the milk market in Panama (Acosta and Valdés 2014), showing that although a cointegrating relationship between producers and wholesalers' prices exists, the speed of adjustment is relatively slow.

5.3 Triangulation of Both Analyses

The results derived from each of the two previous methodologies, qualitative examination of the market structure, and econometric assessment of price interrelationships, are combined in Table 7 to generate insights into how market structure and the behavior of agents are affecting PT.

Table 7. Triangulation.

Proposition	Method	Evidence
The market structure is characterized by oligopsonistic competition.	Market Structure Analysis	CR index and semi-structured interviews with ACODECO.
Oligopsonistic power dampens the degree of PT.	VECM	A change of 1% in WP prices leads to a change of 0.45% in PP.
Price spread narrows when markets become more competitive.	VECM	After antitrust regulations were enforced the price spread decreased from 18% to 13%.

Source: Authors.

The results of the market structure analysis confirm the first proposition that the milk market in Panama is characterized by an oligopsonistic structure, with 6,630 producers facing six major processors, of which the four largest account for 90% of the milk supplied to industrial processing (CR_4 = 0.90). Furthermore, the semi-structured interview with ACODECO revealed that these four processors were found guilty of having exchanged information to set a lower farm-gate prices for raw milk.

The results of the VECM long-term parameter confirm the second proposition indicating that the transmission of milk prices from wholesaler to producers is damped. According to the long-run PT elasticity parameter, a change of 1% in the wholesale price leads to a change of 0.45% in the producer price. Since the cost share cost of raw milk in the final wholesaler price is approximately 80% we would expect the elasticity of PT to be closer to 0.8. Hence, the estimated elasticity of 0.45 suggests that price transmission is being damped.

The results of the VECM estimation with a structural change dummy parameter confirm the third proposition, showing how the introduction of competitive measures affected the marketing margin between wholesale and producer prices. This parameter reveals that after antitrust regulations were imposed, the price spread between wholesalers and producers decreased from

18% to 13%. In other words, the milk producer's share of the wholesaler price increased from 82% to 87% after the regulations were imposed.

Conclusions and Discussion

Price dynamics on food markets have important welfare effects and food security implications. Therefore, substantial attention has been devoted in recent decades to the analysis of vertical and horizontal PT. This analysis has traditionally focused on exclusively applying econometric methods. However, the sole application of econometrics has been acknowledged by various authors as having only limited potential to generate concrete insights to support evidence-based policy-making, as it is difficult to make sense of econometric results without a broader understanding of the institutional structure of the market in question. This study contributes to a broadening of the analytical tool kit beyond the sole use of econometrics.

We propose and illustrate the application of an analytical framework to facilitate a more comprehensive understanding of price dynamics along food supply chains. The analytical framework is composed of three steps, each of which consist of several tasks. Step 1 employs qualitative analysis of the market of interest to obtain detailed insight into its structure and the existence and magnitude of factors that might affect price dynamics along food supply chain. Step 2 uses time-series econometrics to quantitatively assess such price dynamics. Step 3 triangulates the results of the two preceding steps to gain comprehensive insight.

The results of the market structure analysis confirm the first proposition showing that the milk market in Panama is characterized by an oligopsonistic structure. Furthermore, the semi-structured interview with ACODECO reveals that a number of processors were found guilty of having set lower farm-gate prices for raw milk. The VECM long-term parameter confirms the second proposition, showing that the long-run PT elasticity (0.45) is lower than expected (0.8), which suggests that the transmission of price changes from wholesalers to producers is being damped. Finally, the structural change dummy of the VECM reveals that, after antitrust regulations were imposed, the price spread between wholesalers and producers decreased from 18% to 13%, confirming our third proposition. As indicated in the literature one should be wary of inferring too much about the competitive setting of the market based on PT econometric

analysis alone. However the combination of quantitative and qualitative analysis shows that there is not only oligopolistic competition but also strong evidence of collusion.

The proposed methodological framework could be extended in several directions. For example, Hassouneh et al. (2012) point out that more insight is needed to better capture the non-linear behavior of PT processes. In this regard, the use of TVECM or one of its versions could be useful to compare PT when milk powder stocks are below or above certain thresholds. Although our analysis failed to find evidence of seasonal patterns, if milk prices do tend to increase during the dry season and decrease during the rainy season, as suggested by processors in the semi-structured interviews, then model specifications such as proposed by Amikuzuno and von Cramon-Taubadel (2012), or state space models with time-varying parameters (e.g. Adämmer et al., 2016; Vollmer and von Cramon-Taubadel, 2017) could be employed to capture the effects of seasonality in the speed of adjustment.

Further analyses might aim at explaining the exact role of imperfect competition. One might try to better understand "which," "how," and "why" determinants are constraining the transmission of prices along food supply chains. The NEIO literature has suggested a number of market performance measures that could be used to complement the market structure analysis for testing competitive behavior. Examples are rates of returns, price-cost margins or Lerner's measures (Carlton and Perloff 2004). However, such methods require information related to costs, volumes and prices that is often unavailable. Although these methods are powerful in their theoretically explanatory power, their empirical application is difficult if there is no institutional mechanism which compels stakeholders to disclose such information.

The authors declare that they do not have any conflicts of interest.

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