www.jard.edu.pl http://dx.doi.org/10.17306/J.JARD.2019.01258

Journal of Agribusiness and Rural Development

pISSN 1899-5241
eISSN 1899-5772

4(54) 2019, 345–353
Accepted for print: 29.11.2019

PRICE TRANSMISSION ANALYSIS OF PASTEURIZED LIQUID MILK IN SOUTH AFRICA: THE GRANGER CAUSALITY APPROACH

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Abstract. Price transmission studies have become increasingly important in Sub-Saharan Africa over the past decades because of its nature of providing clear and insightful information into these markets. In this study, the price transmission mechanism is described with an agricultural product within the dairy industry, namely pasteurized liquid milk. The aim of this study was to investigate and analyze the nature of the price transmission mechanism for pasteurized liquid milk in South Africa. The study used secondary time series data that covered a sample size of 17 years (2000–2016) for pasteurized liquid milk. The Granger causality test and the Vector Error Correction Model were used for data analysis. The Granger causality tests suggest that a bidirectional causal relationship exists between processor and farmgate prices, and also between retail and processor prices. On the other hand, retail prices were found to have a unidirectional causality effect on farmgate prices. The VECM results showed asymmetric price transmission, implying that retailers and processors react quicker to a price increase than to a price decrease. A price monitoring policy is suggested to be put in place in order to protect the consumers from unfair prices passed on by the retailers.

Keywords: price transmission, Granger causality, pasteurized liquid milk, Vector Error Correction model

INTRODUCTION

Dairy is a universal agricultural produce, and it is a well-known fact that the industry actively contributes to the economies of a number of communities, regions and countries (IDF, 2013). South Africa contributes approximately 0.5% to the world milk production. According to Midgley (2016), South African dairy production is responsive to the growing domestic and regional demand but is also sensitive to producer prices. Increased milk production is stimulated when the producer price for milk rises above a certain edge. The economic value of the dairy industry is spread throughout the supply chain, but there has been a dispute between producers and processors around low producer milk prices (Coetzee, 2015). According to Funke (2006), prices in the supply chain are established through negotiations between farmers and buyers (dairy companies), and between processors and retailers. Farmers predominantly remain "price takers" in this system and experience continuous "price-cost squeeze." Affordability to the consumer is also taken into account. This has generally left the small farmers exiting the industry and/or being bought by larger diaries.

According to Kharin (2015), rising food prices can provide an opportunity for agricultural and economic development, if price changes at one level are efficiently transmitted to another level. Thus, marketing efficiencies will be realized along the value chain. However, little is still known in terms of who along the marketing levels and value chain benefits more from changes in prices in South Africa. Thus, this study attempted to bridge this research information gap by investigating the price transmission mechanism of pasteurized liquid milk in

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South Africa from 2000 to 2016. The main objectives of this analysis are therefore to determine the direction of causality between farmgate prices, processor prices and retail prices of pasteurized liquid milk in South Africa from 2000 to 2016, and to determine whether the transmission of pasteurized liquid milk prices was symmetric or asymmetric in South Africa in that period.

DATA AND ANALYTICAL METHOD

Sources of data

When conducting an econometric analysis based on the objectives of this study, it is crucial to rely on appropriate data relating to pasteurized milk prices in order to enable a quantitative assessment. Historical time series data was extracted from the Department of Agriculture, Forestry and Fisheries (DAFF), Milk Producers Organization and Statistics SA, covering monthly data from a 17-year period (2000–2016).

Analytical technique

Econometric methods were used to analyze the data collected with the use of tables. This was done in order to describe the main features of the variables and examine the relationship between farmgate, processor and retail prices of cheese and pasteurized liquid milk.

Conceptual framework for price transmission analysis

The first step was to examine each pair of logarithmic price series for order of integration using the Augmented Dickey–Fuller test (Dickey and Fuller, 1979). The tests were executed to test the price variables in order to see if they are non-stationary and to check the series' properties. According to Granger (1969), the optimal lag length should be estimated prior to Granger causality tests, and therefore the VAR Lag Order Selection Criteria were employed as they facilitate the correct specification of the VAR model. Granger causality tests were then ran based on the Granger procedure. Proceeding, the Johansen cointegration procedure was used to check the long-run relationship between the variables. In circumstances where price series are found to be cointegrated, price transmission is analyzed using VECM.

Investigating unit-root non-stationarity

The Augmented Dickey-Fuller and Phillips-Perron tests were carried out on farmgate, processor and retail prices to legitimately discover whether they contained a unit

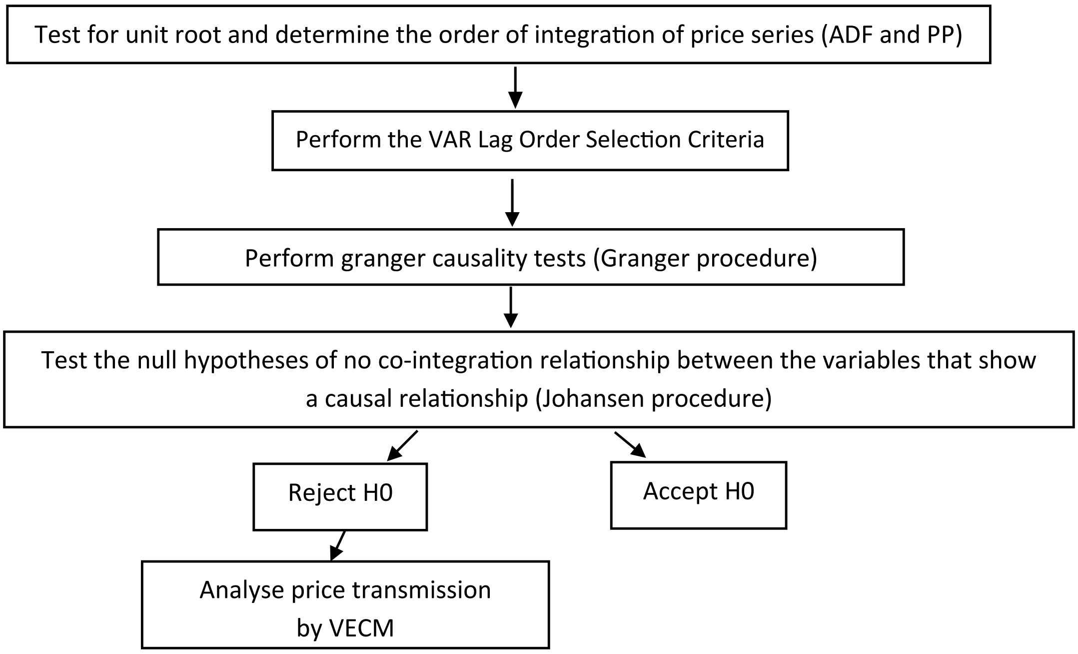

Fig. 1. Framework for price transmission analysis
Source: own elaboration.

root. Vavra and Goodwin (2005) stated that a variable contains a unit root or is *I (1)* if it is non-stationary. In an event where the variables are non-stationary, they must be transformed first in order to proceed with the economic analysis.

Three autoregressive forms of models were established, each for the three separate data series of FGP, PP and RP as demonstrated below:

$$\Delta\log FGP_t = \sigma_1 + \sigma_2 t + \theta\log FGP_{t-1} + \sum_{t=1}^{p}\beta_i\Delta\log FGP_{t-1} + e_t \quad (1)$$

$$\Delta\log PP_t = \sigma_1 + \sigma_2 t + \theta\log PP_{t-1} + \sum_{t=1}^{p}\beta_i\Delta\log PP_{t-1} + e_t \quad (2)$$

$$\Delta\log RP_t = \sigma_1 + \sigma_2 t + \theta\log RP_{t-1} + \sum_{t=1}^{p}\beta_i\Delta\log RP_{t-1} + e_t \quad (3)$$

where:

σ_1 = intercept term, t = trend term

$\log FGP_t$, $\log PP_t$, $\log RP_t$ = natural logarithm of farmgate, processor and retail price series to be tested

$\log FGP_{t-1}$, $\log PP_{t-1}$, $\log RP_{t-1}$ = natural logarithm of farmgate, processor and retail price series lagged by 1 period

$\sum_{t=1}^{p}\beta_i\Delta\log FGP_{t-1}$, $\sum_{t=1}^{p}\beta_i\Delta\log PP_{t-1}$, $\sum_{t=1}^{p}\beta_i\Delta\log RP_{t-1}$ = 1st, 2nd, …, pth lagged first-differenced values of logFGP, logPP and logRP

σ, θ, β_i = coefficients, e_t = error term

Granger causality model

The Granger causality model is considered a suitable statistical hypothesis model for determining whether one time series is useful in forecasting another. As a consequence, the model has been used by researchers since 1969 (e.g. Granger, 1969; Konya, 2004; Bulagi et al., 2016).

The specific model is given by:

- the farmgate and processor prices equation

$$\log FGP_t = \alpha + \sum_{t=1}^{k}\beta\log FGP_{t-1} + \sum_{t=1}^{k}\gamma\log PP_{t-1} + u_t \quad (4)$$

$$\log PP_t = \alpha + \sum_{t=1}^{k}\beta\log PP_{t-1} + \sum_{t=1}^{k}\gamma\log FGP_{t-1} + u_t \quad (5)$$

- the processor and retail prices equation

$$\log PP_t = \varepsilon + \sum_{t=1}^{k}\gamma\log PP_{t-1} + \sum_{t=1}^{k}v\log RP_{t-1} + u_t \quad (6)$$

$$\log RP_t = \varepsilon + \sum_{t=1}^{k}\gamma\log RP_{t-1} + \sum_{t=1}^{k}v\log PP_{t-1} + u_t \quad (7)$$

- the retail and farm gate prices equation

$$\log RP_t = \theta + \sum_{t=1}^{k}v\log RP_{t-1} + \sum_{t=1}^{k}\beta\log FGP_{t-1} + u_t \quad (8)$$

$$\log FGP_t = \theta + \sum_{t=1}^{k}v\log FGP_{t-1} + \sum_{t=1}^{k}\beta\log RP_{t-1} + u_t \quad (9)$$

where:

FGP_t, PP_t, RP_t = farmgate prices, processor prices and retail prices at time t

FGP_{t-i}, PP_{t-i}, RP_{t-i} = lagged farm gate prices, processor prices and retail prices at time $t-i$

k = optimal lag length,

β, θ, v = coefficients to be estimated

u_t = error term.

The equations above state the dependency between prices in determining or predicting future prices. For example, equation 2.4 postulates that current farmgate prices are dependent on past farmgate prices, and past and present processor prices. The same explanation goes for equations 5, 6, 7, 8 and 9.

The VAR Lag Order Selection Criteria (VLOSC) were used to determine the optimal lag length of the formulated VAR models. The Schwarz Information Criterion (SIC), Final Prediction Error (FPE), Sequential Modified LR test statistic, Hannan-Quinn Information Criterion (HQIC) and the Akaike Information Criterion (AIC) were the VLOSC measures used for indicating the goodness of fit of alternative models.

Price asymmetry analysis

Price asymmetry was tested for the cointegrated variables. This is consistent with findings from the Granger causality and with the results of the Johansen cointegration test. The Vector Error Correction model was employed on the cointegrated variables.

Farmgate-retail price transmission and retail-processor price transmission

The error correction model (ECM) was used to determine whether retailers adjust to increases in farmgate prices and processors adjust to increases in retail prices the same way they respond to decreases. The VECM was specified and estimated in compliance with the Engle and Granger (1987) two-step procedure in combination with the error correction term splitting concept and VECM.

After instituting the long-run relationship between farmgate and retail prices as well as between retail and processor prices, the Error Correction Model (ECM) was estimated using the OLS.

$$\begin{aligned}\Delta\log RP_t = \theta + \sum_{i=1}^{5}\gamma\log RP_{t-i} + \sum_{j=1}^{5}\beta\Delta\log FGP_{t-j} + \\ \delta_2^{+}ECT_{t-1}^{+} + \delta_2^{-}ECT_{t-1}^{-} + u_t\end{aligned} \quad (10)$$

$$\begin{aligned}\Delta\log PP_t = \varepsilon + \sum_{i=1}^{5}\gamma\log PP_{t-i} + \sum_{j=0}^{5}\beta\Delta\log RP_{t-j} + \\ ECT_{t-1}^{+} + \delta_2^{-}ECT_{t-1}^{-} + u_t\end{aligned} \quad (11)$$

where:

$\Delta\log RP_t$, $\Delta\log PP_t$ = first-differenced log RP and log PP in period (t)

$\sum_{i=1}^{5}\gamma\Delta\log RP_{t-i}$ = the 1st, 2nd, …, 5th lagged first-differenced values of logRP

$\sum_{j=1}^{5}\beta\Delta\log FGP_{t-j}$ = 1st, 2nd, …, 5th lagged first-differenced values of logFGP in period (t)

$\sum_{i=1}^{5}\gamma\Delta\log PP_{t-i}$ = 1st, 2nd ,… , 5th lagged first-differenced values of logPP

$\sum_{j=0}^{5}\gamma\Delta\log RP_{t-j}$ = 1st, 2nd, …, 5th lagged first-differenced values of logRP in period (t)

ECT_{t-1}^{+} = positive error correction terms lagged by one period

ECT_{t-1}^{-} = negative error correction term lagged by one period

$\gamma, \theta, \delta_2^{-}, \delta_2^{+}$ = estimated coefficients.

According to Vavra and Goodwin (2005), including the error correction terms in long-run equilibrium models allows the estimated price to respond to changes in the explanatory price while also correcting any deviations that may be left over from previous periods. The asymmetric price transmission is possible with the inclusion of positive and negative error correction terms. The error correction terms in equations 10 and 11 measure the deviations from the long-run equilibrium between farmgate prices and retail prices and between processor prices and retail prices.

RESULTS AND DISCUSSION

Unit root test results

The statistical properties of price series are analyzed before carrying out the causality test. Price asymmetry will be tested afterwards.

The unit root of farmgate, processor and retail prices of pasteurized liquid milk was tested firstly using the ADF procedure. Usman (2012) asserts that it is generally a good thing to start with a general ADF model that contains both a constant and a trend. If a unit root is not rejected based on the general test form, one then proceeds with the tests without a time trend and a drift. This improves the efficiency and the power of the test. It is confirmed that both the trend and the drift are statistically insignificant based on the ADF t-statistics at a 5% significance level. Hence, the ADF test at level is performed without a drift or time trend.

The ADF tests were done for all monthly price series covering the study period. As shown in Table 1, the Augmented Dickey-Fuller test for the unit root proves that all variables had a unit root at level form. Hence, the null hypothesis cannot be rejected at 1%, 5% and 10% levels of significance. This was due to the ADF test statistic values of farmgate, processor and retail prices being shown to be greater than the Mackinnon critical values for rejecting the hypothesis of a unit root.

The Durban-Watson statistics are all significant enough to reject the presence of serial correlation in each of the series. Hence, the results are considered reliable and can be trusted. As a consequence, farmgate, processor and retail prices of pasteurized liquid milk are non-stationary.

Vavra and Goodwin (2005) stated that non-stationary economic time series data needs to be transformed through differencing or de-trending because otherwise the results would be spurious. Spurious regressions occur when the mean, variance and covariance of a time series vary with time. The classic results of a usual regression routine cannot be legitimate if a non-stationary data series is used for the analysis. Therefore, all variables were subjected to first difference and turned out to be stationary. The null hypothesis at first difference is rejected, indicating that there is no unit root.

Table 1. Results for unit root tests on FG, PP, RP in levels and 1st difference

	Unit root test at level			Unit root test at 1st difference		
Variables	ADF statistic	p-value	DW statistic	ADF statistic	p-value	DW statistic
FGP	0.252593	0.9752	2.011153	–6.043179	0.0000***	2.012092
PP	–0.144791	0.9417	2.045387	–8.978774	0.0000***	2.048764
RP	0.543754	0.9878	2.120090	–6.982334	0.0000***	2.119022

Source: own elaboration.

Table 2. Vector auto regressive lag order selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	–52.86184	NA	0.000352	0.561426	0.611073	0.581519
1	843.9001	1 757.473	4.69e-08	–8.360805	–8.162214	–8.280430
2	873.4098	56.94232	3.82e-08*	–8.566932*	–8.219398*	–8.426276*
3	879.4028	11.38381*	3.94e-08	–8.536712	–8.040234	–8.335774
4	881.8990	4.666175	4.20e-08	–8.471347	–7.825925	–8.210128
5	893.4599	21.26273*	4.10e-08	–8.497084	–7.702719	–8.175584

*Indicates the lag order selected based on the criterion.
LR – sequential modified LR test statistic (each test at a 5% level)
FPE – final prediction error
AIC – Akaike information criterion
SC – Schwarz information criterion
HQ – Hannan-Quinn information criterion
Source: own elaboration.

Lag order selection criteria

The summary of results in Table 2 shows that HQ, AIC, FPE and SIC resulted in choosing lag 2.

Studies further revealed that HQ gives viable results when there is more than 120 observations. Hence, this study used lag 2 for Granger causality tests as there are 204 observations covered.

Results of Granger causality tests

Causality between farmgate and retail prices

The *p*-value of 0.1198 is above 5%, so the null hypothesis cannot be rejected and is therefore accepted. Farmgate prices do not Granger-cause retail prices. Thus, current and previous prices at farmgate do not help in predicting retail prices. On the other hand, the p-value of 7.E-13 is significant at 1% level and shows a causal relationship between RP and FGP. Therefore, RP Granger-causes FGP, and thus the null hypothesis is rejected. It is evident from the results that a unidirectional relationship exists between farmgate and retail prices as it moves one way from retail to farmgate. Mandizvidza (2013) emphasized that a unidirectional relationship is explained by a high concentration and market power at a specific stage or level. Thus, retailers are concentrated and have a market power as compared to processors. These findings are in contrast with what was established elsewhere. For instance, Kirsten and Cutts (2006) and Uchezuba (2010) found a unidirectional relationship running from farmgate to retail prices. The findings in this study are explained by the highly concentrated retailers selling pasteurized liquid milk in South Africa and the market power they have in price determination. Hence, South African milk producers are forced to a “price taking” behavior.

Causality between processor and farmgate prices

As shown in the Table 5, a causal relationship was found between processor and farmgate prices. There is a bidirectional causal relationship between processor and farmgate prices. This is shown by p-values of (1.E-10 and 0.0002) which are both significant at a 5% level. The null hypothesis stated as “PP does not Granger-cause FGP and FGP does not Granger-cause PP” was rejected. This implies that farmgate prices are helpful and are used in predicting processor prices and vice versa.

Causality between retail and processor prices

Based on observations, both null hypotheses stated as “PP does not Granger-cause RP and RP does not Granger-cause PP” are rejected. This is because the probabilities are significant at a 5% level with *p*-values of 3.E-05 and 0.0005, respectively. It is known that if hypotheses H01 and H02 are both accepted, there exists a bidirectional relationship, thus linear causality runs in two ways. Hence, processor prices are used when forecasting retail prices and retail prices depend on historic and present processor prices.

Table 3. Granger causality test results for pasteurized liquid milk

Null hypothesis	*F* statistic	Df (Lags)	Prob.	Decision
RP does not Granger-cause FGP	32.3021	2	7.E-13	reject
FGP does not Granger-cause RP	2.14532	2	0.1198	do not reject
PP does not Granger-cause FGP	25.7228	2	1.E-10	reject
FGP does not Granger-cause PP	8.88192	2	0.0002	reject
PP does not Granger-cause RP	10.8181	2	3.E-05	reject
RP does not Granger-cause PP	7.99268	2	0.0005	reject

Source: own elaboration.

Table 3 revealed that a bidirectional relationship exists between retail and processor prices and between processor and farmgate prices. This implies that they impact each other; the impact can be positive for both variables, negative for both, or positive for one and negative for the other. The prices depend on each other in making predictions and providing market insights at that level. The relationship is going in two ways, meaning that if farmgate prices increase, it will trigger a movement in prices at other stages of the value chain; even if it starts with the retailers, it will affect farmgate and processor levels. Thus, prices of pasteurized liquid milk are determined at every level.

Tests for price asymmetry

Price determination point and causal direction has been established. Now, asymmetric price transmission needs to be tested. The Johansen cointegration test was carried out in order to ascertain whether prices of pasteurized liquid milk are transmitted symmetrically to processor and retail stages of the marketing chain.

Based on the Johansen test shown in Table 4, variables FGP, PP and RP are cointegrated. Therefore, a long run cointegration relationship exists between the variables. Following this, price transmission was analyzed using the VECM model.

The trace test fails to reject at most one cointegration model (CE) at a 5% significance level. Thus, a long-run relationship exists between farmgate and processor prices. Likewise, the hypothesis of a non-cointegration relationship existing between farmgate prices and retail prices is rejected. The decision was based on the p-value which is significant at a 5% level. Therefore, it can be confirmed that a long-run relationship exists between farmgate and retail prices and between farmgate and processor prices in the market for pasteurized liquid milk.

Table 4. Johansen cointegration rank test results (Trace and Max-Eigen value statistic) for pasteurized liquid milk

Series	Hypothesized No. of CE(s)	Trace statistic	0.05 critical values	Prob*	Max-Eigen statistic	0.05 critical values	Prob*
FGP, PP and RP	none	72.60928	29.79707	0.0000*	51.37560	21.13162	0.0000*
	at most 1	21.23369	15.49471	0.0061*	21.19670	14.26460	0.0034*
	at most 2	0.036988	3.841466	0.8475	0.36988	3.841466	0.8475

*Denotes rejection of the hypothesis at the 0.05 level.
Mackinnan-Haug-Michelis (1999) *p*-values (as reported by EViews).
The trace test indicates r cointegrating model (s) at a 5% significance level.
Source: own elaboration.

Table 5. Farmgate/processor, farmgate/retail prices cointegration

Series	Hypothesized No. of CE(s)	Trace statistic	0.05 critical values	Prob*	Max-Eigen statistic	0.05 critical values	Prob*
FG and PP	none*	15.91909	15.49471	0.0431	15.88783	14.26460	0.0275
	at most 1	0.031267	3.841466	0.8596	0.031267	3.841466	0.8596
FG and RP	none*	17.92075	15.49471	0.0211	17.87743	14.26460	0.0129
	at most 1	0.043316	3.841466	0.8351	0.043316	3.841466	0.8351

*Denotes rejection of the hypothesis at the 0.05 level.
Source: own elaboration.

Empirical results of the Vector Error Correction Model

The error correction term in Table 6 has a negative coefficient and is significant at a 10% level of significance. This implies that the system will revert into equilibrium in a short run, and the long-run disequilibrium will be corrected in a short-run at an adjustment speed of 5.8%.

The error correction term is negative and significant, meaning that a long-run relationship exists between farmgate and processor prices of pasteurized liquid milk. The error correction term is significant at a 10% level with a *p*-value of (0.0510) and it is complemented by the negative coefficient of the error term. It can now be concluded that the system will be able to revert into equilibrium in a short run.

Tables 6 and 7 give evidence of asymmetric price transmission between farmgate and retail as well as between farmgate and processor levels. According to DairyCO (2010), prices are said to be asymmetric if they move in the same direction but not at the same time. The prices were found to move in the same direction but not at the same time. In both cases, the speed of adjustments implies that the prices can revert to equilibrium by 5.8% and 4.6% every month, respectively. This proves and clearly indicates that when prices at farmgate level increase, the retailers and processors respond to it but not very fast. That behavior is explained by the short shelf life of pasteurized liquid milk; if they react quickly to price increases, the probabilities of remaining with rotten products on their shelves are very high. These results were expected since it is common in the real world that if prices of inputs increase, it triggers an increase in output prices. The same is seen with suppliers and final retailers since if supplier prices increase, the final retailer also increases prices in order to make profits. These results concur with other studies (Kirsten

Table 6. Farmgate and retail price transmission

Model	Coefficient	Std. error	t-Statistic	Prob.
ECT_{t-1}	–0.058961	0.032291	–1.825927	0.0694*
$logFGPPLM_{(-1)}$	0.251360	0.082941	3.030607	0.0028**
$logFGPPLM_{(-2)}$	0.204563	0.083718	2.443482	0.0154
$logRPPLM_{(-1)}$	0.264043	0.071241	3.706322	0.0003**
$logRPPLM_{(-2)}$	–0.126044	0.072403	–1.740877	0.0833*
CONSTANT	0.004484	0.004472	1.002669	0.3173

**F*-statistic: 14.16013.
**Prob(*F*-statistic): 0.000000.
Source: own elaboration.

Table 7. Transmission between farmgate and processor prices

Model	Coefficient	Std. error	*t*-Statistic	Prob.
ECT_{t-1}	–0.046048	0.023450	–1.963645	0.0510*
$logFGPPLM_{(-1)}$	0.405639	0.071641	5.662132	0.0000**
$logFGPPLM_{(-2)}$	0.128088	0.073920	1.732797	0.0847*
$logPPPLM_{(-1)}$	0.088559	0.026207	3.379190	0.0009**
$logPPPLM_{(-2)}$	–0.018078	0.026929	–0.671328	0.5028
CONSTANT	0.004258	0.004363	0.976027	0.3303

**F*-statistic: 13.83173.
**Prob (*F*-statistic): 0.000000.
Source: own elaboration.

and Cutts, 2006; Uchezuba, 2010) who argued that the asymmetric price transmission can change because retailers and processors are profit-oriented, so they react to any situation that seems to be threatening their profits. Thus, they respond when their profits are squeezed rather than when they are stretched.

CONCLUSIONS AND RECOMMENDATIONS

This study analyzed the transmission of pasteurized liquid milk prices. Data series were in logarithmic form and were also tested for stationarity before analyzing price transmission. Several diagnostic tests, including Granger causality and VECM, were ran in order to draw results. The findings revealed that prices are determined at all levels, i.e. at farmgate, processor and retail stages. The transmission of pasteurized liquid milk prices is asymmetric between farmgate and also between farmgate and processor levels. The asymmetric price adjustments indicate that the welfare impact of reduced prices is not distributed equally because prices are not fully carried into consumers (Elham, 2018). The study also found that retailers and processors are quick to react to farmgate price increases. Thus, they quickly adjust their prices in order to pass the price increase to consumers. However, the same is not done when prices decrease at farmgate level. Thus, the retailers and processors are benefiting at the cost of consumers. This situation implies that consumers are being exploited when prices increase but they do not enjoy the rewards of a price decrease. In light of this, the study recommends that the South African government implement price-monitoring policies to protect the consumers against this behavior by tracking the future prices of pasteurized liquid milk on a daily basis and giving feedback in advance, affording the department ample time to apply dedicated measures which would help policy interventions in timely preventing undesired behavior from the retailers vis-à-vis the consumers.

SOURCE OF FINANCING

National Agricultural Marketing Council and Services SETA.

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