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EFFECT ON THE INTERNATIONAL PRICE OF MAIZE ON THE RETAIL PRICE OF BROILER CHICKEN IN COSTA RICA

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Abstract

This paper presents the results of an investigation carried out with the objective of estimating the impact of variations in maize international price on the poultry meat domestic price in Costa Rica. For the transmission of international price to CIF import price of maize (main ingredient in the chicken diet), a distributed lag autoregressive model was used after testing for cointegration of time series. The selling price to the final consumer was modeled with a reduced-form structural model. The results show how the international price of maize has an important impact on the formation of domestic chicken meat prices and requires that this be considered in the design of policies to reduce the dependence on the international price, which has a negative impact on the price in cases of unexpected increases or shocks.
Keywords: *Econometrics, GARCH models, price transmission, structural models.*
JEL Codes: *C22, C53, Q13, P17.*

1. Introduction

Broiler meat is a highly consumed source of protein in the world. In 2020, 134 million tons were produced and United States of America, China and Brazil were the main producers (FAO, 2022). In the world market, the main exporters are Brazil and United States of America, which supply 50%, while China is the largest buyer with 3.8 million tons imported in 2020 (FAO, 2022).

In Costa Rica, 137 000 tons of broiler were produced in 2020, 5% less than in 2019; however, since 1950's, production has grown steadily, reflecting a general increase in annual per capita consumption (increased by 5 kg between 2007 and 2020) (ALA, 2018; FAO, 2022; FENAVI, 2019). The preference for chicken meat consumption is attributed to its high digestibility, high protein, vitamin and mineral content, lower price compared to other meats and versatility in culinary preparations.

Forecast indicate that chicken meat will be the most consumed animal protein worldwide by 2030, with an assumed higher demand in developing countries (FAO, 2021). Estimates

indicate that 97% of the Costa Rican population consumes chicken at least once or twice a week (Jiménez Córdoba, 2020; Madrigal et al., 2019).

In addition to the food importance it represents for Costa Rica, poultry farming has become an agricultural activity with a high economic impact in rural areas, since it is mainly carried out by small producers (Martínez & Mora, 2010; Vargas et al., 2018). The last National Agricultural Census of Costa Rica recorded 4749 in 2014 dedicated to meat and egg poultry; in 2020 total flock exceeded 72 million chickens (ALA, 2018; FAO, 2022; INEC, 2015).

From an agri-food perspective, these are some of the reasons why proper production practices should be promoted, aimed at maximizing genetics and optimizing weight gain and feed costs, reducing fattening cycles and improving farm profitability (Cobb-Vantress, 2018; Monestel, 2019).

Due to the relevance of poultry sector in rural areas of Costa Rica, the volatility of raw material prices and the importance of chicken meat in the Costa Rican diet, the purpose of this research is to determine the effect of international corn price transmission on the sale price of broiler chickens to the final consumer. The results obtained will be a baseline of support for the management of this country's dependence on variations in international raw material prices.

2. Literature Review

According to the feed package implemented, the life cycle of the broiler chicken is 2 months, with an average body weight of 2.5 kg (Cordero, 2021). Since feeding is mainly based on concentrate feed, the availability, quality and cost, are key variables to obtain good productivity to ensure competitiveness in the markets (Vargas et al., 2018).

Feed costs range from 60-70% of total production cost and nutritional requirements vary according to age, breed, climate and nutritional diet composition (Arita & Figueroa, 2014; Nilipour, 2012). Therefore, ingredients and feeding system directly affect productivity, with corn being the main ingredient with records of up to 65% of broiler feeds (Barbarino, 2001).

Regarding maize as a primary ingredient in poultry diets, this crop enjoys large planting extensions in the world. By 2020, 243 million hectares were dedicated to maize cultivation and more than 1.1 billion tons were produced to meet human and animal nutrition needs (FAO, 2021, 2022).

Since October 2020, there have been changes in world maize stocks due to climate and market events and the global transportation crisis that affected maritime routes and import costs. On the other hand, since the beginning of 2022, there have been events that put upward pressure on the grain and cereal prices, such as the increase in oil fuel prices, the transportation costs (maritime, land and air) and the fertilizer manufacturing, together with the war between Ukraine and Russia, which are grain producers (mainly wheat and corn) (Nieves, 2022).

In September 2021 the international price of maize was recorded at US$239.65 per ton and in April 2022 it reached US$348.17 (IndexMundi, 2022), although a reduction is expected by the end of 2022 with a closing price of US$285.53 on Chicago Stock Exchange (Grain Stock Exchange, 2022). Specifically in Costa Rica, after the trade liberalization policies of 1990's, the country became an importer of maize for human consumption and animal production (Dutoit et al., 2010). For this reason, the rise in maize prices is transmitted to production costs and sales prices to final consumers, causing a decrease in purchasing power.

In a small economy such as Costa Rica's, price-taker in international markets and with industries intensive in raw materials use, it is to be expected that positive price shocks will be reflected more quickly than negative ones (Álvarez & Esquivel, 2018).

Rigidity in price transmission is an indispensable indicator of competitiveness and efficiency in international and local markets. Its importance is based on its use as a linking tool between different levels of a supply chain (Jaramillo-Villanueva & Palacios-Orozco, 2019; Rossini & Depetris, 2008).

In Mexico, the asymmetry of price transmission in maize chain was studied, showing an immediate adjustment in retail agent prices due to increases in producer prices, but the adjustment was slower when the price decreased, which confers a longer profit margin for the retail links (Cruz, 2010).

Direct relationships have also been identified between the price of poultry meat and the sorghum cost as a main ingredient in broiler diets, which implies an affectation of its dynamism according to price and cost variability (Rebollar et al., 2019). Thus, in market integration, price transmission mechanisms between different actors are studied, as well as the dynamic and casual relationships of international and local prices (Dutoit et al., 2010; Magaña et al., 2016; Tamayo & Palacios, 2016).

3. Methodology

In Costa Rica, broiler feed is based mainly on concentrated feed, and since almost no corn is produced in the country, these concentrates are made with imported corn.

An autoregressive distributed lag model (ADLM) is then proposed in which the CIF import price of maize depends on the international price up to *k* lags and its auto lags until the *m* one. The model can be written as follow:

$$PC_t = \theta_0 + \theta_1 PI_t + \theta_2 PI_{t-1} + \cdots + \theta_k PI_k + \cdots + \gamma_1 PC_{t-1} + \gamma_2 PC_{t-2} + \cdots + \gamma_m PC_{t-m} + v_t \quad (1)$$

where PC_t is Cost, Insurance and Freight value (CIF) for imported maize; PI_t is the international referenced price of maize.

To forecast the price of broiler meat in Costa Rica at the retail level, a structural model for the price (Equation 4) is proposed using the equality of demand (Equation 2) and supply (Equation 3), i.e., under the assumption of a market equilibrium condition.

$$QD_t = \alpha_0 + \alpha_1 PP_t + \alpha_2 PS_t + \alpha_3 IN_t + \alpha_d PS_t + \sum_1^L \alpha_{dL} D_d + u_{dt} \quad (2)$$

$$QS_t = \beta_0 + \beta_1 PP_t + \beta_2 PP_{t-1} + \beta_3 PC_t + \sum_1^L \beta_{sL} D_s + u_{st} \quad (3)$$

where, $QD_t = QS_t = Q$ is equilibrium condition.

Equality between equations (2) and (3) and mathematically clearing the price of broiler meat (PP), a reduced form price function can be obtained:

$$PP_t = \pi_0 + \pi_1 PP_{t-1} + \pi_2 PC_t + \pi_3 PS_t + \pi_4 IN_t + \pi_5 \sum_1^L \alpha_{dL} D_d + \pi_6 \sum_1^L \alpha \beta_{sL} D_s + w_t \quad (4)$$

where,

$\pi_0 = \left(\frac{\beta_0 - \alpha_0}{\alpha_1 - \beta_1}\right), \pi_1 = \left(\frac{\beta_2}{\alpha_1 - \beta_1}\right), \pi_2 = \left(\frac{\beta_3}{\alpha_1 - \beta_1}\right), \pi_3 = \left(-\frac{\alpha_1}{\alpha_1 - \beta_1}\right), \pi_4 = \left(-\frac{\alpha_2}{\alpha_1 - \beta_1}\right), \pi_5 = \left(-\frac{1}{\alpha_1 - \beta_1}\right), \pi_6 = \left(\frac{1}{\alpha_1 - \beta_1}\right)$;

$w_t = \left(-\frac{u_{dt} + u_{st}}{\alpha_1 - \beta_1}\right)$;

PP_t is retail price for broiler chicken at time t;

PP_{t-1} is retail price for broiler chicken lagged one period;

PC_t is CIF price for imported maize as variable that reflects the inputs costs;

$\sum_1^L \alpha_{dL} D_d$ is vector of dummy variables that affects the demand function;

$\sum_1^L \alpha \beta_{sL} D_s$ is vector of dummy variables that affects the supply function.

GLS version of Dickey-Fuller test (DF-GLS) was used as well as Arcos (2020), Baquedano & Liefert (2014) and Dutoit et al. (2010). On the other hand, the definition of variables used in this research is described in Table 1, some of which are quantitative and others are qualitative and, therefore, subject to dumification.

In addition to CIF import price for maize in Costa Rica, we used as regressor variables the monthly economic activity index (MINEA) as a proxy for the population´s purchasing power, the real international price of corn, and the dummy variables STRUCT and D201811 that capture price trend effects, as well as DDIC that captures the seasonal effect for price increases in the month of December.

Table 1. Research Variables

Name	Definition
$RRBRP_t$	Log of real broiler chicken in US dollars per kg.
$RCMP_t$	Log of real C.I.F. maize price in US dollars per kg.
$MINEA_t$	Log of monthly index of economic activity as proxy variable of real income[1].
$RIMP_t$	Real international price of maize in US dollars per kg.
$RRBP_t$	Log of real retail beef price in US dollars per kg (reference to chunk meat).
$STRUC_t$	Structural change condition 1 form 2015-2022, 0 otherwise. Because from 2015 the market shows a general sustained price fall in real terms.
$DDIC_t$	Dummy variable to capture the month-effect trend of price increases in the month of December in the Costa Rican market, mainly because the Christmas's traditional meals.
D201811	Dummy variable to capture the effect of an extraordinarily low behavior in the price data for the month of November 2018. It is an atypical case.
$RCMP_{t-1}$	Log of real C.I.F. maize price in US dollars per kg lagged to on period.

The database was built monthly from January 2002 to February 2022. It was not possible to incorporate more data due to the lack of reliable statistics for months prior to 2002, although data is available but on an annual basis, not monthly.

We worked with a total of 243 data made up of a chronological time series where import prices were estimated by dividing the imported CIF value by the volume according to the official import statistics of Costa Rica. Monthly international price data were taken from the World Bank database.

4. Results

4.1 The Maize Price Transmission

This section presents the results of the econometric model to measure the price transmission of maize in Costa Rica. Table 2 shows the lag selection until the maximum lag order 4. The selected lag in this case is 2 suggested by the information criterions. The asterisks below indicate the best (that is, minimized) values of the respective information criteria AIC (Akaike criterion), BIC (Schwarz Bayesian criterion) and HQC (Hannan-Quinn criterion).

Table 2. VAR System Lag Selection, Maximum Lag Order 4

Lags	loglik	p(LR)	AIC	BIC	HQC
1	665.0389	--	-5.5381	-5.4506	-5.5029
2	678.8215	0.00002	-5.6204*	-5.4745*	-5.6155*
3	679.7933	0.7461	-5.5949	-5.3907	-5.5126
4	685.8653	0.0163	-5.6123	-5.3497	-5.5065

The results of the Granger causality test applied to the relationship between the international price of maize and the CIF import price in Costa Rica using a VAR system with a lag of order 2 (Table 3), confirmed the causal relationship is in the sense that the international price causes the CIF price and not the other way around. This allows us to establish the direction of the price transmission model from the international market to the local market.

Table 3. Granger´s Causality Test Using 2 Lags

Item		**df**	**F**	**p-value**
Equation 1: Dependent variable $RIMP_t$				
All lags of $RIMP_t$		2 , 235	473.4100	0.0000
All lags of $RCMP_t$		2 , 235	0.9400	0.3937
Equation 2: Dependent variable $RCMP_t$				
All lags of $RIMP_t$		2 , 235	51.2100	0.0000
All lags of $RCMP_t$		2 , 235	128.4500	0.0000

Note: VAR system, lag order 2. OLS estimates, observations 2002:03-2022:02 (T = 240). Log-likelihood = 685.74017

The time series of the international price of maize and the CIF price of imports in Costa Rica are cointegrated and therefore a long-term relationship is expected (Table 4). This is confirmed by the Engle-Granger test where the results of the cointegration regression turned out to be stationary when both series are non-stationary and integrated of first order (1). The Johansen test indicates that the null hypothesis of no cointegrating vector is rejected and at 1% the hypothesis of the existence of a single cointegration vector is accepted.

Table 4. Cointegration test for RIMP and RCMP time series

Engel-Granger Test					
Variable	**Augmented Dickey-Fuller Model**		**Estimated Value of (a - 1)**	**tau**	**p-value**
$RIMP_t$	test with constant		-0.0301	-2.2161	0.2006
$RCMP_t$	test with constant		-0.0387	-2.1462	0.2266
$\hat{u}$	test without constant		-0.2702	-4.9147	0.0002
unit-root null hypothesis: a = 1, lag order 2					
Johansen Test					
Rank	**Eigenvalue**	**Trace test**	**p-value**	**Lmax**	**p-value**
0	0.1670	48.5520	0.0000	43.8520	0.0000
1	0.0194	4.6997	0.0302	4.6997	0.0302
Log-likelihood = 1366.83 (including constant term: 685.74)				lag order = 2	
Estimation period: 2002:03 - 2022:02 (T = 240)					

Based on the above results, an OLS model was fitted to forecast the CIF maize import price using as regressor variables the international price lagged one period (one month) and an one-period autoregressive lag for CIF price (Table 5). The model presents the expected signs and explains 94.5% of the variability of the data, it is also free of autocorrelation and according to the White test, it does not present heteroskedasticity at 10% significance.

Table 5. Price Transmission OLS Model Results

Parameter	Coefficient	Std. Error	t-ratio	p-value	
$RIMP_{t-1}$	0.3184	0.0332	9.5960	<0.0000	***
$RCMP_{t-1}$	0.6255	0.0378	16.5400	<0.0001	***
const	-0.0092	0.0211	-0.4350	0.6640	
F(2, 238)	2069.3310			3.30E-15	***
White's test LM	7.6051			0.1072	
Test for normality ji²	69.2425			9.21E-16	
AR(1) LM test	0.7530			0.3864	
Log-likelihood	340.7580				
Akaike criterion	-675.5159				
Schwarz criterion	-665.0616				
Hannan-Quinn	-671.3041				
R^2	0.9456				
Adjusted R^2	0.9452				
MAPE	1.2629				
RMSE	0.0194				

Note: OLS, using observations 2002:02-2022:02 (T = 241). Dependent variable: $RCMP_t$

4.2 The Broiler Chicken Price

In this section we present the main findings of the econometric model for the real price of chicken meat at the retail level using a logarithmic transformation on the dependent variable (Table 6). The signs obtained are consistent with those expected according to theory, however, the model presented significant heteroscedasticity that could not be corrected by applying weighted least squares.

Table 6. Broiler Chicken Price ($RRBRP_t$) OLS Results, 261 Observations

Parameter	Coefficient	Std. Error	t-ratio	p-value	
$RCMP_t$	0.0254	0.0090	2.8500	0.0048	***
$MINEA_t$	0.0365	0.0267	1.3680	0.1726	
$RRBP_t$	0.0314	0.0262	1.2040	0.2298	
$STRUC_t$	-0.0162	0.0073	-2.2310	0.0266	**
$DDIC_t$	0.0120	0.0047	2.5940	0.0101	**
D201811	-0.0652	0.0199	-3.2780	0.0012	***
$RCMP_{t-1}$	0.9444	0.0170	55.4300	<0.0001	***
const	-0.1173	0.0974	-1.2050	0.2295	
F(7, 233)	7303.0290	0.0197		4.70E-269	***
Breusch-Pagan LM	24.7948			0.0008	***
Test for normality (ji²)	2.3495			0.3089	
AR(1) LM test	1.1370			0.2874	
AR(12) LM test	2.1370			0.0321	**
Log-likelihood	608.4890				
Akaike criterion	-1200.9780				
Schwarz criterion	-1173.1000				
Hannan-Quinn	-1189.7460				
R^2	0.9955				
Adjusted R^2	0.9953				
MAPE	1.2629				
RMSE	0.0194				

Note: Dependent variable: $RRBRP_t$ (log of real broiler chicken in US dollars per kg).

The model presented a high adjusted R^2 where the independent variables explained 99.53% of the variability of the retail price, however the presence of heteroscedasticity made it necessary to approach the problem through an autoregressive general conditional heteroscedasticity model (GARCH).

Table 7 shows the results of applying a GARCH (1,1) model since the variance follows a first-order autoregressive model both in the residuals and in the variance itself.

Table 7. Broiler Chicken Price ($RRBRP_t$) GARCH (1,1) Results, 261 Observations

Parameter	**Coefficient**	**Std. Error**	**t-ratio**	**p-value**	
$RCMP_t$	0.0231	0.0086	2.6930	0.0071	***
$MINEA_t$	0.0390	0.0239	1.6300	0.1031	
$RRBP_t$	0.0455	0.0272	1.6720	0.0945	*
$STRUC_t$	-0.0213	0.0073	-2.9240	0.0035	***
$DDIC_t$	0.0102	0.0041	2.4600	0.0139	**
D201811	-0.0645	0.0202	-3.1960	0.0014	***
$RCMP_{t-1}$	0.9377	0.0185	50.5800	<0.0001	***
const	-0.1513	0.0880	-1.7190	0.0856	*
alpha(0)	9.83E-06	9.71E-06	1.0120	0.3113	
alpha(1)	0.0866	0.0482	1.7970	0.0723	*
beta(1)	0.8950	0.0498	17.9800	<0.0001	***
Test for normality (ji^2)	1.6066			0.4479	
Log-likelihood	612.2681				
Akaike criterion	-1200.5360				
Schwarz criterion	-1158.7190				
Hannan-Quinn	-1183.6890				
MAPE	1.2595				
RMSE	0.0194				

Note: Dependent variable: $RRBRP_t$ (log of real broiler chicken in US dollars per kg).

It was found that the signs of the regression coefficients are in accordance with what was expected, the normality test allows confirming the presence of normality of residuals with greater force than the OLS model since the p-value was 0.44785 against 0.308895, respectively. It is also observed how the MAPE improved slightly with the value obtained in the OLS model.

The GARCH model forecast shows an adequate fit for the historical series of real poultry meat price (RRBRP) (Figure 1) and the residuals are uniformly distributed (Figure 2), thus complying with the econometric assumptions that support the results of this research.

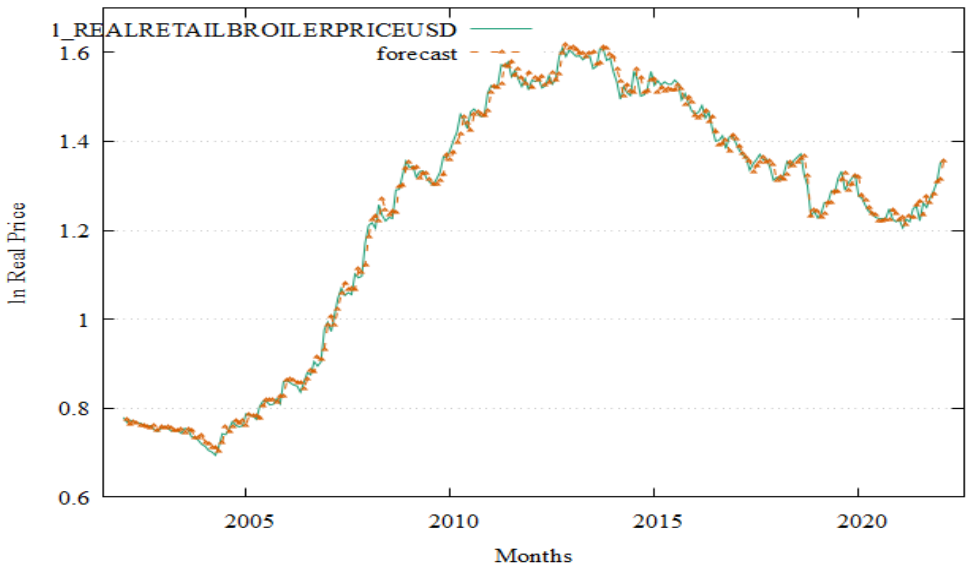

Figure 1. Historical and Forecasted GARCH Model Trend for Retail Broiler Price

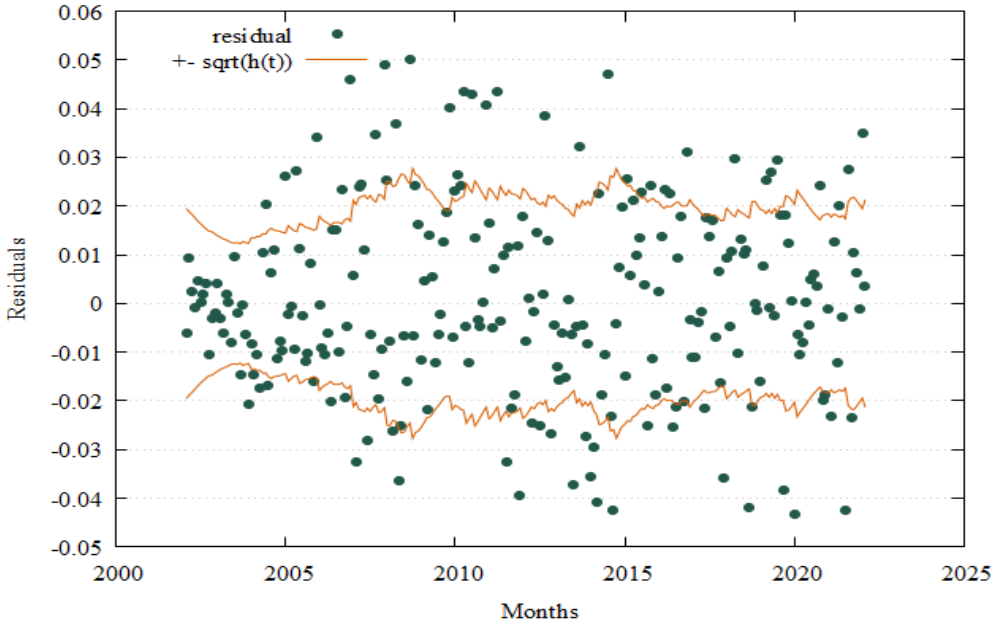

Figure 2. Residual form GARCH Model for Retail Broiler Price Model

5. Discussion

The results show how the local price of corn is strongly explained by the level of the import price of the previous period and the local price also lagged one period.

The model explained 94.56% of the variability and, in practically one month, 94.39% of the impact is transmitted, with 31.84% coming from the import price of the previous period and 62.55% coming from the local price that was self-delayed one month ago. These results are in agreement with Baquedano & Liefert (2014), who analyzed the commodity market including corn and determined that price transmission is approximately 2-4 months in 19 countries studied.

These short-term dependencies can be affected by product and market characteristics, with adjustment rates ranging from 29% to 60%, with lags of one to two months for rice and wheat in Pakistan (Umar et al., 2015). Our results show that there is a long-run relationship between world and domestic prices with respect to Granger causality. For maize the international prices determine domestic prices, similar to the findings of Işik & Özbuğday (2021), who identified a long-lasting relationship between agricultural input and food prices.

In Ghana, the integration of agricultural markets and price transmission of cassava was also analyzed with an ARDL approach revealing a first-order integration in prices (Acquah et al., 2012). In Bangladesh, the same econometric approach was applied to analyze rice price integration in a reference market, where the price was a function of other regional markets and seasonal and policy variables (Abdulai, 2000; Ravallion, 1986).

Distortions in domestic markets imply that the strength of price transmission is greater or lesser. In this sense, variations in the exchange rate of the national currency against the U.S. dollar affect the magnitude of price transmission to the domestic market, since they take international prices expressed in foreign currency (CEPAL et al., 2011). This situation is common for developing countries and has been documented for soybeans in Indonesia, as the international price and exchange rate expressed positive and significant relationships with respect to domestic prices (Ekananda & Suryanto, 2018).

The results of GARCH model for poultry prices show how an increase of one real dollar in the local price of contemporary maize (RCMP) generates an average increase of 2.31% in domestic poultry prices. The effect is stronger if a lag period ($RCMP_{t-1}$), is considered, since for every dollar increase in the previous month, the domestic broiler price is expected to increase 93.77% in the current month. The total pass-through of increase in maize cost already nationalized is achieved at 96.08% practically for two months later.

The MINEA variable that was used to represent the monthly dynamics of consumer income, shows how for each point of increase in that index, an increase of 3.89% in the retail price of broiler is expected.

An increase of 1.02% in the real price of broiler is expected because of the pressure of greater demand for festive activities to celebrate Christmas in Costa Rica (DDIC).

The effect of the outlier for November 2018 (D201811) was isolated, and its impact was estimated at 6.44% down for that month specifically only. Beginning in 2015, there was a downward trend in the overall price in the market that has shown to be sustained and its average effect was estimated at 2.12% downward (STRUC). This may be due to the more diverse offer of meats that the Costa Rican consumer currently has due to the impact of already consolidated trade agreements, veganism trends that reduce demand, among other possible factors.

Our results are in agreement with Parcell & Pierce (2000) who indicate that seasonal components and changes over time are key determinants of variations in the price of chicken meat. Understanding these patterns is fundamental for producers to anticipate changes in market prices.

In this sense, Magaña et al. (2016) emphasize that the decrease in protein intake in Mexican households with lower incomes is associated with the increase in international grain prices, for

example, with an unforeseen 1% change in maize international price, the domestic price would increase by 0.0002% after 3 months, 0.0061% after 6 months and 0.0269% after one year. This is evidence of a constant price adjustment in the medium term that can accumulate.

For the U.S. chicken industry, percentage changes in price have been reported to be five times greater than the change in demand, which confers a high elasticity (Martinez, 1999). Although this research approached the analysis with a reduced form of supply and demand equations, the results are comparative with Martinez (1999) to the extent that factors are used that affect price on the demand side, such as seasonality that are summarized in consumer preferences at certain times of the year more than in other periods.

6. Conclusions

The methodological approach applied in this research meets the requirements for measuring the effect of the international maize price on the selling price of poultry meat in Costa Rica at the retail level. Although the OLS method was not effective in estimating the price of chicken meat, GARCH model presented an adjusted coefficient of determination that shows the high capacity of independent variables to explain the variability in poultry meat price.

Many products traded in the commodities market are important to meet food security objectives, although scientific evidence shows the presence of distortions in the price transmission of domestic and international markets, which threaten the assurance and availability of food at affordable prices for the poor and small producers in rural areas of developing countries such as Costa Rica.

The effect of increases in international commodity prices on production and consumer prices is affected by the dependence on imports; in case of maize in Costa Rica, it is highly sensitive due to the deficit of local production to supply the market demand. This dependence on international prices affects the purchasing power of local consumers and increases the risk for producers, especially for commodities with high volatility or when structural conditions such as war or trade crises occur.

The results obtained in this research provide support for the analysis and decision making of production and its impact on the variability of raw material international prices, which affects the production of chicken meat and other animal meats and cereals that are part of the daily diet of Costa Ricans.

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[1] The Monthly Index of Economic Activity (MINEA, known as IMAE in Spanish) is a short-term indicator whose purpose is to approximate the evolution of the gross value of production (GVP) in a given month for the different industries that make up the Product Gross Domestic (GDP) at basic prices. The interannual variation of MINEA serves as an approximation of the monthly evolution of the VBP. Its calculation corresponds to a Laspeyres-type chained volume index (BCCR, 2012).