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ASYMMETRIC PRICE TRANSMISSION: THE CASE OF POTATO AND ONION IN COSTA RICA

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Abstract

In Costa Rica, the potato and onion agro-chains are of great importance in family nutrition and in the development of small and medium-sized producers in specific areas of the country. The study of price behavior and the way in which information is transmitted throughout the value chain represents a fundamental factor for decision-making both at the productive level and at the public policy level. The objective of this research is to analyze the process of vertical transmission of prices in the potato and onion agro-chains, as a tool to measure the efficiency in the markets. Monthly price time series were used and different modeling techniques were applied to explain the relationship between international prices, producer, wholesale and retail prices in both agricultural chains. It stands out that changes in prices are not immediately transmitted to the price paid at the farm and that the producer price reacts faster when international or wholesale prices fall than when they increase.

Keywords: *Price transmission, price asymmetry, onion prices, potato prices, time series analysis, food prices*
JEL codes: *Q13, C32, C51, E32*

1. Introduction

The study of price transmission has become relevant in the agricultural sector for several decades because there is a relationship between how agricultural markets are linked, how profits are distributed throughout the value chain, and price formation. In this sense, the potato and onion agro-chains in Costa Rica are considered sensitive foods for the population (SEPSA 2016). They are of great importance for the economy of small and medium farmers. Both products represent a little more than 50% of the area planted in vegetables; their production contributes close to 2% of the national agricultural value added (SEPSA 2019).

According to data from the CNP (2020), in recent years, potato and onion prices have shown stable behavior at different levels of marketing. However, research has yet to monitor the behavior of the prices of both products over time, nor has it explained how these prices are adjusted in the face of market shocks. One of the main limitations is the need for more consolidated and systematized information and its processing and characterization (Serrano & Morales, 2017), which weakens decision-making.

Given the above, this research aims to analyze the vertical transmission of prices in the potato and onion agro-chains to measure market efficiency. The aim is to evaluate how the links between the potato and onion value chains are integrated, understand the functioning of the markets, and adjust prices in the event of possible shocks to estimate their future behavior objectively. Although actual price transmission is widely studied internationally, in Costa Rica, it has been studied very little, specifically in horticultural products; this would be the first investigation carried out. For this reason, its contribution to generating knowledge and support for policymakers in this country is original.

2. Literature review

2.1 Price transmission

The price fulfills the function of assigning value along the chain in a market, so a shock that occurs, whether a fall or a rise at any point in the chain upstream or downstream, must be transmitted in the same way in competitive markets. If this transmission is different when it is a positive shock or a negative one from downstream to upstream or vice versa, it is known as asymmetry in price transmission (Ridha et al, 2022; McLaren, 2015; Panagiotuo, 2021).

Price transmission refers to the relationship that exists between the world market price series and a domestic market, from one market to another, or from one link to another in a value chain, which makes it possible to identify how a shock is transmitted between markets (Balcombe & Morrison, 2002).

How information is transmitted represents an essential factor in understanding changes in the prices of goods; according to Bailey & Brorsen (1989), if some actors in the agricultural chain are better informed than others, they can react accordingly. Faster way to market shocks, they will have an advantage over other participants.

Among the causes of asymmetry in the transmission of prices is the market power exercised by certain actors in the value chains, which generates pressure on the weakest links to adjust to the market conditions established by the strongest ones. This causes a poor distribution of profit margins throughout the chain and a distortion of the product's price that is directly reflected in the final consumer.

2.2 Asymmetry in Price Transmission

The transmission of prices can be vertical or horizontal, in the first case it refers to when the transmission is along the chain from producer to retail or vice versa, while the second refers to a transmission between markets (Ridha et al, 2022; Meyer & von-Cramon-Taubadel, 2004). Small farmers, especially in developing countries, are normally price takers since they do not have strong negotiation capacity over the prices of their products (Jambor et al, 2017), which is why an increase in international prices can be transmitted only through partially to the producers, while a drop in international prices can be transmitted completely and at a

greater speed to the farmer (Usman & Haile, 2017; Meyer & von-Cramon-Taubadel, 2004).

As mentioned above, the causes of asymmetry in price transmission generate inefficiency in the markets because they do not react adequately to sudden changes in any link in the chain, which reduces their competitiveness. In this sense, Rajcaniova & Pokrivcak (2013) studied the asymmetry in the transmission of prices in the potato chain in Slovakia, determining that the producer and consumer price series are not cointegrated, there is no long-term relationship between the two. Likewise, the presence of a structural change due to the world crisis in the commodity markets of 2008 was identified. As a main conclusion, it was obtained that consumer prices react more quickly to the decrease in producer prices than to the increase in these prices.

Jurkenaite & Paparas (2018), carried out an analysis on the vertical transmission of prices in the potato chain in Lithuania, in which they determined that there are no problems of inefficiency in the markets and that there is a long-term relationship between the prices paid on the farm and those of retail distributors; On the other hand, it was also confirmed that in the short term the changes in prices are influenced both by producers and by the retailers themselves. They concluded that, in the long term, price changes are transmitted with a similar intensity, and market shocks are fully transmitted between farm-gate and retail prices.

In the Netherlands, a study was carried out to determine the effect of market power on price transmission between producers and retailers in the potato agro-chain. It was concluded that the decrease in farm prices is partially transmitted to consumers, while the increase in these prices is completely transmitted. In addition, it was shown that the power of the oligopoly affects the degree to which prices are transmitted between the links. (Assefa et al., 2014).

In the same way, in the Netherlands, the asymmetry in the vertical transmission of prices in the onion and red pepper chains was analyzed to determine the response of the prices of producers, wholesalers, retailers, and international trade to changes, in both ascending and descending prices in the value chains of both products. It was determined that there is asymmetry in the onion market in this country, where wholesalers exercise power in the market and alter prices in retailers and consumers. The previous shows that shocks in wholesale and export prices directly affect the consumer since retail prices are constantly increasing. They determined that wholesale prices remain high after a market shock, so they pass the effect on to retailers who respond and pass on price growth to consumers (Verreth et al., 2015).

Rajendran (2015) conducted a study of vertical price transmission in the onion market in India. According to the author, the high margins of retailers and wholesalers distort the market and cause price asymmetry. Furthermore, positive and negative asymmetry is shown, caused by the magnitude and speed with which the market responds to price changes.

2.3 The Case of Costa Rica

In the case of Costa Rica, there are very few studies related to the transmission of prices in agricultural markets, and those that have been published have focused on products such as rice, beans, and meat. Mora (2017) carried out an analysis of the price transmission in the Costa Rican rice market and determined that, in the face of shocks in the international prices of the good, the reaction of national prices is slow due to the regulation in the price of the grain; therefore, price adjustments correspond to actions taken by the government. On the other hand, Rodríguez (2014) developed a study on the transmission of prices in the black bean market, in which a stable behavior was observed between the prices of importers and producers since the adjustment parameter accurately demonstrated the behavior of prices in the period analyzed. In addition, it was evidenced how retail prices react to changes in wholesale prices. In this case, the asymmetry in the analyzed time series was not verified. The most recent published research on price transmission in agricultural products is the study by Rodríguez & Montero (2016), who, using a VECM model, determined the existence of a long-term relationship between the meat import price and the retail price. They reported that to return to equilibrium, the retail price corrects an 8% error term monthly.

The importance of measuring this asymmetry of price transmission is to have evidence of the problem so that its causes can be investigated later. As Meyer & von Cramon-Taubadel (2004) mentioned, these causes may be due to market power in competitors, high transaction costs, and asymmetric information, among other things. Likewise, government policies can also affect price asymmetry (Bekkers et al., 2017; Rifin, 2015).

3. Methodology

3.1 Data

In this research, monthly time series of international prices were used, paid on the farm to producers, from wholesale distributors and retail prices, from 1996 to 2021, obtaining a total of 312 observations for each proposed series. The National Production Council (CNP) and the Market Information Services System (SIMM) databases were used to obtain international potato and onion import prices and the prices paid at the farm. Wholesale prices were calculated on average from wholesale distributors such as the National Center for Food Supply and Distribution (CENADA), the Borbón Market, and the Farmers' Fairs. The retail series corresponds to the prices collected in different supermarket chains in the country.

3.2 The model

Different time series modeling techniques explained the relationship between international, producer, wholesale, and retail prices in potato and onion agro-chains. The methodology consists of four stages: 1) the DFA stationarity test, 2) Johansen's cointegration test, 3) the Granger causality test, and 4) the Error Correction Model. Tests were performed using Gretl statistical software. To test the stationarity condition, the Augmented Dickey-Fuller (DFA) test was used, which in turn includes the Dickey-Fuller (DF) test:

$$\mathrm{Y}_t = \rho Y_{t-1} + u_t \tag{1}$$

Where ρ corresponds to an autocorrelation coefficient that oscillates between $-1 \leq \rho \leq 1$ and in this case, the time series (Y_t) converges to stationarity if $\rho < 1$ (Dickey & Fuller, 1979). In addition, to test the corresponding hypotheses and determine the value of "ρ", the equation (1) was transformed in first differences like that:

$$\Delta Y_t = \delta Y_{t-1} + u_t \tag{2}$$

The relationship between the variables was verified using the Johansen test because it allows testing more than one cointegration relationship and it consists of two types of tests, the trace test and maximum eigenvalue test. By applying the Johansen test, the range of cointegration r is found and the null hypothesis that H_0: $r = r_0$, against the alternative hypothesis that $r = r_0 + 1$, that is to say, if $r = 0$ then there is no cointegration relationship between the price time seriess (Johansen, 1991).

In the third phase, the Granger causality test was applied to determine which is the direction in which the causality between prices occurs and to determine if a price causes another price and how much of the selected current price variable is explained by its values. passed and by the values of the second price variable (Granger, 1969).

The last phase corresponds to the error correction model (ECM) which, according to Vavra & Goodwin (2005), is a dynamic model in which the movement of the variables in period *t* is related to the deviation of period *t-1* from equilibrium. long-term.

The error correction models (ECM) divide the data into two components, long-run equilibrium dynamics and short-run imbalance dynamics.

Accordint to von Cramon-Taubadel (1998), let be Y_t y X_t first order integrated time series I (1), with a stationary error for the cointegration regression:

$$\Delta Y_t = \beta_0 + \beta_1 \Delta X_t + \beta_2 ECT_{t-1} + \mathcal{E}_t \tag{3}$$

Where,

$$ECT_{t-1} = (Y_{t-1} - \alpha_0 - \alpha_1 X_{t-1}) \tag{4}$$

In (3) y (4), the ECT_{t-1} represents the error correction mechanism that corresponds to the error of the cointegrated equation lagged one period.

β_1 explains the short-term effect, which measures the immediate impact that a change in X_t generates on Y_t. β_2 represents the equilibrium error term whose absolute value is interpreted as the long-run equilibrium adjustment speed.

This study follows von Cramon-Taubadel & Loy (1996) and von Cramon-Taubadel (1998), where ECM are separated into symmetric error correction and asymmetric error correction; in addition, they divide the transmission of prices into short and long-term transmission.

The symmetric ECM was estimated using the residuals of the long-term cointegrating regression of the variables, called Error Correction Term (ECT). The ECM that supposes asymmetry was calculated similarly, except that the residuals are divided into positive ones (ECT+) and negative ones (ECT-), thus establishing two different adjustment speeds depending on whether the balance deviation is positive or negative.

The models created for the potato and onion agricultural chains were carried out considering the first difference of all the time series in their logarithmic transformation, with the respective bivariate analysis developed between the different levels of both markets.

These ECMs were estimated for three relationships between the potato and onion agricultural chain links: international producer, wholesale producer, and wholesale retailer. It should be noted that the onion agro-chain also includes the Retail-Producer price relationship.

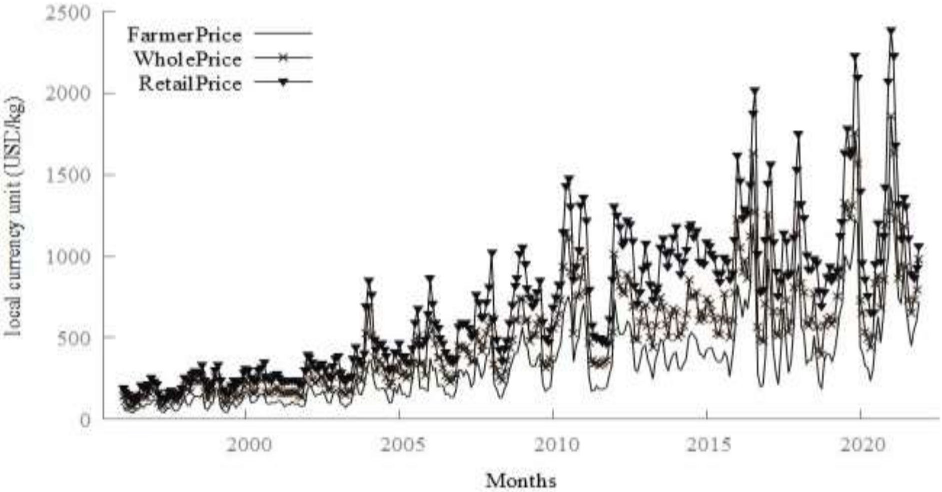
Finally, an *F* test was applied to define which of the two is better suited. For this, we start from the fact that $ECT = ECT^{+} + ECT^{-}$ therefore, to examine the presence of asymmetry in price transmission, the null hypothesis is tested that, H_0: $\beta^{+} = \beta^{-}$.

4. Results and Discussion

4.1 Historical Behavior of Potato and Onion Prices, 1996-2021

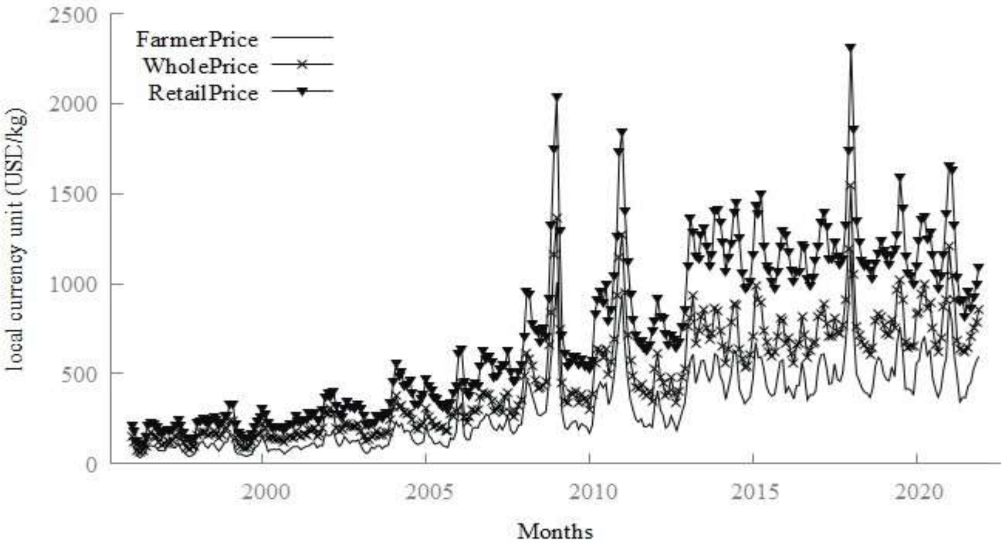
The price analysis is carried out in local currency called "colons," where the exchange rate concerning the US dollar is around 545 colons per US dollar. Figure 1 shows the behavior of the price series of the four actors (international, producer, wholesaler, and retailer) that make up the potato agro-chains; Figure 2 shows the same but for onion. From 1996 to the end of 2008, the growth of these prices did not change significantly; however, due to the food crisis in 2008 and the first months of 2009, prices increased, presenting themselves as the highest of that decade, mainly in potato case.

After the crisis, in December 2010 and early 2011, prices showed a new increase, after which the trend continued upwards. For the last months of 2017 and the beginning of 2018, there was an increase in prices attributed to weather events that affected different countries in the region. The onion price series had higher peaks in 2021, specifically attributable to the effects of the SARS-COV-2 virus.



Source: National Production Council (CNP) and the Market Information Services System (SIMM)

Figure 1. Potato prices in Costa Rica at different levels of the value chain, in local currency per kilogram (¢/kg). 1996-2021



Source: National Production Council (CNP) and the Market Information Services System (SIMM

Figure 2. Onion prices in Costa Rica at different levels of the value chain, in local currency per kilogram (¢/kg). 1996-2021)

Tables 1 and 2 present the descriptive statistics for the time series of nominal potato and onion prices, such as average values, standard deviations, maximum and minimum prices. High variability in the data during that time series can be observed.

Table 1. Potato Price Statistics for The Different Levels of the Value Chain, in Local Currency per Kilogram (¢/Kg). 1996-2021

Variable	International Price	Farmer Price	Wholesale Price	Retail Price
Mean	366.59	300.75	463.68	723.41
Standard Deviation	240.10	211.07	293.32	452.68
C.V. (%)	65.50	70.18	63.26	62.58
Min	44.61	32.00	63.33	100.94
Max	1260.84	1194.50	1543.51	2315.78

Source: National Production Council (CNP) and the Market Information Services System (SIMM)

Table 2. Onion Price Statistics for The Different Levels of the Value Chain, in Local Currency per Kilogram (¢/Kg). 1996-2021

Variable	International Price	Farmer Price	Wholesale Price	Retail Price
Mean	423.95	331.17	504.72	712.08
Standard Deviation	294.66	253.87	332.95	451.12
C.V. (%)	69.50	76.66	65.97	63.35
Min	53.83	39.00	78.75	122.99
Max	1734.53	1420.63	1855.44	2380.68

Source: National Production Council (CNP) and the Market Information Services System (SIMM)

4.2 Stationarity Testing

The Augmented Dickey-Fuller (ADF) test was applied to the variables to determine the stationarity of the respective time series, which was transformed into logarithms. Tables 3 and 4 show that all potato and onion price series are non-stationary in levels. Although the series presents stationarity in the scenario with constant and trend, the other two scenarios show the non-stationarity of prices. The test was performed with 15 lags for both cases based on the Akaike Information Criterion (AIC).

Table 3. ADF Test for Potato Prices Time Series in Levels

Variable	Lags	*P*- value		
		Without constant	With constant	With constant and trend
l_International	15	0.9223	0.5620	0.0001***
l_Farmer	15	0.9156	0.6950	6.73e-12***
l_Wholesale	15	0.9655	0.6111	2.857e-11***
l_Retail	15	0.9607	0.5459	0.0153**

Note: *, **, *** indicate significance at 10%, 5% and 1% respectively.

Table 4. ADF Test for Onion Prices Time Series in Level

Variable	Lags	*P*- value		
		Without constant	With constant	With constant and trend
l_International	15	0.9840	0.4655	0.0720*
l_Farmer	15	0.9879	0.6456	0.0402**
l_Wholesale	15	0.9899	0.5120	0.0759*
l_Retail	15	0.9958	0.4275	0.4831

Note: *, **, *** indicate significance at 10%, 5% and 1% respectively.

The results presented in Tables 5 and 6, where the first difference was applied to each price series, indicate that they are stationary in the first difference; that is, the international, farm, wholesale, and retail prices are integrated into order one. I (1), likewise, determined the number of lags applied by the AIC.

Table 5. ADF Test for Potato Prices Time Series in First Difference

Variable	Lags	*P*- value		
		Without constant	With constant	With constant and trend
l_International	15	1.225e-11***	1.119e-10***	1.534e-09***
l_Farmer	15	9.656e-12***	6.187e-11***	3.97e-10***
l_Wholesale	15	2.135e-11***	1.094e-10***	6.339e-10***
l_Retail	15	5.343e-11***	3.215e-10***	1.534e-09***

Note: *, **, *** indicate significance at 10%, 5% and 1% respectively

Table 6. ADF Test for Onion Prices Time Series in First Difference

Variable	Lags	*P*- value		
		Without constant	With constant	With constant and trend
l_International	15	1.054e-20***	3.004e-22***	5.809e-24***
l_Farmer	15	2.356e-19***	1.353e-20***	1.444e-21***
l_Wholesale	15	3.674e-19***	1.368e-20***	9.967e-22***
l_Retail	15	3.597e-18***	8.813e-20***	5.419e-21***

Note: *, **, *** indicate significance at 10%, 5% and 1% respectively

4.3 Cointegration Testing

A scheme of pairs of variables was established to identify the relationship between the main actors of the agro-chains. As seen in Table 7, the first pair corresponds to the relationship between international prices and prices paid to the producer on the farm, the second to the relationship between international and wholesale prices, the third to the relationship between producer and wholesale prices, followed by the relationship between retail and producer prices and finally, the relationship between wholesale and retail prices.

Table 7. Johansen´S Cointegration Test for Potato Prices

Relationship	lags	Rank	Eigenvalue	Trace	*P* value	Lmáx	*P* value
International/ Farmer	7	0	0.097018	33.600	0.0000	31.126	0.0000
		1	0.0080779	2.4738	0.1158	2.4738	0.1158
International/ Wholesaler	7	0	0.091142	31.100	0.0001	29.148	0.0001
		1	0.0063809	1.9524	0.1623	1.9524	0.1623
Farmer/ Wholesaler	7	0	0.088493	31.192	0.0001	28.260	0.0001
		1	0.0095686	2.9325	0.0868	2.9325	0.0868
Farmer/ Retailer	7	0	0.061345	22.547	0.0030	19.309	0.0060
		1	0.010562	3.2386	0.0719	3.2386	0.0719
Wholesaler/ Retailer	7	0	0.033797	13.128	0.1102	10.486	0.1850
		1	0.0086243	2.6418	0.1041	2.6418	0.1041

Note: Tests performed at a significance level of 5%.

According to Table 8, onion prices cointegrate between all pairs of variables. The proposed variable relationships show evidence of a long-term relationship between the prices. At least one cointegration vector exists between the series.

Table 8. Johansen´s Cointegration Test for Onion Prices

Relationship	Lags	Rank	Eigenvalue	Trace	*P* value	Lmáx	*P* value
International/ Farmer	11	0	0.048080	17.574	0.0223	14.832	0.0386
		1	0.0090712	2.7429	0.0977	2.7429	0.0977
International/ Wholesaler	8	0	0.16409	57.307	0.0000	54.488	0.0000
		1	0.0092298	2.8189	0.0932	2.8189	0.0932
Farmer/ Wholesaler	11	0	0.055074	19.691	0.0097	17.051	0.0158
		1	0.0087327	2.6401	0.1042	2.6401	0.1042
Farmer/ Retailer	8	0	0.093535	33.112	0.0000	29.853	0.0000
		1	0.010662	3.2587	0.0710	3.2587	0.0710
Wholesaler/ Retailer	8	0	0.063874	23.085	0.0024	20.066	0.0043
		1	0.0098835	3.0195	0.0823	3.0195	0.0823

Note: Tests performed at a significance level of 5%.

4.4 Causality Testing

As can be seen in Table 9, the international and producer price series present bidirectional causality in both directions. This means that the producer's price is explained by its past values and by the past values of the international price, so there is a Granger causality and vice versa. Given this situation, a discrepancy arises in the system since national farm prices should not explain international prices, but logically, international prices cause the producer's local prices.

In the series of international and wholesale prices, it is possible to observe that the direction of causality is from wholesale prices to international prices, a situation contrary to what the market dictates, so it is better to discard that model.

In the case of the producer and wholesaler variables, the results indicate that the direction occurs in only one direction, as is expected in Costa Rica, from wholesaler to producer, which means that the price paid on the farm is explained by both its past values as well as past values of the wholesale price. Regarding the series of producer and retail prices, a bidirectional causality is evident between both variables. Given this, it is concluded that the producer's prices are explained by their past and past retail price values. However, these retail prices can also be explained by their previous values and the producer's prices.

Finally, the series of wholesale and retail prices concludes that the relationship between both prices is unidirectional (Wholesale → Retail).

Table 9. Granger´S Causality Test for Potato Prices

Relationship	Lags	H_0	F-test	*P* value	Causality detected
International/ Farmer	5	Farmer price not causes intern. price	5.2254	0.0001	They cause each other
		Intern. price not causes farmer price	3.4808	0.0045	
Internationa/ Wholesaler	5	Wholesale price not causes intern. price	8.748	0.0000	Wholesale→ International
		Intern. price not causes wholesale price	1.961	0.0844	
Farmer/ Wholesaler	6	Wholesale price not causes farmer price	3.8288	0.0011	Wholesale → Farmer
		Farmer price not causes wholesale price	0.6452	0.6940	
Farmer/ Retailer	5	Retail price no causes farmer price	3.4073	0.0052	They cause each other
		Farmer price not causes retail price	3.9723	0.0017	
Wholesaler/ Retailer	7	Retail price not causes wholesale price	2.0231	0.0522	Wholesale → Retail
		Wholesale Price not causes retail price	5.4713	0.0000	

Note: Tests performed at a significance level of 5%.

Regarding onion, the results are seen in Table 10, where it is evident that the international price influences the producer's price, where the direction of causality between both time series happens in one direction, International → Producer. Likewise, in the international and wholesale onion price variables, a setback is perceived in the national market. The causality test shows a unidirectional relationship between Wholesale → International. On the other hand, it is possible to determine that the prices paid on the farm are explained by the past values of wholesale prices and by their previous values. Contrary to what happens in the potato chain, the relationship between producer and retail prices presents a relationship where the prices paid to onion producers, in addition to being explained by their previous values, are also described by retail prices. Furthermore, there is a direct relationship between wholesale and retail prices. In this case, wholesale prices influence retail prices.

Table 10. Granger´S Causality Test for Onion Prices

Relationship	Lags	H_0	F-test	*P* value	Causality detected
International/ Farmer	3	Farmer price not causes intern. price	1.2677	0.2856	International → Farmer
		Intern. price not causes farmer price	4.3182	0.0053	
International/ Wholesaler	3	Wholesale price not causes intern. price	6.4102	0.0003	Wholesale → International
		Intern. price not causes wholesale price	1.567	0.1974	
Farmer/ Wholesaler	4	Wholesale price not causes farmer price	7.2378	0.0000	Wholesale → Farmer
		Farmer price not causes wholesale price	0.2857	0.8872	
Farmer/ Retailer	9	Retail price no causes farmer price	2.9035	0.0027	Retail→ Farmer
		Farmer price not causes retail price	1.7444	0.0789	
Wholesaler/ Retailer	4	Retail price not causes wholesale price	0.74303	0.5633	Wholesale → Retail
		Wholesale Price not causes retail price	5.1501	0.0005	

Note: Tests performed at a significance level of 5%.

4.5 Error Correction Models (ECM)

Firstly, the error correction model was used to explain the relationship between the time series of international and farm prices in the potato value chain. In this case, it was decided to take the producer's price as the dependent variable while the independent variable corresponds to the international price (see Table 11). The causality test showed a bidirectional relationship between the series; however, the prices paid on the farm in Costa Rica should not explain the international prices, but the speculation of different agents could express the relationship. Furthermore, a possible cause of this situation can be explained by the size of the Costa Rican potato market, which is considerably small compared to the international market, so it moves at a different speed and, therefore, its prices can react faster to the internal market itself than to the international one.

In the symmetric model, a coefficient of 1.0052 is observed, which explains the significant short-term effect between both price series and indicates that with a 1% change in the international price, the producer price increases by 1.0052% in the same period. Regarding the long-term adjustment mechanism (ECTt-1), it is expected to present a negative sign to maintain the balance of the system. The symmetric ECM yielded a long-term adjustment effect with a correct sign significantly different from zero. Its elasticity towards the long-term equilibrium indicates that for every 1% change in the long-term equilibrium relationship, it is expected to adjust by 0.7219% each month. The asymmetric error correction model shows a significant short-term effect, demonstrating that for every 1% change in the international price in one month, an impact of 1.0122% is expected in the change in the producer price in the same month.

Two long-term adjustment mechanisms are presented, ECT+ and ECT-, which describe the condition of price deviations when they are above or below the long-term equilibrium, respectively. It is possible to see in Table 11 that the ECT+ is 0.5245 and ECT- is 0.9065, both with a negative sign and statistically significant. The margin is below its long-run equilibrium value, suggesting that producer prices react faster when the margin contracts than when it expands. The F-test determined that there is no statistical evidence to demonstrate that the asymmetric model is better than the symmetric one.

Table 11. Error Correction Model Between the International Price and the Producer Price in the Potato Agro-Chain (Variables with A Difference)

	Symmetrical Error Correction			Asymmetric Error Correction		
Variable	Coefficient	Standard test	*P* value	Coefficient	Standard test	*P* value
const	−0.000437314	0.00504732	0.9310	−0.0136233	0.0073928	0.0663*
d_l_INT	1.00521	0.0246926	<0.0001***	1.0122	0.0246688	<0.0001***
ECT_{t-1}	−0.721907	0.0544705	<0.0001***	-	-	-
ECT^{+}_{t-1}	-	-	-	−0.524486	0.0977253	<0.0001***
ECT^{-}_{t-1}	-	-	-	−0.906497	0.093364	<0.0001***
R^2			0.846255			0.849143
R^2 ajust			0.845256			0.847669
F-Stat			847.6558			576.0133
P value (*F*)			5.90e-126			1.00e-125
SC			-608.0445			-608.2031
HQ			-614.7793			-617.1829
AIC			-619.2639			-623.1622

Note 1: *, **, *** indicate significance at 10%, 5% and 1% respectively
Note 2: SC, HQ, AIC= Schwarz, Hannan-Quinn and Akaike information criteria.

Table 12. Error Correction Model Between the Wholesale Price and the Producer Price in the Potato Agro-Chain (Variables with A Difference)

	Symmetrical Error Correction			Asymmetric Error Correction		
Variable	Coefficient	Standard test	Variable	Coefficient	Standard test	Variable
const	−0.00159819	0.00453005	0.7245	−0.00249477	0.00682629	0.715
d_l_MAY	1.16267	0.0263956	<0.0001***	1.16243	0.0264722	<0.0001***
ECT_{t-1}	−0.518123	0.0482094	<0.0001***	-	-	-
ECT^{+}_{t-1}	-	-	-	−0.506577	0.0815235	<0.0001***
ECT^{-}_{t-1}	-	-	-	−0.532125	0.0931428	<0.0001***
R^2			0.876199			0.876212
R^2 ajust			0.875395			0.875002
F-Stat			1089.934			724.3475
P value (*F*)			1.90e-140			7.00e-139
SC			-675.4147			-660.7065
HQ			-682.1496			-678.6863
AIC			-686.6341			-684.6657

Note 1: *, **, *** indicate significance at 10%, 5% and 1% respectively.
Note 2*:* SC, HQ, AIC= Schwarz, Hannan-Quinn and Akaike information criteria.

Regarding the relationship between wholesale and producer prices in the potato agro-chain, the producer price was applied as a dependent variable, and the independent wholesaler price was used. According to Table 12, the symmetric model presents a short-term effect that measures the immediate impact that a change in the wholesale price generates on a change in the farm price, where a 1% variation in the wholesale price causes an increase of 1.1627% in the producer price over the same period.

The long-term adjustment mechanism determines that for every 1% deviation from the long-term equilibrium relationship, it % is expected that 0.5181% will be adjusted each month. A coefficient close to -1 would imply a more incredible speed in the transmission of prices, and if it is equal to -1, the transmission would be immediate. In this case, it is observed that a little more than half of the short-term shock seeks to return to the cointegrating relationship.

For its part, the asymmetric error correction model shows a significant short-term effect whose elasticity indicates that for every 1% change in the wholesale price in a month, an impact of 1.1624% is expected on the change in the producer price. In the same period. The long-term adjustment mechanisms show a negative sign and are significant. Therefore, the margin is below its long-term equilibrium value, suggesting that producer prices react faster when wholesale prices decrease than when they increase. In this case, it is also concluded that the asymmetric model is not statistically better than the symmetric one.

The cointegration test determined that the ECM for the wholesale and retail price series is not cointegrated. Therefore, their short-term relationship can be estimated. Still, it is impossible to establish a sufficiently stable equilibrium relationship in the short term, so it is decided not to apply the symmetric or asymmetric model.

Table 13. Error Correction Model Between the International Price and The Producer Price in the Onion Agro-Chain (Variables with a Difference)

	Symmetrical Error Correction			Asymmetric Error Correction		
Variable	Coefficient	Standard test	Variable	Coefficient	Standard test	Variable
const	0.00058515	0.00611086	0.9238	−0.00279154	0.00905855	0.7582
d_l_INT	1.02421	0.0226448	<0.0001***	1.02379	0.022687	<0.0001***
ECT_{t-1}	−0.598621	0.0522251	<0.0001***	-	-	-
ECT^{+}_{t-1}	-	-	-	−0.554791	0.101257	<0.0001***
ECT^{-}_{t-1}	-	-	-	−0.633477	0.08654	<0.0001***
R^2			0.873083			0.873189
R^2 ajust			0.872259			0.871949
F-Stat			1059.392			704.6389
P value (*F*)			8.80e-139			2.80e-137
SC			-489.0609			-483.5796
HQ			-495.7958			-492.5594
AIC			-500.2803			-498.5388

Note 1: *, **, *** indicate significance at 10%, 5% and 1% respectively.
Note 2: SC, HQ, AIC= Schwarz, Hannan-Quinn and Akaike information criteria.

Regarding the onion agro-chain, the first error correction model was carried out between the time series of international and producer prices. The independent variable of farm price and global price represents the dependent variable. The symmetric ECM represents the elasticity of the short-term effect; it shows that with a 1% change in the international price, the producer price increases by 1.0242% in the same period. The long-term adjustment mechanism indicates that for every 1% change in the long-term equilibrium relationship, it is expected that

0.5986% will be adjusted each month. The asymmetric error correction model shows a coefficient of 1.0238 in the international price on the producer price in the same month. The long-term adjustment mechanisms deduce that the margin is below its equilibrium value, suggesting that farm prices react faster when the margin contracts than when it expands. As in previous cases, it is concluded that the asymmetric model does not fit better than the symmetric one.

In Table 14, a short-term effect is observed in the symmetric model, indicating that a 1% change in the wholesale price generates an increase of 1.1330% in the farm price in the same period. The long-term adjustment mechanism of the symmetric ECM shows that the price transmission is not immediate, and the short-term shock seeks to return to the cointegrating relationship by more than half of its value in the following period.

Table 14. Error Correction Model Between the Wholesale Price and the Producer Price in the Onion Agro-Chain (Variables with a Difference)

	Symmetrical Error Correction			Asymmetric Error Correction		
Variable	Coefficient	Standard test	Variable	Coefficient	Standard test	Variable
const	−0.00019942	0.00634227	0.9749	−0.00798500	0.00985057	0.4182
d_l_MAY	1.13302	0.0279798	<0.0001***	1.13156	0.0280124	<0.0001***
ECT_{t-1}	−0.627252	0.0534891	<0.0001***	-	-	-
ECT^{+}_{t-1}	-	-	-	−0.523141	0.114108	<0.0001***
ECT^{-}_{t-1}	-	-	-	−0.696997	0.0861404	<0.0001***
R^2			0.863319			0.863792
R^2 ajust			0.862431			0.862461
F-Stat			972.7077			648.9679
P value (*F*)			7.90e-134			1.60e-132
SC			-466.0096			-461.3486
HQ			-472.7445			-470.3284
AIC			-477.2290			-476.3078

Note 1: *, **, *** indicate significance at 10%, 5% and 1% respectively.
Note 2: SC, HQ, AIC= Schwarz, Hannan-Quinn and Akaike information criteria.

Regarding the asymmetric ECM, the short-term effect shows that for every 1% change in one month in the wholesale price, an impact of 1.1316% is expected in the change in the producer price. For their part, long-term adjustment mechanisms determine that producer prices react faster when wholesale prices decrease than when they increase. The asymmetric model is not statistically better than the symmetric one.

The symmetrical and asymmetrical models were applied for the pair of retailer/producer variables, taking the producer's price as the dependent variable and the retail price as the independent variable, as shown in Table 15. The symmetrical model indicates that a 1% change in The retail price causes an increase of 1.4848% in the price paid at the farm in that same period. For its part, the long-term adjustment mechanism determines that for every 1% deviation in the long-term equilibrium relationship, it is expected to adjust 0.4815% each month, so the transmission is not immediate and the shock in the short term it takes almost half of its value to return to the cointegrating relationship.

The asymmetric error correction model shows a significant short-term effect with an elasticity of 1.4859 of the retail price on the price paid at the farm. For their part, long-term adjustment mechanisms demonstrate that producers react faster when retail prices increase than when they contract. The asymmetric model is not statistically better than the symmetric one.

Table 15 Error Correction Model Between the Producer Price and the Retail Price in the Onion Agro-Chain (Variables with a Difference)

	Symmetrical Error Correction			Asymmetric Error Correction		
Variable	Coefficient	Standard test	Variable	Coefficient	Standard test	Variable
const	−0.00195331	0.00759593	0.7972	0.00209056	0.012871	0.8711
d_l_MIN	1.48481	0.0429288	<0.0001***	1.48591	0.04308	<0.0001***
ECT_{t-1}	−0.481537	0.0427968	<0.0001***	-	-	-
ECT^{+}_{t-1}	-	-	-	−0.514465	0.0947877	<0.0001***
ECT^{-}_{t-1}	-	-	-	−0.457389	0.0753713	<0.0001***
R^2			0.804013			0.802196
R^2 ajust			0.802740			0.804110
F-Stat			631.7668			420.0682
P value (F)			1.00e-109			2.70e-108
SC			-353.9267			-348.3405
HQ			-360.6616			-357.3202
AIC			-365.1461			-363.2996

Note 1: *, **, *** indicate significance at 10%, 5% and 1% respectively.
Note 2: SC, HQ, AIC= Schwarz, Hannan-Quinn and Akaike information criteria.

Table 16. Error Correction Model Between the Wholesale Price and the Retail Price in The Onion Agro-Chain (Variables with a Difference)

	Symmetrical Error Correction			Asymmetric Error Correction		
Variable	Coefficient	Standard test	Variable	Coefficient	Standard test	Variable
const	0.00171011	0.00353799	0.6292	−0.00333699	0.00593533	0.5744
d_l_MAY	0.694318	0.0154592	<0.0001***	0.694279	0.0154562	<0.0001***
ECT_{t-1}	−0.486093	0.0337834	<0.0001***	-	-	-
ECT^{+}_{t-1}	-	-	-	−0.432448	0.0608856	<0.0001***
ECT^{-}_{t-1}	-	-	-	−0.553362	0.0719467	<0.0001***
R^2			0.877803			0.878247
R^2 ajust			0.877009			0.877058
F-Stat			1106.257			738.1684
P value (*F*)			2.60e-141			5.50e-140
SC			-829.0739			-824.4678
HQ			-835.8087			-833.4476
AIC			-840.2933			-839.4270

Note 1. *, **, *** indicate significance at 10%, 5% and 1% respectively.
Note 2. SC, HQ, AIC= Schwarz, Hannan-Quinn and Akaike information criteria.

Ultimately, the retail price is established as the dependent variable for the wholesale and retail price of the onion value chain. In contrast, the wholesale price corresponds to the independent variable. The symmetric ECM shows an elasticity of 0.6943 in the retail price change in the month. The long-term adjustment mechanism projected a coefficient of 0.4861, which concludes that with a 1% change in the long-term equilibrium relationship, the short-term shock is corrected by 0.4861% in the following period.

As seen in Table 16, the asymmetric error correction model obtained an elasticity of 0.6943 in the retail price. Long-term adjustment mechanisms show that the margin is below its long-term equilibrium value, suggesting that retail prices react faster when the margin contracts than when it increases. The asymmetric model is not statistically better than the symmetric one.

Regarding the series of retail and farm prices of potatoes, like Jurkenaite & Paparas (2018), it was shown that there is a long-term relationship between the two series. These authors found a bidirectional causal relationship between the prices paid at the farm and the retail prices in the Costa Rican potato market. This confirms that both the producer and the retailers influence short-term price shocks in both countries. Due to this condition of causality, it is impossible to determine the symmetric and asymmetric error correction models since it is necessary to have more information to explain the relationship between the variables and other statistical tests that are out of focus in this investigation.

In contrast, Rajcaniova & Pokrivcak (2013) found no long-term relationship between retail and farm-gate prices of the potato agro-chain in Slovakia. The authors determined the presence of a structural change due to the global crisis 2008, which they attribute as the cause of the non-cointegration between these series. The opposite happens in Costa Rica because, as has been demonstrated, potato prices have remained stable throughout the period analyzed, and the price series maintain a relationship in the long term.

Regarding the relationship between the potato agro-chain's wholesale and retail price series, it was shown that the retail price presents a short-term relationship with the wholesale price. Despite this, in the short term, the adjustment showed a significant effect that considers the wholesale price as a reference for setting the retail price.

In the case of the onion agro-chain, it was demonstrated that there is a long-term equilibrium relationship between the international and producer price series. The short-term adjustment is significant and proves that a change in the global price causes an impact on the price paid to the producer. In turn, the magnitude of the adjustment parameters, both symmetrical and asymmetric, show that variations in international prices are not immediately transmitted to the producer's price. In the asymmetric MCE, it was estimated that the margin is below its long-term equilibrium value, which implies that farmgate prices react faster when the margin contracts than when it expands.

The cointegration analysis also demonstrated that the prices paid to the producer present a long-term equilibrium relationship with wholesale prices, represented in the ECM. The short- and long-term adjustment coefficients are statistically significant, indicating that the Costa Rican onion market considers wholesale prices to set the prices paid at the farm. Furthermore, it was shown that the shocks that occur in wholesale prices are not immediately transmitted to farm prices. Based on the asymmetric model, it was determined that producer prices react faster when wholesale prices decrease than when they increase.

Ultimately, the wholesale and retail prices of the onion value chain have a long-term equilibrium relationship, which the symmetric and asymmetric error correction models express. Both the short-term and long-term adjustment coefficients are statistically significant, which is why wholesale prices are considered to define retail prices within the national onion market. Variations in the wholesale price are not fully transmitted to the retail price. The asymmetric model shows that the margin is below the long-term equilibrium line; retail prices react faster when the margin contracts than when it grows. Similarly, Rajendran (2015) demonstrated that retail prices in the onion value chain in India respond faster to the decrease in wholesale prices than to their increase. This situation occurs in the Costa Rican market.

As happens in the Costa Rican onion value chain, Verreth et al. (2015) found that there is cointegration between producer, wholesale, retail, import and export prices in the onion agro.

The chain in the Netherlands demonstrates that the series maintains a stable long-term relationship in both markets. As in Costa Rica, the authors highlight the market power of wholesalers over retailers and producers. In this way, in both countries, it is evident that the market shocks that occur in wholesale prices directly affect producers and consumers. However, unlike the Costa Rican situation, asymmetric price adjustments were found in the relationship between producer-wholesale prices and between import-producer prices, which, as determined, in Costa Rica, there is no evidence of asymmetry in the onion market.

5. Conclusions

This research focused on price transmission since it is one of the most determining components that influences price formation in agricultural markets. It is observed that, at the national level, prices present the same pattern in the potato and onion agro-chains. The CENADA market has historically been used to define the prices in the rest of the links of both chains to establish the price paid at the farm and the price paid by the final consumers placed by the supermarkets.

The error correction models explained the short- and long-term effects that the different variables analyzed cause on one another and the speed at which the price series return to equilibrium in the event of a market shock. It should be noted that the presence of asymmetry was not verified in any relationship proposed. Therefore, symmetric models are sufficient to describe the relationship between the variables; however, asymmetric models should be considered due to significant differences between the ECT+ and ECT- of some of the relationships.

Based on the above, it is possible to conclude that wholesale prices directly influence the prices paid at the farm and retail for both agricultural chains. This shows the excellent market power in this link between the country's potato and onion value chains. As the markets are so concentrated in one agent, there are market failures that do not allow an efficient mechanism to define prices.

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