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ASYMMETRIC PRICE TRANSMISSION IN THE TUNISIAN VEGETABLE MARKET

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Abstract

This paper examines asymmetric price transmission in farm and retail markets for four major vegetable products in Tunisia: potatoes, tomatoes, green peppers, and onions. These markets experience considerable price volatility, primarily due to the influence of various intermediaries. Analysing price transmission across different levels of the supply chain is essential for assessing market efficiency and identifying issues such as market failures, opportunistic behaviour, and information asymmetries. We employ Johansen's cointegration techniques (1988, 1995) and conduct both long-run and short-run Granger causality tests. Subsequently, we apply the Asymmetric Error Correction Model developed by Von Cramon-Taubadel (1998) and Von Cramon-Taubadel and Loy (1999) to estimate Price Transmission Elasticities (EPT) and test for asymmetric transmission. Our results reveal asymmetric price transmission in the short term for all products. However, long-term asymmetry is observed only in the potato and green pepper markets. This asymmetry is attributed to factors such as market power, government interventions, and parallel commercial channels, indicating general non-competitiveness, except in the case of tomatoes and onions over the long term.
Keywords: *Asymmetric Error Correction Model, Asymmetric price transmission, Farm Prices, Retail Prices, Tunisia, Vegetables*.
JEL Codes: *D41, Q02, Q11, Q13, Q18.*

1. Introduction

The Tunisian vegetable sector is essential to both agriculture and the national economy, playing a crucial role in securing the country’s food supply and contributing to exports. This sector is particularly significant due to the prominence of four major vegetables: potatoes, tomatoes, green peppers, and onions. These vegetables are central to the Tunisian diet and provide substantial income for farmers, with vegetable consumption estimated at 85.3 kg per capita per year in 2015. However, recent years have seen a sharp increase in vegetable prices, with price spikes even more pronounced than in previous years. This escalation has led to tensions among stakeholders, with farmers arguing that rising prices have not kept pace with production costs, and consumers expressing concerns over reduced purchasing power due to higher retail prices.

Given these challenges, it is crucial to examine the production and marketing dynamics within the vegetable sector. Policymakers require accurate information on pricing and market conditions to implement effective measures for stabilising the market and controlling intermediary profit margins. The analysis will provide insights and recommendations for policymakers to enhance agricultural policy in Tunisia. In this context, price transmission refers to the mechanism through which changes in upstream prices affect downstream prices. It is measured as the percentage change in retail price in response to a 1% change in farm price (Caps and Sharewell, 2005). Gardner's static model (1975) and the derived demand theory describe the relationships between different stages of the supply chain. Price analysis seeks to understand how prices are related across markets (Goodwin and Holt, (1999); Miller and Hayenga, (2001); Asche et al. (2002)).

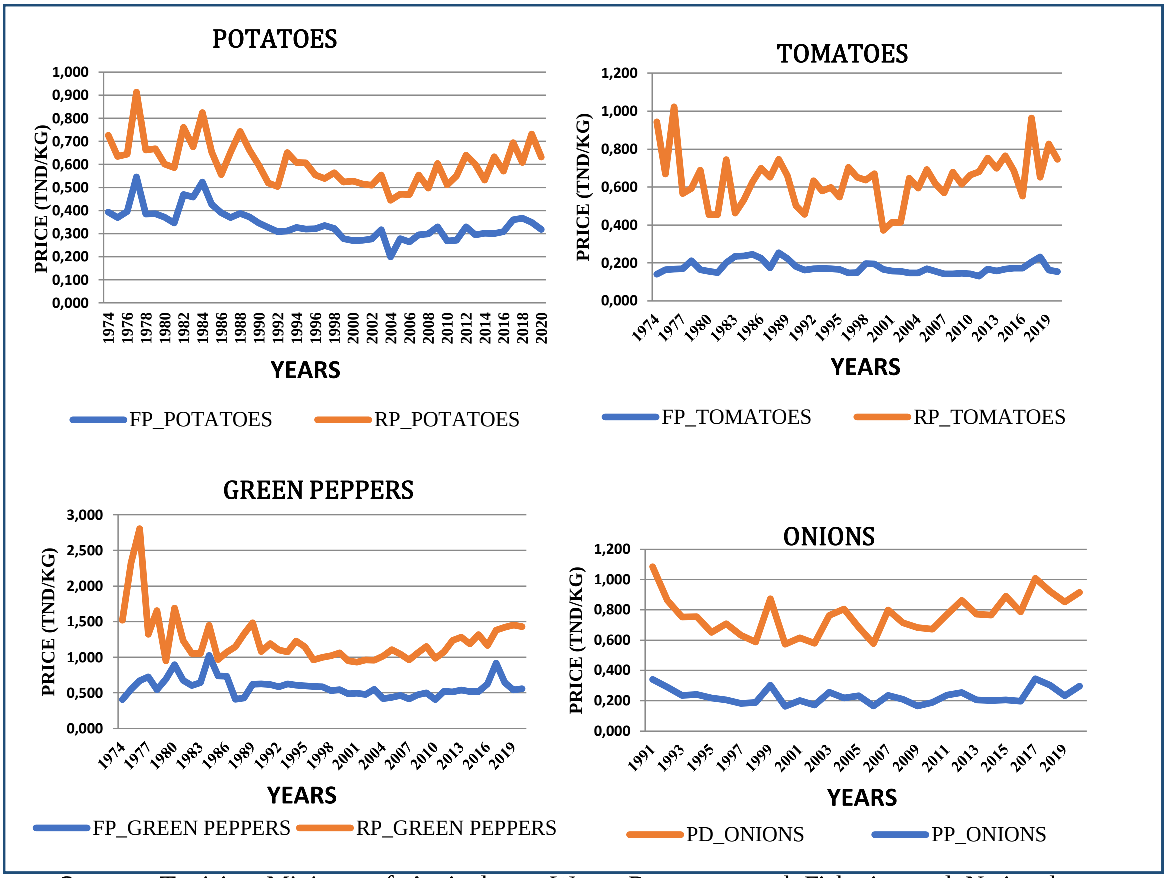
2. Overview of the Vegetable Sector in Tunisia

In 2020, the vegetable sector contributed approximately 20.4% to the value added in agriculture and fishing in Tunisia. The average value added by vegetables was around 2.51 million dinars. Green peppers led in total vegetable value with 551 million dinars, representing 21.89% of vegetable crops and 4.46% of the value added in agriculture and fishing. Tomatoes followed with a production value of 506 million dinars, accounting for 20.1% of vegetable production and 4.1% of the value added in agriculture and fishing. Potatoes had a production value of 299 million dinars, which is 11.87% of vegetable production and 2.42% of the value added in agriculture and fishing, with an export surplus estimated at 3% of total vegetable exports. Onions contributed 249 million dinars, or 9.89% of the vegetable sector's value and 2% of the overall agricultural sector.

Vegetable farming in Tunisia is highly productive, with an average production of 4.13 million tonnes in 2020. The four main products, potatoes, tomatoes, green peppers, and onions account for 70.31% of total vegetable production.Potato production reached 452 thousand tonnes in 2020. Tomato production increased from 1.01 thousand tonnes in 2013 to 1.47 thousand tonnes in 2020, marking a growth of 45.5%. Green pepper production grew from 268 thousand tonnes in 2011 to 476 thousand tonnes in 2020, an increase of 77.62%. Onion production saw a more modest rise, from 350 thousand tonnes in 2011 to 404.6 thousand tonnes in 2020, a growth of 15.6%.

The distribution of vegetables is regulated by Law No. 94-96 of 23 July 1994, which segments the market into four categories: farm markets, wholesale markets, retail markets, and refrigerated warehouses. Historically, the wholesale market has been the primary venue for transactions between farmers, wholesalers, and retailers. However, many farmers lack the equipment necessary for storage and transportation to effectively reach the wholesale market and negotiate prices. In recent years, the vegetable sector has operated under total price freedom during the production phase, following the principle of supply and demand. To protect consumers' purchasing power, the government employs several intervention mechanisms, including importing vegetables to balance supply and demand during shortfalls, offering incentives for storage or export in cases of overproduction, and setting price ceilings in wholesale markets.

Additionally, in retail markets, government interventions aim to prevent speculation and reduce gross profit margins, as outlined in the decrees of 18 January 1988 and 20 October 2020. Price trends from 1974 to 2020 show that, with the exception of onions between 1991 and 2020, farm and retail prices generally increase and decrease simultaneously.



Source: Tunisian Ministry of Agriculture, Water Resources and Fisheries and National Institute of Statistics.

Figure 1. Evolution of Real Vegetable Prices (Base Year: 2005).

3. Theoretical Framework

The marketing margin (M_m), defined as the difference between the retail price (P_R) and the farm price (P_F), reflects consumer expenditures during the marketing process, including costs for storage, transportation, and other related expenses. This margin can be modelled as a fixed component, a percentage of the retail or farm price, or a combination of both, as suggested by Tomek and Robinson (2003) and Barros (2007). The mark-up model, which applies when prices are determined at the farm level, is represented by Equation [1].

$$\text{Ln}(P_R) = \alpha_1 + EPT^F * \text{Ln}(P_F) \quad (1)$$

Where (EPT^F) represents the price transmission elasticity from the farm to the retail market. Conversely, the mark-down model, used when prices are set at the retail level, is expressed by Equation [2].

$$\text{Ln}(P_F) = \alpha_2 + EPT^R * \text{Ln}(P_R) \quad (2)$$

Where (EPT^R) denotes the price transmission elasticity from the retail to the farm market. Asymmetry in price transmission, where price changes are not uniformly transmitted between markets, can manifest in differences in magnitude, speed, or both.

The study of vertical price transmission examines four key aspects: magnitude, speed of adjustment, direction of price movements, and nature of price adjustment. Magnitude pertains to the extent of price changes transmitted through the supply chain. Speed of adjustment refers to how quickly price changes in one market affect another. Direction identifies which market's price changes influence another market. Nature concerns whether price changes (increases or decreases) are transmitted between different levels in the supply chain. Recent research has highlighted the intricate nature of price transmission, particularly emphasizing asymmetry, where the receiving market responds differently to price shocks compared to the sending market. Asymmetry can be categorized into magnitude, speed, and both magnitude and speed.

Current research employing a range of econometric models have significantly enhanced our understanding of price transmission dynamics across various markets. For instance, Kumar Paul and Karak (2022) utilized VECM Models and Threshold Autoregressive (TAR /MTAR) models in India to investigate wheat price transmission. In Indonesia, Surbakti et al. (2022) applied the Model AECM to analyze asymmetries in red chili price transmission. Kamaruddin et al. (2021) employed the NARDL model to explore coffee price asymmetries influenced by global prices and GDP. Gizaw (2021) examined the transmission of fresh and smoked salmon prices across Norway, France, and Spain using Threshold Cointegration and AECM approaches. Similarly, Ozgur Bor and Berna Tuncay (2021) used Threshold Cointegration and AECM to analyze consumer milk prices in Turkey. In Bangladesh, Deb et al. (2020) applied Johansen Cointegration techniques to study rice prices. Acosta et al. (2019) also employed Johansen Cointegration and VECM to investigate milk prices in Panama. Mandizvidza (2018) analysed tomato price transmission in South Africa using Johansen Cointegration and the Houck approach, while Zainalabidin and Iliyasu (2017) utilized the Houck approach and Granger causality tests to explore mustard and spinach prices in Malaysia. These studies underscore the importance of advanced econometric methods in unraveling the complexities of agricultural price transmission across diverse markets and economic contexts.

4. Analysis of Vertical Price Transmission

Empirical analysis of vertical price transmission typically involves econometric techniques designed to explore the relationships between prices over time and to identify any asymmetrical characteristics. Key methods include stationarity tests, cointegration analysis, asymmetric error correction models, short-term causality tests, and weak exogeneity tests. One commonly used test is the Augmented Dickey-Fuller (ADF) test, which estimates three different models to determine the presence of unit roots. The ADF test evaluates the null hypothesis ($|\rho| = 1$) against the alternative hypothesis ($|\rho| < 1$). If the null hypothesis is accepted in any of these processes, then the series is considered non-stationary. This test relies on the use of the Ordinary Least Squares (OLS) method to estimate the following three models: [1] model without constant and trend; [2] model with constant but without trend; and [3] model with both constant and trend.

4.1. Cointegration Analysis

Cointegration analysis is used to test for long-term equilibrium relationships between non-stationary series. Johansen's cointegration method (1988) is employed, which involves estimating the following Vector Error Correction Model (VECM):

$$\Delta X_t = B_1 \Delta X_{t-1} + B_2 \Delta X_{t-2} + \cdots + B_{P-1} \Delta X_{t-P+1} + \Pi X_{t-1} + \varepsilon_t \qquad (3)$$

Where, $B_j = -\left(I - \sum_{j=1}^{i} \Phi_j\right)$and $\Pi = (I - \sum_{i=1}^{P} \Phi_i)$

Here, *Π* is a matrix representing the cointegration relationships, and $(B_1, \dots \dots \dots \dots .. B_{P-1})$ are matrices capturing the short-term dynamics. The number of cointegration vectors is determined using trace and maximum eigenvalue statistics. Weak exogeneity tests are conducted to assess whether the variables are weakly exogenous, which affects the speed of adjustment and causality.

4.2. Asymmetric Error Correction Model

To investigate asymmetry in price transmission, we employ the Asymmetric Error Correction Model (AECM) developed by Von Cramon-Taubadel and Loy (1999). This model is widely regarded for its ability to test for asymmetry in both the short and long term. Granger and Lee (1989), Von Cramon-Taubadel (1998), and Von Cramon-Taubadel and Loy (1999) have constructed Error Correction Models (ECMs) that facilitate the examination of price asymmetry across these different time horizons. The most popular and extensively used model is that of Von Cramon-Taubadel and Loy (1999), which segments the error correction term (ECT_{t-1}) and exogenous price changes (B_j). The model is expressed as follows:

$$\Delta P_t^r = \alpha + \sum_{j=1}^{K}(B_j^+ D^+ \Delta P_{t-j+1}^f) + \sum_{j=1}^{L}(B_j^- D^- \Delta P_{t-j+1}^f) + \alpha^+ ECT_{t-1}^+ + \alpha^- ECT_{t-1}^- + \sum_{j=1}^{P} \Delta P_{t-j}^r \, \varepsilon_t \qquad (4)$$

The error correction term (ECT_{t-1}) is derived from the cointegration relationship, $(ECT_{t-1} = \mu_{t-1} = P_{R;t-1} - \lambda_0 - \lambda_1 P_{F;t-1})$, where $\lambda_0$and λ_1 are coefficients. In equation [4], this term (ECT_{t-1}) is decomposed into an increasing phase (ECT_{t-1}^+) and a decreasing phase (ECT_{t-1}^-), so that $(ECT_{t-1} = ECT_{t-1}^+ + ECT_{t-1}^-)$. Based on this asymmetric representation in equation [4], we can easily test the hypothesis of symmetry in both the long term and the short-term using standard tests such as the Fisher test or the White test. Specifically, we test the equality of the coefficients for price increases and decreases in equation [5] as follows:

$$H_0: \alpha_{i1}^+ = \alpha_{i1}^- \text{ et } B_{i1}^+ = B_{i1}^- \qquad (5)$$
$$H_1: \alpha_{i1}^+ \neq \alpha_{i1}^- \text{ et } B_{i1}^+ \neq B_{i1}^-$$

Rejecting the null hypothesis (H_0)at a certain significance level indicates the presence of asymmetry between the two prices in both the long term and the short term. In other words, a significant difference between the coefficients suggests that the degree of adjustment in price transmission varies between price increases and decreases, depending on the price level. Asymmetry in price transmission is confirmed when the null hypothesis, that the estimated coefficients of the respective positive and negative variables are equal, is rejected by the Fisher test, as noted by Geoetz et al. (2008).

In this study, we will use this approach, which is more widely accepted than that of Wolfram and Houck. Initially, we will apply Student's t-test to confirm the individual significance of these coefficients. Secondly, we will use the Fisher test (F) to assess the equality between the positive and negative coefficients. The non-significance of either of these coefficients can also be interpreted as evidence of asymmetry between the prices studied.

4.3. Data, Results, and Discussion

4.3.1 Description of Data and Variables Used

The variables selected for this research are solely the series of real prices observed in the initial sale markets and the final retail distribution markets. The data for this analysis consist of annual figures covering the period from 1974 to 2020, except for onion data, which begins in 1991 and continues until 2020. The prices considered include the production and retail prices of potatoes (FP_POTATOES and RP_POTATOES), tomatoes (FP_TOMATOES and RP_TOMATOES), green peppers (FP_GREEN_PEPPERS and RP_GREEN_PEPPERS), and onions (FP_ONIONS and RP_ONIONS). These data are sourced from the Ministry of Agriculture, Rural Development, and Fisheries and the National Institute of Statistics.

The Augmented Dickey-Fuller (ADF) test was employed to evaluate the stationarity properties of the price time series. This test was applied to each series of production and retail prices, both in levels and first differences. The results indicate that all price series in levels are non-stationary, but they become stationary once differenced. Consequently, each series exhibits a unit root and is integrated of order one, I (1). This finding suggests that the cointegration approach is the most suitable method for analysing asymmetric price transmission (APT).

4.3.2 Cointegration tests and long-term relationship estimations

Before proceeding with the cointegration tests, it is essential to determine the optimal number of lags between the production prices and retail prices of the three vegetables. Using a selected set of information criteria, we found that the optimal number of lags is (p* = 1). The application of the Johansen trace test (1988), with results presented in Table 1 below. The trace test indicates a single cointegration relationship between the production prices and retail prices of each vegetable product, with significance levels of 5% for potatoes and green peppers, and 10% for tomatoes and onions. At this stage, we proceed to estimate the Vector Error Correction Model (VECM) between production prices and retail prices, primarily focusing on determining the long-term relationship.

Table 1. Results of The Cointegration Test

MODELS	TRACE TEST		
POTATOES	H_0	*Trace Stat*	*Critical Value (5%)*
	r=0	18.713	15.495
	$r \leq 1$	3.686**	3.841
TOMATOES	H_0	*Trace Stat*	*Critical Value (5%)*
	r=0	19.886	17.980
	$r \leq 1$	7.014***	7.557
PEPPERS	H_0	*Trace Stat*	*Critical Value (5%)*
	r=0	28.468	25.872
	$r \leq 1$	11.447**	12.518
ONIONS	H_0	*Trace Stat*	*Critical Value (5%)*
	r=0	17.994	17.980
	$r \leq 1$	4.173***	7.557

Source: Calculated by the author using EViews 10 software.
Note: *; **; *** denote significance at the 1%, 5%, and 10% levels, respectively.

The estimated long-term relationships between production prices and retail prices for the three products are presented by product, as follows in Table 2.

Table 2. Estimation of Long-Term Relationships

POTATOES: LRP_ POTATOES = 2.608 + 0.650 *LPP_POTATOES (0.422) (0.072) {0.000}** {0.000}**
TOMATOES: LRP_TOMATOES = 10.968 - 0.880*LPP_TOMATOES (1.930) (0.374) {0.000}** {0.019}**
GREEN PEPPERS: LRP_GREEN PEPPERS = - 4.531 + 0.008 @TREND + 1.795*LPP_PEPPERS (2.705) (0.006) (0.417) {0.109} {0.142} {0.000} **
ONIONS: LRP_ ONIONS = - 4.594 + 2.012*LPP_ONIONS (2.010) (0.372) {0.022}** {0.000}**

It is well established that the price transmission elasticities between the production and retail markets of potatoes and tomatoes are less than unity, indicating imperfect price transmission for these two products. This can be attributed to several economic factors, such as logistical constraints in the supply chain, high transportation costs, and significant seasonal variations that limit rapid price adjustments between markets. Conversely, the price transmission elasticities for green peppers and onions are greater than unity, suggesting imperfect price transmission for these products as well. This over-transmission may result from factors such as high demand sensitivity to price changes, more aggressive pricing strategies in the retail sector, and storage and distribution costs that encourage swift price adjustments.

4.3.3 Causality Analyses.

Error correction models indicate that, for potatoes and tomatoes, retail price adjustments significantly contribute to restoring long-term equilibrium, with annual corrections of 88.8% and 47.2%, respectively. In the case of green peppers, only the adjustment of production prices is significant, with an annual correction of 31.9%. Onions exhibit significant adjustments in both production and retail prices, with corrections of 21.7% for production prices and 59.9% for retail prices, the latter adjusting more rapidly. The results of the weak exogeneity and Granger causality tests are summarised in Table 3. For green peppers, the hypothesis of weak exogeneity is rejected only for production prices (α_{LFP}), indicating that these prices take time to adjust to restore long-term equilibrium. In contrast, for onions, weak exogeneity is rejected for both production and retail prices, suggesting that onion prices mutually adjust to achieve long-term equilibrium.

Regarding short-term Granger causality, there is no significant causality between production prices and retail prices for potatoes and tomatoes, indicating that these prices evolve independently in the short term. In contrast, for green peppers and onions, retail prices Granger-cause production prices at the 10% significance level, suggesting short-term price transmission from retail markets to production markets. This transmission is imperfect, as an increase in retail prices results in a decrease in farmer prices, putting farmers at a disadvantage in the short term.

Table 3. Results of The Causality Tests

WEAK EXOGENEITY		
VARIABLES	Weak Exogeneity Test	P-Value
LFP_POTATOES	$\alpha_{LFP\_POTATOES} = 0$	0.404
LRP_POTATOES	$\alpha_{LRP\_POTATOES} = 0$	0.771
LFP_TOMATOES	$\alpha_{LFP\_TOMATOES} = 0$	0.024**
LRP_TOMATOES	$\alpha_{LRP\_TOMATOES} = 0$	0.179
LFP_PEPPERS	$\alpha_{LFP\_PEPPERS} = 0$	0.778
LRP_PEPPERS	$\alpha_{LRP\_PEPPERS} = 0$	0.027**
LFP_ONIONS	$\alpha_{LFP\_ONIONS} = 0$	0.096***
LRP_ONIONS	$\alpha_{LRP\_ONIONS} = 0$	0.002
GRANGER CAUSALITY		
Granger Causality test		P-Value
DLFP_POTATOES does not Granger-cause DLRP_POTATOES		0.404
DLRP_POTATOES does not Granger-cause DLFP_POTATOES		0.771
DLFP_TOMATOES does not Granger-cause DLRP_TOMATOES		0.115
DLRP_TOMATOES does not Granger-cause DLFP_TOMATOES		0.232
DLFP_GREEN PEPPERS does not Granger-cause DLRP_PEPPERS		0.902
DLRP_GREEN PEPPERS does not Granger-cause DLFP_PEPPERS		0.079***
DLFP_ONIONS does not Granger-cause DLRP_ONIONS		0.119
DLRP_ONIONS does not Granger-cause DLFP_ONIONS		0.075***

Source: Calculated by the author using EViews 10 software.
Note: *; **; *** significance at the 1%, 5%, and 10% levels, respectively.

4.3.4 Estimation of the asymmetric error correction model

To strengthen the previous results, we furthered the analysis by estimating the AECM to test for potential asymmetry in the speed of adjustment or in the coefficients of exogenous price changes. This involves segmenting the error correction term (ECT_{t-1}) into ($ECT^{-}_{t-1}$and ECT^{+}_{t-1}) and segmenting exogenous price changes (ΔLRP_{t-1}) into ((ΔLRP^{+}_{t-1})and (ΔLRP^{-}_{t-1})) and (ΔLFP_{t-1}) into (ΔLFP^{+}_{t-1} and ΔLFP^{-}_{t-1}),distinguishing between positive and negative components. The results of the estimation of the AECM, as well as the tests for equality of positive and negative coefficients using Fisher's test statistics and Wald's test, are presented succinctly in Tables 4 and 5.

POTATOES: It is noted that only the coefficient of the positive change in production price ($\Delta LFP\_POTATOES^{+}_{t-1}$) is significant at the 10% level, and the F-test rejects the null hypothesis of symmetry. This implies that, in the short term, only increases in production prices transmit to retail prices, resulting in decreases; thus, a 10% increase in production prices leads to a 5.33% decrease in retail prices. Furthermore, the negative error correction term associated with retail price (α^{-}_{LRP}) of ECT^{-}_{t-1}) is the only one that is significant, indicating that retail prices adjust each year to correct price decreases, with 86.5% of decreases being corrected annually in the retail market. In conclusion, the potato markets are characterised by asymmetric price transmission in both the short and long term. Several factors explain this phenomenon. First, the intervention of multiple traders engaging in speculation often reduces the quantity available in the market, leading to an increase in retail prices. Secondly, regulatory authorities intervene whenever deemed necessary, particularly concerning the price of this essential product for Tunisian consumers, ensuring its availability in the markets. This intervention by the Ministry of Commerce often involves resorting to imports or capping prices in the wholesale market, resulting in a decrease in retail prices.

Table 4: Estimation of Asymmetric Error Correction Models.

POTATOES						
VARIABLES	Dependent Variable					
	Eq [1]: ($\Delta LRP_{POTATOES_t}$)			Eq [2]: ($\Delta LFP_{POTATOES_t}$)		
	Coefficient	t-Stat	P-value	Coefficient	t-Stat	P-value
$\mathbf{\Delta LRP_{POTATOES_{t-1}}}$	-0.069	-0.261	0.794	-----	-----	-----
$\mathbf{\Delta LFP_{POTATOES_{t-1}}}$	-----	-----	-----	-0.391	-1.651	0.106
$\mathbf{\Delta LRP_{POTATOES^{+}_{t-1}}}$	-----	-----	-----	-0.591	-1.554	0.128
$\mathbf{\Delta LRP_{POTATOES^{-}_{t-1}}}$	-----	-----	-----	0.509	1.294	0.203
$\mathbf{\Delta LFP_{POTATOES^{+}_{t-1}}}$	-0.533	-1.857	0.070*	-----	-----	-----
$\mathbf{\Delta LFP_{POTATOES^{-}_{t-1}}}$	0.130	0.474	0.637	-----	-----	-----
C	0.030	0.832	0.410	0.060	1.410	0.166
$\mathbf{ECT^{-}_{t-1}}$	-0.865	-1.679	0.101*	0.179	0.325	0.746
$\mathbf{ECT^{+}_{t-1}}$	-0.822	-1.404	0.168	0.211	0.325	0.746
$\alpha^{+}=\boldsymbol{\alpha}^{-}$	F-statistic (1, 39) = 0.002 Probability=0.959			F-statistic (1, 39) = 0.001 Probability=0.972		
$\delta^{+}=\boldsymbol{\delta}^{-}$	F-statistic (1, 39) = 3.613 Probability=0.064			F-statistic (1, 39) = 4.444 Probability= 0.041		
TOMATOES						
VARIABLES	Dependent Variable					
	Eq [1]: ($\Delta LRP_{TOMATOES_t}$)			Eq [2]: ($\Delta LFP_{TOMATOES_t}$)		
	Coefficient	t-Stat	P-value	Coefficient	t-Stat	P-value
$\mathbf{\Delta LRP_{TOMATOES_{t-1}}}$	-0.288	-2.120	0.040**	-----	-----	-----
$\mathbf{\Delta LFP_{TOMATOES_{t-1}}}$	-----	-----	-----	-0.002	-0.013	0.989
$\mathbf{\Delta LRP_{TOMATOES^{+}_{t-1}}}$	-----	-----	-----	0.294	1.733	0.090*
$\mathbf{\Delta LRP_{TOMATOES^{-}_{t-1}}}$	-----	-----	-----	-0.001	-0.009	0.992
$\mathbf{\Delta LFP_{TOMATOES^{+}_{t-1}}}$	0.390	1.053	0.298	-----	-----	-----
$\mathbf{\Delta LFP_{TOMATOES^{-}_{t-1}}}$	0.319	0.882	0.382	-----	-----	-----
$\mathbf{ECT^{-}_{t-1}}$	-0.445	-2.414	0.020**	-0.069	-0.507	0.614
$\mathbf{ECT^{+}_{t-1}}$	-0.516	-2.147	0.037**	-0.369	-2.238	0.030**
$\boldsymbol{\alpha^{+} = \alpha^{-}}$	F-statistic (1, 40) = 0.054 Probability=0.816			F-statistic (1, 40) = 1.779 Probability= 0.189		
$\boldsymbol{\delta^{+} = \delta^{-}}$	F-statistic (1, 40) = 0.015 Probability= 0.902			F-statistic (1, 40) = 1.595 Probability= 0.213		

Source: Author's calculation using Eviews 10 software
Note: *; **; *** significance at the 1%, 5%, and 10% levels, respectively

TOMATOES: In the short term, asymmetric price transmission is observed, as only the coefficient of positive exogenous changes ($\Delta LRP\_TOMATOES^{+}_{t-1}$) in retail price is significant at the 10% level. This means that a 10% increase in retail price results in a 2.94% increase in production price. Regarding price adjustment in the long term, we find that in the first equation (Eq [1]), both the positive error correction terms (α^{+}_{LRP}) of (ECT^{+}_{t-1}) and negative error correction terms (α^{-}_{LRP}) of (ECT^{-}_{t-1}) are significant, and the F-test does not reject the null hypothesis of long-term symmetry. This indicates that, in the long term, both price increases and decreases in tomatoes are corrected each year in the same manner by retail prices, with 44.5% of decreases and 51.6% of increases corrected in the retail market.

Table 5. Estimation of Asymmetric Error Correction Models

VARIABLES	Eq [1]: ($\Delta LRP_{PEPPERS_t}$)			Eq [2]: ($\Delta LFP_{PEPPERS_t}$)		
GREEN PEPPERS						
	Dependent Variable					
	Coefficient	t-Stat	P-value	Coefficient	t-Stat	P-value
$\mathbf{\Delta LRP_{PEPPERS_{t-1}}}$	-0.458	-3.020	0.004**	-----	-----	-----
$\mathbf{\Delta LFP_{PEPPERS_{t-1}}}$	-----	-----	-----	0.133	0.876	0.386
$\mathbf{\Delta LRP_{PEPPERS^+_{t-1}}}$	-----	-----	-----	-0.603	-1.964	0.056*
$\mathbf{\Delta LRP_{PEPPERS^-_{t-1}}}$	-----	-----	-----	-0.057	-0.308	0.759
$\mathbf{\Delta LFP_{PEPPERS^+_{t-1}}}$	-0.168	-0.479	0.634	-----	-----	-----
$\mathbf{\Delta LFP_{PEPPERS^-_{t-1}}}$	0.145	0.520	0.605	-----	-----	-----
C	-0.011	-0.233	0.816	0.018	0.425	0.673
$\mathbf{ECT^-_{t-1}}$	-0.140	-0.685	0.497	0.231	1.442	0.157
$\mathbf{ECT^+_{t-1}}$	0.031	0.188	0.851	0.404	2.842	0.007**
$\alpha^+ = \boldsymbol{\alpha}^-$	F-statistic (1,39) = 0.286 Probability=0.595			F-statistic (1,39) = 0.456 Probability= 0.503		
$\delta^+ = \boldsymbol{\delta}^-$	F-statistic (1,39) = 0.342 Probability= 0.561			F-statistic (1,39) =1.822 Probability= 0.18		
ONIONS						
	Dependent Variable					
VARIABLES	Eq [1]: (ΔLRP_{ONIONS_t})			Eq [2]: (ΔLFP_{ONIONS_t})		
	Coefficient	t-Stat	P-value	Coefficient	t-Stat	P-value
$\mathbf{\Delta LRP_{ONIONS_{t-1}}}$	-0.620	-2.584	0.016**	-----	-----	-----
$\mathbf{\Delta LFP_{ONIONS_{t-1}}}$	-----	-----	-----	0.207	0.835	0.412
$\mathbf{\Delta LRP_{ONIONS^+_{t-1}}}$	-----	-----	-----	-0.815	-1.808	0.083***
$\mathbf{\Delta LRP_{ONIONS^-_{t-1}}}$	-----	-----	-----	-0.244	-0.518	0.609
$\mathbf{\Delta LFP_{ONIONS^+_{t-1}}}$	0.488	1.719	0.098***	-----	-----	-----
$\mathbf{\Delta LFP_{ONIONS^-_{t-1}}}$	0.133	0.551	0.586	-----	-----	-----
$\mathbf{ECT^-_{t-1}}$	0.381	1.944	0.064*	0.488	2.028	0.054**
$\mathbf{ECT^+_{t-1}}$	0.079	0.432	0.669	0.667	2.828	0.009**
$\boldsymbol{\alpha^+ = \alpha^-}$	F-statistic (1, 23) = 1.034 Probability= 0.319			F-statistic (1, 23) = 0.250 Probability= 0.621		
$\boldsymbol{\delta^+ = \delta^-}$	F-statistic (1, 23) = 0.928 Probability= 0.345			F-statistic (1, 23) = 0.710 Probability= 0.407		

Source: Author's calculation using Eviews 10 software .
Note: *; **; *** significance at the 1%, 5%, and 10% levels, respectively

Therefore, we can conclude that tomato markets exhibit asymmetric transmission in the short term and symmetric transmission in the long term. This short-term asymmetry may be attributed to factors such as seasonal harvests, rapid fluctuations in demand, and transportation costs. In the long term, the symmetry in price correction suggests that adjustments in the retail market also influence production prices proportionately, indicating a gradual stabilisation of prices across both markets. The short-term asymmetry is primarily explained by the perishability of the product. Tomatoes are highly perishable, which sometimes leads retailers to refrain from increasing their prices whenever production costs rise, for fear of not being able to sell their products and risking spoilage due to a lack of customers.

GREEN PEPPERS: It is observed that all coefficients in equation (Eq [1]) ($\Delta LFP\_GREEN\ PEPPERS^{+}_{t-1}$; $\Delta LFP\_PEPPERS^{-}_{t-1}$) are not significant. However, in equation (Eq [2]), the coefficient for positive exogenous changes associated with retail price ($\Delta LFP\_PEPPERS^{+}_{t-1}$) is significant at the 10% level, indicating that a 10% increase in the retail price leads to a 6.03% decrease in the production price in the short term. This suggests that in the short term, price transmission in the green pepper market is asymmetric, in that retailers increase prices only in the retail market. This asymmetry may be due to factors such as consumer demand dynamics in the retail sector, where quick adjustments aim to maintain profitability despite fluctuations in production costs.

Similarly, only the positive component of the error correction term associated with production price (α^{+}_{LFP}) in (ECT^{+}_{t-1}) is significant at the 5% level. This also implies that, in the long term, the production price adjusts annually to offset increases occurring solely in the retail market, accounting for 40.4% of these increases each year. This asymmetry in price adjustment may reflect strategies related to production cost management and profit margins within the green pepper supply chain. In summary, it is observed that price transmission in the green pepper market is asymmetric in both the short and long terms. This could certainly be explained by the influence of traders and retailers in both types of markets.

ONIONS: Lastly, in the case of onions, it is noted that only the coefficients of positive exogenous changes associated with farm price ($\Delta LFP\_ONIONS^{+}_{t}$) and retail price ($\Delta LRP\_ONIONS^{+}_{t}$) in equations (Eq [1] and Eq [2]) are significant at the 10% level. We observe that in the short term, a 10% increase in retail price translates into a 4.88% increase in farm price, while a 10% increase in farm price leads to an 8.15% decrease in retail price. Therefore, we can conclude that in the short term, onion markets are characterised by asymmetric price transmission, as only price increases are transmitted between levels, reflecting the dominance of retailers in the markets. Indeed, any price increase from their side leads to a decrease in farm prices.

Consequently, this negatively impacts the interests of farmers. Regarding the speed of price adjustment, from the second equation (Eq [2]), we deduce that both coefficients of the error correction terms associated with production price (α^{-}) in (ECT^{-}_{t-1}) and (α^{+}) in (ECT^{+}_{t-1}) are statistically significant at the 10% and 5% levels. This leads us to test the equality between these two coefficients using the Fisher statistic (F-test). This test decides not to reject the hypothesis of symmetry at the 5% significance level, proving that in the long term, price transmission between onion markets is symmetric. Given that onion farmers adjust their prices annually in response to decreases and increases in the retail market in the same manner.

5. Conclusions and Policy Implications

5.1. Research Conclusions

This research examines asymmetric price transmission between farm and retail prices of four main vegetable products in Tunisia: potatoes, tomatoes, green peppers, and onions. The methodology adopted includes Johansen's cointegration approach (1988, 1995) and the asymmetric error correction model by Von Cramon-Taubadel and Loy (1999), followed by tests for weak exogeneity and Granger causality (1969). The empirical results indicate that the retail and farm markets in Tunisia are characterised by joint fluctuations in prices. In the long term, price transmission is imperfect for all four products. Prices for potatoes and tomatoes are primarily determined in the production markets, while retailers adjust their prices on an annual basis. This imperfection in price transmission can be attributed to the nature of production costs, farmer pricing strategies, as well as the dynamics of supply and demand in retail markets. In contrast, the price of green peppers is primarily determined in the retail market, with farmers adjusting their prices annually. As for the price of onions, it is primarily determined in the retail market, with these two prices adjusting annually to unequal extents. In the short term, there is no price transmission in the potato markets and in the tomato markets, indicating a significant imbalance between these two markets. In contrast, there is price transmission in the onion markets and the green pepper markets, moving from retail markets to farm markets.

Finally, asymmetry in price transmission was detected and validated for potatoes and green peppers in the long term through the estimation of the asymmetric error correction model (AECM) and coefficient equality tests. For potatoes, this price asymmetry is the inevitable result of speculation by various actors and intervention by regulatory authorities in the supply chain, which often resort to importing and/or imposing price ceilings in the wholesale market. For green peppers, this asymmetry is primarily the result of the influence exerted by traders and retailers in these markets. In the short term, asymmetric price transmission between the two markets has been detected and validated for all four products, indicating that the markets for the four main Tunisian vegetables are significantly imbalanced and exhibit several dysfunctions. This asymmetry arises from the involvement of multiple stakeholders in the supply chain, speculation, and the storage of certain sensitive products in the market, alongside the dominance of retailers and traders. Ultimately, based on these results, Tunisian vegetable markets appear non-competitive and are affected by various dysfunctions.

Consequently, they are not efficient in the short term, which impacts both consumer and farmer interests. This inefficiency can be economically explained by barriers to entry in the market, non-competitive behaviours such as price manipulation by supply chain actors, and speculation and storage practices that disrupt the normal functioning of the market. Currently, vegetable farmers are in a weakened position due to the dominance and control that traders and retailers exert over the markets.

5.2. Implications and Policy Recommendations

Asymmetric price transmission in Tunisian vegetable markets has political repercussions. The dominance of intermediaries and the practice of selling outside legal channels—meaning without going through wholesale markets—along with the Ministry of Commerce's intervention in wholesale markets through various regulations (such as imports and price ceilings), hinder the effective formation of prices in the absence of reliable price information. All of these impacts purchasing power, living standards, and income distribution. It also leads to a misalignment in production and marketing efforts. Currently, the living standards of the main actors (farmers and consumers) have significantly deteriorated, while those of intermediaries have improved year after year due to accumulated gains from handling large quantities of goods and from certain questionable or illegal business practices, such as false invoicing or hoarding.

The current marketing system, farmer support programmes, and price regulations may disproportionately benefit intermediaries at the expense of farmers and consumers. For these reasons, I propose the following recommendations and suggestions:

(1) Strengthen and enhance the mechanism for the distribution of vegetables and the organisation of farmers.

It is clear that the Tunisian government should support and guide vegetable farmers, enabling them to access wholesale markets to sell their products and negotiate prices directly.Indeed, these farmers often lack familiarity with wholesale markets and tend to sell directly from the field. Setting up and organising production cooperatives is recommended to supervise farmers, coordinate their efforts, improve production conditions, and safeguard their interests. This approach would enable farmers to strengthen their position in the market and address the existing imbalance between farmers and consumers.

(2) Strengthen the oversight of the wholesale vegetable market and reformulate the relevant laws and regulations.

(3) Establish a daily price announcement platform for major vegetables to accurately inform supply and demand.

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