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Sustainable Food Value Chains: Approaches to Transaction Costs in Agro-Alimentary Systems of Developing Countries—A Chile Case Study

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Abstract: This study delves into the dynamics of price linkages and transaction costs in agricultural markets, emphasizing the sustainability of food supply chains. By exploring vertical and horizontal price linkages in agro-farming value chains of a developing country, it addresses the efficiency of market information transmission and the capacity for arbitrage among chain participants. The methodological core of the research involves analyzing price linkages in Chilean horticultural wholesale markets, focusing on key vegetables such as, onions, lettuce, maize, and tomatoes. This analysis is underpinned by a novel approach that models and estimates time-dependent, conditional threshold bands, extending the traditional cointegration models. This method allows a more nuanced understanding of how agricultural market linkages evolve over time, enhancing our comprehension of price transmission behavior and market integration. The results reveal significant non-linear relationships between fuel prices and vegetable prices, particularly in central Chilean regions. This finding challenges the traditional linear perspective, suggesting that factors such as storage capacity and arbitrage behavior can influence price signal transmission. Such insights are crucial for stakeholders in the agribusiness value chain, offering a deeper understanding of market dynamics and aiding in the development of more sustainable and efficient market strategies. This research contributes significantly to the field of agricultural economics by providing a more robust framework for analyzing market behaviors and transaction costs in the context of sustainability and value chains. Its findings have profound implications for both theory and practice, informing policy-making and strategic decision-making in the agribusiness sector.

Keywords: food supply chains; transaction costs; market integration; developing countries; Chile

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1. Introduction

Prices carry economic insights, and analyzing price relationships across distant markets can elucidate economic connections within agricultural supply chains. These connections play a crucial role in understanding the transmission of information across space and time, particularly in the context of volatile economic conditions. Accurately modeling price relationships is crucial, as it shapes the ability of market participants to engage in price discovery, effectively market products, and enhance profit margins [1].

Agricultural markets provide a rich context for studying price connections in geographically dispersed food systems. Daily price determination and diverse delivery options inherent in these markets lead to arbitrage opportunities. The increasing focus on sustainability in food supply chains, driven by various stakeholders, necessitates industry and retail assessment and enhancement of environmental and social performance [2]. Establishing sustainable supply chains is crucial for future competitiveness and stakeholder approval. This study aims to comprehensively evaluate sustainability in supply chains, emphasizing collaboration and sustainable relationships beyond traditional economic, social, and environmental dimensions [3]. The theoretical framework delves into business-level dynamics of sustainability within supply chain relationships. The research examines vertical and horizontal price connections among agents in agro-farming value chains, assessing their arbitrage capacity and market information transmission efficiency.

In agricultural value chains, transaction costs play a crucial role in determining the sustainability of commodity prices across spatially separated yet economically interconnected markets. In this sense, ref. [4] highlights the significance of integrating sustainable development into supply chains, emphasizing the life cycle assessment in oil, gas, and agricultural biotechnology. Transaction costs within these chains can impact ecological capital exchanges, affecting agri-environmental goods and sustainability efforts contribute insights into the exploration of future competitive advantages through sustainable supply chains [5]. These costs between market "i" and "j" comprise transport costs (fij), where distance significantly influences how transaction costs are formed, variable costs (vij) related to rates, cargo insurance, contracts, financial expenses, hedging, sanitary and phytosanitary barriers, customs duties (dij), and unmeasurable costs (wij), such as opportunity cost, the cost of searching for information, and risk premiums [5]. Though difficult to pinpoint precisely, these expenses can be depicted by a neutral threshold band illustrating price differentials among markets. This principle, termed "regime-dependent" price transmission in scholarly works, suggests that surpassing typical transaction costs initiates arbitrage, forming a sustained price association defined by a band where prices deviate solely due to transaction costs [6]. The upper and lower bounds of this neutral band act as triggers for arbitrage actions when breached, specifically when price differentials surpass either limit.

Threshold models, vital in capturing regime-dependent spatial price transmission, categorize observations into subclasses based on a variable, assuming constant thresholds. While extensively explored in econometric theory, attention has shifted towards varying-coefficient models, especially in cross-sectional and time series analyses. In supply chain analysis, assuming time-invariant thresholds may be overly restrictive. Economic models rarely maintain constant parameters, necessitating models with time-dependent thresholds. Time-varying thresholds offer a better understanding of economic variables, especially concerning transaction costs in a typical food chain, affected by changing factors like agricultural imports/exports relative to macroeconomic variables. The literature questions constant thresholds, inadequately capturing inaction bands due to seasonal supply variations, favoring time-varying threshold models for accuracy [7–9].

This study presents a novel methodology for modeling time-dependent, conditional threshold bands to understand agricultural market evolution, enhancing comprehension of price transmission and market integration within the food chain. By extending the cointegration model, it estimates conditional, time-dependent thresholds, improving modeling flexibility and capturing factors influencing price-linkage behaviors, especially during dynamic chain changes. Additionally, it assesses the impact of these factors and quantifies their effects. Using a flexible cointegration model, it analyzes weekly wholesale prices in Chilean markets, focusing on key vegetables. Employing data sourced from Chilean governmental records, this analysis calculates thresholds for transaction costs. It demonstrates that models incorporating variable thresholds yield superior correlations, thereby improving our understanding of market connections. Such results are essential for the processes of price discovery and marketing within linked markets. This marks a notable progress in the development of models that capture the temporal dynamics of price interconnections, offering a more accurate depiction of behaviors within unstable agricultural markets. Ultimately, this study enhances our comprehension of market mechanisms and supports the formulation of effective strategies for stakeholders in these markets [10].

2. Methodology

2.1. Data

An examination of price connections in Chilean wholesale markets for horticultural products (WMs) was undertaken to assess variable thresholds and the associated transaction cost bands. According to ODEPA, these WMs account for 79% of the domestic horticultural production. The regions of Arica (IR), Coquimbo (IVR), Valparaiso (VR), Metropolitan (MR), and Maule (VIIR) collectively contribute to 81% of the national annual agricultural production volume. Weekly wholesale prices (in USD/Kg) from August 2021 to August 2023 for these regions were considered, focusing on the four most cultivated vegetables in Chile: onion, lettuce, maize, and tomato. These vegetables represent 38% of the total cultivated vegetable surface, 28% of total domestic trade (in value), and 18% of total producer units. Fuel prices (CHF) were derived from Chilean real prices obtained from ODEPA (2023), the Chilean Statistical Office (INE), the Chilean Institute for Agricultural Development (INDAP), and the National Petroleum Company of Chile (ENAP). These series are expressed in USD (for vegetables) and USD/Liter (for Chilean fuel retail prices). The list of markets and regions considered in this article are presented in Figure 1.

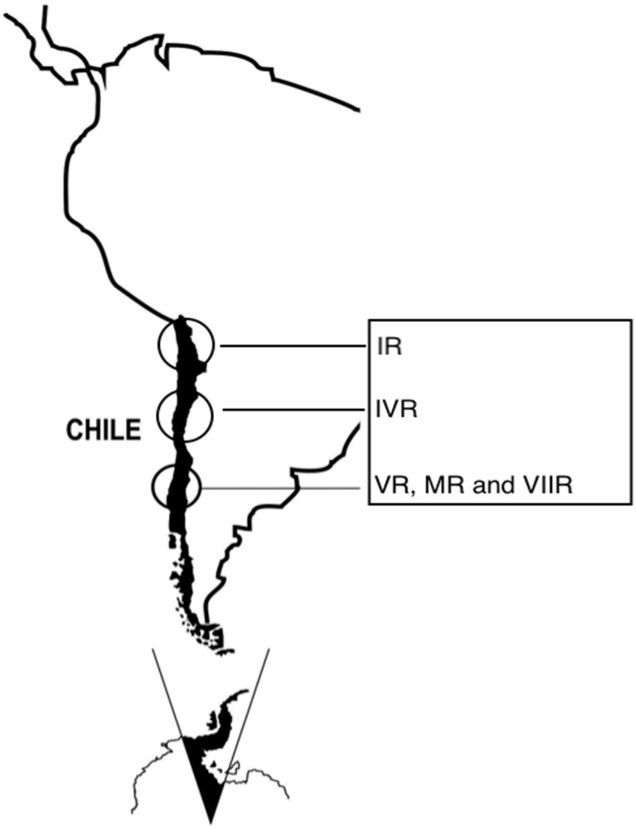

Figure 1. Geographical location of the markets considered in this study. Source: Own elaboration based on map sourced from the Military Geographic Institute of Chile. Available online: https://www.igm.cl (accessed on 11 March 2021).

2.2. Empirical Framework

The empirical objectives of this research were focused on identifying thresholds and estimating threshold parameters within a time-varying framework (if thresholds exist). The utilization of fuel prices (diesel) as an exogenous variable allows for an understanding of its impact on the price transmission process. The estimation strategy comprises several steps. Initially, the Elliot–Rothemberg–Stock (ERS) test for non-stationarity was executed [11]. Heterogeneity, autocorrelation, and non-normality were evaluated using the Alexandersson SNHT, Breusch–Godfrey LM, and Lomnicki–Jarque–Bera tests, respectively. Subsequently, series with missing values underwent interpolation using the Kalman method, ensuring uniformity across vegetables. The Keenan test identified nonlinearity. Employing interpolated data, the approach outlined in [12] was followed, involving the calculation of the first difference in price values before determining the price difference between localities (in logarithmic terms) to eliminate seasonality patterns. Fuel prices (CHF) are based on Chilean real prices obtained from ODEPA, the Chilean Statistical Office, the Chilean Institute for

Agricultural Development, and the National Petroleum Company of Chile. These series are expressed in USD (for vegetables) and USD/Liter (for Chilean fuel retail prices). In reference to the price transmission model, it is postulated that the autoregressive connection is intrinsically influenced by the historical price parity relationship. Consequently, the regime-switching framework can be delineated in the following manner:

$$\begin{cases} \theta = 1\ and\ \delta^{(1)} = 1, & if\ \leq \widetilde{P}_{t-1} \leq \tau_t^{upper} \\ \theta = 1,\ \gamma = 1,\ and\ \left|\delta^{(2)}\right| < 1, & if\ \widetilde{P}_{t-1} > \tau_t^{upper} \\ \theta = 1,\ \gamma = 1,\ and\ \left|\delta^{(3)}\right| < 1, & if\ \widetilde{P}_{t-1} < \tau_t^{lower} \\ . \end{cases} \quad (1)$$

In situations where the lagged price parity relationship does not intersect either the upper or lower threshold ($\tau_t^{lower} \leq \widetilde{P}_{t-1} \leq \tau_t^{upper}$), the regime θ = 1 becomes active. In this scenario, the autoregressive parameter $\delta^{(1)}$ is employed to elucidate the connection between $\widetilde{P}_t$ and $\widetilde{P}_{t-1}$. Conversely, upon crossing a threshold, assuming a stationary price parity relationship, autoregressive parameters $\left|\delta^{(2)}\right| < 1$ and $\left|\delta^{(3)}\right| < 1$ depict a return to a long-term price relationship.

As denoted by Equation (1), when upper or lower thresholds cross, equilibrium regimes display a symmetric autoregressive mechanism. Nevertheless, research indicates that asymmetric adjustments can arise (e.g., [13,14]). Many extant studies presuppose constant thresholds for transaction cost bands over time, τ_(t) = τ. However, it has been contended that this assumption might compromise statistical analyses in spatial price evaluations [15]. Moreover, recent scholarship underscores that a neutral transaction cost band may not persist inconstantly over the long term [16]. Consequently, both symmetric and constant threshold assumptions are relaxed by permitting the threshold value, $\tau_t^h(h = \{lower, upper\})$, to be contingent upon exogenous factors. This affords a more comprehensive and adaptable depiction of transaction costs and facilitates the comprehension of its price interconnections in spatially disjointed but linked markets. Following [17], three regimes were chosen for the analysis: down, middle, and up. Initially, autoregression order estimation for each series was conducted. Constant thresholds were calculated using a SETAR analysis, symmetric thresholds via cointegration, and asymmetric thresholds also through a cointegration method. The fuel and vegetable series were considered for the estimation of the last two models.

3. Results and Analysis

3.1. Preliminary Tests

The ERS test was performed for both the series corresponding to each vegetable and the common series between vegetable and fuel prices (cointegration). The critical values (1%, 5% and 10%) are also shown (see Table 1).

Table 1. Unit root tests.

Vegetable	Zone	Type	Statistic	Critical Value_1%	Critical Value_5%	Critical Value_10%
Onion	VR-VIIR	vegetable	−9.39	−3.48	−2.89	−2.57
		vegetable–diesel	−8.60	−3.48	−2.89	−2.57
	VR-MR	vegetable	−7.09	−3.48	−2.89	−2.57
		vegetable–diesel	−6.19	−3.48	−2.89	−2.57

Table 1. *Cont.*

Vegetable	Zone	Type	Statistic	Critical Value_1%	Critical Value_5%	Critical Value_10%
Lettuce	VR-IVR	vegetable	−9.40	−3.48	−2.89	−2.57
		vegetable–diesel	−9.43	−3.48	−2.89	−2.57
	VR-MR	vegetable	−6.11	−3.48	−2.89	−2.57
		vegetable–diesel	−6.52	−3.48	−2.89	−2.57
Maize	VR-VIIR	vegetable	−3.16	−3.48	−2.89	−2.57
		vegetable–diesel	−2.73	−3.48	−2.89	−2.57
	VR-MR	vegetable	−2.89	−3.48	−2.89	−2.57
		vegetable–diesel	−2.53	−3.48	−2.89	−2.57
Tomato	VR-IR	vegetable	−8.08	−3.48	−2.89	−2.57
		vegetable–diesel	−8.89	−3.48	−2.89	−2.57
	VR-MR	vegetable	−7.24	−3.48	−2.89	−2.57
		vegetable–diesel	−6.8157	−3.48	−2.89	−2.57

Drawing from the results, it becomes apparent that the null hypothesis is rejected for both the vegetable-related series and the cointegrated series. To evaluate the superiority of the non-linear specification over the linear counterpart, the Hansen and Seo test was employed. The outcomes of this test reveal the statistical significance of the non-linear specification. Finally, the residuals exhibited neither heterogeneity nor autocorrelation, indicating their adherence to the model assumptions. Test results are available upon request.

3.2. Model Parameter Estimates

Tables 2–5 present the estimated transaction costs, expressed in the threshold value between each price pair. Following [16], three types of threshold band models are presented in these tables. Initially, a transaction cost band featuring an unchanging symmetric threshold was assumed, a prevalent assumption in numerous scholarly works. Estimating this framework serves as a benchmark for appraising the proposed variable threshold band framework. The inferred parameters from the unchanging threshold framework furnish insights into the robustness of market connections, exposing essential price differences that are essential for stimulating arbitrage activities. Subsequently, two categories of variable threshold band frameworks were computed. One presupposes uniform transaction costs across markets, whereas the other permits asymmetry, mirroring the diverse expenses linked to trade orientations. For example, infrastructural aspects of transportation often favor one-way streams, thereby affecting transaction costs correspondingly. An initial comparison of the adequacy between constant and variable band model estimations aids in evaluating the appropriateness of variable threshold specifications for delineating price linkage configurations [17].

The onion ranks second in both acreage and production value in Chile. Predominantly grown in the Central regions (Metropolitan, Fifth, and Seventh regions), the cultivated area has maintained an annual average of 10,000 hectares over the last decade. Approximately 40% of this area is allocated to early and mid-season onions, while 60% is dedicated to storing onions [18].

The results for price pairs, specifically VR-VIIR and VR-MR, reveal negative thresholds, indicating a potential non-linear relationship between fuel prices and vegetable prices in these regions. Significant p-values in the Keenan test support the evidence of non-linearity in the relationship between market flows and fuel prices. This implies that changes in fuel prices exhibit non-linear effects on onion prices, underscoring the importance of accounting for such complexities in the analysis.

Table 2. Estimation results for both constant and variable threshold models (onion).

Onion Price Parity by Regions	Keenan Test (p-Value)	Constant Thresholds (SETAR)		Symmetric Threshold (TVAR)		
		$\tau_t^h = \phi_0$	SSE	$\tau_t = \phi_0 + \phi_1 D_t$		SSE
				ϕ_0	$\phi_1 D_t$	
VR-VIIR	3.1977×10^{-22}	−1.8817 *** (0.2547)	5.1262	−1.1726 (0.2256) ***	0.0032 (0.0069)	6.8679
VR-MR	4.6749×10^{-26}	−0.5988 * (0.2488)	4.5597	−0.6382 (0.2381) **	−0.0095 (0.0077)	7.3712

Onion price parity by regions	Asymmetric threshold (TVECM)					
	$\tau_t^{lower} = \phi_0 + \phi_1 D_t$		$\tau_t^{upper} = \phi_0 + \phi_1 D_t$		SSE	Hansen test (p-value)
	ϕ_0	$\phi_1 D_t$	ϕ_0	$\phi_1 D_t$		
VR-VIIR	−0.5429 (0.1777)	0.0012 (0.9122)	−0.1966 (0.0074) **	−0.0016 (0.4003)	27.1262	0.075
VR-MR	−0.9018 (0.0094) **	−0.0024 (0.8084)	−0.0783 (0.1864)	−0.0032 (0.0608)	29.1618	0.085

The symbols *, **, and *** represent statistical significance at the 10%, 5%, and 1% levels, respectively, while bootstrapped standard errors are enclosed in parentheses.

Table 3. Estimation results for both constant and variable threshold models (Lettuce).

Lettuce Price Parity by Regions	Keenan Test (p-Value)	Constant Thresholds (TAR)		Symmetric Threshold (TVAR)		
		$\tau_t^h = \phi_0$	SSE	$\tau_t = \phi_0 + \phi_1 D_t$		SSE
				ϕ_0	$\phi_1 D_t$	
VR-IVR	3.2515×10^{-17}	−0.8533 *** (0.0905)	26.9672	−1.0594 (0.2080) ***	−0.0156 (0.0058) **	8.2499
VR-MR	2.7143×10^{-12}	−0.9112 *** (0.0933)	34.652	−0.8418 (0.0992) ***	−0.0041 (0.0026)	36.8569

Lettuce price parity by regions	Asymmetric threshold (TVECM)					
	$\tau_t^{lower} = \phi_0 + \phi_1 D_t$		$\tau_t^{upper} = \phi_0 + \phi_1 D_t$		SSE	Hansen test (p-value)
	ϕ_0	$\phi_1 D_t$	ϕ_0	$\phi_1 D_t$		
VR-IVR	−0.4447 (0.1827)	−0.0055 (0.5362)	−0.1196 (0.2272)	0.0008 (0.7493)	23.1302	0.14
VR-MR	−0.1523 (0.4557)	−0.0015 (0.7570)	0.0334 (0.8503)	−0.0031 (0.4691)	32.3235	0.375

The symbols **, and *** represent statistical significance at the 5%, and 1% levels, respectively, while bootstrapped standard errors are enclosed in parentheses.

Previous evidence suggests that storing capacity can limit the extent of price transmission, influenced by the smoothing effect of arbitrage on the price formation process [19]. Producers' ability to market stored onions at any time restricts the impact on price signal transmission. These findings bear significant implications for understanding price dynamics in agribusiness value chains within these key producing regions. Strategies and policies related to vegetable production and marketing in these areas, such as improving storage capacity and encouraging infrastructure investments, can contribute to a more resilient and equitable onion market in Chile.

In contradistinction to alternative vegetables, half of the lettuce cultivation transpires within the Chilean central vicinity (IVR, VR, and MR). This area undergoes dual sowing intervals (March–May and October–November) with a concise post-harvest duration (averaging 3 weeks). Assessments employing the Keenan examination within the TAR framework unveil exceedingly diminished metrics, robustly repudiating the null hypothesis of non-cointegration.

Table 4. Estimation results for both constant and variable threshold models (maize).

Maize Price Parity by Regions	Keenan Test (p-Value)	Constant Thresholds (TAR)		Symmetric Threshold (TVAR)		
		$\tau_t^h = \phi_0$	SSE	$\tau_t = \phi_0 + \phi_1 D_t$		SSE
				ϕ_0	$\phi_1 D_t$	
VR-VII	0.0006	−0.5791 *** (0.1653)	9.3058	−0.2837 (0.3699)	−0.0285 (0.0117) *	6.2216
VR-MR	0.0020	−0.8092 *** (0.1661)	15.2168	−0.4703 (0.2814)	−0.0164 (0.0083)	13.882
Maize price parity by regions	Asymmetric threshold (TVECM)					
	$\tau_t^{lower} = \phi_0 + \phi_1 D_t$		$\tau_t^{upper} = \phi_0 + \phi_1 D_t$		SSE	Hansen test (p-value)
	ϕ_0	$\phi_1 D_t$	ϕ_0	$\phi_1 D_t$		
VR-VII	−0.3757 (0.0131) *	−0.0023 (0.6123)	0.0484 (0.6469)	−0.0035 (0.2756)	27.2056	0.89
VR-MR	−0.3373 (0.3422)	−0.0041 (0.7044)	−0.0717 (0.1352)	−0.0002 (0.9163)	29.4019	0.115

The symbols * and *** represent statistical significance at the 10% and 1% levels, respectively, while bootstrapped standard errors are enclosed in parentheses.

Table 5. Estimation results for both constant and variable threshold models (tomato).

Tomato Price Parity by Regions	Test de Keenan (p-Value)	Constant Thresholds (TAR)		Symmetric Threshold (TVAR)		
		$\tau_t^h = \phi_0$	SSE	$\tau_t = \phi_0 + \phi_1 D_t$		SSE
				ϕ_0	$\phi_1 D_t$	
VR-IR	1.7780×10^{-16}	−0.8994 *** (0.1679)	11.8204	−0.7632 (0.1031) ***	−0.0088 (0.0025) ***	34.5434
VR-MR	1.6816×10^{-8}	−0.0647 (0.2682)	5.1138	−0.9564 (0.1382) ***	−0.0021 (0.0039)	25.6269
Tomato Price parity by regions	Asymmetric threshold (TVECM)					
	$\tau_t^{lower} = \phi_0 + \phi_1 D_t$		$\tau_t^{upper} = \phi_0 + \phi_1 D_t$		SSE	Hansen test (p-value)
	ϕ_0	$\phi_1 D_t$	ϕ_0	$\phi_1 D_t$		
VR-IR	−0.6969 (0.0037) **	−0.0148 (0.0087) **	−0.1713 (0.0013) **	−0.0014 (0.2659)	55.2996	0.005
VR-MR	−0.8354 (0.0002) ***	0.0029 (0.6273)	−0.0512 (0.4139)	−0.0020 (0.2316)	38.5256	0.705

The symbols **, and *** represent statistical significance at the 5% and 1% levels, respectively, while bootstrapped standard errors are enclosed in parentheses.

The negative and significant ϕ_0 coefficients in the TAR model indicate substantial price differences between regions, necessary for triggering arbitrage. In the TVAR model, both ϕ_0 coefficients are negative and significant, suggesting similar transaction costs in both directions, while $\phi_1 D_1$ coefficients are small. The TVEC model allows transaction costs to vary based on trade flow, reflecting typical seasonality effects. For IVR, the positive but small $\phi_1 D_1$ coefficient contrasts with the negative but also small coefficient for MR.

In summary, the presence of constant and variable thresholds highlights clear price differences needed to activate arbitrage between markets. Consequently, fuel prices prove inefficient as a trimming parameter in the context of a threshold cointegration model. Moreover, arbitrage advantages from seasonality effects are challenging to obtain, resulting in a more sensitive response of wholesale prices to fuel price increases and relatively lower profitability compared to other species. As per [3], these conditions directly impact the gross margin of wholesale markets, exacerbated by irregular supply behavior and a short post-harvest period for lettuce.

Regarding maize, the TAR model assumes constant price differences are necessary for arbitrage activation. The τ values for VR-VIIR and VR-MR, −0.5791 *** and −0.8092 ***, respectively, indicate narrow price differences required for arbitrage. This supports our earlier observation that arbitrage for yearly crops (with low producer prices) is more elastic than for cash crops (with higher price segmentation), aligning with prior research [20,21].

The symmetric threshold model (TVAR) posits uniform transaction costs in both directions, reflected in τ values closer to zero. This could imply lower transaction costs or greater market integration, possibly influenced by the geographic location and high population density of both markets. Studies suggest that, in the absence of infrastructure limitations, logistical capacity responds effectively to demand [22], leading to decreased arbitrage conditions through more efficient information flows. These factors seem fulfilled in the analyzed markets for maize.

The asymmetric threshold model (TVECM) allows variable transaction costs depending on trade flow direction, with τ_lower and τ_upper values indicating variability. Compared to other vegetables, the effect of the threshold variable is among the lowest, implying that lower fuel prices only narrowly affect the margin where trade between markets remains profitable.

Tomatoes are among the most consistently supplied vegetables in Chilean markets, constituting 70% of all greenhouse production and complementing outdoor production when it cannot meet market demands [23]. Despite being sensitive to winter frost, fresh tomatoes are available throughout the year. Cultivated across diverse conditions from the Arica Region (North-IR) to Valparaiso and Metropolitan Regions (Central-VR and MR), the crop predominantly comes from the north during April–September, ensuring a steady supply. This stability is reflected in the observed regime structure. Estimates reveal consistent transaction costs for moving tomatoes in both directions. The variable asymmetric threshold allows transaction costs to vary based on trade flow direction, which is crucial when commodity flows are primarily unidirectional. Despite production areas in distant regions (e.g., first region-IR), a constant vegetable flow minimizes the impact of transaction costs on arbitrage capacity. Differences in price transmission elasticity seem tied more to infrastructure and logistics than market supply/demand factors, highlighting that farmer profitability hinges on the speed of product supply, rather than fuel price differences between regional and central markets.

4. Conclusions and Recommendations

This study uses a flexible cointegration model to analyze weekly wholesale vegetable prices in Chile, aiming to elucidate the dynamics of agricultural market linkages and price transmission over time. Key findings show that storage capacity significantly influences price transmission, restricted by arbitrage and seasonality, impacting wholesale price sensitivity to fuel cost increases and profitability. Non-linear relationships between fuel and specific vegetable prices indicate varied effects across different vegetables, highlighting the need for nuanced policy approaches to improve market efficiency and sustainability by enhancing storage and infrastructure. Policy interventions focusing on storage capacity improvement, addressing seasonality challenges, promoting market integration, regulating intermediaries, and encouraging infrastructure investments can contribute to a more resilient and equitable vegetable market in Chile. Finally, the study emphasizes the necessity of considering time-dependent threshold bands when modeling price transmission behaviors in agro-farming value chains, providing valuable insights for stakeholders. Future research should explore climate change's impact on agricultural market dynamics and the role of technology in market efficiency. Studies should assess public policies promoting sustainable agriculture, infrastructure investments, and subsidies for climate-resilient practices to stabilize markets and reduce volatility.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The datasets utilized in this study are available from the corresponding author upon reasonable request.

Conflicts of Interest: The author declares no conflicts of interest.

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