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Quantifying the Impact of Cereal Price Changes on Food Security in Tunisia: A Panal Threshold Regression Model

Ibtissem Gannoun[1]*, Naoufel Liouane[2], Dorsaf Jammali[3], Hassen Ben Jenana[4]

[1]Department of Economics and International Trade, Higher Institute of Business, University of Sousse, Sousse, Tunisia, [2]Department of Economics, Higher Institute of Finance and Taxation, University of Sousse, Sousse, Tunisia, [3]Department of Economics, Higher School of Economic and Commercial Sciences Tunis, University of Tunis, Tunis, Tunisia, [4]Arab East College, Riyadh, KSA. *Email: ibtissemgannoun@gmail.com

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ABSTRACT

This study examines the relationship between cereal price volatility and food security in Tunisia from 1991 to 2021 using a Panel Threshold Regression (PTR) model. The findings reveal a significant regime shift at a cereal price index of 4.6131, delineating low- and high-price regimes. Results show that rising cereal prices negatively impact food security but to a lesser extent during high-price volatility periods, highlighting the importance of ingrained consumption patterns and government interventions, such as subsidies. GDP per capita, real effective exchange rate, and external debt show varying influences across regimes. The study recommends diversifying import sources, enhancing local agricultural productivity through sustainable practices, and improving debt allocation efficiency. Policymakers should focus on price stabilization, targeted subsidies, and trade competitiveness to strengthen food security and resilience. The study underscores the need for comprehensive strategies addressing structural vulnerabilities and fostering long-term sustainability in Tunisia's food system.

Keywords: Food Safety, Panel Threshold Regression, Tunisia
JEL Classifications: Q18, C23, C12, F32, E32

1. INTRODUCTION

Tunisia's food security is heavily reliant on imported grains, with over 50% of its cereal needs, including wheat, barley, and maize, sourced from international markets. This substantial import dependency exacerbates the country's trade deficit, strains foreign exchange reserves, and poses risks to macroeconomic stability.

While fluctuations in global grain prices have a limited impact on overall domestic demand, Tunisian smallholder farmers are particularly vulnerable to input price volatility. Rising production costs, without commensurate increases in output prices, erode farmers' profitability and livelihoods. In 2019, Tunisia recorded an agricultural trade deficit of approximately US$2 billion, and the FAO reported that 15% of the population faced moderate to severe food insecurity. Despite government interventions aimed at enhancing food security, challenges persist due to economic volatility, socioeconomic disparities, climate shocks, and limited access to food.

Fluctuations in grain prices exert a significant influence on food inflation in Tunisia, given the substantial role of grains and their derivatives in household consumption. These price increases are affecting low-income households, eroding their purchasing power at the micro level and exacerbating poverty at the macro level.

This paper examines the relationship between cereal price fluctuations and food security in Tunisia from 1991 to 2021

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using the Panel Threshold Regression (PTR) model. The choice of the Panel Threshold Regression (PTR) model in this research is driven by its ability to capture non-linear dynamics and regime shifts, which are essential for understanding the complex relationship between cereal price volatility and food security. Unlike linear models, which assume constant relationships across the entire dataset, the PTR model allows for the identification of distinct regimes based on a threshold variable. This offers a more nuanced understanding of the impact of cereal price variations on food security in different contexts. The PTR model aims a comprehensive analytical framework to examine the specific effects of each regime, providing more arguments to policymakers to design targeted interventions that strengthen food security, particularly during periods of high price volatility. This approach ensures that the results obtained are not only statistically significant but also grounded in a robust theoretical framework. Indeed, the use of the Panel Threshold Regression (PTR) model allows for the identification of non-linear effects and regime shifts that would have been overlooked by classical linear approaches.

The PTR model results are thus based on a rigorous methodology that takes into account contextual specificities and structural variations in the data. Therefore, grounded in established economic theories related to food security, price volatility, and household and market responses, this approach enables a coherent interpretation of results. The model incorporates key explanatory variables such as GDP per capita, inflation, terms of trade, external debt, poverty, and the real effective exchange rate, recognized for their impact on food security. This connection between empirical findings and underlying economic forces strengthens the research's relevance and utility for policy and strategic guidance.

The remainder of this paper is structured as follows: the next section provides a literature review, section 3 describes the data used and explains the empirical methods, section 4 presents the results of the descriptive and empirical analysis, section 5 offers recommendations and concludes the paper.

2. LITERATURE REVIEW

There is mixed evidence on the effects of rising food prices on food insecurity. The majority of studies have found increased food insecurity (Compton et al., 2010; D'Souza and Jolliffe, 2012; Akter and Abul Basher, 2014). However, others have not seen any change or even improvement in food security (Dorward, 2012; Verpoorten et al., 2013). Others have concluded outright that the effects are ambiguous (Amolegbe et al., 2021).

Several studies have examined the link between price volatility and food security, highlighting the need for government intervention, particularly in developing countries, to mitigate the effects of price volatility on hunger levels (Gouel, 2013; Gouel, 2014).

Verpoorten et al. (2013) analyzed data from over 50,000 individuals across 18 sub-Saharan African countries between 2005 and 2008 and found that the dramatic rise in global food prices significantly exacerbated existing levels of food insecurity. However, the impact was highly heterogeneous: food security improved in eight of the countries studied, while it deteriorated in ten others.

Matz et al. (2015) demonstrated that elevated cereal prices exert a negative influence on food security indicators in both urban and rural Ethiopia. Their study, utilizing quarterly household survey data and market price data, revealed a pronounced adverse effect, particularly among urban populations. The research highlighted the challenges faced by poor households in maintaining adequate food consumption, especially during periods of moderate drought.

Diagne (2014) cautioned that government interventions, while often intended to enhance food security, can inadvertently introduce market distortions that increase price volatility and may ultimately worsen food insecurity. He proposed that agricultural liberalization could be a viable alternative to address these challenges.

Other studies have examined household welfare under conditions of high price volatility (Bellemare et al., 2013; Shittu et al., 2018, Grami and Rejeb, 2015, Arib and Et-Touile, 2022). Wossen et al. (2018) investigated the combined effects of climate change and price fluctuations on food security, concluding that both factors significantly reduce household income and compromise food security. The authors argued that existing adaptation mechanisms are inadequate to address the complex challenges posed by climate change and price volatility. They advocated for complementary policy interventions to enhance resilience.

Contributing to the growing body of literature on the nexus between energy and food prices, Taghizadeh-Hesary et al. (2019) provide empirical evidence supporting the hypothesis that energy price shocks, particularly those related to oil, have a significant impact on agricultural food prices. Their findings corroborate the results of previous studies by Ibrahim (2015), Cabrera and Schulz (2016), Mawejje (2016), Al-Maadid et al. (2017), and Osei et al. (2024), which have examined the transmission of volatility between energy and agricultural commodity markets.

Pawlak and Kołodziejczak (2020) emphasize the critical role of agricultural productivity in bolstering food security and price stability. In contrast, Amolegbe et al. (2021) examine the negative impacts of rice price volatility on household food security in Nigeria. Their panel data analysis reveals that the increased volatility of imported rice prices poses a significant threat to household food security. While the study provides evidence supporting income and consumption patterns consistent with economic theory, the heterogeneous effects across households with different rice production levels remain inconclusive. The findings underscore the need for caution when implementing policies that could influence imported food prices.

Using the Herfindahl-Hirschman Index and Shannon-Wiener Index, Ali et al. (2023) conducted a comprehensive assessment of the vulnerability of the UAE's food system to external shocks. Their analysis, spanning from 2012 to 2020, revealed that the

country's concentrated reliance on a limited number of grain suppliers, notably Russia, increases its susceptibility to supply chain disruptions, thereby jeopardizing food security. The study highlights the need for a more diversified and resilient food supply chain.

Shagaida and Ternovsky (2023) contribute to the literature on food security by examining the impact of price volatility and policy interventions in Russia. Their study reveals that the price caps introduced in 2021 were ineffective in safeguarding food security. The authors argue that a more nuanced understanding of the factors influencing food security is necessary to develop effective policy measures. They propose a reassessment of Russia's food security indicators over the 2020-2022 period as a first step in this direction.

Alam et al. (2024) employed a panel data analysis to investigate the immediate and long-term effects of food price shocks, triggered by the COVID-19 pandemic, on household food security in Burkina Faso· Their findings indicate that price shocks led to significant and persistent increases in food insecurity, particularly among the poorest and rural households. These results highlight the vulnerability of these populations to food price fluctuations.

The global cereal price index exhibited considerable volatility over the period 1991-2021, with pronounced spikes in 2008 and 2011. In 2008, the index surged by 23.2 points to 117.5, and in 2011, amid the European sovereign debt crisis, it reached a peak of 131.9. However, as highlighted by Wossen et al. (2018), Tunisian domestic grain prices remained relatively insulated from these global market fluctuations due to government subsidies.

Tunisian food security is largely contingent on the availability of cereals, given that the national diet heavily relies on cereal products and their derivatives (Abis, 2012). Considering that countries dependent on food imports are particularly susceptible to global price fluctuations (De Schutter, 2009). Several studies and research efforts have been conducted on food security and its dimensions in in Tunisia, however, often the work focusing on descriptive and qualitative analyses, (Chebbi and Lachaal, 2004; Ben Kahla, 2019; Chebbi et al., 2023). Indeed, there are econometric studies on food safety, but none of them employ the threshold model, (Chebbi and Lachaal (VAR model, 2007), Jeder et al. (VECM, 2020), Ben Abdallah et al. (VECM, 2023), Habib and Jmaii (MLM, 2024). Nevertheless, in this study, we aim to assess the level of cereal food security in Tunisia by identifying the threshold for regime change within the context of persistent high price volatility of cereal, using the Panel Threshold Regression model (PTR) as defined by Hansen (1999). This study will focus on analyzing the impact of these price fluctuations on Tunisia's food security, specifically through the lens of cereal demand.

3. ECONOMETRIC MODEL AND METHODOLOGY

In this study, we employ a threshold model to examine the nonlinear relationship between price volatility and food security in Tunisia. This approach, pioneered by Hansen (1999), allows for regime shifts in the data based on a threshold variable. By identifying these thresholds, we can capture potential asymmetries in the impact of price shocks on food security, providing a more nuanced understanding of the relationship compared to traditional linear models. We note that food security is subject to a complex interplay of macroeconomic and climatic factors, with varying impacts across different contexts. The PTR model enables us to:

- Analyze the dynamic interactions between these factors under diverse price volatility scenarios.
- Develop targeted policy recommendations for each regime, particularly during periods of heightened price instability

Our threshold model describing the relationship between food security and the cereal price index, and having a single transition function, can be written as follows:

$$y_{it} = \mu_{it} + \alpha_0 \pi_{it} \Pi (q_{it} < k) + \alpha_1 \pi_{it} \Pi (q_{it} > k) + \beta_\gamma x_{it} + \varepsilon_{it} \quad (1)$$

Where $i = 1,\ldots, N$ is the number of individuals and $t = 1,\ldots, T$ determines the analysis period, y_{it} represents domestic demand as a proxy for the food security of each product i, with, x_{it} the vector of control variables, ε_{it} the error term. Annual series, covering the period 1990-2021, were used for this purpose and transformed into log variation so that the results could be interpreted as elasticity.

Domestic demand serves as a pivotal indicator of a country's food security, measuring the overall accessibility of food within its borders. Building on the four pillars of food security availability, access, utilization, and stability established at the 1996 World Food Summit, we contend that availability is the foundational dimension. The IFPRI (2010a) has developed a composite index to assess food security, incorporating factors such as the food trade balance, agricultural productivity, and the Global Hunger Index. While the choice of proxy variables for food security is context-specific (Pinstrup, 2009; Barrett, 2010), we propose using net domestic demand as a comprehensive measure of national food security, aligning with Mhiri's (2022) framework:

Food security = domestic production - exports + imports.

We have adopted this approach insofar as it is rare for a country to be self-sufficient in food, and national production alone cannot guarantee availability. It is in this sense that we support the presence of export and import flows of foodstuffs.

As for the control variables, x_t, we specify that we have retained five control variables, namely, per capita GDP expressed in US dollars and in constant 2015 terms (GDPc), (Chianeh et al., 2021; Mashref, 2024), the ratio of the poor population based on the national poverty line (SP), (Padilla, 2008; Abdulai and Kuhlgatz, 2012; Kumar and Sharma, 2013; Moncada et al., 2022), the net barter terms of trade index (2000 = 100) (ITE), (Mary, 2019), the stock of external debt (expressed in current US$) (DE), (Yerima and Tahir, 2020), the real effective exchange rate index (2010 = 100) (TCER), (Huchet et al., 2013; Applanaidu et al., 2014) and

the inflation rate in Tunisia, approximated by the consumer price index (IPC), (Jeder et al., 2020; Yerima and Tahir, 2020). π_t is the threshold variable being the cereal price index (IP), (Verpoorten et al. (2013), Applanaidu et al. (2014), Kalkuhl and Maximo (2016), KoÃ et al. (2017), Shittu et al. (2018), Wossen et al. (2018), Mashref, 2024). And μ_t the random effect. The table above provides a complete list of the variables retained, along with their corresponding definitions and data sources.

The transition function in Hansen's (1999) threshold model is defined by an indicator function that equals one when a specified condition is met and zero otherwise. To ensure model identification, Hansen imposes two key restrictions: The explanatory variable and the threshold variable must be time-varying, and the error terms must be independently and identically distributed with a constant variance. The model allows for a regime shift at the threshold, where the coefficient on the explanatory variable changes. In the simplest case of a two-regime model, the threshold value is estimated from the data. The parameters α_i is the coefficient α_0 if $q_t \leq k$ and α_1 if $q_t > k$. This model presents panel data with several distinct regimes, each characterized by linear dynamics. The transition is abrupt, given that a product can switch from one regime to another in one period. In our case, the panel threshold regression (PTR) model takes the following form:

$$logSA_{it} = \alpha_0 + \alpha_1 log\,(IP)_{it} + \alpha_2 log\,(GDPc)_{it} + \alpha_3 log\,(IPC)_{it} + \alpha_4 log\,(SP)_{it} + \alpha_5 log\,(ITE)_{it} + \alpha_6 log\,(DE)_{it} + \alpha_7 log\,(TCER)_{it} + \varepsilon_t, si\ (q_t \leq k) \quad (2)$$

Where i = 1..., 4 is the number of individuals, i.e. the 4 cereal components (soft wheat, durum wheat, barley and maize), and t = 1991,…, 2021 determines the analysis period. The table below, Table 2, reports the descriptive data used in our estimate.

To mitigate the distorting effects of price fluctuations, we measured national cereal production, imports, and exports in physical units rather than monetary terms. It is noteworthy that wheat constitutes the most consumed cereal component in Tunisia, representing 72% of total cereal consumption, as evidenced by the following Figure 1.

Prior to model estimation, we rigorously tested for stationarity using the Levin-Lin-Chu unit root test to ensure the time-series properties of our data were consistent with our econometric assumptions.

Table 3 confirms the stationarity of all variables, providing a solid foundation for our empirical analysis. To further validate the suitability of the panel threshold regression (PTR) model in our study, we employed the Fisher linearity test, which indicated a nonlinear relationship between food security and the cereal price index and the graphical test of non-linearity, witch a visual examination tool of the relationship between our two primary variables.

Our analysis, using Fisher's test and Lowess smoothing, revealed a nonlinear association between price and food security. As visualized in Figures 2 and 3 the smoothed curve exhibits significant variations, suggesting the presence of regime shifts in the data. These graphics indicate that a standard linear model is not suitable for the actual structure of the data and the importance of using nonlinear models to capture the complex dynamics between food security and cereal prices (Alimi and Dhiab, 2023; Ben Abdallah et al., 2024). Furthermore, determining the number of thresholds is crucial for defining the various policy regimes. Figure 4 reveals a single breakpoint, indicating a clear shift in food security caused by price index volatility.

Overall, a single significant transition is observed along the curve, with no multiple distinct changes, but rather a unique zone of high variation corresponding to the threshold location. If multiple thresholds were possible, several significant variations or multiple breakpoints would be expected. Outside this transition zone, the curve stabilizes or fluctuates very slightly. This stability apart from a single critical point indicates that there are no other significant thresholds within these intervals. Moreover, we note that the threshold identified in Figure 4 corresponds to the years 2007-2015 and 2020-2021, effectively the two historically emphasized phases of sharp increases in cereal prices, coinciding with the 2008 financial-real estate crisis and the 2019 Covid-19 pandemic. In the following Figure 5, we depict the evolution of the cereal price index over the selected period, 1991-2021.

4. RESULTS AND DISCUSSION

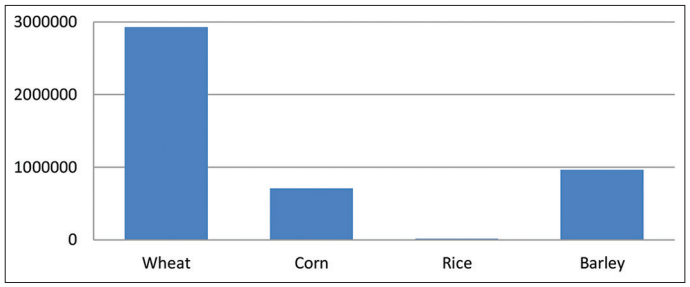
Our baseline linear model demonstrates a robust explanatory power of the independent variables on food security. As expected,

Table 1: Model variables, definitions and sources

Variables	Definitions	Sources
SA	Food security/SA=P + M-X where P=Domestic Production, X=Exports and M=Imports, all measured in tonnes.	FAO
IP	Cereals price index	FAO
GDPc	GDP per capita (constant 2015 US $)	WDI
IPC	Consumer price index in Tunisia. Proxy variable for inflation	WDI
SP	Ratio of poor population to national poverty line (% of total population)	WDI
ITE	Net goods terms of trade index (2000=100)	WDI
DE	Stocks of external debt, total (Debt outstanding and disbursed, current US$)	WDI
TCER	Real effective exchange rate index (2010=100)	WDI

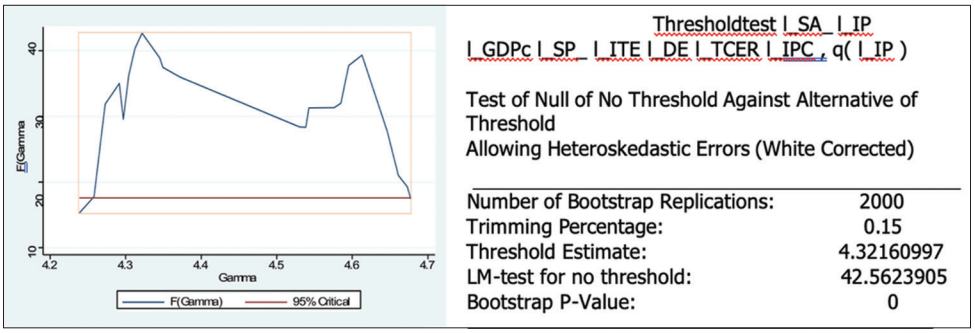
Source: Authors

Figure 1: SA per product, average over the period



Sources: Authors, INS data base

Figure 2: Fisher's test



Source: Authors, STATA output

Table 2: Descriptive statistics

Variables	Number of observations	Average	Standard deviation	Min	Max
Domestic production	124	495	666	0	2687
Exports	107	5647	15887	0	70313
Imports	124	664760	606207	118	2237134
SA	124	1154584	1133738	47	4072495
IP	124	91	21	65	134
IPC	124	96	33	52	173
GDPc	124	3257	665	2121	4095
SP	124	22	4	15	26
ITE	124	101	8	89	118
DE	124	2080 109	992 109	830 109	4200 109
TCER	124	110	19	78	133

Source: Authors, STATA output

Table 3: Stationarity test

Variables (in log)	Statistics	Probabilities
l_SA	−10.9636***	0.0074
l_IP	−5.6299**	0.0334
l_IPC	−4.6291**	0.0453
l_GDPc	−4.1455***	0.0006
l_SP	−2.7990**	0.0415
l_ITE	−7.5306**	0.0112
l_DE	−6.9921***	0.0004
l_TCRE	−6.1049**	0.0445

***P<0.01, **P<0.05
Source: Authors, STATA output

the cereal price index exhibits a negative correlation with food security, while the terms of trade and exchange rate, despite a persistent deficit and depreciation, exert a positive influence. Counterintuitively, inflation shows a positive association with food security. However, GDP per capita, social protection, and external debt do not significantly affect food security. Given these results, we explored the linearity of our observations. The estimated coefficients for both regimes are detailed in Table 4.

Moreover, to capture potential nonlinearities, we employed a panel threshold regression (PTR) model. This analysis revealed a significant threshold at a cereal price index value of 100.783, corresponding to a threshold parameter (q) of 4.6131. This threshold divides the data into two distinct regimes: A low-price regime ($q \leq 4.6131$) characterized by stable cereal prices, and a high-price regime ($q > 4.6131$) marked by sharp increases in cereal prices. Notably, the cereal price index exceeded 100 during periods of global crises, such as 2007-2015 and 2020-2021, corroborating the existence of two regimes.

In the regime characterized by sharp price fluctuations, regime 2, most control variables exhibit significantly greater sensitivity at the 1% level compared to the first regime. This suggests that these variables have a more pronounced impact on the dependent variable during periods of high price volatility. Notably, inflation, as measured by the consumer price index, does not follow this pattern, its coefficient is not significant.

Thus, our analysis uncovers a nonlinear connection between food security and cereal prices, marked by a significant regime shift at a cereal price index of 4.6131. Interestingly, during times of elevated cereal prices, the adverse effect on food security appears somewhat less pronounced compared to periods of lower prices.

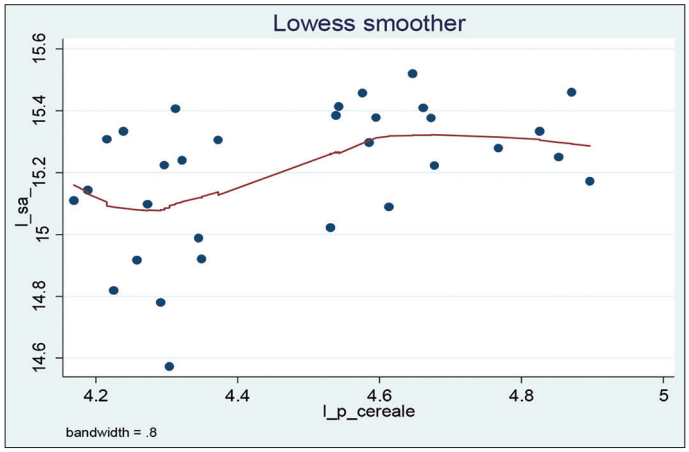
The findings advocate that even as cereal demand for does react to charge changes, it does so in a low elastic way, with price elasticities recorded at −0.50 and −0.42 in regimes 1 and a couple of, respectively. This shows that cereal demand for, encouraged by way of factors which includes eating habits and ingrained consumption behavior and, display a degree of resistance to cutting back on when prices rise. Additionally, government measures like social safety nets and subsidies have played a role in softening the volatility cereal prices, further reducing the price elasticity of demand. These results are constant with the studies of Diaz-Bonilla and Ron (2010), who underscore the importance of threat management strategies in curbing rate volatility. The inverse relationship between grain prices and home demand has profound implications for food protection. However, we word that rising grain price can erode food affordability, restrict food diversity and nutritional range,

Table 4: Impact of cereal prices on food security, PTR model estimate

V. independent	Non-threshold MCO		PTR model			
			Regime 1: q≤4.6131		Regime 2: q>4.6131	
	Coefficient	T-student	Coefficient	T-student	Coefficient	T-student
Intercept	2.913	1.118	10.532***	3.848	19.682***	7.219
l_IP	−0.286***	−6.720	−0.509***	−5.756	−0.428***	−27.199
l_GDPc	−0.112	−0.725	−1.903***	−6.255	−3.134***	−25.795
l_SP_	0.130	1.248	0.083	0.860	−1.975***	−27.620
l_ITE	1.166***	4.564	2.655***	5.853	−1.232***	−22.096
l_DE	0.023	0.147	−0.350	−1.598	0.542***	6.446
l_TCER	0.705***	4.869	1.030***	7.632	4.744***	14.283
l_IPC	1.077***	4.218	2.936***	6.148	0.088	0.898
R2	0.84		0.89		0.99	
Number of observations	124		88		36	

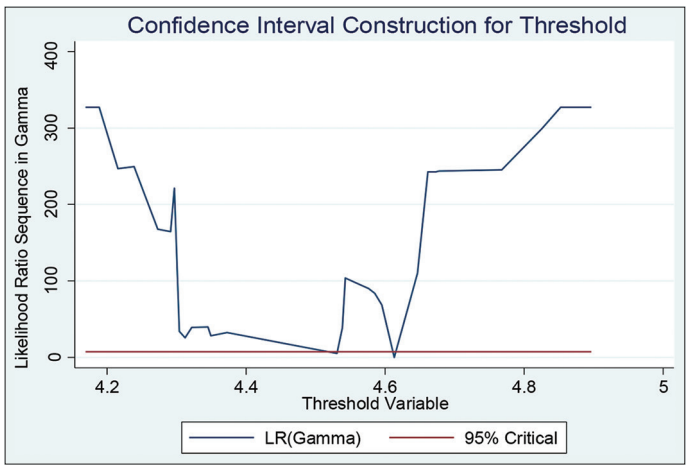
***Statistically significant at the 1% level
Source: Authors, STATA output

Figure 3: Graphical test of non-linearity, Lowess Smoother



Source: Authors, STATA output

Figure 4: Number of threshold, Confidence Interval Construction for Threshold



Source: Authors, STATA output

and decrease farm earning and hence undermine meals safety. Moreover, increased import dependency and inefficiencies in government measures can exacerbate those poor affects. To mitigate those effects, coverage interventions should be designed to protect inclined populations from the destructive outcomes of higher grain prices.

Our study examining the impact of various control variables on food security in Tunisia from 1991 to 2021 indicates that GDP per capita and the real effective exchange rate consistently influence both economic regimes under analysis. However, the effects and statistical significance of other factors, like the terms of trade, external debt, poverty line, and consumer price index, differ notably between these regimes.

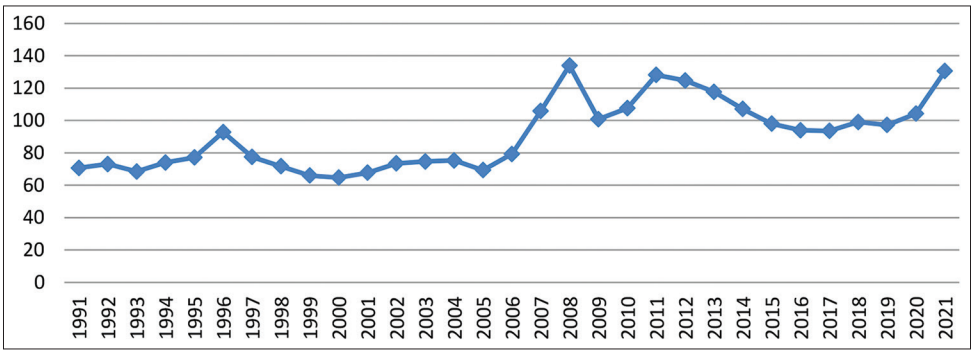
Interestingly, our findings reveal a counterintuitive negative correlation between GDP per capita and food security in Tunisia, which challenges the typical assumptions about economic growth. Across both regimes, a 1% increase in GDP is linked to a marked reduction in food security, with this effect being stronger in Regime 2 (3.13%) than in Regime 1 (1.9%). This unexpected outcome can be explained by several factors.

As incomes grow, people often shift their spending toward more costly, imported foods, making the country more susceptible to global food price fluctuations and possibly worsening disparities in food access. Additionally, if economic gains are not distributed equitably, growth can widen existing inequalities, leaving vulnerable groups more exposed to food insecurity.

Therefore, while GDP per capita is an important measure of a country's economic health, it alone does not guarantee sustained food security. Addressing this complex challenge requires targeted policies aimed at enhancing both physical and economic access to food, supporting sustainable agricultural practices, and developing robust food systems that can endure shocks and crises. Although GDP growth is essential for improvement, it must be complemented with the aid of guidelines that make sure the equitable distribution of economic blessings so that everybody can enjoy the fruits of development.

Our analysis of regimes 1 and 2 reveals a counterintuitive, yet statistically significant, positive correlation between real effective exchange rate depreciation and food security in Tunisia, contradicting the findings of de Huchet et al. (2013). The high elasticity of this relationship suggests a pronounced sensitivity of food security to exchange rate fluctuations. This outcome can be attributed to the improved competitiveness of home cereal producers following a currency depreciation. Given

Figure 5: Trends in the Cereal Price Index, 1991-2021



Sources: Authors, INS data base

the complicated and nuanced interaction among real effective exchange rate and food safety, Tunisian policymakers must carefully don't forget the capacity implications of financial and financial rules on food price, especially the cereal prices.

Our research has revealed a strong link between favorable terms of trade index and food security during periods of stable prices, Regime 1. Specifically, enhancing Tunisia's export competitiveness in cereal products, particularly durum wheat, can boost agricultural incomes and strengthen food security. However, the relationship between trade terms and food security is more complex, submitted by broader economic and policy factors. During periods of sharp price fluctuations, as observed in Regime 2, deteriorating trade terms have exacerbated food insecurity by eroding household purchasing power. These findings underscore the need for a comprehensive agricultural development strategy that capitalizes on the benefits of favorable trade conditions while mitigating the risks associated with adverse price shocks.

The outside debt variable suggests a significant and substantial impact on food security inside the unstable Regime 2, where in a 1% increase is likely to affect the agricultural sector by 0.54%. However, this variable loses its significance in Regime 1 and does now not appear to affect food security in that context. The impact of elevated outside debt on food security in Tunisia is complex. It relies upon on how the borrowed budget are allocated and their effectiveness in stimulating financial boom, decreasing inequalities, and improving get entry to to sufficient food to satisfy Tunisia's grain demand. Notably, the growth in Tunisia's outside debt has now not been often directed closer to investments inside the agricultural sector, and specially to durum wheat, the Tunisian cereal specialty. In truth, the proportion of agricultural loans has step by step declined, averaging simply five. 5% over the 1991-2021 length. However, the upward thrust in debt has helped to support local grain demand and fund social protection programs, inclusive the food subsidies distribution to prone populations. These measures have alleviated meals insecurity by way of making sure access to fundamental meals commodities. Conversely, counting on borrowed funds to finance food imports may want to growth Tunisia's dependence on global food markets, making the country a susceptible to international food price fluctuations. This should jeopardize long-time period food security. Therefore, prudent debt management and powerful useful resource allocation are important to maximizing the advantages of external debt, specially as Tunisia faces developing reimbursement duties and has handed the brink of public debt sustainability.

Our empirical studies reinforce the theoretical connection between poverty and meals insecurity, revealing a sturdy negative correlation. This finding illustrates that as poverty increase, food security submitted a pressure and decrease, underscoring the crucial role poverty plays in driving food insecurity and wider socioeconomic. However, our analysis also shows that this relationship's intensity relies upon on the broader monetary surroundings. For instance, in contexts with low cereal price volatility, like Regime 1, the hyperlink among poverty and meals protection is much less evident. This indicates that while poverty is a key factor in food insecurity, other elements also play a more significant and impactful position.

Moreover, our research emphasizes the detrimental consequences of inflation on the food security, highlighting the need for policies that address both poverty and food price volatility. In Regime 1, where cereal price stay notably stable, moderate inflation correlates undoubtedly with food security. This correlation likely arises because mild inflation can incentivize agricultural production; as costs increase, farmers may additionally raise manufacturing to maintain income, thereby enhancing a food availability. On the opposite hand, in Regime 2, characterized through more unstable cereal prices, inflation seems to have little impact on meals security. This could be because of households' resilience, developed through numerous coping strategies, and government measures like meals subsidies. Nevertheless, prolonged excessive inflation may undermine those coping mechanisms, posing lengthy-term risks to food security.

5. CONCLUSION AND RECOMMENDATIONS

The vulnerability of food security systems to external shocks, such as inflation, exchange rate fluctuations, and external debt, is exacerbated in highly volatile environments ($q > 4.65\%$), as highlighted by our PTR model. Our findings suggest a counterintuitive positive correlation between poverty and cereal food security in Tunisia, implying that social safety nets and

targeted interventions may enhance food access for the poor. Nevertheless, the interplay of economic, environmental, and social factors underscores the complexity of building resilient food systems. Climate change and water scarcity pose significant challenges, particularly for cereal production, and could jeopardize progress towards the SDGs.

Our findings highlight the need for policies to enhance the resilience of Tunisian food systems to shocks. Sustainable agriculture, crop diversification, agroecology, and agricultural research can contribute to this goal. Risk management measures, such as price-indexed insurance, safety stocks, and early warning systems, are essential to protect farmers and consumers from price volatility. Improving infrastructure and supporting small-scale producers can also enhance food security. Regional cooperation can facilitate better coordination of agricultural policies and build greater resilience to shocks.

These results underscore the need for a more nuanced understanding of food security in Tunisia. Future research should explore the role of factors such as climate change, conflicts, and trade policies. Moreover, evaluating the impact of different policy interventions on food security is essential for informing effective policymaking.

Our study emphasizes the need for a multifaceted approach to food security in Tunisia, given the high volatility ($q > 4.65\%$) of the economic environment. Combining short-term crisis response measures with long-term investments in food system resilience is essential to ensure a more secure future for the Tunisian people.

Based on our results, we recommend a series of strategic and policy measures to address the negative impacts observed and to leverage potential opportunities. Given the volatility of cereal prices and its implications for food security, it is essential to implement policies that regulate cereal prices. Specifically, we propose maintaining and expanding targeted food subsidies to safeguard vulnerable populations from rising cereal prices, especially during periods of high price volatility (Regime 2). The Central Bank of Tunisia should play a pivotal role in monitoring price stability and mitigating the effects of international price fluctuations.

The Central Bank of Tunisia (BCT) is also tasked with implementing monetary and fiscal policies to maintain moderate inflation that stimulates agricultural production without compromising food accessibility, and to closely monitor food price volatility and intervene promptly in the event of severe shocks. The experience of the Russia-Ukraine conflict has revealed the need to diversify imports to reduce dependence on a limited number of suppliers. By diversifying its sources of supply and implementing effective price stabilization measures, Tunisia can enhance its food security and resilience to future shocks.

While the agricultural sector is a cornerstone of the Tunisian economy, it remains a critical area that requires greater attention to its economic, social, and vital impacts on food security. Therefore, it is recommended to increase funding for the agricultural sector, which receives merely 3% of the overall funding allocated to all sectors of the Tunisian economy, prioritizing durum wheat to reduce import dependency, develop modern infrastructure to improve agricultural yields and minimize post-harvest losses. It is also essential to adopt sustainable agricultural practices, including the implementation of climate-resilient agricultural techniques to enhance local productivity and the promotion of technologies such as smart irrigation to reduce water consumption.

Moreover, food security is contingent upon maximizing revenue and effectively managing debt. In this regard, it is strongly recommended to enhance the competitiveness of agricultural exports by promoting Tunisian agricultural products on international markets through diversification, capitalizing on flagship products such as durum wheat and further develop its trade agreements with its neighboring and traditional partners. Additionally, exploiting periods of favorable terms of trade can support agricultural incomes and bolster food security. However, streamlining the import process to ensure a constant and cost-effective supply of cereals on the domestic market is equally important.

Ultimately, it is essential to prioritize objectives and expected outcomes based on the prevailing circumstances. We believe that it is both urgent and imperative to focus on mitigating the immediate impact of price shocks on vulnerable populations through efficient subsidies and safety nets. In the medium term, the objectives center around strengthening local production and agricultural incomes, as well as reducing import dependency and improving terms of trade. In the long term, Tunisia should establish a resilient and sustainable food system capable of ensuring food security even during crises. We believe that these recommendations are crucial for balancing structural challenges, reducing external dependence, and enhancing the resilience of the Tunisian food system.

REFERENCES

Abdulai, A., Kuhlgatz, C. (2012), Food security policy in developing countries. In: The Oxford Handbook of the Economics of Food Consumption and Policy. United Kingdom: Oxford University Press.

Abis, S. (2012), Wheat in the Mediterranean. Sociétés, commerce et stratégies. Économie et Territoire/Relations Commerciales, 387, 241-247.

Akter, S., Abul Basher, S. (2014), The impacts of food price and income shocks on household food security and economic well-being: Evidence from rural Bangladesh, Global Environmental Change, 25, 150-162.

Alam, S.A., Liu, S.X., Pörtner, C.C. (2024), Navigating food price shocks in a pandemic: Food insecurity and coping mechanisms in Burkina Faso. World Development, 182, 106714.

Ali, B.M., Manikas, I., Sundarakani, B. (2022), Food security in the United Arab Emirates: External cereal supply risks. Cogent Economics and Finance, 10(1), 214949.

Alimi, N., Ben Dhiab, L. (2023), Governance and economic growth in developing countries: A panel threshold regression analysis. Economic Horizons, 25(2), 105-120.

Al-Maadid, A., Caporale, G.M., Spagnolo, F., Spagnolo N. (2017), Spillovers between food and energy prices and structural breaks, International Economics, 150(C), 1-18.

Amolegbe, K.B., Upton, J., Bageant, E., Blom, S. (2021), Food price volatility and household food security: Evidence from Nigeria, Food Policy, 102, 102061.

Applanaidu, S.D., Abu Bakar, N., Baharudin, A. (2014), An econometric analysis of food security and related macroeconomic variables in Malaysia: A vector autoregressive approach (VAR). UMK Procedia, 1, 93-102,

Arib, F., Et-Touile, H. (2022), Econometric study of the impacts of climate change on food security in Morocco. African Scientific Journal, 3(4), 525-545.

Barrett, C.B. (2010), Measuring food insecurity. Science, 327(5967), 825-828.

Bellemare, M.F., Barrett, C.B., Just, D.R. (2013), The welfare impacts of commodity price volatility: Evidence from rural Ethiopia. American Journal of Agricultural Economics, 95(4), 877-899.

Ben Abdallah, A., Guidara, S., Aloulou, R., Kalai, M., Helali, K. (2024), Enquête sur la relation entre l'inflation et la croissance économique en Mauritanie: Une analyse empirique utilisant le modèle de changement de régime. SN Business and Economics, 4(1), 1-25.

Ben Abdallah, M., Farkas, M., Vasa, L., Lakner, Z. (2023), Food security of Tunisia: Comprehensive analysis of a composite index. Acta Polytechnica Hungarica, 20(10), 199-216.

Ben Kahla, K. (2019), From Food Security to food Sovereignty in Tunisia Main Challenges and Obstacles, Working Papers.

Cabrera, B.L., Schulz, F. (2016), Volatility linkages between energy and agricultural commodity prices. Energy Economics, 54, 190-203.

Chebbi, H., Amrani, M., Bouallegui, F. (2023), Le système agricole et agroalimentaire tunisien face aux crises: Focus sur la chaîne de valeur céréalière: Constats et réflexions pour la proposition d'un plan de relance à court et à moyen termes. France: Food and Agriculture Organization of the United Nations.

Chebbi, H., Lachaal, L. (2007), Agricultural Sector and Economic Growth in Tunisia: Evidence from Co-integration and Error Correction Mechanism, I Mediterranean Conference of AgroFood Social Scientists. In: 103rd EAAE Seminar "Adding Value to the Agro-Food Supply Chain in the Future Euromediterannean Space". Barcelona, Spain.

Chebbi, H.E., Lachaal, L. (2004), L'agriculture et la sécurité alimentaire: Une étude comparative des pays du Maghreb. New Medit, 3(3), 4-11.

Chianeh, L.H., Mohammad, A., Zeraatkish, S.Y., Moghaddasi, R. (2021), The mathematical analysis of the impact of macroeconomic variables on various dimensions of food security in developing countries. Advances and Applications in Discrete Mathematics, 26(1), 63-81.

Compton, J., Wiggins S., Keats, S. (2010), Impact of the Global Food Crisis on the Poor: What is the Evidence? Report, Overseas Development Institute, London.

De Schutter, O. (2009), UN Human Rights Council, Report of the Special Rapporteur on the Right to Food, The role of Development Cooperation and Food Aid in Realizing the Right to Adequate Food: Moving from Charity to Obligation, A/HRC/10/5. Available from: https://www.refworld.org/reference/themreport/unhrc/2009/en/66280

Diagne, R. (2014), Sécurité Alimentaire et Libéralisation Agricole, Ph.D. Dissertation, Université Nice Sophia Antipolis, Nice. Available from: https://tel.archives-ouvertes.fr/tel-00998276/document

Diaz-Bonilla, E., Ron, J.F. (2010), Food Security, Price Volatility and Trade: Some Reflections for Developing Countries, Price Volatility and Beyond 320195. Geneva: International Centre for Trade and Sustainable Development (ICTSD).

Dorward, A. (2012), The short- and medium- term impacts of rises in staple food prices. Food Security, 4, 633-645.

D'Souza, A., Jolliffe, D. (2012), Rising food prices and household coping strategies: Evidence from Afghanistan. Journal of Development Studies, 48(2), 282-299.

Gouel, C. (2013), Optimal food price stabilization in a small open developing country. European Economic Review, 57, 118-134.

Gouel, C. (2014), Food Price Volatility and Domestic Stabilization Policies in Developing Countries. United States: National Bureau of Economic Research, Inc. p261-306.

Grami, D., Ben Rejeb, J. (2015), The impact of climate change on cereal crop yields in the North-West Region of Tunisia (Béja). New Medit 4, 38-41.

Habib, H., Jmaii, A. (2024), Effect of income instability and social transfers on food security during COVID-19 in Tunisia. International Journal of Social Economics, 51, 108-122.

Hansen, B.E. (1999), Threshold effects in non-dynamic panels: Estimation, testing, and inference. Journal of Econometrics 93, 345-368.

Huchet, M., Laroche-Dupraz, C., Senadin, A.L. (2013), Impact du Taux de Change sur la Sécurité Alimentaire des Pays en Développement, Working Paper SMART-LERECO N 13-10.

Ibrahim, M.H. (2015), Oil and food prices in Malaysia: A nonlinear ARDL analysis. Agricultural and Food Economics, 3, 2.

IFPRI. (2010a), Food Security and Economic Development in the Middle East and North Africa: Current State and Future Perspectives. Washington, DC: IFPRI.

Jeder, H., Hattab, S., Frija, I. (2020), An econometric analysis for food security in Tunisia. New Medit, 19(4), 10-20.

Kalkuhl, M., von Braun, J. (2016), Food Price Volatility and its Implications for Food Security and Policy. Berlin: Springer.

KoÃ, A., Ozdamar, O., Uysal, P. (2017), The economic determinants of food security in the MENA region. International Journal of Food and Beverage Manufacturing and Business Models, 2(1), 1-19.

Kumar, A., Sharma, P. (2013), Impact of Climate Variation on Agricultural Productivity and Food Security in Rural India, Economics Discussion Papers 2013-43, Kiel Institute for the World Economy.

Mary, S. (2019), Hungry for free trade? Food trade openness and extreme hunger in developing countries. Food Security, 11, 461-477.

Mashref, M. (2024), Measuring the impact of public agricultural spending on food security by applying it to the MENA region. Scientific Journal of Agricultural Sciences, 6(1), 249-272.

Matz, J.A., Kalkuhl, M., Abegaz, G.A. (2015), The short-term impact of price shocks on food security-Evidence from urban and rural Ethiopia. Food Security, 7, 657-679.

Mawejje, J. (2016), Food prices, energy and climate shocks in Uganda. Agricultural and Food Economics, 4(1), 1-18.

Mhiri, A. (2022), La Sécurité Alimentaire en Tunisie et le Défi de L'agriculture Tunisienne à accroître Durablement sa Contribution à L'équilibre de la Balance Alimentaire du Pays. In: Paper Presented at the Ibn Khaldoun Forum for Development.

Moncada, L., De la O Campos, A.P., Tornarolli, L. (2022), Food insecurity and poverty: A cross-country analysis using national household survey data. FAO Agricultural Development Economics Working Paper, No. 22-14. Rome: FAO.

Osei, A., Etuah, S., Nimoh, F., Asante B.O., Abunyuwah, I., Mensah, N.O. (2024), Does fuel price volatility induce price instability in the agricultural commodity supply chain? Empirical evidence from Ghana. Journal of Agriculture and Food Research, 17, 101216.

Padilla, M. (2008), Dietary patterns and trends in consumption. In: Mediterra: The Future of Agriculture and food in Mediterranean Countries, International Centre for Advanced Mediterranean Agronomic Studies. Paris: Presses de Sciences Po. p149-170.

Pawlak, K., Kołodziejczak, M. (2020), The role of agriculture in ensuring food security in developing countries: considerations in the context of the problem of sustainable food production. Sustainability, 12(13), 1-20.

Pinstrup, A. (2009), Food security: Definition and measurement. The Science, Sociology and Economics of Food Production and Access to Food, 1(1), 5-7.

Shagaida, N.I., Ternovsky, S. (2023), Food Price Volatility in 2021-2022 in the Context of Food Security, Voprosy Ekonomiki, NP Voprosy Ekonomiki.

Shittu, A.M., Akerele, D., Haile, M. (2018), Effects of Food Price Spikes on Household Welfare in Nigeria, ZEF-Discussion Papers on Development Policy No. 248.

Taghizadeh-Hesary, F., Rasoulinezhad, E., Yoshino, N. (2019), Energy and food security: Linkages through price volatility. Energy Policy, 128, 796-806.

Verpoorten, M., Arora, A., Stoop, N., Swinnen, J. (2013), Self-reported food insecurity in Africa during the food price crisis. Food Policy, 39, 51-63.

Wossen, T., Berger, T., Hailé, M.G., Troost, C. (2018), Impacts of climate variability and food price volatility on household incomes and farm household food security in East and West Africa. Agricultural Systems, 163, 7-15.

Yerima, A.U., Tahir, H.M. (2020), The impact of external debt on agricultural production in Nigeria (1980-2016): Autoregressive Distributed Lag Modelling. Bullion, 44(2), 79-90.