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Supply Response of Syrian Wheat Farmers using Time Series Data with Special Attention to Crisis: A Nerlovian Partial Adjustment Model Approach

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Food security in Syria constituted the main objective of the Syrian agricultural strategy. Agricultural strategies and policies until the mid-1980s were largely directed towards achieving self-sufficiency in strategic crops. The wheat crop is one of the most important strategic crops in Syria, as its strong association with food security policies gives it great importance. The study estimates wheat supply response in Syria using time series data from 1991 to 2020. This study analyses the effects of price and non-price factors on the supply response of wheat using the Nerlovian partial adjustment model. The results show a long-run and short-run price elasticity which indicate that wheat farmers easily adjust area devoted to wheat given price changes, suggest the success of the pricing policy adopted by the government before the crisis as a strategy to achieve self-sufficiency in strategic crops. An adjustment coefficient indicates that the time taken to adjust from the actual to the desired area level is relatively fast. The results confirm that crisis period (2011-2020) had a negative and significant impact on area ($p < 0.01$). Given this finding, the government needs to focus during the period of reconstruction on pricing policy and should make great efforts to direct investments to rebuild the infrastructure that was greatly affected during the crisis period and to provide support to farmers in the form of agricultural loans, which could play a pivotal role in increasing production.

1. Introduction

Wheat is the most important crop in Syria, as it constitutes almost 24% of the total cultivated arable land and 42% of the total winter crops area (MAAR, 2023). Wheat is the main crop to achieve food security in Syria, and it is the basic food item for the population, which is often consumed in the form of bread. Therefore, the government encouraged the cultivation of wheat in both rainfed and irrigated areas, thus achieving self-sufficiency in wheat in the mid-1990s (NAPC, 2009).

Wheat is one of the crops that the government classifies as strategic crops (wheat, barley, cotton, sugar beet, tobacco, chickpeas, and lentils). From the 1960s until the mid-2000s, the government also played a vital role in the production of strategic crops (FAO, 2019; NAPC, 2009). The prices of these crops are directly affected by government pricing policies, either by setting a fixed price or setting a minimum price (NAPC, 2009). Pricing of these crops relies on assessing the actual costs by the MAAR and adding up a profit margin of 25% to the estimated total cost. The prices of the aforementioned strategic crops, including wheat, have started to increase since 2005 in line with the increase of international prices, fuel prices and fertilizer prices (NAPC, 2010).

Moreover, wheat farmers can sell their produce to the private sector (traders) who may enable them to get a higher price and the selling procedures to traders are easier than selling by government institutions (NAPC, 2009).

Prior to 2011, the country was a significant exporter of agricultural produce. As a result of government agricultural policies, Syria was able to achieve self-sufficiency in wheat, and until 2007 was a net wheat exporter, but it was forced to import after the drought that Syria witnessed in 2008. And it got worse after 2011 as a result of the continuation of the crisis or its consequences which caused a loss in cultivated areas, displacement of farmers from affected areas, the destruction of agricultural machinery and irrigation structures, high production costs (FAO, 2021). The area planted with irrigated and rainfed wheat reached about 61 and 75 percent respectively of those planned, giving an overall implementation rate of 68 percent (FAO, 2015).

The goal of this study is to estimate the supply response (area response) of wheat crop in Syria. Specifically, the study covers the period 1991 to 2020, focused on estimate elasticity of wheat supply with respect to price as one of the agricultural policy tools that the government focused on and non-price variables in Syria, and to clarify the impact of the crisis in Syria that began in 2011.

The rest of this research is arranged as follows. Section 2 introduces the literature review. Sections 3 presents trends of wheat supply in Syria. Section 4 illustrates materials and methods Section 5 discusses the results and discussion. Finally, Section 6 conclusions.

Figure 1: Wheat Growing Areas in Syria.
Source: (NAPC, 2009).

2. Literature Review

For several years great effort has been devoted to the study of supply response. Waqas et al. (2019) analyzed the effects of price, area, temperature and rainfall on production for unirrigated wheat in Khyber Pakhtunkhwa, Pakistan and reported long and short run elasticities of unirrigated wheat production in response to wheat price, chickpea price, area, temperature and rainfall on production. Farhan & Shah (2019) estimated the supply response of wheat growers in Pakistan and concluded that response of output supply to the price of wheat and land was positive and elastic, while the wage rate and fertilizer was negative. Khan & Khair-Uz-Zaman (2010) attempted to determine the influence of market price (price factor) and rainfall (non-price factor) on wheat production and acreage by employing Nerlovian Adjustment Model over a period of time (1981-82 to 2007-08) in Pakistan. They found that in case of wheat production, short and long run elasticities of market price was worked out 0.014 and 0.027 and of rainfall 0.130 and 0.256, respectively. While in case of wheat acreage, the short and long run elasticities of market price was estimated as -0.016 and -0.078 and of rainfall as 0.032 and 0.150, respectively. Another study in Turkey indicated that wheat farmers are not responsive to the price changes and the wheat supply is shaped according to structural characteristics of wheat production (Özkan, Ceylan, & Kizilay, 2011). Alboghdady (2016) found out that wheat harvested area is affected significantly and positively by wheat price in the preceding year and negatively by the prices of the competing crops like clover and barley. The study conducted by Tenaye (2020) indicated that the supply of major cereal crops (teff, wheat, and barley) in Ethiopia is affected positively by their own prices and negatively by the prices of substitute crops. Nonprice factors such as education, farm size, fertilizer, land quality, and precipitation also affect supply of major cereals. Moreover, the adjustment coefficients are positive for teff, barley, and wheat.

In comparison with these developing countries, Syria presents a distinctly different case because its agricultural system has been subjected to a severe institutional and economic shock due to the ongoing crisis since 2011. While the previous studies reflect supply response under relatively stable conditions or normal climatic variability, the Syrian context is characterized by partial market collapse, acute input shortages, and farmer displacement, which may weaken or delay the supply response to market prices compared

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to what has been observed in Pakistan or Ethiopia. Therefore, incorporating a crisis dummy variable alongside climatic variables in the present model allows a more accurate understanding of farmers' behavior under conflict and fills a gap in the literature on fragile and crisis-affected countries.

2.1. Trends of Wheat Supply in Syria

Table 1 highlights some indicators including area, yield and production related to wheat from 1991 to 2020. It could be seen that there were in average 1517 thousand ha. Their trend showed certain level of stability in the analyzed period (CV = 14.82%). On the other hand, in same period instability of trend was shown at wheat yield (CV = 21.55%), whose average value was 2.19 tons/ ha. Average wheat production was 3375 thousand ton with higher level of instability than the other two production indicators (CV = 30.63%).

Table 1: Descriptive Statistics of the Production Indicators.

Description	Mean	SD	Interval of variation		C.V (%)
			Min.	Max	
Area Harvested ('000ha)	1517	225	1097	1904	14.82
Yield (t/ha)	2.19	0.47	1.12	2.84	21.55
Production ('000t)	3375	1034	1223	4932	30.63
Source: Calculation according to FAO 2020.					

Figure 1. is presented the trend of harvested wheat area within the observed period. In the area equation, the trend appeared with negative sign. Production trends have been increasing until 2005. Since 2006, production has seen sharp decreases and reached its lowest level in 2018.

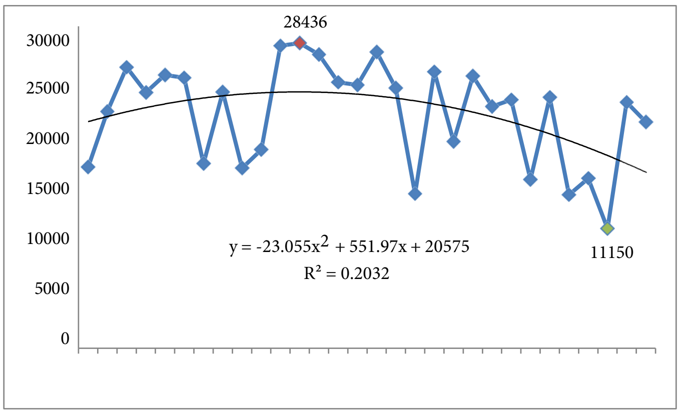

Figure 2: Trend of Harvested Wheat Area.

The yield trend for 1991-2020 is summarized in Figure 3. The average yield over the study period is 2.19 t/ha with a standard deviation of 0.47 t/ha. Though the yield trend of 30 years shows the instability of productivity. The coefficient of variation of yield of 21.55% is indicative of high variable.

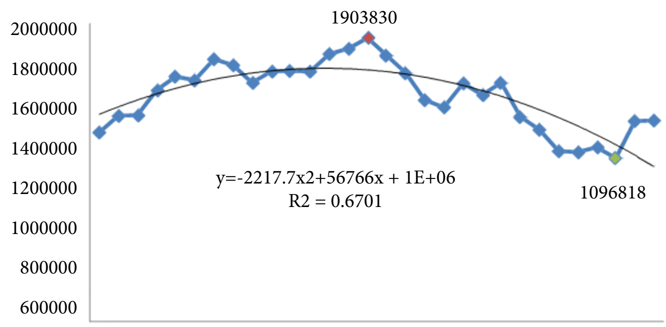

Figure 3: Trend of Yield.

An unstable trend in production is also observed from 1991 to 2020. The production of wheat increased to 4932000 tons in 2006. The wheat production reached 1222988 tons in 2018, which was the lowest production.

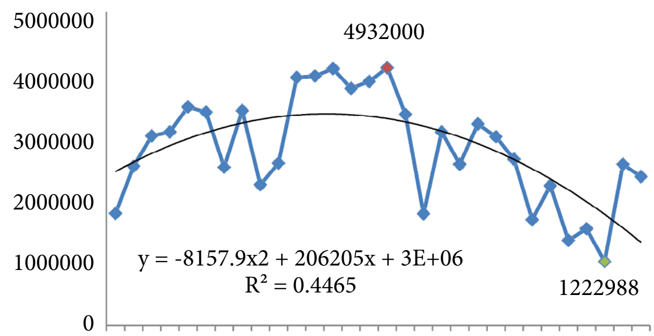

Figure 4: Trend of Production.

3. Materials and Methods

3.1. Data Source

To conduct this study, time series data for the period 1991 to 2020 is used at the national level in Syria. Data relating to area harvested, yield, production and prices are obtained from Food and Agriculture Organization (FAOSTAT, n.d.). Prices data for some years (2010, 2013-2014 and 2018- 2020) were not available from the FAO website, so it was obtained from the annual agricultural statistical abstract provided by the Ministry of Agriculture and Agrarian Reform (MAAR, 2023). The climate data (rainfall) were acquired from the NASA Langley Research Center (n.d.).

3.2. The Nerlovian Supply Response Model

In the light of previous studies conducted widely by researchers, this study depends on the Nerlovian supply response model to investigate how the supplies of wheat crop in Syria respond to price and nonprice factors.

Economic theory assumes that the quantity of production is determined by the product price relative to the prices of alternatives and input costs (Fisher, 1975). Farmers' decisions to farm start with land allocation decisions. Their decisions about allocating the area under cultivation depend on own price, competing crop prices, weather conditions, and input prices (Yami, Meyer, & Hassan, 2020). The Nerlovian partial-adjustment model specifies the outcome variable of interest (area) as a function of the expected output price, cultivated-area adjustment, and a set of nonprice variables (Tenaye, 2020). The commonly adopted Nerlovian model for an annual crop consists of three equations (Nerlove, 1979):

$$\boldsymbol{At - At{-}1 = \gamma\ (A^{*} - At{-}1)} \quad (1)$$

$$\boldsymbol{Pt * - Pt *{-}1 = \beta\ (Pt{-}1 - Pt *{-}1)} \quad (2)$$

$$\boldsymbol{At * = a0 + a1\ Pt * + a2Zt + ut} \quad (3)$$

where

$\boldsymbol{At}$: actual wheat area in t,
$\boldsymbol{Pt}$: actual price of wheat crop S.P/ton in t,
$\boldsymbol{At *}$: desired area of wheat to be under cultivation in t,
$\boldsymbol{Pt *}$: expected price in t for future periods,
$\boldsymbol{Zt}$: other observed non-price factors,
$\boldsymbol{ut}$: unobserved factors affecting area under cultivation in t, and β and γ are of expectation and adjustment respectively.

The Nearlove model is one of the most used models in recognizing the behavior of farmers, as it enables the computation of short run and long run responses and the speed of adjustment in moving from the actual to the desired level of area (Tenaye, 2020). This study used a Nerlove model to identify factors influencing the supply response of farmers producing wheat crop. In the model, we used the area as depending variable, due to the reason that area decision is totally under the control of farmers (Mythili, 2006), with set of price (own price and prices of competing products) and non-price factors (rainfall, area and crisis) as independent variables. Prices of competing crops becomes imperative when farmers make decisions to grow multiple crops jointly (Mustafa et al., 2021), as the wheat and barley crops in Syria are a realistic example of competing crops.

Table 2: Variables included in Econometric Model.

Variable	Symbol	Unit	Expected sign
Area under Wheat in year t. (dependent variable)	AWt	hectares	
Area under Barley in year t.	ABt	hectares	-
Area under Wheat in year t-1.	AW(t-1)	hectares	+
Price of wheat in year t-1.	PW(t-1)	SP/tonnes	+
Area under Barley in year t-1.	AB(t-1)	hectares	-
Price of Barley in year t-1.	PB(t-1)	SP/tonnes	-
Rainfall in October in year t-1	ROCT (t-1)	mm	+
Rainfall in November in year t-1	RNOV(t-1)	mm	+
Rainfall in December in year t-1	RDEC(t-1)	mm	+
Crisis (Dummy variable) 0=before crisis, 1=after crisis	Cis	-	-

The selection of rainfall variables for October, November, and December is based on the agronomic calendar of wheat cultivation in Syria. These months correspond to the sowing and early vegetative growth stages, during which soil moisture availability is critical for seed germination and crop establishment. Rainfall during this period significantly influences farmers' expectations regarding crop success, thereby affecting their decisions on land allocation.

Barley was included as a competing crop variable due to its close agronomic and economic relationship with wheat. Both crops are cultivated under similar rainfed conditions and compete for the same land resources. Farmers often substitute between wheat and barley depending on relative prices, risk considerations, and expected climatic conditions. Therefore, including barley prices helps capture cross-price effects in farmers' decision-making process and after converting. Based on the foregoing, all continuous variables to logarithms, it was possible to express the area response according to the following equations:

$$Awt = \beta 0 + \beta 1\ AW(t{-}1) + \beta 2\ PW(t{-}1) + \beta 3\ PB(t{-}1) + \beta 4\ ABt + \beta 5\ AB(t{-}1) + \beta 6\ ROCT(t{-}1) + \beta 7RNOV(t{-}1) + \beta 8\ RDEC(t{-}1) + \beta 9\ \mathrm{Cis} + et \quad (4)$$

Coefficient of each explanatory variable directly gives short run elasticities and the long run elasticities are obtained by dividing short run elasticities by (1- coefficient of the lagged dependent variables) (Mythili, 2006). Short run supply elasticity is the response of supply to a price change in the first period of reaction. While the long run elasticity indicates supply responses to price change in long run (Khan et al., 2019). The Nerlovian model was estimated in EViews 10 using OLS method.

4. Results and Discussion

Table 2 reports the regression results for the area responses models of wheat. The results show that most of the variables in the area response equation are statistically significant. Regarding the wheat crop, the results illustrate that own and competing crop (barley) prices have positive and negative coefficients respectively, consistent with economic theory (Haile, Kalkuhl, & von Braun, 2016; Tenaye, 2020). On average, if the price of wheat crop increases by 1%, the wheat area rises by 5.05%. This indicates the effectiveness of the Syrian agricultural policy during the previous years in providing support to wheat producers and reaching the desired goal of achieving self-sufficiency providing support to wheat producers and reaching the desired goal of achieving self-sufficiency that Syria experienced before the years of the crisis. Similar results were obtained by Begum et al. (2002), Shoko, Chaminuka, & Belete (2016) and Nhundu et al. (2022).

The barley price shows negative effect on the area response of wheat i.e. increase in barley price will decrease wheat area response. 1% increases in barley price will decrease wheat area response by 6.39%.

As expected, the area response of wheat is affected positively by the area planted in the previous year and negatively by the current area planted with barley. When the area of wheat increases by 1% in previous year, wheat area in the following year increases by 0.47% whereas the increase in barley area is in the current year, wheat area tends to decline by 0.3%.

Rainfall is one of the most important factors affecting the cultivation of wheat crop in Syria, as the rainfed cultivated areas in Syria amounted to about 770857 ha (57.07% of the total cultivated area) (MAAR, 2023). Positive and significant relationship of rainfall in November is observed with the wheat area, which indicates that there is a positive and significant influence of rainfall on area allocation (Shoko et al., 2016). As shown in Table 3, the area response elasticity is very high. A 1% increase in the lagged rainfall in November would increase the current wheat area by 1886.44 %. This result shows the significant role of rainfall in the area cultivated with wheat.

This is not surprising, as the wheat crop in Syria is one of the most important winter crops, which farmers begin to sow in mid-October and generally completed by December. The late onset of autumn rains force farmers to delay the planting date (FAO, 2021). The farmers' decision is often affected by the rainfall in the previous season, and this constitutes a strong motivation for them to plant in the next season, and they allocate part of their production as seeds that they store for the next season.

Since 2011, Syria has been suffering from a crisis that has affected all aspects of social and economic life. Like all sectors of the Syrian Arab Republic's economy, despite being one of the most resilient pillars of the economy, agriculture has suffered serious setbacks since the beginning of the current crisis in 2011 (FAO, 2019). be interpreted with caution. Such high elasticity values may arise due to several factors, including the scaling of variables, the presence of extreme climatic variability, or the log-linear functional form of the model.

In the Syrian context, rainfall is a critical determinant of agricultural production under predominantly rainfed conditions. Small variations in rainfall during the planting season can lead to disproportionately large changes in cultivated area, particularly under conditions of uncertainty and risk. Additionally, the coexistence of crisis-related disruptions may amplify farmers' sensitivity to climatic signals.

Nevertheless, the magnitude of this elasticity likely reflects a combination of statistical and structural factors rather than a purely economic response. Therefore, it is important to interpret this coefficient qualitatively—as an indicator of strong dependence on rainfall—rather than focusing solely on its numerical value.

The crisis variable was treated as a dummy variable, with 0 representing the period before the crisis (before 2011), while a value of 1 represented otherwise. We expect that crisis will have a negative influence on the area response. As shown in Table 3, the variable was significant at the 1% level with a negative coefficient value of –209276.6. The results suggest that the continuation of the crisis that began in 2011 will inevitably lead to a decrease in the area cultivated with the wheat crop in Syria. This is because the continuing crisis or its aftermath which have devastated the previously flourishing agricultural sector by the loss of cultivated land, the movement of farmers away from insecure areas, the destruction of farm machinery and irrigation structures, high costs of farm inputs and fuel, a severely damaged infrastructure and compromised power supplies (FAO, 2021). These results are in line with (Bhatti et al., 2011) who found a negative impact of the war with India (1965-1971) on the supply response of Pakistani wheat growers.

Table 3: Regression Results for wheat Area Response: 1991–2020.

Variable	Coefficient	t-Statistic	Prob.
Constant	1099394 **	2.559576	0.0192
AW(t-1)	0.466229**	2.603005	0.0175
PW(t-1)	5.055944*	2.057782	0.0536
PB(t-1)	-6.390638*	-1.965174	0.0642
ABt	-0.299442**	-2.359518	0.0292
AB(t-1)	0.122302	1.177477	0.2535
ROCT (t-1)	50.65885	0.039790	0.9687
RNOV(t-1)	1886.441*	1.993323	0.0608
RDEC(t-1)	353.6137	0.339894	0.7377
Diagnostic Tests			
Cis	-209276.6***	-3.355501	0.0033
R-squared	0.88	BG-LM(2)	1.03 [0.38]
Adjusted R-squared	0.83	JB	0.27 [0.87]
F-statistic	16.48***	Heteroskedasticity	0.91 [0.53]
Note: ***, **, and * denote significance at 1%, 5%, and 10% levels, respectively. Figures in brackets [ ] are p-values.			

The adjusted R2 is 0.83. It indicates that the chosen explanatory variables explain 83% of variation in wheat area. The P-value of the Jarque-Bera was greater than 0.05 which revealed that the model has no problem of normality and the residuals are normally distributed. However, the Breusch–Godfrey LM (BG-LM) test determined that there is no autocorrelation. Breusch-Pagan- Godfrey test of heteroscedasticity confirmed that the data is homoscedastic. The F-statistic is 74.47288 and also indicates overall significant relationships ($p < 0.0000$).

4.1. Short Run and Long Run Supply Response

The short- and long run elasticities of supply are shown in Table 4. The short- and long price elasticities of wheat are 5.055944 and 9.472122 respectively. Thus both the short-run and the long-run price elasticities are elastic, suggesting that wheat farmers adjust easily to area allocated for the production of wheat relative to agricultural pricing policy adopted by the Syrian government to achieve self-sufficiency in strategic crops. This indicates that the farmers of the wheat crop do not grow it to meet their subsistence needs only, but rather consider it a profitable cash crop. These findings are consisted with Begum et al. (2002) who found that wheat farmers in Bangladesh are responsive to price incentives in long- run. Both the short-run and long-run non- price elasticities for wheat area are inelastic and significant. Tenaye (2020) estimated the area response of wheat in Ethiopia and reported the short run and long run elasticities of –0.07 and –0.10 respectively. Özkan et al. (2011) concluded that wheat supply in Turkey is price inelastic both in the short and long run.

Overall, the coefficient of adjustment is 0.533771. The coefficient estimates time taken to adjust from the level of actual area to the level of desired area (Nhundu et al., 2022). This means that the Syrian wheat farmers could adjust only 53.38% of wheat area within one year, indicating that the adjustment speed is higher (Coefficient of adjustment > 0.5). This shows the farmers' persistence to continue cultivating this important crop despite the difficulties they faced during the crisis period.

Table 4: Estimations of Short Run and Long Run Wheat Supply Response and Adjustment Coefficient.

Items	Short-run	Long-run
AW(t-1)	0.466229**	0.873463
PW(t-1)	5.055944*	9.472122
PB(t-1)	-6.390638*	-11.9726
ABt	-0.299442**	-0.56099
RNOV(t-1)	1886.441*	3534.177
Coefficient of adjustment	0.533771	

5. Conclusions

This study examined the supply response of wheat farmers in Syria over the period 1991–2020 using a Nerlovian partial adjustment model. The findings indicate that both price and non-price factors significantly influence farmers' land allocation decisions, with rainfall and crisis-related conditions playing a particularly important role. From a policy perspective, several recommendations can be drawn:

1. Strengthening price support policies to provide stable and predictable incentives for wheat production.
2. Investing in water management and supplemental irrigation systems to reduce dependence on rainfall variability.
3. Enhancing institutional support and input availability, particularly in post-crisis recovery phases.

Despite its contributions, the study has some limitations. Data constraints during the crisis period may affect the accuracy and consistency of the estimates. In addition, the model does not explicitly account for other potentially relevant factors such as input prices, technological changes, or regional heterogeneity.

Future research could extend this analysis by incorporating more detailed micro-level data and exploring alternative econometric approaches such as ARDL or panel data models to better capture dynamic relationships.

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