

## **Estimating Supply Response of Some Strategic Crops in Egypt Using ARDL Model**

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### **Authors' contributions**

*This work was carried out in collaboration among all authors. Author ME designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Authors ME, AM and AES collected the data. Author ME managed the analyses of the study. All authors read and approved the final manuscript.*

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### **ABSTRACT**

This paper estimated the areas of main cereal crops in Egypt (Wheat, Maize, Rice) supply response of farm price, area harvested and net revenue by using Autoregressive Distributed Lag Model (ARDL) methodology to define the integral relationship between the dependent variable and independent variables, both in the long and short-run, in addition to determining the magnitude of the impacts of all dependent variables on the dependent variable, Main findings indicate that farmgate price has a statistically significant impact on wheat, maize and rice cultivated areas. Impact of yield on wheat cultivated area proved insignificant, while proved statistically significant on maize and rice cultivated areas. Impact of net revenue on wheat and maize cultivated areas were significant but was insignificant in case of rice. Applying ARDL bounds test revealed a long-term relationship between all variables in the model for wheat, but not for maize and rice, the study used the data during the period (2000-2017).

**Keywords:** Autoregressive Distributed Lag (ARDL) Model; supply response; farm price; net revenue.

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## 1. INTRODUCTION

Cereal crops, mainly wheat, maize and rice, staple food crops for many nations, especially in developing countries. They also play a strategic role in the policies of developed countries as they use such crops as a tool for practising pressure on other countries. That is why most developing countries seek to achieve self-sufficiency in cereal crops. In Egypt, official statistics indicate that cereal production reached 22.37 million tons, while domestic consumption reached 47.47 million tons, indicating a gap of 25 million tons worth US\$ 4.3 billion. In 2017, self-sufficiency in cereals reached 47.12% [1].

Average areas under wheat, maize and rice cultivated over the period 2000-2017 reached 2.86, 1.913 and 1.441 million acres, respectively [2].

The current search problem arises the supply of the response analysis has become more complicated in the light of changing agricultural policies that induce significant structural changes in supply response; since variations in the costs, prices, production technologies, and climate conditions that occur over time are considered of the main factors that affect the supply response of any crop; and since decisions regarding which crops to produce are optional (entirely up to farmers), there is a dire need for recent estimates of the relationships specifying the supply response of various crops in order to identify potential responses of farmers to dominant economic conditions. The identification and assessment of such relationships are expected to increase the likelihood of obtaining accurate forecasts of future cultivated areas, which enables farmers to make short and long-run decisions. Therefore, the current research aimed to estimate the supply response of wheat, maize, and rice crops planted areas in the short and long-run.

## 2. REVIEW OF LITERATURE

A study by (Al-Shourbagy,2007), that was conducted to measuring the impact of economic growth on employment in the short and long term of the Egyptian economy during the period (1982-2005). The study applied (ECM) through the use of the bounds testing, approach to cointegration and the Autoregressive distributed lag (ARDL) approach to estimate long and short-term elasticities [3]. Abu Taleb and El-Beigawy (2008) used an error correction model (ECM)

with Approach to Cointegration to study the supply response of some crops in Egypt to study the farmers' response to the movement of economic changes. Except for alfalfa, it is negatively affected by current prices, and the long-term equilibrium (less than one period) is corrected in the next period [4]. Al-Momani and Al-Hazeem,2011 determine the impact of local variables of net domestic demand surplus, the impact of foreign trade variables on import prices, quantities, and quantity of exports on prices in Jordan for the period (1992-2006). The study used the Johansen Cointegration Test and methodology for this purpose. (ARDL) (Auto-Regressive) Distributive Lag Technique. The results of the Johansen test showed a unique and long-term relationship between the variables used in this study. The results of using (ARDL) methodology showed that there is a positive and statistically significant effect of both the net domestic demand surplus, and import prices on the inflation rates in Jordan, and the presence of a negative and statistically significant impact on the quantities of exports on inflation in Jordan, while the amounts of imports did not have. Statistically significant effect [5]. According to the study by (Kamal,2016) The Impact of Currency Reduction on the Total Trade Balance and Non-Oil Trade Balance from 1980 to 2015 Using ARDL Model. The study found that this effect of the dinar reduction was delusional because the hydrocarbons sector dominates exports while imports are not flexible because there are no substitute goods for imports except to a limited extent [6].

According to study by (Attallah and Ali, 2016) To study the long-term equilibrium relationship of some crops by estimating distributed gap models such as the Quick Distributed Slowdown model, the partial modification model and the Distributed Slow Autonomous Self-Regression Models (ARDL) through the use of the boundary test method for common integration and derivation of the unrestricted error correction model. Distributed slows that the impact of this year's area outweighs the impact of this year's price on wheat production and that the price of the previous year exceeds the area of the last year in wheat production, while the area of the last year has a little impact on maize production [7].

## 3. MATERIALS AND METHODS

The research relied on data published by MALR (Bulletin of Agricultural Statistics), in addition to data published by the Central Agency for Public

Mobilization and Statistics (CAPMAS) and Bulletin of Water Resources for the period 2000-2017. The research mainly focuses on analyzing the supply response of wheat, maize and rice planted area to some variables likely to influence it.

### 3.1 Theoretical Framework of the Applied Model

Dependence of the dependent variable Y on the values of the explanatory variable X is not instantaneous. Y is usually dependent on X with a time difference. Such time difference is referred to as "lag". In case there is more than one period, the model is called the distributed lag model, and takes the following formula [4].

$$Y = \alpha + \beta_1 X_t + \beta_2 X_{t-1} + \beta_3 X_{t-2} + \dots + \beta_k X_{t-k} + u_t \quad (1)$$

Where k is the number of lag periods,  $\beta_1$  is the short-run impact because it gives the impact of change in X on Y during the same period. If the same level of impact carries on,  $(\beta_1 + \beta_2)$  gives the change that occurs in the average value of Y in the coming period; whereas  $(\beta_1 + \beta_2 + \beta_3)$  gives the change that occurs in the average value of Y in period that follows, etc., and is referred to as the separator or average multipliers. The sum of Ks is the long-run or the sum of the distributed lagged multiplier is given by:

$$\sum_{i=0}^k \beta_i = \beta_1 + \beta_2 + \beta_3 + \dots + \beta_k = \beta \quad (2)$$

The standard coefficient is a percentile of the long-run impact. It gives the impact at a specific period using the following formula:

$$\beta^* = \frac{\beta_i}{\sum \beta_i} = \frac{\beta_i}{\beta} \quad (3)$$

Which equals:

$$\frac{\partial E(Y_{it})}{\partial x_{t-i}} = \beta$$

### 3.2 Autoregressive and Distributed Lag Models

These are regression models applied to time series data on current and lagged values of the explanatory variables. It can be expressed as follows [8].

$$Y_t = \alpha + \beta_0 X_t + \beta_1 X_t + \dots + U_t \quad (4)$$

In case the model contains one (or more) value of the dependent variable that is/are used as the explanatory variable(s), it is referred to as the Autoregressive Model. It takes the following formula:

$$Y_t = \alpha + \beta X_t + \gamma Y_{t-1} + \dots + U_t \quad (5)$$

Coefficients associated with the model variables give the short-run impacts, while partial summation of the coefficients (for the same variable) gives the long-run impacts. Ordinary least square cannot be directly applied here due to entering the lagged dependent variable as the explanatory variable in the model, which leads to the problem of autocorrelation.

### 3.3 Autoregressive Distributed Lag (ARDL) Models

ARDL approach can be used to define the complementary relationship between the dependent variable and explanatory variables in both the short and long-run, in addition to defining the integral relationship between [9]. The dependent and explanatory variables, both in the long and short-run, in addition to determining the magnitude of the impacts of all dependent variables on the explanatory variable. ARDL models are standard least squares regression models containing lags in both the dependent and explanatory variables. Such models have been used in econometrics in selecting long-term relationships and common integration between variables over the last 10 years. They can be expressed as ARDL (p, q<sub>1</sub>, ..., q<sub>k</sub>), where p is the number of lags in the dependent variable, q<sub>1</sub> is the number of lags in the first explanatory variable, q<sub>k</sub> is the number of lags in the k<sup>th</sup> explanatory variable. Accordingly, the model takes the following form [10].

$$y_t = \alpha + \sum_{i=1}^p \gamma_i y_{t-i} + \sum_{j=1}^k \sum_{i=0}^{q_j} X_{j,t-i} \beta_{j,i} + \varepsilon_t \quad (6)$$

Explanatory variables X<sub>j</sub> with no lags (q<sub>j</sub> = 0) are called stationary regressions, whereas those containing lags are called dynamic regressions.

To build an ARDL model, the number of lags in each variable should first be determined. In other words, p, q<sub>1</sub>, ..., q<sub>k</sub> must first be determined in the light of criteria set by Akaike AIC, Schwarz SC and Hannan-Quinn (H-Q) as an alternative

for the adjusted coefficient of determination (adjusted  $R^2$ ) to select the appropriate model.

Since ARDL model estimates the dynamic relationships between the dependent variable and explanatory variables [11], the model can be transformed into a long-run form to capture the long-run supply response of the dependent variable to changes in the explanatory variable. Long-run coefficients can be estimated by:

$$\theta_j = \frac{\sum_{i=1}^{q_j} \hat{\beta}_{j,i}}{1 - \sum_{i=1}^p \gamma_i} \quad (7)$$

Standard error associated with long-run coefficients can be calculated from the standard error of the original regression with the help of the delta method [12]. which is a method for solving equations using a specific number called delta.

### 3.4 Co-integration

The most popular single equation testing for co-integration between a set of  $I(1)$  variables rely on the Engle-Granger (1987) residual-based tests. System co-integration testing is mostly based on Johansen's (1991, 1995) system based reduced-rank approach.

To address this problem, Pesaran and Shin (1999) clarified that cointegration systems can be estimated as ARDL, a technique that is reported to offer several advantages. Unlike the Johansen approach, restrictions on the number of lags can be applied to each variable separately. Also, the ARDL approach does not require pre-testing for the order of integration of variables used in the model, i.e., whether the variables are integrated of order zero  $I(0)$ , or of order one  $I(1)$ . [13]. The cointegration regression form of ARDL model

can be obtained by converting equation (6) to differences and substitution for long-run coefficients in equation (7) to obtain:

$$\Delta y_t = -\sum_{i=1}^{p-1} \gamma_i^* \Delta y_{t-i} + \sum_{j=1}^k \sum_{i=0}^{q_j-1} \Delta X_{j,t-i} \beta_{j,i}^* - \hat{\phi} EC_{t-1} + \varepsilon_t \quad (8)$$

Where,

$$EC_t = y_t - \alpha - \sum_{j=1}^k X_{j,t} \hat{\theta}_j \quad (9)$$

$$\hat{\phi} = 1 - \sum_{i=1}^p \hat{\gamma}_i \quad (10)$$

$$\gamma_i^* = \sum_{m=i+1}^p \hat{\gamma}_m \quad (11)$$

$$\beta_{j,i}^* = \sum_{m=1}^{q_j} \beta_{j,m} \quad (12)$$

The standard error for the long-run regression coefficients can be computed from the standard error for the original regression with the help of the delta method.

### 3.5 Bounds Testing

Using the cointegration form expressed by equation (8), Pesaran and Shin (2001) developed a new approach to solve the problem of testing for the existence of a level relationship between a dependent variable and a set of regressors, when it is not known with certainty whether the underlying regressors are trend- or first-difference stationary, or the existence of a long-run relationship between the dependent and explanatory variables. Derived from equation (8), bounds testing can be written as [14].

$$\Delta y_t = -\sum_{i=1}^{p-1} \gamma_i^* \Delta y_{t-i} + \sum_{j=1}^k \sum_{i=0}^{q_j-1} \Delta X_{j,t-i} \beta_{j,i}^* - \rho y_{t-1} - \alpha - \sum_{j=1}^k X_{j,t-1} \delta_j + \varepsilon_t \quad (13)$$

Testing for relationships with no difference in level is therefore:

$$\rho = 0, \quad \delta_1 = \delta_2 = \dots = \delta_k = 0$$

Coefficients obtained from the regression equation (6) can be directly obtained from the regression equation (13). The statistical base of the test in equation (13) is that it has a different distribution

under the null hypothesis (no relationships without differences in level), depending on whether the explanatory variables are  $I(0)$  or  $I(1)$ . Moreover, under both cases, the distribution is not standard. Pesaran, Shin and Smith defined the critical values where explanatory variables in the model are of order zero  $I(0)$  or one  $I(1)$  in order to use such critical values as bounds for similar cases when the explanatory variables are a mixture of both  $I(0)$  and  $I(1)$ .

This means that the bounds test is used to test the existence of an equilibrium relationship between variables, the value of the standard F-statistic is compared with the critical values obtained under  $I(0)$  and  $I(1)$ . In case F-value is higher the null hypothesis is rejected, i.e., lack of a long-run equilibrium relationship is rejected, in which case the alternative hypothesis is accepted, i.e., there exists a long-run equilibrium relationship.

### 3.6 Stability Testing

To test the stability of ARDL Models, a proper test should be selected, like the cumulative sum of recursive residuals (Cusum), which helps identify the stability of and harmony between long and short-run parameters.

Advantages of ARDL Approach [15]. ARDL approach does not require that the set of time series be integrated of the same order. Pesaran explained that the bounds test is applicable irrespective of the characteristics of time series and whether the underlying regressors are purely  $I(0)$ , purely  $I(1)$  or a mixture of both. The only restriction is that it should not be integrated of order two (not applicable in the ARDL approach). ARDL approach is also more consistent in short time series compared to other approaches of testing for cointegration like the two-stage Engle-Granger test, or Durbin-Watson method (CRDW Test) [16], and Johansen Cointegration test. ARDL is characterized by taking a sufficient number of lag periods to yield the best results. It yields the best long-run parameters. Also, it allows isolation between the long and short-run impacts while capturing them in the same equation. Detailed advantages of ARDL approach include:

- i. Since variables are represented in a single reduced form equation, ARDL approach is less in problems faced due to lack of autocorrelation (assuming that all variables are endogenous). Also, it allows the analysis of residues model.

- ii. In case there is a single relationship in the long-run, ARDL allows distinguishing between the dependent and explanatory variables. Also, the ARDL approach assumes the existence of a single relationship between the dependent variable and exogenous variables in the reduced form [17],
- iii. ARDL approach allows determining cointegration vectors when there are multiple ones.
- iv. Error Correction Model (ECM) can be derived from ARDL model by a simple linear transformation that integrates short-run adjustments with the long-run equilibrium without losing long-run information.

## 4. RESULTS AND DISCUSSION

### 4.1 Wheat Crop

#### 4.1.1 Planted area as the dependent variable and farmgate price as the independent variable

Applying the ARDL model to estimate the supply response of wheat planted area to the farmgate price of the main crop indicates that farmgate price has a significant impact on wheat planted area at the 0.01 level of significance. It is also clear from the Table 1 that the estimated model fulfilled all the applied statistical tests, indicating that the model is statistically valid and has no specification problems that may cause biases or negatively affect the accuracy of the obtained results. In other words, all the assumptions behind the model (error normality, error non-heteroscedasticity, error non-auto-correlation) have been validated by the data used in the estimated model, where results of applying Breusch-Godfrey Serial Correlation LM Test proved error non-autocorrelation<sup>(\*\*)</sup>; results of applying Breusch Pagan test proved error non-heteroscedasticity, and results of applying Jarque-Bera test proved error normality.

The coefficient of the error correction term  $CointEq(-1)$ , which measures the model's ability and speed of adjustment towards long-run equilibrium and is required to be statistically significant negative<sup>(\*\*\*)</sup>, has been estimated at -0.50, indicating that changes in the farmgate

<sup>\*\*</sup> This is considered the principal and most important test.

<sup>\*\*\*</sup> A positive value indicates that equilibrium in the long-run is not achieved.

price are corrected at a speed of 50%, which means that adjustment toward the long-run equilibrium occurs after two years.

The short-run impact proved statistically insignificant. However, the long-run relationship proved statistically significant, returning a value of 3.09 for farmgate price. Applying the bounds test to test the long-run relationship between variables in the model returned a statistically significant F value, indicating a long-run relationship that moves from the independent variable to the dependent variable. It is clear from Fig. 1 (which reflects the results of applying the stability test) that stability and homogeneity exist between the long and short-run parameters for farmgate price.

#### **4.1.2 Planted area as the dependent variable and yield as the independent variable**

Applying the ARDL model to estimate the supply response of wheat planted area to yield indicates that farmgate price has no impact on wheat planted area at the 0.01 level. It is clear from the Table 1 that the estimated model fulfilled all the applied statistical tests, indicating that the model is statistically valid and has no specification problems that may cause biases or negatively affect the accuracy of the obtained results. In other words, all the assumptions behind the model (error normality, error non-heteroscedasticity, error non-auto-correlation) have been validated by the data used in the estimated model, where results of applying Breusch-Godfrey Serial Correlation LM Test proved error non-autocorrelation; results of applying Breusch Pagan test proved error non-heteroscedasticity; and results of applying Jarque-Bera test proved error normality.

Results also show that the coefficient of the error correction term  $CointEq(-1)$  reached 0.19, indicating that changes in yield are corrected by 19%, indicating that adjustment toward the long-run equilibrium occurs after five years.

The short-run impact proved statistically significant, returning a value of 3087.30 for yield. Such a result indicates that yield has a statistically significant positive impact on the wheat planted area. Accordingly, a 1% increase in this variable in the short-run results in 3087.30% increase in planted area. The long-run relationship proved insignificant. Applying the bounds returned a statistically significant F value, indicating a long-run relationship that moves from the independent variable to the dependent

variable. It is clear from Fig. 2 that stability and homogeneity exist between the long and short-run parameters for yield.

#### **4.1.3 Planted area as the dependent variable and revenue as the independent variable**

Applying the ARDL model to estimate the supply response of wheat planted area to net revenue from the main crop indicates that net return has no impact on wheat planted area at the 0.01 level. It is clear from the Table 2 that the estimated model fulfilled all the applied statistical tests, indicating that the model is statistically valid and has no specification problems that may cause biases or negatively affect the accuracy of the obtained results. In other words, all the assumptions behind the model (error normality, error non-heteroscedasticity, error non-auto-correlation) have been validated by the data used in the estimated model, where results of applying Breusch-Godfrey Serial Correlation LM Test proved error non-autocorrelation; results of applying Breusch Pagan test proved error non-heteroscedasticity; and results of applying Jarque-Bera test proved error normality.

The estimated coefficient of the error correction term  $CointEq(-1)$  reached -0.42, i.e., changes in net return are corrected by 42%, indicating that adjustment toward the long-run equilibrium occurs after two years.

The short-run impact proved statistically significant, returning a value of 0.35, indicating that net revenue has a statistically significant positive impact on the wheat planted area. Accordingly, a 1% increase in net revenue results in 0.35% increase in planted area. Applying the bounds test to test the long-run relationship between variables in the model returned a statistically significant (F) value for net revenue from the main crop, indicating a long-run relationship that moves from the independent variable to the dependent variable. It is clear from Fig. 3 that stability and homogeneity exist between the long and short-run parameters for net revenue.

#### **4.1.4 Planted area as the dependent variable and farmgate price, yield and net revenue as the independent variables**

Applying the ARDL model to estimate the supply response of wheat planted area to farmgate price, yield and net revenue indicates that the three variables have a statistically significant

impact on wheat planted area at the 0.01 level. It is clear from the Table 2 that the estimated model fulfilled all the applied statistical tests, indicating that the model is statistically valid and has no specification problems that may cause biases or negatively affect the accuracy of the obtained results. In other words, all the assumptions behind the model (error normality, error non-heteroscedasticity, error non-auto-correlation) have been validated by the data used in the estimated model, where results of applying Breusch-Godfrey Serial Correlation LM Test proved error non-autocorrelation; results of applying Breusch Pagan test proved error non-heteroscedasticity; and results of applying Jarque-Bera test proved error normality.

The estimated coefficient of the error correction term  $CointEq(-1)$  for the three variables reached -0.32, i.e., indicating that the long-run equilibrium for this variable occurs after three years.

The short-run impact of the variables proved significant insignificant. Likewise, the long-run relationship proved statistically insignificant. Applying the bounds test to test the long-run relationship between variables in the model returned a statistically significant (F) value for the three variables, indicating a long-run relationship that moves from the independent variables to the dependent variable. It is clear from Fig. 4 that stability and homogeneity between the long and short-run parameters are validated for the three variables.

## 4.2 Maize Crop

### 4.2.1 Planted area as the dependent variable and farmgate price as the independent variable

Applying ARDL model to estimate the supply response of maize planted area to farmgate price of the main crop indicates that farmgate price has a statistically significant impact on maize planted area at the 0.01 level of significance. It is also clear from Table 3 that the estimated model fulfilled all the applied statistical tests, indicating that the model is statistically valid and has no specification problems that may cause biasness or negatively affect the accuracy of the obtained results. In other words, all the assumptions behind the model (error normality, error non-heteroscedasticity, error non-auto-correlation) have been validated by the data used in the estimated model, where results of applying Breusch-Godfrey Serial Correlation LM Test proved error non-autocorrelation; results of

applying Breusch Pagan test proved error non-heteroscedasticity; and results of applying Jarque-Bera test proved error normality.

The estimated coefficient of the error correction term  $CointEq(-1)$  for farmgate price reached -0.37, i.e., changes in farmgate price are corrected at a speed of 37%, which means that adjustment toward the long-run equilibrium occurs after two years and a half.

The short-run impact proved statistically significant, returning a value of -2.458, which means that farmgate price has a negative impact on maize planted area. However, the long-run relationship proved insignificant. Results of applying the bounds test returned an insignificant F value, indicating absence of a long-run relationship between variables in the model. It is clear from Fig. 5 that stability and homogeneity between the long and short-run parameters are validated for farmgate price.

### 4.2.2 Planted area as the dependent variable and yield as the independent variable

Applying ARDL model to estimate the supply response of maize planted area to yield indicates that yield has a statistically significant impact on maize planted area at the 0.01 level. It is clear from Table 3 that the estimated model fulfilled all the applied statistical tests, indicating that the model is statistically valid and has no specification problems that may cause biasness or negatively affect the accuracy of the obtained results. In other words, all the assumptions behind the model (error normality, error non-heteroscedasticity, error non-auto-correlation) have been validated by the data used in the estimated model, where results of applying Breusch-Godfrey Serial Correlation LM Test proved error non-autocorrelation; results of applying Breusch Pagan test proved error non-heteroscedasticity; and results of applying Jarque-Bera test proved error normality.

The estimated coefficient of the error correction term  $CointEq(-1)$  reached -0.21, i.e., changes in yield are corrected by 21%, indicating that adjustment toward the long-run equilibrium occurs after four years and a half.

None of the variables proved significant in the short-run. The long-run relationship also proved insignificant. Results of applying the bounds test returned an insignificant F value, indicating absence of a long-run relationship between variables in the model. It is clear from Fig. 6 that

stability and homogeneity between the long and short-run parameters are validated for yield.

#### **4.2.3 Planted area as the dependent variable and net revenue as the independent variable**

Applying ARDL model to estimate the supply response of maize planted area to net revenue from the main crop indicates that net revenue has a statistically significant impact on maize planted area at the 0.01 level. It is clear from Table 3 that the estimated model fulfilled all the applied statistical tests, indicating that the model is statistically valid and has no specification problems that may cause biasness or negatively affect the accuracy of the obtained results. In other words, all the assumptions behind the model (error normality, error non-heteroscedasticity, error non-auto-correlation) have been validated by the data used in the estimated model, where results of applying Breusch-Godfrey Serial Correlation LM Test proved error non-Autocorrelation; results of applying Breusch Pagan test proved error non-heteroscedasticity; and results of applying Jarque-Bera test proved error normality.

The estimated coefficient of the error correction term  $CointEq(-1)$  reached -0.23, indicating that adjustment toward the long-run equilibrium does not occur for this variable.

The short-run impact amounted to -2.750 and -2.678 and proved statistically significant, indicating that net revenue has a negative impact on maize planted area. This means that a 1% increase in net revenue results in -2.750 % and -2.678% change planted area. However, the long-run relationship proved insignificant. Results of applying the bounds test returned an insignificant (F) value, indicating the long-run relationship between variables in the model is absent. It is clear from Fig. 7 that stability and homogeneity between the long and short-run parameters are validated for net revenue.

#### **4.2.4 Planted area as the dependent variable and farmgate price, yield and net revenue as the independent variables**

Applying ARDL model to estimate the supply response of maize planted area to farmgate price, yield and net revenue indicates that three variables have a statistically significant impact on maize planted area at the 0.01 level. It is clear

from Table 4 that the estimated model fulfilled all the applied statistical tests, indicating that the model is statistically valid and has no specification problems that may cause biasness or negatively affect the accuracy of the obtained results. In other words, all the assumptions behind the model (error normality, error non-heteroscedasticity, error non-auto-correlation) have been validated by the data used in the estimated model, where results of applying Breusch-Godfrey Serial Correlation LM Test proved error non-autocorrelation; results of applying Breusch Pagan test proved error non-heteroscedasticity; and results of applying Jarque-Bera test proved error normality.

The estimated coefficient of the error correction term  $CointEq(-1)$  reached -0.39, indicating that adjustment toward the long-run equilibrium occurs after two years and a half.

The short-run impact proved statistically significant for farmgate price only. The long-run relationship proved insignificant. Results of applying the bounds test returned an insignificant F value, indicating the absence of a long-run relationship between variables in the model. It is clear from Fig. 8 that stability and homogeneity between the long and short-run parameters are validated for the three variables.

### **4.3 Rice Crop**

#### **4.3.1 Planted area as the dependent variable and farmgate price as the independent variable**

Applying ARDL model to estimate the supply response of rice planted area to the farmgate price of the main crop indicates that farmgate price has a statistically significant impact on rice planted area at the 0.01 level of significance. It is also clear from the Table 5 that the estimated model fulfilled all the applied statistical tests, indicating that the model is statistically valid and has no specification problems that may cause biases or negatively affect the accuracy of the obtained results. In other words, all the assumptions behind the model (error normality, error non-heteroscedasticity, error non-auto-correlation) have been validated by the data used in the estimated model, where results of applying Breusch-Godfrey Serial Correlation LM Test proved error non-autocorrelation; results of applying Breusch Pagan test proved error non-heteroscedasticity; and results of applying Jarque-Bera test proved error normality.



**Table 1. Results of applying ARDL model on wheat crop grown in Egypt over the period 2000-2017**

Independent = Farmgate price				Independent = Yield			
Variable	Coefficient	t-Statistic	Prob.*	Variable	Coefficient	t-Statistic	Prob.*
Area_Wheat(-1)	0.500268	3.181825	0.0072	Area_W(-1)	0.644084	1.779175	0.1498
Price_Wheat	0.695326	1.408919	0.1823	Area_W(-2)	-0.489671	-1.400987	0.2338
Price_Wheat(-1)	0.850143	1.453079	0.1699	Area_W(-3)	0.999231	2.747565	0.0515
C	1053.205	2.785401	0.0155	Area_W(-4)	-0.343666	-0.920734	0.4093
R-squared	0.808105	Mean dep var	2969.706	Pro_W	-341.2846	-0.779758	0.4791
Adjusted R-squared	0.763822	S.D. dep var	342.5728	Pro_W(-1)	42.03782	0.084633	0.9366
S.E. of regression	166.4840	AIC	13.27000	Pro_W(-2)	-1018.076	-1.971819	0.1199
Sum squared resid	360320.1	Schwarz C	13.46605	Pro_W(-3)	-870.6959	-1.883298	0.1328
Log-likelihood	-108.7950	H-Q criter.	13.28949	Pro_W(-4)	-1198.535	-2.461881	0.0696
F-statistic	18.24850	D-W stat	1.310020	C	9760.114	3.159957	0.0342
Prob(F-statistic)	0.000061			R-squared	0.891711	Mean dependent var	3082.643
				Adjusted R-squared	0.648059	S.D. dependent var	255.2406
				S.E. of regression	151.4204	Akaike info criterion	13.05381
				Sum squared resid	91712.59	Schwarz criterion	13.51028
				Log-likelihood	-81.37664	Hannan-Quinn criter.	13.01155
				F-statistic	3.659784	Durbin-Watson stat	2.751020
				Prob(F-statistic)	0.112012		
<b>ARDL cointegrating and long run form</b>							
<b>Cointegrating form</b>							
Variable	Coeff	t-Statistic	Prob.	Variable	Coeff	t-Statistic	Prob.
D(area._wheat)	0.695326	1.637051	0.1256	D(Area_W(-1))	-0.165895	-0.742150	0.4992
CointEq(-1)	-0.499732	-3.620491	0.0031	D(Area_W(-2))	-0.655565	-3.174064	0.0337
				D(Area_W(-3))	0.343666	1.622544	0.1800
				D(Pro_W)	-341.284573	-1.098695	0.3336
				D(Pro_W(-1))	3087.307219	4.878247	0.0082
				D(Pro_W(-2))	2069.231337	3.784331	0.0194
				D(Pro_W(-3))	1198.535422	3.135623	0.0350
				Coint Eq(-1)	-0.190021	-4.759396	0.0089

<b>Long run coeffs</b>							
<b>Variable</b>	<b>Coeff</b>	<b>t-Statistic</b>	<b>Prob.</b>	<b>Variable</b>	<b>Coeff</b>	<b>t-Statistic</b>	<b>Prob.</b>
Price_Wheat	3.092595	3.596475	0.0033	Pro_W	17821.99973	-0.897684	0.4201
C	2107.538683	8.224437	0.0000	C	51363.34972	0.954353	0.3939
<b>Breusch-Godfrey Serial Correlation LM Test</b>							
F-statistic	1.263401	Prob. F(2,11)	0.3207	F-statistic	9.534509	Prob. F(2,2)	0.0949
<b>Heteroskedasticity Test: Breusch-Pagan-Godfrey</b>							
F-statistic	1.032316	Prob. F(3,13)	0.4106	F-statistic	1.349492	Prob. F(9,4)	0.4126
<b>Series: Residuals</b>							
Jarque-Bera	0.391500	Probability	0.822218	Jarque-Bera	0.449611	Probability	0.798671
<b>ARDL Bounds Test</b>							
F-statistic	3.786742			F-statistic	5.033744		
Significance	I(0) Bound	5%=3.62	1%=4.94	Significance	I(0) Bound	5%=3.62	1%=4.94
	I(1) Bound	5%=4.16	1%=5.58		I(1) Bound	5%=4.16	1%=5.58

Table 2. Results of applying ARDL to wheat crop grown in Egypt over the period 2000-2017

<b>Independent =Net Revenue</b>				<b>Independent =Farmgate Price, Yield and Net Revenue</b>			
<b>Variable</b>	<b>Coefficient</b>	<b>t-Statistic</b>	<b>Prob.*</b>	<b>Variable</b>	<b>Coefficient</b>	<b>t-Statistic</b>	<b>Prob.*</b>
Area_W(-1)	0.582885	4.914590	0.0003	Area_W(-1)	0.683236	3.359149	0.0064
net_W	0.359912	1.917481	0.0774	Price_W	-1.206040	-0.713502	0.4904
Net_W(-1)	0.514064	2.381354	0.0332	Pro_W	-41.39723	-0.097107	0.9244
C	887.9193	2.796784	0.0151	Net_W	0.875282	1.185978	0.2606
R-squared	0.848459	Mean dep var	2969.706	Net_W(-1)	0.580851	2.311598	0.0412
Adjusted R-squared	0.813488	S.D. dep var	342.5728	C	808.4331	0.798220	0.4416
S.E. of regression	147.9470	AIC	13.03391	R-squared	0.855564	Mean dep var	2969.706
Sum squared resid	284548.0	Schwarz C	13.22996	Adjusted R-squared	0.789912	S.D. dep var	342.5728
Log likelihood	-106.7882	H-Q criter.	13.05340	S.E. of regression	157.0195	AIC	13.22118
F-statistic	24.26180	D-W stat	1.537052	Sum squared resid	271206.3	Schwarz C	13.51526
Prob(F-statistic)	0.000013			Log likelihood	-106.3800	H-Q criter.	13.25041
				F-statistic	13.03170	D-W stat	1.715256
				Prob(F-statistic)	0.000259		

<b>ARDL Cointegrating And Long Run Form</b>							
<b>Cointegrating Form</b>							
<b>Variable</b>	<b>Coeff</b>	<b>t-Statistic</b>	<b>Prob.</b>	<b>Variable</b>	<b>Coeff</b>	<b>t-Statistic</b>	<b>Prob.</b>
D(NET_W)	0.359912	2.298706	0.0388	D(PRICE_W)	-0.859146	-0.628712	0.5424
CointEq(-1)	-0.417115	-4.592140	0.0005	D(PRO_W)	-233.079028	-0.893581	0.3907
				D(NET_W)	0.736771	1.302274	0.2194
				CointEq(-1)	-0.321959	-4.498503	0.0009
<b>Long Run Coeffs</b>							
<b>Variable</b>	<b>Coeff</b>	<b>t-Statistic</b>	<b>Prob.</b>	<b>Variable</b>	<b>Coeff</b>	<b>t-Statistic</b>	<b>Prob.</b>
NET_W	2.095285	3.462457	0.0042	Price_W	-3.807374	-0.518019	0.6147
C	2128.714449	8.228947	0.0000	Pro_W	-130.687820	-0.094076	0.9267
				Net_W	4.596897	0.906817	0.3839
				C	2552.159968	0.679307	0.5110
<b>Breusch-Godfrey Serial Correlation LM Test</b>							
F-statistic	0.712733	Prob. F(2,11)	0.5116	F-statistic	1.070130	Prob. F(2,9)	0.3829
<b>Heteroskedasticity Test: Breusch-Pagan-Godfrey</b>							
F-statistic	0.424421	Prob. F(3,13)	0.7387	F-statistic	0.561292	Prob. F(5,11)	0.7280
<b>Series: Residuals</b>							
Jarque-Bera	0.479747	Probability	0.786727	Jarque-Bera	0.338238	Probability	0.844408
<b>ARDL Bounds Test</b>							
F-statistic	6.092017			F-statistic	3.781078		
Significance	I(0) Bound	5%=3.62	1%=4.94	Significance	I(0) Bound	5%=2.79	1%=3.65
	I(1) Bound	5%=4.16	1%=5.58		I(1) Bound	5%=3.67	1%=4.66

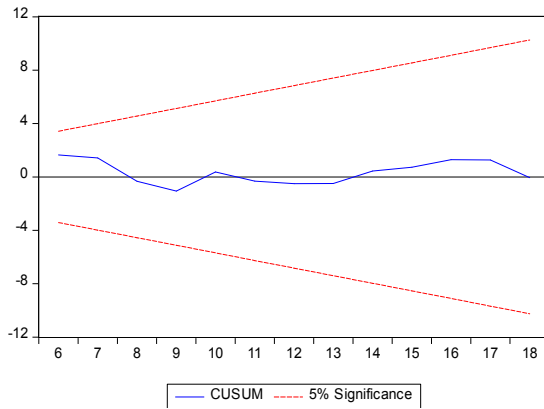
Source: Authors Calculation

Table 3. Results of applying ARDL model on maize crop grown in Egypt over the period 2000-2017

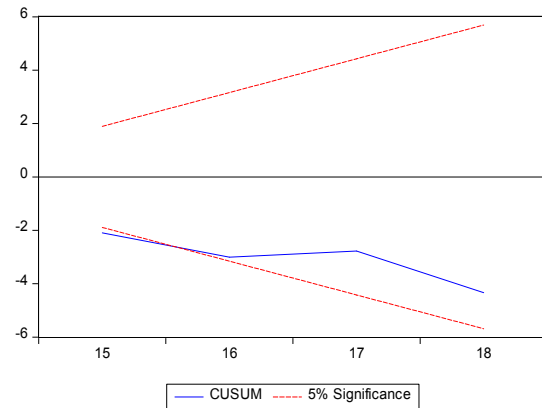
<b>Independent = Farmgate price</b>				<b>Independent = Yield</b>			
<b>Variable</b>	<b>Coefficient</b>	<b>t-Statistic</b>	<b>Prob.*</b>	<b>Variable</b>	<b>Coefficient</b>	<b>t-Statistic</b>	<b>Prob.*</b>
Area_C(-1)	0.384814	1.398289	0.2047	Area_C(-1)	0.777747	3.435940	0.0040
Area_C(-2)	0.031110	0.101515	0.9220	Pro_C	-90.29059	-0.359857	0.7243
Area_C(-3)	-0.138477	-0.374118	0.7194	C	762.6105	0.652992	0.5243
Area_C(-4)	0.685576	2.180580	0.0656	R-squared	0.613748	Mean dependent var	1927.176
Price_C	-1.158835	-1.297157	0.2357	Adjusted R-squared	0.558569	S.D. dependent var	235.5383
Price_C(-1)	1.648996	1.997501	0.0859	S.E. of regression	156.4923	Akaike info criterion	13.10268

Independent = Farmgate price				Independent = Yield			
Variable	Coefficient	t-Statistic	Prob.*	Variable	Coefficient	t-Statistic	Prob.*
C	74.49385	0.108149	0.9169	Sum squared resid	342858.0	Schwarz criterion	13.24971
Adjusted R-squared	0.803747	Mean dependent var	1975.929	Log likelihood	-108.3728	Hannan-Quinn criter.	13.11729
R-squared	0.635529	S.D. dependent var	230.5477	F-statistic	11.12286	Durbin-Watson stat	2.182865
S.E. of regression	139.1849	Akaike info criterion	13.01634	Prob(F-statistic)	0.001283		
Sum squared resid	135607.0	Schwarz criterion	13.33586				
Log likelihood	-84.11435	Hannan-Quinn criter.	12.98676				
F-statistic	4.778029	Durbin-Watson stat	1.979491				
Prob(F-statistic)	0.029804						
<b>ARDL Cointegrating and Long Run Form</b>							
<b>Cointegrating Form</b>							
Variable	Coeff	t-Statistic	Prob.	Variable	Coeff	t-Statistic	Prob.
D(Area_C(-1))	-0.578209	-2.457773	0.0436	D(Pro_C)	-164.242305	-1.148827	0.2699
D(Area_C(-2))	-0.547099	-2.487458	0.0418	CointEq(-1)	-0.208160	-1.366200	0.1934
D(Area_C(-3))	-0.685576	-2.631834	0.0338				
D(Price_C)	-1.158835	-1.975560	0.0888				
CointEq(-1)	-0.036977	-2.974843	0.0207				
<b>Long Run Coeffs</b>							
Variable	Coeff	t-Statistic	Prob.	Variable	Coeff	t-Statistic	Prob.
PRICE_C	13.255733	0.102825	0.9210	Pro_C	-406.252300	-0.438206	0.6679
C	2014.585380	0.676730	0.5203	C	3431.279546	1.107997	0.2865
<b>Breusch-Godfrey Serial Correlation LM Test</b>							
F-statistic	0.001795	Prob. F(2,5)	0.9982	F-statistic	1.021846	Prob. F(2,12)	0.3892
<b>Heteroskedasticity Test: Breusch-Pagan-Godfrey</b>							
F-statistic	1.054114	Prob. F(6,7)	0.4661	F-statistic	0.130512	Prob. F(2,14)	0.8787
<b>Series: Residuals</b>							
Jarque-Bera	0.877462	Probability	0.644854	Jarque-Bera	0.704947	Probability	0.702947
<b>ARDL Bounds Test</b>							
F-statistic	2.294364			F-statistic	1.023195		
Significance	I(0) Bound	5%=3.62	1%=4.94	Significance	I(0) Bound	5%=3.62	1%=4.94
	I(1) Bound	5%=4.16	1%=5.58		I(1) Bound	5%=4.16	1%=5.58

Source: Authors calculation

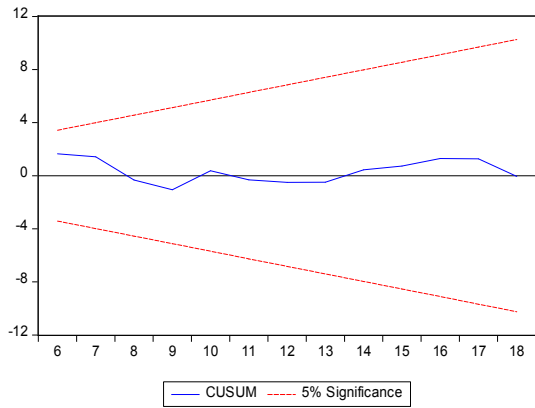


**Fig. 1. Stability test results for farmgate price of wheat**

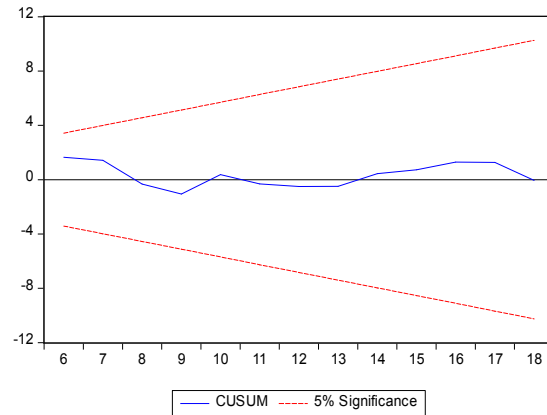


**Fig. 2. Stability Test Results for Wheat Yield**

Source: Table 1

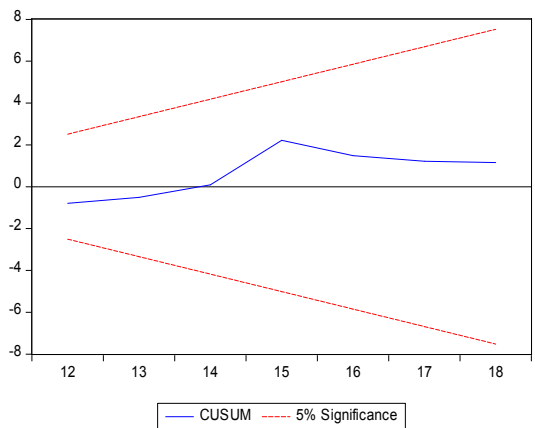


**Fig. 3. Stability test results for net revenue from wheat**

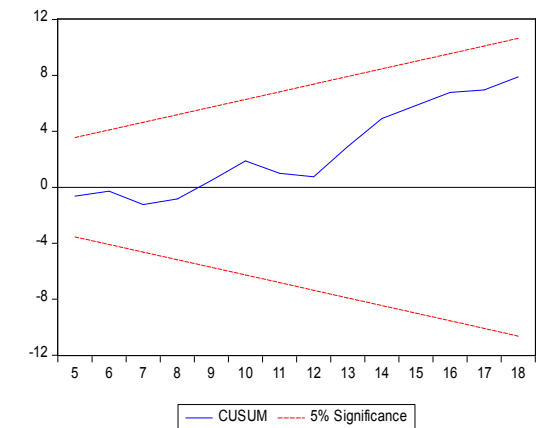


**Fig. 4. Stability test results for the three variables**

Source: Table 2

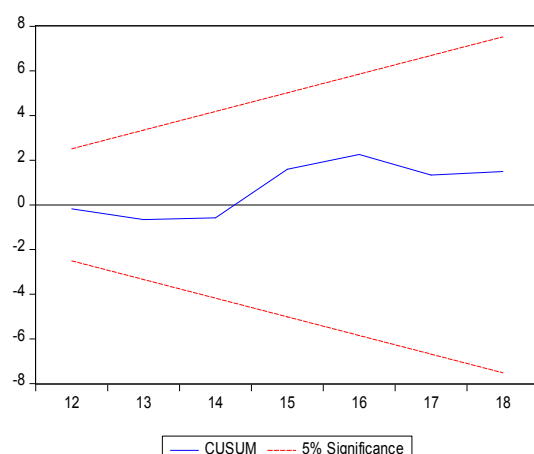


**Fig.5. Stability test results for farmgate price of maize**

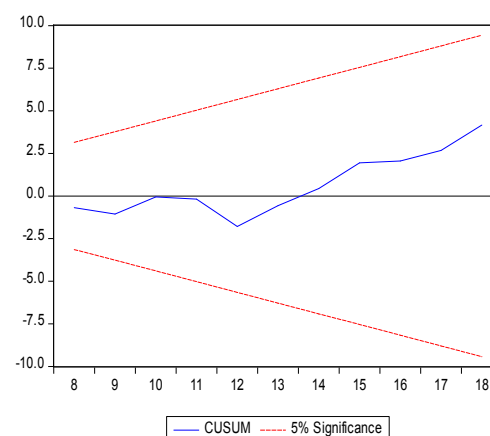


**Fig. 6. Stability test results for maize yield**

Source: Table 3



**Fig. 7. Stability test results for net revenue from maize**



**Fig. 8. Stability test results for the three variables**

Source: Table 4

The estimated coefficient of the error correction term  $CointEq(-1)$  for farmgate price reached -1.29, i.e., changes in farmgate price are corrected at a speed of 129%, which means that adjustment toward the long-run equilibrium occurs in less than one year.

Analysis results revealed that the short-run impact proved statistically significant and amounted to 3.44 and 4.5, indicating that farmgate price has a positive impact on rice planted area. Such finding means that a 1% increase in farmgate price results in 3.44% and 4.5% change in rice planted area. The long-run relationship also proved statistically significant and amounted to -2.60. Applying the bounds test returned a statistically significant (F) value, indicating a long-run relationship that moves from the independent variable to the dependent variable. It is clear from Figure (9) that stability and homogeneity between the long and short-run parameters are validated for farmgate price.

#### 4.3.2 Planted area as the dependent variable and yield as the independent variable

Applying the ARDL model to estimate the supply response of rice planted area to yield indicates that yield has a statistically significant impact on planted area at the 0.01 level of significance. It is also clear from the Table 5 that the estimated model fulfilled all the applied statistical tests, indicating that the model is statistically valid and has no specification problems that may cause biases or negatively affect the accuracy of the obtained results. In other words, all the assumptions behind the model (error normality,

error non-heteroscedasticity, error non-autocorrelation) have been validated by the data used in the estimated model, where results of applying Breusch-Godfrey Serial Correlation LM Test proved error non-autocorrelation; results of applying Breusch Pagan test proved error non-heteroscedasticity; and results of applying Jarque-Bera test proved error normality.

The estimated coefficient of the error correction term  $CointEq(-1)$  reached -0.89, i.e., changes are corrected at a speed of 89%, which means that adjustment toward the long-run equilibrium occurs after one year.

Analysis results revealed that the short-run impact proved insignificant. The long-run relationship also proved insignificant. Applying the bounds test returned a statistically significant F value, indicating a long-run relationship that moves from the independent variable to the dependent variable. It is clear from Fig. 10 that stability and homogeneity between the long and short-run parameters are validated for yield.

#### 4.3.3 Planted area as the dependent variable and net revenue as the independent variable

Applying the ARDL model to estimate the supply response of rice planted area to net revenue indicates that net revenue has a statistically significant impact on planted area at the 0.01 level of significance. It is also clear from the Table 6 that the estimated model fulfilled all the applied statistical tests, indicating that the model is statistically valid and has no specification

problems that may cause biases or negatively affect the accuracy of the obtained results. In other words, all the assumptions behind the model (error normality, error non-heteroscedasticity, error non-auto-correlation) have been validated by the data used in the estimated model, where results of applying Breusch-Godfrey Serial Correlation LM Test proved error non-autocorrelation; results of applying Breusch Pagan test proved error non-heteroscedasticity; and results of applying Jarque-Bera test proved error normality.

The estimated coefficient of the error correction term  $CointEq(-1)$  reached -1.92, i.e., changes are corrected at a speed of 192%, which means that adjustment toward the long-run equilibrium occurs in less than one year.

Analysis results revealed that the short-run impact proved insignificant. The long-run relationship also proved insignificant. Applying the bounds test returned a statistically significant F value, indicating a long-run relationship that moves from the independent variable to the dependent variable. It is clear from Fig. 11 that stability and homogeneity between the long and short-run parameters are validated for net revenue.

#### 4.3.4 Planted area as the dependent variable and farmgate price, yield and net revenue as the independent variable

Applying ARDL model to estimate the supply response of rice planted area to farmgate price,

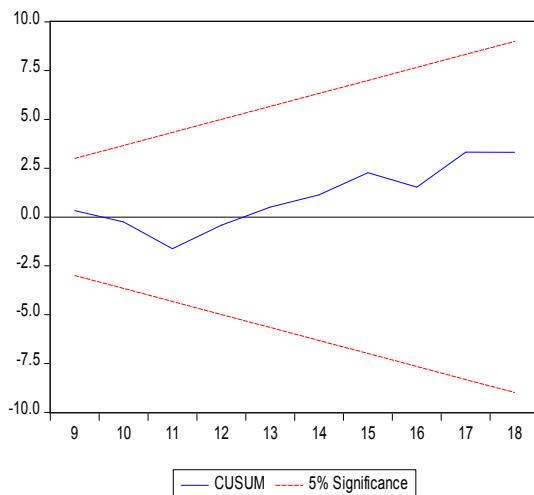


Fig. 9. Stability test results for farmgate price of rice

yield and net revenue indicates that the impacts of the three variables are insignificant at the 0.01 level of significance. It is also clear from the Table 6 that the estimated model fulfilled all the applied statistical tests, indicating that the model is statistically valid and has no specification problems that may cause biases or negatively affect the accuracy of the obtained results. In other words, all the assumptions behind the model (error normality, error non-heteroscedasticity, error non-auto-correlation) have been validated by the data used in the estimated model, where results of applying Breusch-Godfrey Serial Correlation LM Test proved error non-autocorrelation; results of applying Breusch Pagan test proved error non-heteroscedasticity; and results of applying Jarque-Bera test proved error normality.

The estimated coefficient of the error correction term  $CointEq(-1)$  reached -0.67, i.e., changes are corrected at a speed of 67%, which means that adjustment toward the long-run equilibrium occurs after one year and a half.

Analysis results revealed that the short-run impact proved insignificant. The long-run relationship also proved insignificant. Applying the bounds test returned a statistically significant F value, indicating a long-run relationship that moves from the independent variables to the dependent variable. It is clear from Fig. 12 that stability and homogeneity between the long and short-run parameters are validated for the three variables.

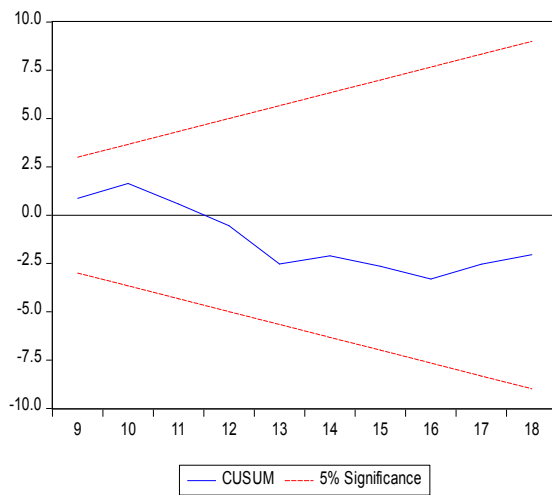


Fig. 10. Stability test results for rice yield

Source: Table 5

Table 4. Results of applying ARDL model on maize crop grown in Egypt over the period 2000-2017

Independent = Net Revenue				Independent =Farm Price, Yield and Net Revenue			
Variable	Coefficient	t-Statistic	Prob.*	Variable	Coefficient	t-Statistic	Prob.*
Area_C(-1)	0.402440	1.230749	0.2582	Area_C(-1)	0.607050	2.717724	0.0200
Area_C(-2)	0.117623	0.329876	0.7511	Price_C	-1.628724	-1.818398	0.0963
Area_C(-3)	0.089612	0.246921	0.8121	Pro_C	-101.7180	-0.444962	0.6650
Area_C(-4)	0.617655	1.829125	0.1101	Net_C	0.528965	0.941739	0.3665
Net_C	0.036636	0.064598	0.9503	Net_C(-1)	0.878081	2.044276	0.0656
Net_C(-1)	0.585803	1.260998	0.2477	C	977.7647	0.905045	0.3848
C	-533.3063	-0.676608	0.5204	R-squared	0.749193	Mean dep var	1927.176
Adjusted R-squared	0.771734	Mean dependent var	1975.929	Adjusted R-squared	0.635190	S.D. dep var	235.5383
R-squared	0.576077	S.D. dependent var	230.5477	S.E. of regression	142.2640	AIC	13.02381
S.E. of regression	150.1080	Akaike info criterion	13.16744	Sum squared resid	222629.6	Schwarz C	13.31789
Sum squared resid	157727.0	Schwarz criterion	13.48697	Log likelihood	-104.7024	H-Q criter.	13.05304
Log likelihood	-85.17208	Hannan-Quinn criter.	13.13786	F-statistic	6.571679	D-W stat	2.369502
F-statistic	3.944330	Durbin-Watson stat	1.921560	Prob(F-statistic)	0.004580		
Prob(F-statistic)	0.047684						
<b>ARDL Cointegrating And Long Run Form</b>							
<b>Cointegrating Form</b>							
Variable	Coeff	t-Statistic	Prob.	Variable	Coeff	t-Statistic	Prob.
D(Area_C(-1))	-0.824890	-2.749762	0.0285	D(Price_C)	-1.828375	-2.265257	0.0447
D(Area_C(-2))	-0.707267	-2.677865	0.0316	D(Pro_C)	-88.749030	-0.735156	0.4776
D(Area_C(-3))	-0.617655	-2.284788	0.0562	D(Net_C)	0.595916	1.387441	0.1928
D(Net_C)	0.036636	0.105211	0.9192	CointEq(-1)	-0.385688	-2.767699	0.0183
CointEq(-1)	0.227330	2.926463	0.0221				
<b>Long Run Coeffs</b>							
Variable	Coeff	t-Statistic	Prob.	Variable	Coeff	t-Statistic	Prob.
Net_C	-2.738	-0.729211	0.4895	Price_C	-4.144860	-1.427724	0.1811
C	2345.96	3.089279	0.0176	Pro_C	-258.857223	-0.506983	0.6222
				Net_C	3.580721	1.528277	0.1547
				C	2488.266	1.365029	0.1995
<b>Breusch-Godfrey Serial Correlation LM Test</b>							
F-statistic	0.007049	Prob. F(2,5)	0.9930	F-statistic	0.559010	Prob. F(2,9)	0.5904



<b>Heteroskedasticity Test: Breusch-Pagan-Godfrey</b>							
F-statistic	0.262771	Prob. F(6,7)	0.9379	F-statistic	0.235073	Prob. F(5,11)	0.9389
Series: Residuals							
Jarque-Bera	0.769111	Probability	0.680753	Jarque-Bera	0.641989	Probability	0.725427
<b>ARDL Bounds Test</b>							
F-statistic	2.220344			F-statistic	0.914249		
Significance	I(0) Bound	5%=3.62	1%=4.94	Significance	I(0) Bound	5%=2.79	1%=3.65
	I(1) Bound	5%=4.16	1%=5.58		I(1) Bound	5%= 3.67	1%= 4.66

Source: Authors calculation

Table 5. Results of applying ARDL model to rice grown in Egypt over the period 2000-2017

Independent = Farmgate price				Independent = Yield			
Variable	Coefficient	t-Statistic	Prob.*	Variable	Coefficient	t-Statistic	Prob.*
Area_R(-1)	0.322829	1.643862	0.1312	Area_R(-1)	0.343397	1.250790	0.2395
Area_R(-2)	-0.617193	-3.067604	0.0119	Area_R(-2)	-0.232746	-0.898272	0.3902
Price_R	0.651836	0.613536	0.5532	Pro_R	774.1870	1.756053	0.1096
Price_R(-1)	2.299215	1.690376	0.1218	Pro_R(-1)	-167.9049	-0.255203	0.8037
Price_R(-2)	-4.200362	-4.089942	0.0022	Pro_R(-2)	273.8855	0.572647	0.5795
C	2139.933	5.175525	0.0004	C	-2286.446	-1.402952	0.1909
R-squared	0.733185	Mean dep var	1426.106	R-squared	0.489477	Mean dep var	1426.106
Adjusted R-squared	0.599777	S.D. dep var	166.5907	Adjusted R-squared	0.234215	S.D. dep var	166.5907
S.E. of regression	105.3906	AIC	12.43322	S.E. of regression	145.7821	AIC	13.08210
Sum squared resid	111071.7	Schwarz C	12.72294	Sum squared resid	212524.2	Schwarz C	13.37182
Log-likelihood	-93.46576	H-Q criter.	12.44806	Log-likelihood	-98.65680	H-Q criter.	13.09694
F-statistic	5.495827	D-W stat	2.242146	F-statistic	1.917550	D-W stat	1.936036
Prob(F-statistic)	0.010887			Prob(F-statistic)	0.178193		
<b>ARDL cointegrating and long run form</b>							
<b>Cointegrating Form</b>							
Variable	Coeff	t-Statistic	Prob.	Variable	Coeff	t-Statistic	Prob.
D(Area_R(-1))	0.617193	3.439611	0.0063	D(Area_R(-1))	0.232746	1.049197	0.3188
D(Price_R)	0.651836	0.737326	0.4779	D(Pro_R)	774.187047	2.117499	0.0603
D(Price_R(-1))	4.200362	4.498763	0.0011	D(Pro_R(-1))	-273.885490	-0.657263	0.5258
CointEq(-1)	-1.294364	-5.818020	0.0002	CointEq(-1)	-0.889349	-3.633151	0.0046

Long run coeffs							
Variable	Coeff	t-Statistic	Prob.	Variable	Coeff	t-Statistic	Prob.
Price_R	-0.965193	-2.600958	0.0264	PRO_R	989.676	2.068016	0.0655
C	1653.270	18.201246	0.0000	C	-2570.919	-1.327319	0.2139
Breusch-Godfrey Serial Correlation LM Test							
F-statistic	0.200448	Prob. F(2,8)	0.8224	F-statistic	1.594479	Prob. F(2,8)	0.2613
Heteroskedasticity Test: Breusch-Pagan-Godfrey							
F-Statistic	0.187591	Prob. F(5,10)	0.9607	F-Statistic	0.915599	Prob. F(5,10)	0.5087
Series: Residuals							
Jarque-Bera	1.030746	Probability	0.597278	Jarque-Bera	0.693810	Probability	0.706872
ARDL Bounds Test							
F-Statistic	9.402600			F-Statistic	3.666608		
Significance	I(0) Bound	5%=3.62	1%=4.94	Significance	I(0) Bound	5%=3.62	1%=4.94
	I(1) Bound	5%=4.16	1%=5.58		I(1) Bound	5%=4.16	1%=5.58

Source: Authors Calculation

Table 6. Results of Applying ARDL Model on Rice Crop Grown in Egypt over the Period 2000-2017

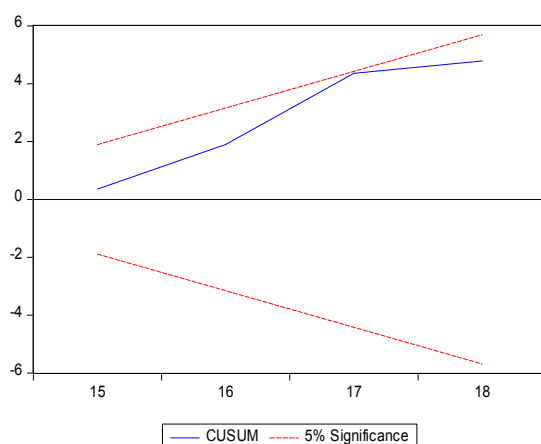
Independent = Net returns				Independent =Farm price, yield and net revenue			
Variable	Coefficient	t-Statistic	Prob.*	Variable	Coefficient	t-Statistic	Prob.*
Area_R(-1)	0.342138	0.898618	0.4197	Area_R(-1)	0.433854	1.749123	0.1081
Area_R(-2)	-0.083965	-0.213970	0.8410	Price_R	-3.197579	-1.561713	0.1466
Area_R(-3)	-0.549382	-1.058219	0.3496	Pro_R	145.8446	0.308210	0.7637
Area_R(-4)	-0.629859	-1.536932	0.1991	Net_R	0.341247	0.545166	0.5965
Net_R	0.457062	0.709492	0.5172	Net_R(-1)	0.903876	1.380648	0.1948
Net_R(-1)	1.122491	1.930265	0.1258	C	473.3186	0.264285	0.7964
Net_R(-2)	-1.273059	-1.575829	0.1902	R-squared	0.517722	Mean dep var	1434.512
Net_R(-3)	-1.276805	-1.437256	0.2240	Adjusted R-squared	0.298505	S.D. dep var	164.9819
Net_R(-4)	0.596615	0.840829	0.4478	S.E. of regression	138.1811	AIC	12.96557
C	2958.964	2.571160	0.0619	Sum squared resid	210034.1	Schwarz C	13.25965
R-squared	0.783439	Mean dependent var	1426.414	Log-likelihood	-104.2074	H-Q criter.	12.99480
Adjusted R-squared	0.296176	S.D. dependent var	175.9112	F-statistic	2.361688	D-W stat	1.960679
S.E. of regression	147.5794	Akaike info criterion	13.00242	Prob(F-statistic)	0.109129		
Sum squared resid	87118.68	Schwarz criterion	13.45889				
Log-likelihood	-81.01692	Hannan-Quinn criter.	12.96016				
F-statistic	1.607835	Durbin-Watson stat	1.469386				
Prob(F-statistic)	0.341607						

<b>ARDL cointegrating and long run form</b>							
<b>Cointegrating Form</b>							
<b>Variable</b>	<b>Coeff</b>	<b>t-Statistic</b>	<b>Prob.</b>	<b>Variable</b>	<b>Coeff</b>	<b>t-Statistic</b>	<b>Prob.</b>
D(Area_R(-1))	1.263206	2.655933	0.0566	D(Price_R)	-2.865749	-2.038479	0.0663
D(Area_R(-2))	1.179241	2.355007	0.0781	D(Pro_R)	-167.243815	-0.445340	0.6647
D(Area_R(-3))	0.629859	1.911473	0.1285	D(Net_R)	0.280448	0.656172	0.5252
D(Net_R)	0.457062	1.015997	0.3671	CointEq(-1)	-0.671459	-3.925413	0.0024
D(Net_R(-1))	1.953249	3.596713	0.0228				
D(Net_R(-2))	0.680189	1.258123	0.2768				
D(Net_R(-3))	-0.596615	-1.239487	0.2829				
CointEq(-1)	-1.921068	-3.195529	0.0330				
<b>Long Run Coeffs</b>							
<b>Variable</b>	<b>Coeff</b>	<b>t-Statistic</b>	<b>Prob.</b>	<b>Variable</b>	<b>Coeff</b>	<b>t-Statistic</b>	<b>Prob.</b>
NET_R	-0.194525	-0.815244	0.4607	Price_R	-5.647977	-1.102007	0.2940
C	1540.270173	14.982017	0.0001	Pro_R	257.609625	0.326809	0.7499
				Net_R	2.199297	0.890083	0.3925
				C	836.036381	0.253931	0.8042
<b>Breusch-Godfrey Serial Correlation LM Test</b>							
F-statistic	2.066040	Prob. F(2,2)	0.3262	F-statistic	0.843425	Prob. F(2,9)	0.4616
<b>Heteroskedasticity Test: Breusch-Pagan-Godfrey</b>							
F-statistic	0.519702	Prob. F(9,4)	0.8095	F-statistic	1.673566	Prob. F(5,11)	0.2212
<b>Series: Residuals</b>							
Jarque-Bera	0.606284	Probability	0.738494	Jarque-Bera	1.094842	Probability	0.578440
<b>ARDL Bounds Test</b>							
F-statistic	2.269201			F-statistic	3.002759		
Significance	I(0) Bound	5%=3.62	1%=4.94	Significance	I(0) Bound	5%=2.79	1%=3.65
	I(1) Bound	5%=4.16	1%=5.58		I(1) Bound	5%= 3.67	1%= 4.66

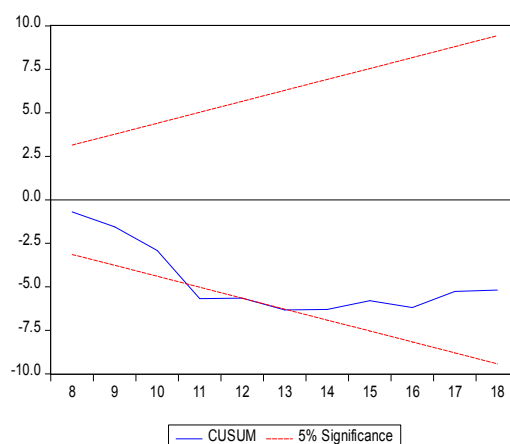
Source: Authors Calculation

**Table 7. Summary results of supply response models estimated by employing ARDL to annual data of crops grown in Egypt over the period 2000-2017**

	Wheat				Maize				Rice			
	Farmgate price	Yield	NET revenue	Farmgate price, yield, net revenue	Farmgate price	Yield	NET revenue	Farmgate price, yield, net revenue	Farmgate price	Yield	NET Revenue	Farmgate price, yield, net revenue
Area	Significant	Insignificant	Significant	Significant	Significant	Significant	Significant	Significant	Significant	Insignificant	Insignificant	Insignificant
Breusch-Godfrey	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
Serial Correlation												
LM Test												
Breusch-Pagan-Godfrey	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
Jarque-Bera	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant	Insignificant
CointEq(-1)	Significant	Significant	Significant	Significant	Significant	Significant	Insignificant	Significant	Significant	Significant	Significant	Significant
Short-Run	Insignificant	Significant	Insignificant	Insignificant	Significant	Insignificant	Significant	Insignificant, except for Farmgate Price	Significant	Insignificant	Insignificant	Insignificant
Long-Run F Value	Significant Long-run relationship is validated	Insignificant Long-run relationship is validated	Significant Long-run relationship is validated	Insignificant Long-run relationship is validated	Insignificant Long-run relationship is not validated	Insignificant Long-run relationship is not validated	Insignificant Long-run relationship is not validated	Insignificant Long-run relationship is not validated	Significant Long-run relationship is not validated	Insignificant Long-run relationship is not validated	Insignificant Long-run relationship is not validated	Insignificant Long-run relationship is not validated
<b>Cusum</b>	<b>Stability and homogeneity between the long and short-run parameters for all the variables are validated</b>											
Speed of adjustment toward the long-run equilibrium	50%	19%	42%	32%	37%	21%	-	39%	129%	89%	192%	67%



**Fig. 11. Stability test results for net revenue from rice**



**Fig. 12. Stability test results for the three variables**

Source: Table 6

## 5. CONCLUSION

Since decisions regarding which crops to produce are optional, there is a need for recent estimates of the relationships specifying supply response of various crops to identify potential responses of farmers to dominant economic conditions. The identification and assessment of such relationships are expected to increase the likelihood of obtaining accurate forecasts of the future cultivated areas of different crops, which enables farmers to make short and long-term decisions. Therefore, the current research focuses on estimating the response of areas under the study crops. To achieve the research objective, Autoregressive Distributed Lag Model (ARDL) has been applied to define the integral relationship between the dependent variable and independent variables, both in the long and short-run, in addition to determining the magnitude of the impacts of all dependent variables on the dependent variable. ARDL models are standard least squares regression models containing lags in both the dependent and explanatory variables. ARDL models have been used in econometrics in selecting long-term relationships and common integration between variables over the last 10 years. Main findings indicate that farmgate price has a statistically significant impact on wheat, maize and rice cultivated areas. Impact of yield on wheat cultivated area proved insignificant, while proved statistically significant on maize and rice cultivated areas. Impact of net revenue on wheat and maize cultivated areas proved statistically significant, while could be insignificant in case of rice. Applying the ARDL bounds test revealed a

long-term relationship between all variables in the model for wheat, but not for maize and rice. Findings indicate stability and harmony between the results of the long and short-run coefficients for all variables.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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