

# 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 between all authors.*

*Author Moataz designed the study, performed the statistical analysis and wrote the first draft of the manuscript. Authors Moataz, Abbas and Ahmed collected the data. Author Moataz 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 proved statistically significant, while proved 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.*

## 1. INTRODUCTION

Cereal crops, mainly wheat, maize and rice, are 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 practicing 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].

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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 with the aim of estimating 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 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 time period, the model is called 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 time 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 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 percent of the long-run impact. It gives the impact at a specific period of time 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].

$$Y_t = \alpha + \beta_0 X_t + \beta_1 X_{t-1} + \dots + U_t \quad (4)$$

In case the model contains one (or more) value of the dependent variable that is/are used as 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 lagged dependent variable as 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 ( $p, q_1, \dots, q_k$ ), where  $p$  is the number of lags in the dependent variable,  $q_1$  is the number of lags in the first explanatory variable,  $q_k$  is number of lags in the  $k^{\text{th}}$  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  $X_j$  with no lags ( $q_j = 0$ ) 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,  $p, q_1, \dots, q_k$  must first be determined in the light of criteria set by Akaike AIC, Schwarz SC and Hannan-Quinn (H-Q) as alternative for the adjusted coefficient of determination (adjusted  $R^2$ ) in order 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 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. In addition, 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,

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

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

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

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

Standard error for the long-run regression coefficients can be computed from the standard error for the original regression with the help of 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 regression equation (6) can be directly obtained from 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, 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 exist a long-run equilibrium relationship.

### 3.6. Stability Testing

To test the stability of ARDL Models, a proper test should be selected, like 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 mixture of both. The only restriction is that it should not be integrated of order two (not applicable in 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. In addition, 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). In addition, 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. In addition, 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 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 ARDL model to estimate the supply response of wheat planted area to farmgate price of the main crop indicates that farmgate price has a statistically significant impact on wheat planted area at the 0.01 level of significance. It is also clear from 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 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<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 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 Figure (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 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 table (1) that the estimated model fulfilled all the applied statistical tests, indicating

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\*\* This is considered the principal and most important test.

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

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.

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 result indicates that yield has a statistically significant positive impact on 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 Figure (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 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 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 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.

**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>                             |             |               |          | <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   |
|   |             |               |          | CointEq(-1)               | -0.190021   | -4.759396             | 0.0089   |
| <b>Long Run Coeffs</b>                                |             |               |          | <b>Long Run Coeffs</b>    |             |                       |          |
| Variable  | Coeff       | t-Statistic   | Prob.    | Variable                  | Coeff       | t-Statistic           | Prob.    |
| 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  |



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 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 Figure (3) that stability and homogeneity exist between the long and short-run parameters for net revenue.

Fig. 1: Stability Test Results for Farmgate Price of Wheat

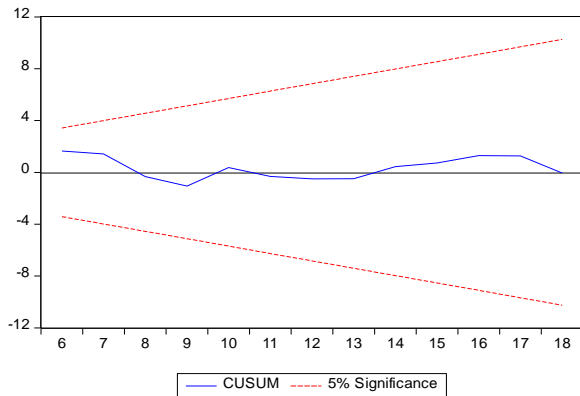
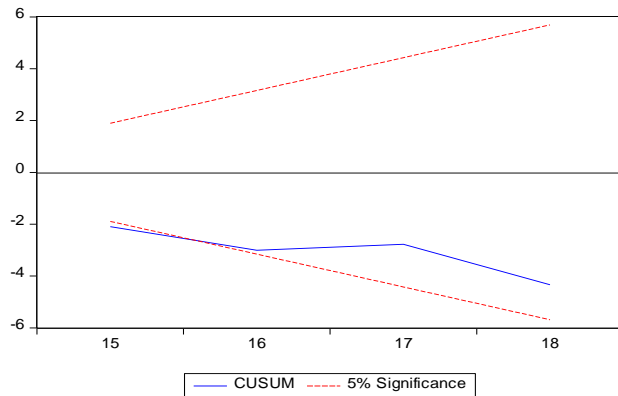


Fig 2: Stability Test Results for Wheat Yield



Source: Table 1

#### 4.1.4. 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 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 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 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 the three variables reached  $-0.32$ , i.e., indicating that the long-run equilibrium for this variable occurs after three years.

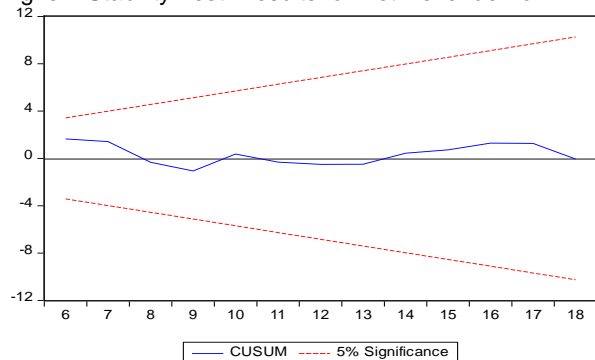
The short-run impact of the variables proved significant insignificant. Likewise, the long-run relationship proved statistically insignificant. Applying the bounds test to test the long-run relationship between variables in the model returned a statistically significant (F) value for the three variables,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

**Table 2: Results of Applying ARDL to Wheat Crop Grown in Egypt over the Period 2000-2017**

| Independent =Net Revenue                              |             |               |          | Independent =Farmgate Price, Yield and Net Revenue |             |               |          |
|---|-------------|---------------|----------|--|-------------|---------------|----------|
| Variable  | Coefficient | t-Statistic   | Prob.*   | Variable   | Coefficient | t-Statistic   | Prob.*   |
| 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>Cointegrating Form</b>                          |             |               |          |
| Variable  | Coeff       | t-Statistic   | Prob.    | Variable   | Coeff       | t-Statistic   | Prob.    |
| 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>Long Run Coeffs</b>                             |             |               |          |
| Variable  | Coeff       | t-Statistic   | Prob.    | Variable   | Coeff       | t-Statistic   | Prob.    |
| 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  |

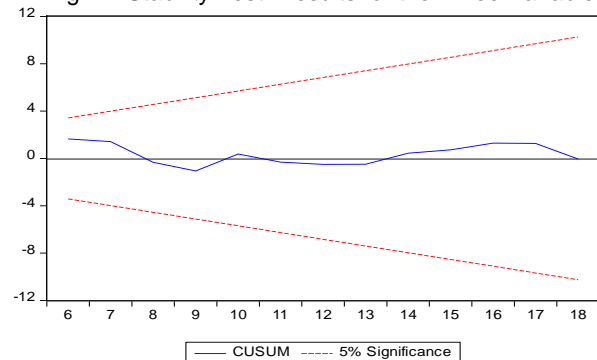
Source: Authors Calculation

Fig. 3: Stability Test Results for Net Revenue from Wheat



Source: Table 2

Fig 4: Stability Test Results 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 Figure (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 Figure (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 Figure (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.

**Table 3: Results of Applying ARDL Model on Maize 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_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   | <b>R-squared</b>          | 0.613748    | Mean dependent var    | 1927.176 |
| PRICE_C                      | -1.158835   | -1.297157             | 0.2357   | <b>Adjusted R-squared</b> | 0.558569    | S.D. dependent var    | 235.5383 |
| PRICE_C(-1)                  | 1.648996    | 1.997501              | 0.0859   | <b>S.E. of regression</b> | 156.4923    | Akaike info criterion | 13.10268 |
| C                            | 74.49385    | 0.108149              | 0.9169   | <b>Sum squared resid</b>  | 342858.0    | Schwarz criterion     | 13.24971 |
| <b>Adjusted R-squared</b>    | 0.803747    | Mean dependent var    | 1975.929 | <b>Log likelihood</b>     | -108.3728   | Hannan-Quinn criter.  | 13.11729 |
| <b>R-squared</b>             | 0.635529    | S.D. dependent var    | 230.5477 | <b>F-statistic</b>        | 11.12286    | Durbin-Watson stat    | 2.182865 |
| <b>S.E. of regression</b>    | 139.1849    | Akaike info criterion | 13.01634 | <b>Prob(F-statistic)</b>  | 0.001283    |                       |          |
| <b>Sum squared resid</b>     | 135607.0    | Schwarz criterion     | 13.33586 |                           |             |                       |          |
| <b>Log likelihood</b>        | -84.11435   | Hannan-Quinn criter.  | 12.98676 |                           |             |                       |          |
| <b>F-statistic</b>           | 4.778029    | Durbin-Watson stat    | 1.979491 |                           |             |                       |          |
| <b>Prob(F-statistic)</b>     | 0.029804    |                       |          |                           |             |                       |          |

| ARDL Cointegrating And Long Run Form |           |             |        |                    |             |             |        |
|--------------------------------------|-----------|-------------|--------|--------------------|-------------|-------------|--------|
| Cointegrating Form                   |           |             |        | Cointegrating Form |             |             |        |
| 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 |                    |             |             |        |

| Long Run Coeffs |             |             |        |          |             |             |        |
|-----------------|-------------|-------------|--------|----------|-------------|-------------|--------|
| 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 |

| Breusch-Godfrey Serial Correlation LM Test            |          |              |          |             |          |               |          |
|---|----------|--------------|----------|-------------|----------|---------------|----------|
| 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 |

| ARDL Bounds Test |            |         |         |              |            |         |         |
|------------------|------------|---------|---------|--------------|------------|---------|---------|
| F-statistic      | 2.294364   | 5%=3.62 | 1%=4.94 | F-statistic  | 1.023195   | 5%=3.62 | 1%=4.94 |
| Significance     | I(0) Bound | 5%=4.16 | 1%=5.58 | Significance | I(0) Bound | 5%=4.16 | 1%=5.58 |
|                  | I(1) Bound |         |         |              | I(1) Bound |         |         |

Source: Authors calculation

**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   |
| <b>Series: Residuals</b>                              |             |                       |          |                    |             |               |          |
| 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

Fig. 5: Stability Test Results for Farmgate Price of Maize

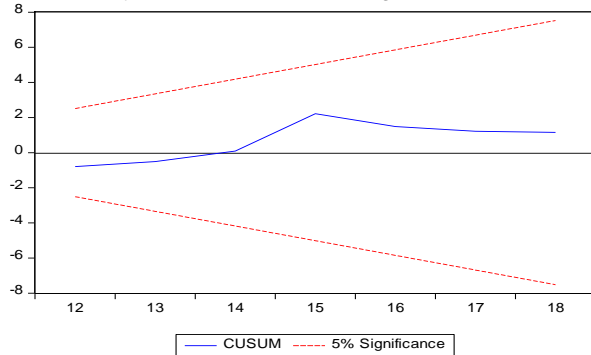
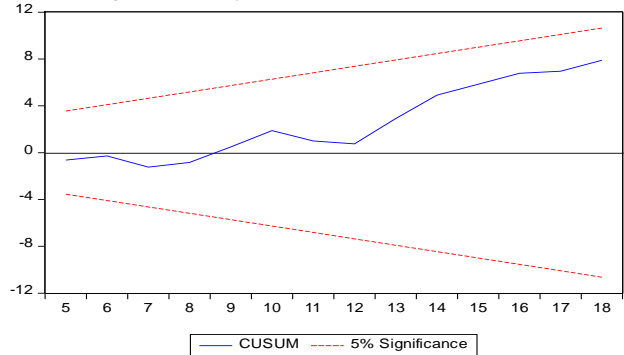


Fig 6: Stability Test Results for Maize Yield



Source : Table 3

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 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 absence of a long-run relationship between variables in the model. It is clear from Figure (8) that stability and homogeneity between the long and short-run parameters are validated for the three variables.

Fig. 7: Stability Test Results for Net Revenue from Maize

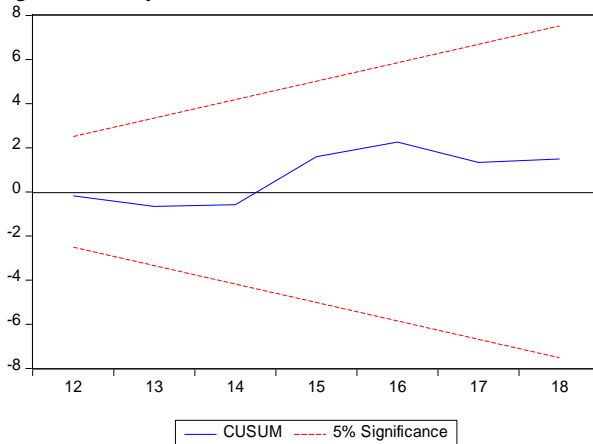
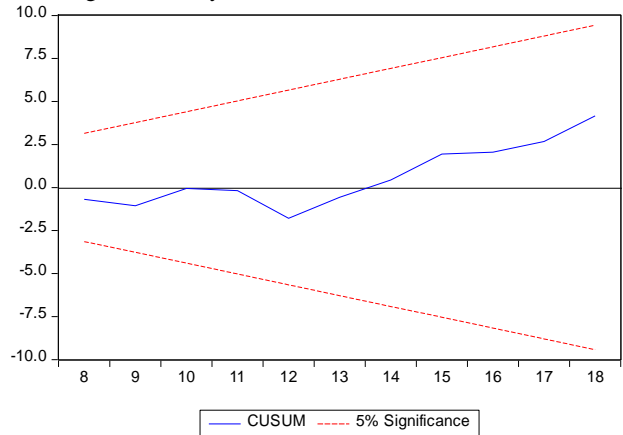


Fig 8: Stability Test Results for the Three Variables



Source : Table 4

### 4.3. Rice Crop

#### 3.3.1. 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 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 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 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  $-1.29$ , 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 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 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 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 -0.89, 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 Figure (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 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 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 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 -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 Figure (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, yield and net revenue indicates that the impacts of the three variables is insignificant at the 0.01 level of significance. It is also clear from 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 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  $-0.67$ , 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 Figure (12) that stability and homogeneity between the long and short-run parameters are validated for the three variables.

Fig. 9: Stability Test Results for Farmgate Price of Rice

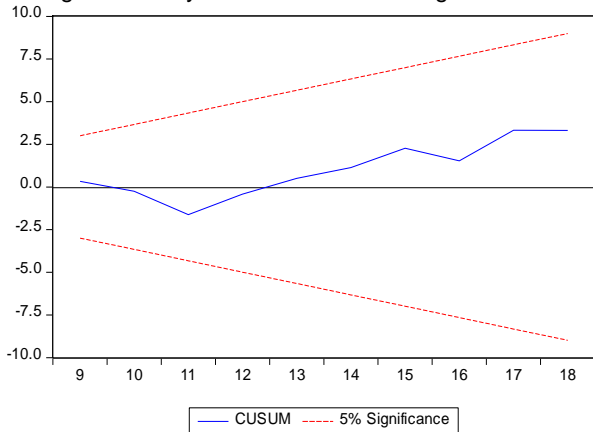
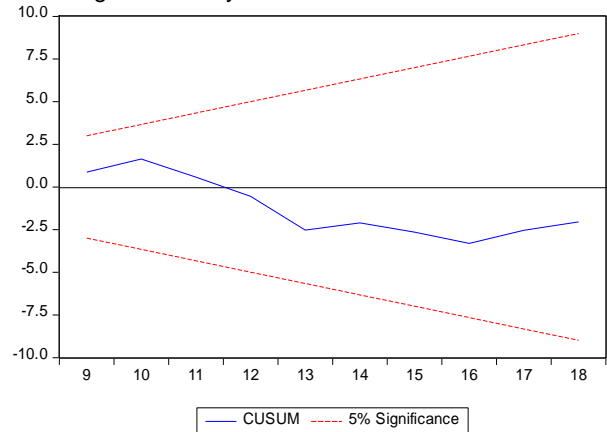


Fig 10: Stability Test Results for Rice Yield



Source : Table 5

Fig. 11: Stability Test Results for Net Revenue from Rice

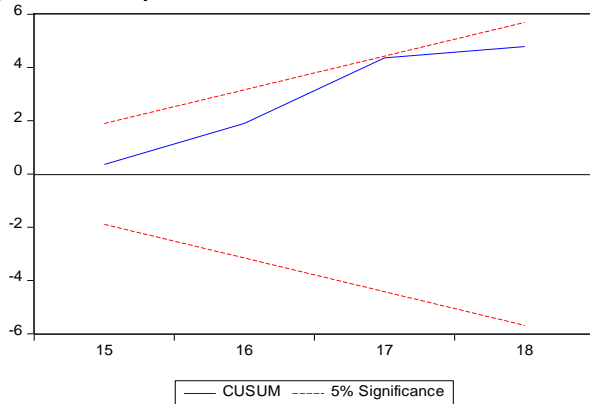
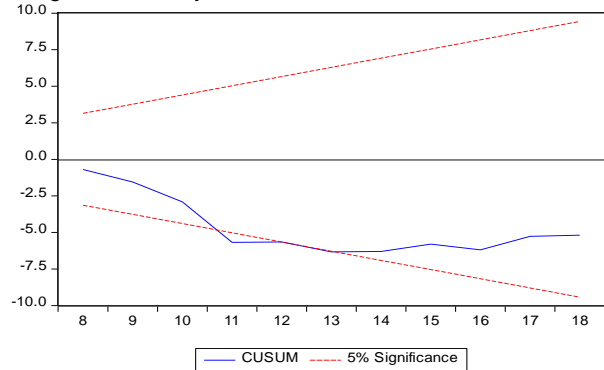


Fig 12: Stability Test Results for the Three Variables



Source : Table 6

**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>                             |             |               |          | <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   |
| <b>Long Run Coeffs</b>                                |             |               |          |                           |             |               |          |
| 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   |
| <b>Breusch-Godfrey Serial Correlation LM Test</b>     |             |               |          |                           |             |               |          |
| F-statistic   | 0.200448    | Prob. F(2,8)  | 0.8224   | F-statistic               | 1.594479    | Prob. F(2,8)  | 0.2613   |
| <b>Heteroskedasticity Test: Breusch-Pagan-Godfrey</b> |             |               |          |                           |             |               |          |
| F-statistic   | 0.187591    | Prob. F(5,10) | 0.9607   | F-statistic               | 0.915599    | Prob. F(5,10) | 0.5087   |
| <b>Series: Residuals</b>                              |             |               |          |                           |             |               |          |
| Jarque-Bera   | 1.030746    | Probability   | 0.597278 | Jarque-Bera               | 0.693810    | Probability   | 0.706872 |
| <b>ARDL Bounds Test</b>                               |             |               |          |                           |             |               |          |
| 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 Cointegrating Form</b> |             |                       |          |  |             |               |          |
| Variable   | Coeff       | t-Statistic           | Prob.    | Variable                                       | Coeff       | t-Statistic   | Prob.    |
| 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>   |             |                       |          |  |             |               |          |
| Variable   | Coeff       | t-Statistic           | Prob.    | Variable                                       | Coeff       | t-Statistic   | Prob.    |
| 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

**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     |
| <b>Area</b>  | Significant   | Insignificant                      | Significant                        | Significant                        | Significant                            | Significant                            | Significant                            | Significant                              | Significant                            | Insignificant                          | Insignificant                          | Insignificant                          |
| <b>Breusch-Godfrey Serial Correlation LM Test</b>          | Insignificant   | Insignificant                      | Insignificant                      | Insignificant                      | Insignificant                          | Insignificant                          | Insignificant                          | Insignificant                            | Insignificant                          | Insignificant                          | Insignificant                          | Insignificant                          |
| <b>Breusch-Pagan-Godfrey</b>                               | Insignificant   | Insignificant                      | Insignificant                      | Insignificant                      | Insignificant                          | Insignificant                          | Insignificant                          | Insignificant                            | Insignificant                          | Insignificant                          | Insignificant                          | Insignificant                          |
| <b>Jarque-Bera</b>   | Insignificant   | Insignificant                      | Insignificant                      | Insignificant                      | Insignificant                          | Insignificant                          | Insignificant                          | Insignificant                            | Insignificant                          | Insignificant                          | Insignificant                          | Insignificant                          |
| <b>CointEq(-1)</b>   | Significant   | Significant                        | Significant                        | Significant                        | Significant                            | Significant                            | Insignificant                          | Significant                              | Significant                            | Significant                            | Significant                            | Significant                            |
| <b>Short-Run</b>   | Insignificant   | Significant                        | Insignificant                      | Insignificant                      | Significant                            | Insignificant                          | Significant                            | Insignificant, except for Farmgate Price | Significant                            | Insignificant                          | Insignificant                          | Insignificant                          |
| <b>Long-Run</b>  | Significant   | Insignificant                      | Significant                        | Insignificant                      | Insignificant                          | Insignificant                          | Insignificant                          | Insignificant                            | Significant                            | Insignificant                          | Insignificant                          | Insignificant                          |
| <b>F Value</b>   | Long-run relationship is validated  | Long-run relationship is validated | Long-run relationship is validated | Long-run relationship is validated | Long-run relationship is not validated | Long-run relationship is not validated | Long-run relationship is not validated | Long-run relationship is not validated   | Long-run relationship is not validated | Long-run relationship is not validated | Long-run relationship is not validated | Long-run relationship is not validated |
| <b>Cusum</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</b> | %50   | %19                                | %42                                | %32                                | %37                                    | %21                                    | -                                      | %39                                      | %129                                   | %89                                    | %192                                   | %67                                    |

## 5. Conclusions

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 in order to identify potential responses of farmers to dominant economic conditions. The identification and assessment of such relationships is expected to increase the likelihood of obtaining accurate forecasts of the future cultivated areas of different crops, which enables farmers 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 proved 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. Findings indicate a stability and harmony between results of the long and short-run coefficients for all variables.

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