
# Water Resources and Agricultural Productivity in Pakistan: An Empirical Analysis

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**Abstract**
The study has examined the impact of water resources on agricultural productivity in Pakistan from 1975 to 2015. For examining the stationarity of variables, Augmented Dickey-Fuller (ADF) unit root test is used. Autoregressive Distributed Lag Approach (ARDL) is used for cointegration among the variables of the model. The estimated results of the study show that water resources have a positive and significant impact on agricultural productivity in Pakistan over the selected time period. The results of the study show that water resources are useful for agricultural productivity. On the basis of empirical results, this study proposes that water resources must be improved in the case of Pakistan, to enhance the agricultural productivity.

**Keywords:** agricultural productivity, water resources, ARDL
**JEL Codes:** N5, O13

## I. Introduction

It has long been recognized that agricultural growth is important for overall economic development (Johnston and Mellor, 1961). As highlighted by Martin and Mitra (2001), most economists since Adam Smith have considered that productivity grows more slowly in agriculture than in the 12manufacturing sector. 1 Smith attributed this alleged weakness of agriculture to a lower potential for labor specialization than that allowed by other industries. According to Ruttan (2002), research on the rate of productivity growth in agriculture has gone through three stages. Initially, the research focused on the measurement of partial productivity ratios and indexes, such as output per worker or hectare. These early studies showed wide differences in labor and land productivities across the world. Recent studies show that these differences have persisted. The second stage of the research on technical change in agriculture involved the estimation of cross-country production functions and multifactor productivity estimates. Increasing data availability and improvements in econometric techniques made this approach increasingly reliable. The diminishing returns on factor inputs, declining arable land, water supplies and natural resources, concern over climate change and environmental degradation and high fuel and fertilizer prices continue to posture challenges for agriculture. The agriculture sector is the backbone of Pakistan`s economy. The development of Agriculture sector is necessary because in Pakistan one third of the economy is based on agriculture sector. Pakistan is an agricultural country. Its land and atmosphere has suitable for agricultural productivity. 66% of Pakistan exports is based on agricultural goods. Agriculture sector provided raw material for the industrial sector. As Pakistan textile industry based on cotton, which comes from the agriculture sector. So, this creates a burden on agriculture sector. The agriculture sector is very important for Pakistan economy. Firstly, agriculture sector achieves nearly all the food requirement of the nation. Secondly, it serves as a market for industrial products where it uses industrial products such as machinery, fertilizers and pesticides. The continuous growth of the world's population, urbanization, industrialization and global warming impose an additional burden on agriculture enterprises. As World Bank experts predict, the demand for agriculture products will increase twice by 2030. Therefore, countries that are major in agriculture production should increase their productivity to satisfy future excess demand, considering that less land and Water resources will be available in the future. Pakistan is one among the minority of countries which have good conditions for the cultivation of plants (temperature, climate, dense net of rivers and lakes and fertile land). Agriculture and industry have complementary relation. In this way, higher agricultural productivity leads to higher productivity of the manufacturing sector through backward and forward linkage. Being the second largest sector of Pakistan economy, its growth reflects the overall growth trend of the economy. That is why, when agricultural sector suffers from adverse supply shocks such as floods, droughts or failure of crops, growth of other sectors as well as of GDP also declines and vice versa.

Agricultural production relationships are conventionally explored by specifying a production function that relates output or output per hectare to traditional inputs such as labor, animal power, and water and to modern inputs such as fertilizers. The sector itself is composed of five subsections, namely crops other than cocoa, livestock, fisheries and forestry. Agricultural production is still highly dominated by the small holder farming system. The farms are dominated by small scale farmers who are responsible for about 95% of total production. This is not unconnected with the unattractiveness of agriculture, which is a result of lack of necessary infrastructures in the rural areas which forms the bulk of the agricultural zones in the country. In addition, small scale agriculture has in the time past suffered from limited access to credit facilities, modern technology farm inputs and inefficient use of resources. The food prices in Pakistan have phenomenally risen in the last few years, pushing many people below the poverty line. An immediate development challenge for Pakistan government, in view of deepening poverty and overall poor economic growth, is to enhance agriculture growth. It is well recognized that the key to reduction in poverty is to enhance agricultural productivity. To enhance the agricultural productivity the policy makers should an insight to devise and implement the most suitable policies for ensuring food security and lowering the incidence of poverty in the country. The average agriculture total factor productivity (TFP) growth in Pakistan during 1965-2005 has been only 0.28percent, which is significantly lower than other countries of the region. This necessitates the need for a rigorous study to identify the determinants of agriculture TFP so that appropriate policies can be adopted to raise agricultural productivity and food supplies in the country. Water resources have a positive relation to agricultural productivity. As proper water is available for the cultivation, then their growth will be increased which leads to enhance agricultural productivity in Pakistan. Tractors, broad money, fossil fuels, secondary school enrollment and agriculture raw material also have a positive and significant relation with agricultural production.

## II. Literature Review

Bravo-Ortega et al., (2004) analyze the determinants of agricultural productivity on the whole world developing and developed countries. The agriculture growth rate is more in developing countries. Special focus on Latin American and Caribbean countries by testing the heterogeneity. The results show that the agricultural total factor productivity

has a positive effect by generating the electricity. Roads and credit availability and literacy also affect the agricultural productivity. Helfand and Levine (2004) estimate the technical efficiency of farm in the center west of Brazil by using the data envelopment analysis and use of regression techniques to determine efficiency. There are many determinants like infrastructure market facilities irrigations fertilizers and rural electricity that affect the efficiency. The center west of Brazil is the region of farm and high technology is providing equality and efficiency. This research shows that the land reform and technology create the positivity between farm size and productivity. Matsuyama (1992) studies the role of agricultural productivity in economic development. To see the relationship between agricultural productivity and growth it uses the endogenous growth model. The result shows that the tradable factors as well as non-tradable factors are important for the growth. The inputs such as fertilizers, pesticides drainage pipes and harvesting equipment to improve the productivity. The capital accumulation is also considerable in the agricultural development. Gollin et al., (2002) analyze the impact of agricultural productivity on industrialization sector. It uses the simple method that slow agricultural productivity slows the process of industrialization. Due to poor technology in agriculture sector the per capita income of the whole country is decreasing. The results show that by improving the agricultural productivity determents will enhance less develop countries industry and improve the process of development.

Rosegrant and Evenson (1992) analyze the total factor productivity measures the amount of increase in total output not accounted for by increases in total inputs. The total factor productivity index is computed as the ratio of an index of aggregate output to an index of aggregate inputs. Growth in TFP is therefore the growth in total output less the growth rate in total inputs. Tornquist-Theil, TFP indices are computed for 271 districts covering 13 states in India, 1956-87. The productivity growth has been public research and extension and private research. The spillover benefit from private research is substantial, indicating that private firms capture only part of the real value of improved inputs through higher price. Ahmed and Hang (2012) study the determinants of agricultural total factor productivity growth in Pakistan. For this purpose, it applies autoregressive distributed lag model by taking four determinants credit on agriculture, human capital, fertilizers and area under cultivation. It gives more importance to fertilizers, as it is the responsibility of government to provide cheap and timely fertilizers. The farmer should be educated and skilled in efficient techniques. So, in this way agricultural growth can be increased. Deininger and Okidi (1999) study the financial markets of agriculture and non-agriculture investment in rural areas of a developing country. It researches the importance of financial development to supporting the macro literature. The results show that it is important to adopt a proper strategy for the economic development.

Adams et al., (2014) research the inputs of the agricultural productivity of the Rajasthan. Panel data approach is used to know the factors that affect agricultural productivity of sixteen important crops that vulnerability over time from 1990 to 2010 covering all districts. The research shows that the fertilizers are the important inputs that enhance the productivity of all crops except few crops like soybean cotton and kharif pulses. It analyzes that roads and tube wells also play an important role in the development of agricultural productivity. Grigin (2011) analyze the relationship between agriculture productivity and education through the analysis of the Turkish phenomenon of village institute VIs. Coefficient of variation is used to analyses the data. The study shows the positive relationship between agricultural productivity and literacy rate. In the Turkish village due to VIs institute the graduate teachers are provided in the rural areas. The primary education becomes compulsory and after this the three-year technical education also provided in the rural areas. This study results that due to education the agricultural productivity increases. Darku et al., (2016) study about the variation in total factor productivity growth of cops and livestock production in the provinces of Canada over the period of 1940-2009. By using the stochastic frontier approaches it determines the growth of technical change, scale effect and technical efficiency changes. The result shows that crop productivity is changing with the change in technology. Scale effect changes the productivity growth in livestock. The technical efficiency is positive for both agricultural and livestock sectors.

Behjat and Ostry (2013) research to investigate the factors that has affected the regional farm profitability. The OLS method is used to investigate the regional farm profitability in British Colombia. The analysis shows that the agricultural enterprises are almost two third of the LHAs are profitable. The research shows that there is positive impact on soil conservation, farm area and farm size of the gross margin. But it is the negative impact of age, increasing on the farm profitability. Pitter (2013) studies the hunger in rural areas due to the agricultural unemployment crises. It uses the multivariable statistical method to analyze the economic and social conditions. It is also studied the inequalities of the rural areas in the developing countries. It found a strong correlation between the inequalities and agriculture unemployment. The results show that the proper policies should be adopted for the agricultural and rural development. Human capital is always important for the agriculture development. And human capital needs education and skills. Munoz et al., (2012) analyze the factors which effected the organic farming of the Germany. It uses the

penal data of different forms and apply a system GMM method to analyze the economic growth of organic forms. It uses two methods to measure the productivity growth of forms. First is economic aspect, using revenue as an indicator and the second is physical growth by the number of hectares per farm. The results show that there is a negative relation between farm size and economic growth. Suphannachart and Warr (2010) study the total factor productivity of agriculture in Thai. It uses the conventional growth accounting model to estimate the crops and livestock and error correction model to measure the TFP for investigating the determinants. The results show that the determinants of TFP are not restricted only for agriculture, but it also provides other services. The study also analyzes that the TFP is the public investment in agriculture research, foreign research, infrastructure and the world commodity boom. Urgessa (2015) study the determinants of agricultural productivity and rural household income in Ethiopia. Three models, pooled ordinary least square (POLS), Fixed effects (FE) and random effects (RE) are used to analyze the relationship between productivity and income. He focused on the agriculture labor productivity. The results of the fixed effect show that labor-land ratio, use of fertilizers, pesticides and the size of household members and extension service variables are the most beneficial variables by which we can improve the farm productivity of rural households. The research shows that the agriculture labor productivity is the most important factor of production to improve the agriculture productivity then the land productivity.

Olujeny (2008) research about the determinants of agriculture production specially focuses on the maize in a Koko north east and south west local government areas of Ondo-state. The OLS method is used to estimate the determinants of the production function. The results show that mostly the formers are mature and expert in maize production. The productivity and efficiency analyses show that the production was in stage two of production function and the factors were efficiently used. Teryomenko (2008) analyze the relationship between farm size and the productivity of the Ukrainian farmers to know that the suspension of land selling in Ukraine should be cancelled or not. Farm productivity means the technical efficiency and value of output per hectare. Technical efficiency measures by the two methods non-parametric DEA and parametric DFA. The relationship between farm size and the productivity is non-linear. The results show that moratorium cancelling should be taking place to avoid the other problems. Byiringiro (1995) study the determinants of farm productivity for small-holders of Rwanda. And the relationship of farm size and farm productivity in order to change the quality of land change in output. Three determinants are used in the research (1) variable inputs, (2) land quality, (3) crop composition of output. Variable inputs are land and labor. The research shows that better land can improve the efficiency of producing. Results show that the productivity of small farm size is better than the high farm size. Formers need to invest in those crops which cash income is more. So, then can be purchase high prices of inputs. Gutierrez (2000) examines the agricultural labor productivity is different in different areas of the world. It uses the new theories of economic growth and new data sets to know about the differences. The data uses from the period of 1980-1993. The study finds the results that agricultural labor productivity growth, investment and education are also found for the environmental factor. Free trade is adaptive the agricultural productivity and liberalizing trade reforms may reduce the productivity differentials. The results show that the agricultural labor productivity in hot areas is low as compared to temperate countries. If other variables are remaining constant, then the high agricultural labor productivity growth in response to lower starting GDP per worker.

Wongnaa (2013) explores the determinants of cashew production, especially the cashew production in the range Municipality of Brong-Ahafo region of Ghana. The random sampling technique is the use of the collection of data. Parameters of production function are estimated by the ordinary least square method (OLS). Cashew farmers use their personal savings in production. The research showed that cashew farmers are inexperienced in cashew production. It is also analyzed that the variables like farm size, fertilizers, education, and pesticides have positive relation with the output of cashew production. The government should take steps like education of farmers to improve the cashew production. Oli et al., (2012) study that the tree production is very important in rural areas of Nepal for the use of firewood and fodder. The determinants of farm growing tree are education, land livestock holdings and the consumption of firewood has positive relationships with the trees of the household farm land. The main factors which have not properly contributed on-farm growing trees are six of household's income ethnicity and network. The results show the problems of the forestry community like poverty mitigation.

**III. Theoretical Model**

The objective of this paper is to investigate the agricultural productivity for the period 1975-2015 using the fully modified cointegration and long run technique. The study has investigated the impact of agricultural raw material, water availability, fossil fuels, tractors, secondary school enrollment, and broad money in Pakistan. We collected the data over the period of 1975 to 2015.the data for all the selected variables is taken from the world development indicators and economic survey of Pakistan. Following the methodologies of Ali (2011), Ali (2015), Ali (2018), Ali

and Bibi (2017), Ali and Ahmad (2014), Ali and Audi (2016), Ali and Audi (2018), Ali and Rehman (2015), Ali and Zulfiqar (2018) and Ali et al., (2016), the functional form of the model becomes as:

$$Y = f (LAR01, BM, LSSE, LFF, T, LWA)$$

Where,
Y is agricultural productivity(output)
AR01 = agricultural raw material.
FF = fossil fuels.
SSE = Secondary school enrollment.
WA =water availability.
T = tractors.
BM = broad money.

$$LAGRIt = \beta1+\beta2LAR01t+\beta3BMt+\beta4LSSEt+\beta5LFFt+\beta6Tt+\beta LWAt+et \quad (1)$$

Econometric methodology:
Mostly time series data has non-stationary problem and the estimated regression results of this data became spurious for policy suggestion (nelson and ploser, 1982). All co-integration method also demand, the stationary of the variables. this study comprises with the different econometric method or used different test to show our result is stationary or significant, fact of time series data that it contains unit root problem and regression results of this data are spurious. For the solution of unit root problem, this study uses Augmented Dickey-Fuller (ADF) unit root test, the calculated results of ADF test are presented in this paper.

**IV. Empirical Results and Discussion**
The descriptive statistics is presented at below:

**Table 1**

| | LAGRI | LAR01 | LFF | LWA | LSSE | T | BM |
|---|---|---|---|---|---|---|---|
| Mean | 27.77305 | 1.440841 | 4.003882 | 4.780836 | 8.050275 | 28118.55 | 16.33740 |
| Median | 27.80272 | 1.414139 | 4.038876 | 4.864839 | 8.223091 | 23276.00 | 16.46711 |
| Maximum | 28.42431 | 1.819655 | 5.189090 | 4.927109 | 8.815370 | 71607.00 | 45.53201 |
| Minimum | 27.01977 | 1.194370 | 3.597928 | 4.437560 | 7.128496 | 7190.000 | 4.314225 |
| Std. dev. | 0.439061 | 0.155378 | 0.280662 | 0.156692 | 0.547691 | 16459.70 | 7.324840 |
| Skewness | -0.174 | 0.576454 | 2.030888 | -0.909 | -0.357 | 1.139941 | 1.555567 |
| Kurtosis | 1.720898 | 2.600625 | 9.912362 | 2.433731 | 1.774561 | 3.548605 | 7.722122 |
| Jarque-Bera | 3.003691 | 2.543190 | 112.4878 | 6.200049 | 3.438273 | 9.622946 | 55.96079 |
| probability | 0.222719 | 0.280384 | 0.000000 | 0.045048 | 0.179221 | 0.008136 | 0.000000 |
| Sum | 1138.695 | 59..07450 | 168.1630 | 195.0143 | 330.0613 | 1180979 | 686.1707 |
| Sum sq.dev. | 7.710977 | 0.965692 | 3.229610 | 0.982096 | 11.99860 | 1.11E+10 | 2199.785 |
| Observation | 41 | 41 | 42 | 41 | 41 | 42 | 42 |

The estimated results reveal that agriculture raw material, fossil fuels, tractors and broad money are positively skewed and agricultural output and water availability and secondary school enrollment are negative skewed. The results show that all the variables have positive kurtosis. The values of Jarque-Bera show that all the variables have zero mean and finite covariance, this confirms that selected data sets are normally distributed.

**Table 2**

| Variables | LAGRI | LAR01 | LFF | LSSE | LWA | T | BM |
|---|---|---|---|---|---|---|---|
| LAGRI | 1.00000 | | | | | | |
| LAR01 | 0.315595 | 1.000000 | | | | | |
| LFF | 0.876965 | 0.273546 | 1.000000 | | | | |
| LSSE | 0.987665 | 0.306812 | 0.879951 | 1.000000 | | | |
| LWA | 0.931324 | 0.338666 | 0.844989 | 0.949938 | 1.000000 | | |
| T | 0.713664 | 0.323947 | 0.504575 | 0.658594 | 0.572236 | 1.000000 | |
| BM | -0.121 | -0.443 | -0.176 | -0.109 | -0.155 | -0.097 | 1.000000 |

The unit root test is used to check the stationarity of variables. The results show that the agricultural raw material, broad money, and water availability are stationary at level. And agricultural output, fossil fuels, secondary school enrollment and tractors are non-stationary at level but at 1st difference all variables become stationary. Hence there is mix order of integration among the variables of the model which is suitable condition for applying auto-regressive distributed lag (ARDL) bound testing approach to co integration.

**Table 3: Results of unit root test**

| Variables | At Level | | At 1st Difference | |
|---|---|---|---|---|
| | t-statistics | p-value | t-statistics | p-value |
| LAgri | -1.06318 | 0.7208 | -7.80199 | 0.0000 |
| LAr01 | -6.24852 | 0.0000 | -6.56723 | 0.0000 |
| Bm | -5.08191 | 0.0001 | -7.47263 | 0.0000 |
| LFf | 2.195783 | 0.9999 | -2.98214 | 0.0452 |
| LSse | -1.04272 | 0.7286 | -6.57893 | 0.0000 |
| T | -2.0273 | 0.2744 | -4.54027 | 0.0008 |
| LWa | -3.6317 | 0.0095 | -8.18891 | 0 |

The results of bound testing approach show that F-statistic is greater than the upper bound value at 5 percent so there is co-integration among the variables of the model.

**TABLE 3: Bound testing analysis: F-statistics=4.738483**

| Level of significance | Lower bound values | Upper bound values |
|---|---|---|
| 5% | 2.45 | 3.61 |
| 10% | 2.12 | 3.23 |

**TABLE 4: Cointegration Short Run Resutls: Dependent variable=agri**

| Variables | Coefficient | Std. Error | t-statistic | Prob. |
|---|---|---|---|---|
| D(LAR01) | -0.007815 | 0.043046 | -0.181553 | 0.8585 |
| D(BM) | -0.001174 | 0.000849 | -1.381949 | 0.1886 |
| D(LFF) | 0.202910 | 0.064333 | 3.154044 | 0.0070 |
| D(LSSE) | 0.335784 | 0.116052 | 2.893395 | 0.0118 |
| D(T) | 0.000002 | 0.000001 | 1.440905 | 0.1716 |
| D(LWA) | 0.194252 | 0.220684 | 0.880227 | 0.3936 |

| | | | | |
|---|---|---|---|---|
| CointEg(-1) | -0.400466 | 0.097462 | -4.108948 | 0.0011 |

Cointeg = LAGRI_ -(0.1131*LAR01 -0.0143*BM -4.3967*LFF+1.2350*LSSE+0.0000 *T+3.2565*LWA+196691)

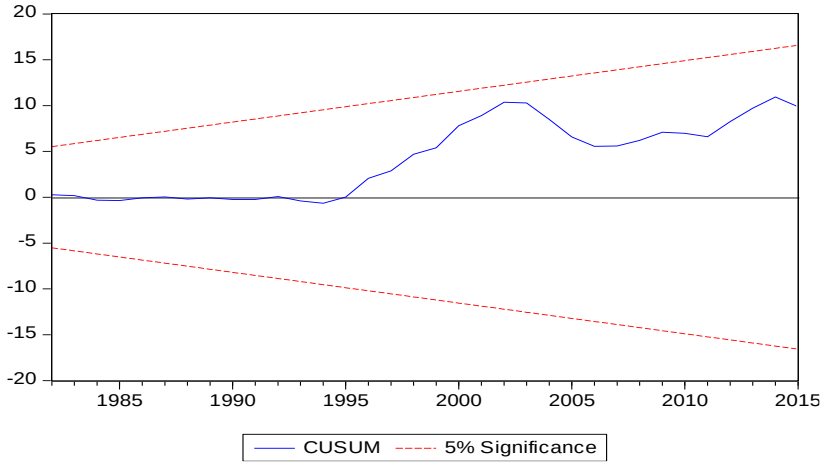
After finding cointegration and long run results now we use examining the short run relationship among the variables of the model. The coefficient of Cointeg(-1) gives the adjustment speed of the model towards long-run equilibrium. The estimated coefficient of Cointeg is statistically significant and the negative sign shows the convergence to the equilibrium. Highly significant estimated coefficient of Coin also indicates cointegration among variables of our model. The long run results of study are presented at below,

**TABLE 5: Long run results: Dependent variable=agri**

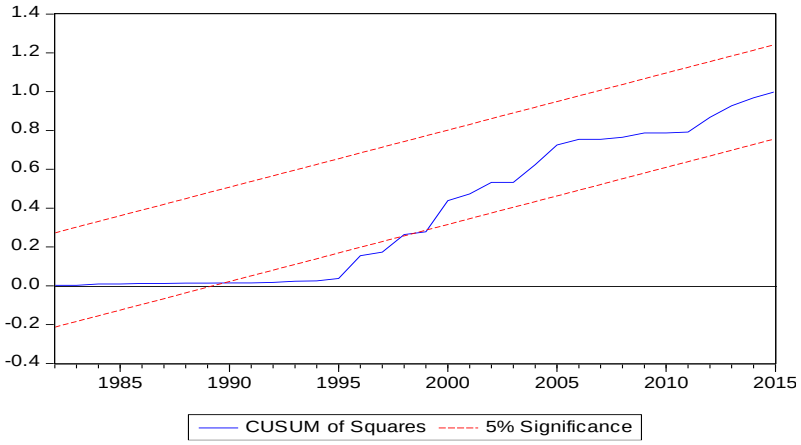
| Variables | Coefficient | Std. Error | t-statistic | Prob |
|---|---|---|---|---|
| LAR01 | 0.113146 | 0.164041 | 0.689744 | 0.5016 |
| BM | -0.014305 | 0.004055 | -3.528107 | 0.0033 |
| LFF | -4.396665 | 1.413048 | -3.111476 | 0.0077 |
| LSSE | 1.234968 | 1.254677 | 4.849155 | 0.0003 |
| T | 0.000001 | 0.000002 | 0.646515 | 0.5284 |
| LWA | 0.256542 | 1.385589 | 2.350293 | 0.0339 |
| C | 19.669122 | 1.668647 | 11.787468 | 0.0000 |

The results show that agricultural raw material has positive and insignificant relation with agriculture output in Pakistan. The results highlight that broad money has negative and significant impact on agriculture productivity. The estimated results show that fossil fules has negative and significant impact on agricultural output. secondary school enrollment has positive and significant impact on agriculture output in Pakistan. Tractors has positive and insignificant relation with agriculture output. Water availability show the positive and significant relation with agriculture output.

**Plot of cumulative sum of recursive residuals**




**Plot of sum of square of recursive residual**




The cumulative sum (CUSUM) and CUSUMQ of recursive residuals are used to detect the structural stability of the equations. The systematic changes in the regression coefficients are detected through diagnostic tests. While the abrupt changes in the regression coefficients are identified through CUSUM and CUSUMQ. The results found in figures indicate that the test statistics are within a band of 5 percent confidence interval. This implies the stability of the estimated model over the selected period.

## V. Conclusions

The core idea behind this study is to examine the connection between water resources and agricultural productivity of Pakistan. Particularly, the present study provides the empirical evidence that water availability has a positive impact on agricultural productivity of Pakistan. The findings of the study reveal that the coefficient of water availability has found to be robust and negative. This confirms that water resources significantly increase the agriculture of Pakistan.

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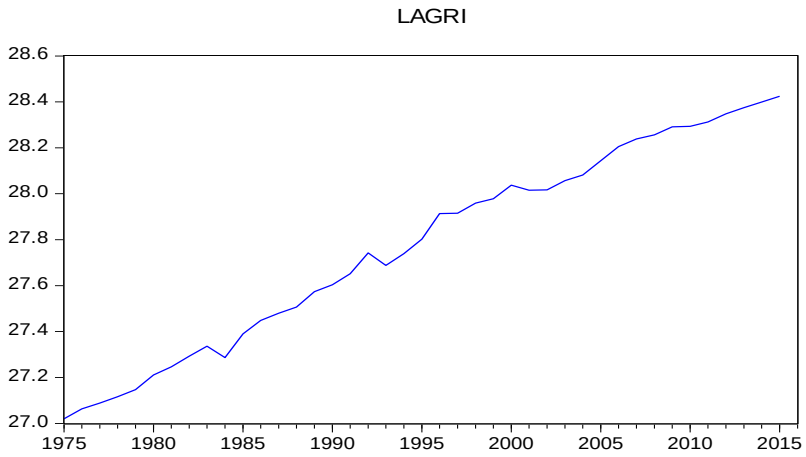


**FIGURE 1**

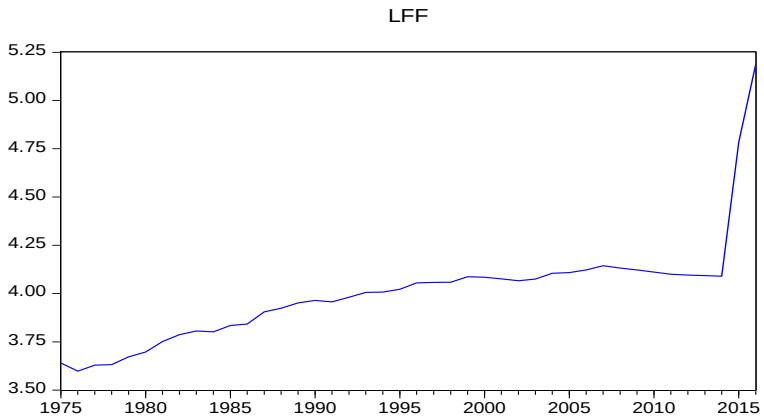


**FIGURE 2**

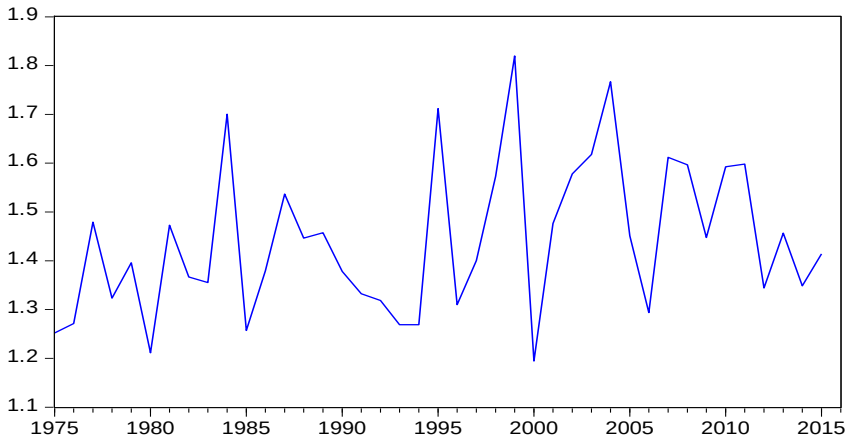


**FIGURE 3**

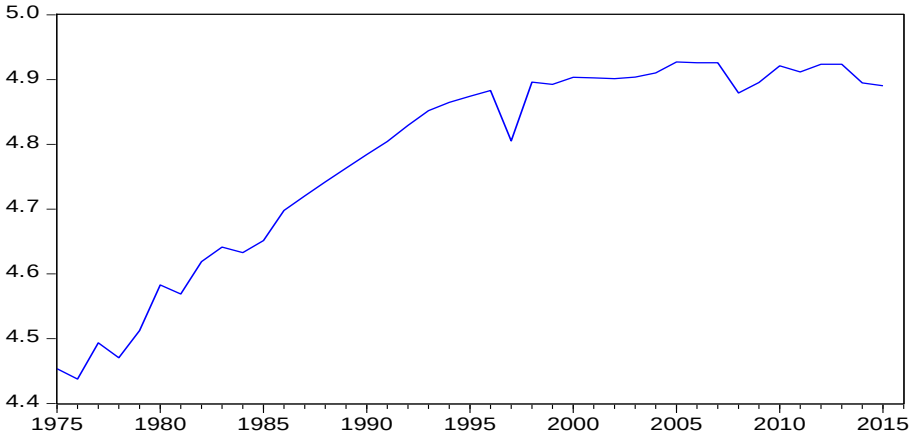


**FIGURE 4**

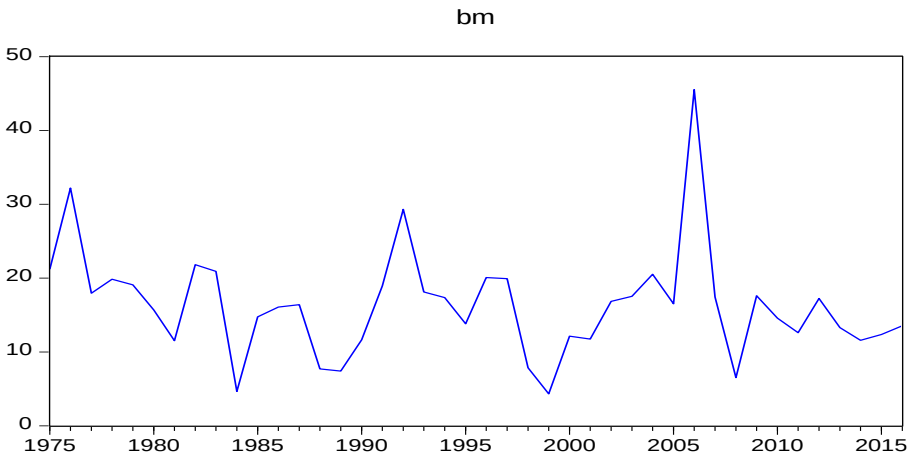


**FIGURE 5**

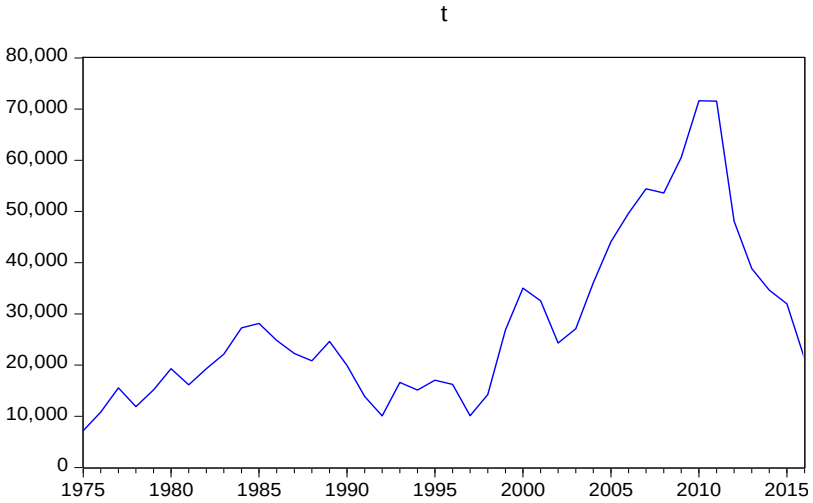


**FIGURE 6**

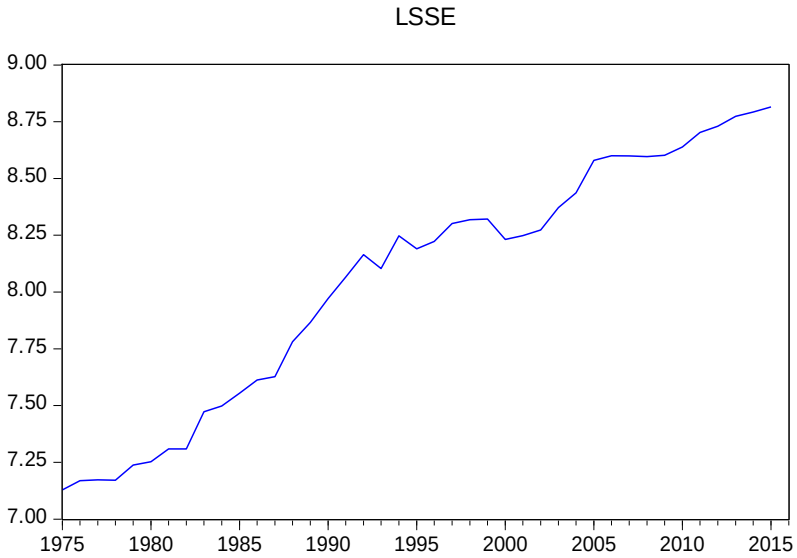


**FIGURE 7**