Determinants of Agricultural productivity in the United State of America During the period 1970 - 2017

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Abstract
This study aims to identify the most important determinants of agricultural productivity in the United States through an econometric study of annual data using autoregressive distributed lag approach during the period 1970-2017. The study found a long-term equilibrium relationship between agricultural productivity and its determinants in the econometric model. This is represented by agricultural research and development funding, use of fertilizer, government spending on transportation infrastructure and farm sector debt, in addition to the effect of these determinants positively on agricultural productivity except for farm sector debt.

Keywords: Agricultural productivity, agricultural productivity determinants, cointegration, autoregressive distributed lag model, the United State of America.

محددات الإنتاجية الفلاحية في الولايات المتحدة الأمريكية خلال الفترة 1970 – 2017

ملخص
تهدف هذه الدراسة إلى تبيان أهم محددات الإنتاجية الفلاحية في الولايات المتحدة الأمريكية، من خلال دراسة قياسية لبيانات سنوية باستخدام منهج الانحدار الذاتي لفترات الإبطاء الموزعة خلال الفترة 1970–2017، وقد توصلت الدراسة إلى وجود علاقة توازنية طويلة الأجل بين الإنتاجية الفلاحية ومحدداتها الداخلة في تكوين النموذج القياسي، والمتمثلة في تمويل البحث والتطوير الفلاحي، استخدام الأسمدة، والإنفاق الحكومي على البنية التحتية للنقل وديون القطاع الفلاحي، بالإضافة إلى تأثير هذه المحددات إيجابا على الإنتاجية الفلاحية باستثناء ديون القطاع الفلاحي.

الكلمات المفاتيح: إنتاجية فلاحية، محددات الإنتاجية الفلاحية، تكامل مشترك، نموذج الانحدار الذاتي لفترات الإبطاء الموزعة، الولايات المتحدة الأمريكية.

Déterminants de la productivité agricole aux États-Unis d'Amérique au cours de la période 1970 - 2017

Résumé
Cette étude vise à identifier les déterminants les plus importants de la productivité agricole aux États-Unis, à travers une étude économétrique de données annuelles utilisant le modèle ARDL au cours de la période 1970-2017, L'étude a trouvé une relation d'équilibre à long terme entre la productivité agricole et sa déterminants du modèle économétrique, représentés par le financement de la recherche et du développement agricoles, l'utilisation d'engrais, les dépenses publiques en infrastructures de transport et la dette du secteur agricole, en plus de l'effet positif de ces déterminants sur la productivité agricole à l'exception de la dette du secteur agricole..

Mots-clés : Productivité agricole, déterminants de la productivité agricole, cointégration, modèle autorégressif a retards échelonnés, États-Unis d'Amérique.

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Introduction:

The agricultural sector is one of the largest sectors in the United States. It makes an important contribution to the U.S. economy by contributing to the gross domestic product and foreign trade, ensuring a safe and reliable food supply, supporting job growth, and improving energy security. In this context, Agriculture's productivity growth is the major source of U.S. agricultural sector growth. Agriculture, in particular, has been a very successful sector of the U.S. economy in terms of productivity growth. Agriculture's productivity performance, compared with all other industries in the U.S. economy, is noteworthy. The U.S. farm sector has provided an abundance of output while using inputs efficiently.

Over the last decades, the U.S. farm sector has undergone structural, organizational, and technological changes, with agricultural production shifting to larger and more specialized farms and farmers relying more heavily on contracting to manage their risk. Besides adopting new technologies, applying more efficient practices, increasing farm size, and becoming more specialized. The farm sector has also experienced significant shifts in both outputs composition and inputs use. These shifts affect the sources of agricultural productivity growth.

In light of the above, this study examines the factors determining the agricultural productivity in the United State of America, by answering the following question:

What are the determinants of agricultural productivity in the United States of America during the period 1970 - 2017?

The problematic of the Study is subdivided into the following two questions:

1. Is there a significant effect of agricultural research and development funding, use of fertilizer, government spending on transportation infrastructure and farm sector debt on agricultural productivity?

2. Is there a short- term and long- term relationship between agricultural productivity and its determinants in the United States of America during the period 1970-2017 ?

Study hypotheses:

Based on the research questions, the following hypotheses can be formulated:

1. There is a positive statistically significant effect of agricultural research and development funding, use of fertilizer, government spending on transportation infrastructure and farm sector debt on agricultural productivity in the United States of America in study period.

2. There is a long-term integrative relationship between agricultural productivity and its determinants in the United States of America in study period.

The importance of the study:

The subject of the study is important because it seeks to identify different sources of agricultural productivity, which is one of the major factors contributing to the sustained economic growth of a nation.

Objectives of the study:

The aim of this study is to examine the determinants of agricultural productivity in the United States of America, through an econometric model that determines the relationship between agricultural productivity as a dependent variable and its determining factors as independent variables, based on the available data during the study period.

Methodology of the study :

In view of the nature of the study, the descriptive and analytical approaches are used in this study in analyzing the trend of the development of agricultural productivity, outputs and inputs in the United State of America, and also the quantitative approach is followed, where the autoregressive distributed lag model (ARDL approach) is using in order to determine the determinants of agricultural productivity. ARDL approach deals with single cointegration and is introduced originally by Pesaran and Shin (1999) and further extended by Pesaran et al. (2001). Autoregressive Distributed Lag (ARDL) cointegration test is used due to a number of econometric advantages compared to other cointegration procedures, such as, the Granger (1981), Engle and Granger (1987), and Johansen and Juselius (1990). It allows the long and short-run parameters of the model in question to be estimated simultaneously yet evade the problems posed by non-stationary data. In addition, and according to Narayan (2004), the small sample properties of the bounds testing approach are far more superior to that of multivariate cointegration. Also, there is no need to determine the order of the integration among the variables in advance. Other approaches however, do require that variables have the same order of integration.

Previous studies:

There are a number of studies that have examined the determinants of agricultural productivity. These studies varied in terms of treatment methods and asymmetric results. A review of these studies is given below. Key Nigel (2019) estimated the total factor productivity of five size classes of grain producing farms in the U.S. Heartland (Corn Belt) region, in order to understand whether economies of size provided an incentive for the consolidation of production. The author also estimates the extent to which sectoral productivity growth can be attributed to structural change versus other factors including technological change, using quinquennial Agricultural Census data from 1982 to 2012 its study also compares TFP growth rates across farm sizes to gain insight into whether observed productivity differences are likely to persist. The finding of a strong positive relationship between farm size and TFP suggests that consolidation of production has contributed to recent aggregate productivity growth in the crop sector(1).

The study of Beth Wanjuri Muraya and George Ruigu (2017) examined the determinants of agricultural productivity in Kenya. The authors employed Johansen-Granger Cointegration procedures and Error Correction Model (ECM) to forecast long-run relationships and to check for short-run relationship respectively among the study variables. The long- run relation highlights the negative impact of exchange rate and inflation on agricultural productivity, while Labour force, rainfall, and government expenditure impact agricultural productivity positively. The results of Error Correction Model imply that in the short- run Labour, rainfall, and government expenditure are the main determinants of agricultural productivity in Kenya(2).

Tessema Urgessa (2015) aims at investigating the determinants of agricultural productivity and rural household income in Ethiopia. Three econometric models namely: Pooled ordinary least square (POLS), fixed effects (FE) and random effects (RE) model were used to examine the relationship between productivity and income. Results showed that, land-labor ratio, use of fertilizer, use of pesticide, manure and household size are found to be the most significant variables that affect agricultural labor and land productivity. However, drought has statistically significant and has negative effect on both labor and land productivity by the same magnitude. Labor productivity, non-farm income and land productivity are found to be the most determinants of household income. However, number of dependency ratio is significantly and negatively affects the rural household income. The study also concludes that, Labor productivity is the most potent for factor of production and rural household income enhancement. The policy implication of the study is that, increasing land-labor ratio is important for agricultural productivity enhancement and promotion of both farm labor and non-farm income are best focusing to speed up for the enhancement of rural household income(3) .

Boubaker Dhehibi and all (2014) aim to identify the patterns of agricultural productivity in Tunisian agriculture during the period 1981-2007. To undertake this analysis, the authors examined own and cross price elasticities of different production factors using a translog production function which provides a convenient framework for analysing output reaction to changes in prices. Moreover, a regression approach was used to test the hypotheses that government funded research, development and extension, private and investment, terms of trade, and share of irrigated area are significant determinants of total factor productivity in the agricultural sector. The results of the study showed that total factor productivity growth was the result of investments in the agricultural sector, with the use of intensive irrigated production systems and the adoption of new production technologies[(4)].

Khalil Ahmad and Anthony Chin Theng Heng (2012) examined the determinants of agricultural productivity growth in Pakistan by employing autoregressive distributed lag model for the period 1965- 2009. The findings of the study suggested that fertilizer is the most important determinant with long-run and short-run elasticities of 0.16 and 0.20, respectively. Human capital is the next important determinant with 0.14 and 0.09 long-run and short-run elasticities, respectively. Agriculture credit has relatively lower short-run and long-run elasticities of 0.06 and 0.1 respectively. Area under crops is insignificant in both the short-run and long-run. Speed of adjustment as captured by error correction term is 0.67[(5)].

Burja Camelia (2012) aims to analyze agricultural productivity growth among Romanian regions. To identify the factors that influenced agricultural labour productivity in terms of the territorial profile, the study used a factor analysis model for the Farm net value added indicator on labour time unit. The evaluation of total agricultural productivity was performed by using efficiency scores determined with the Data Envelopment Analysis method. The results highlight the determinants of productivity variations in dynamic and territory [(6)].

In general, the literature shows that determinants of agricultural productivity vary depending on the period studied, the econometric methods used, and the country.

1-Trends in agricultural productivity, outputs, and inputs use in the United State of America (1970 - 2017):

The farm sector has ~~also~~ experienced significant shifts in both input use and output composition. Farmers today use more capital and chemicals and less labor and land than they did over the last decades, and they purchase more services for tasks that they used to perform themselves. On the other hand, the mix of items that farms produce has also changed. These changes in the mix of outputs and inputs affect how the farm sector is organized and the sources of agricultural productivity growth.

1-1- Productivity Trends:

Productivity is the expression of the efficiency with which production factors are being used and mattes the competitiveness of economic systems. Increased productivity is a key to a healthy and thriving economy. In the United State of America, total factor productivity (TFP) has grown continuously, and most of the growth is attributed to technological developments in agriculture, which have been influential in driving long-term growth in agricultural productivity. Innovations in animal and crop genetics, chemicals, equipment, and farm organization have enabled continuous output growth while using much less labor and farmland. As a result, total agricultural output nearly tripled between 1970 and 2017 even as the amount of labor and land (two major inputs) used in farming declined by about 45 percent and 17 percent, respectively [(7)].

According to the newest economic research service (ERS) data, American farm output grew by 111 percent between 1970 and 2017 at an average annual rate of 1.75 percent. With total input use rising only 0.75 percent over the same period, productivity growth accounted for most of total output growth during that period[(8)].

Annual productivity growth rates were generally positive during 1970-2017 (table 1). The average annual rate of growth in productivity during the 1970's, however, was not even two-thirds of the growth rate of the 1960's, since nearly half of the growth in output over this period was accounted for by growth in inputs. In the 1980's, growth in agricultural output aver- aged only 1.68 percent, but total factor input decreased at the same rate. Negative growth rates were observed in all major input categories, as the sector went through financial restructuring. Although labor had consistently declined since 1970, capital (equipment and land) and intermediate inputs also declined during the period. The decline in inputs resulted in fairly high rates of growth in total factor productivity. The early 1990's saw a continuation of above-average rates of growth in productivity. Not only was growth in input levels fairly low in 1990-94, but output growth was at historically high levels[9].

Table n°1: Average annual rates of productivity growth (percent)

Year	Total factor productivity (TFP)
1970-1973	2.04
1973-1979	0.88
1979-1981	3.84
1981-1990	2.09
1990-2000	1.6
2000-2007	0.64
2007-2017	1.21

Source: USDA, Economic Research Service, Productivity in the United States data product, 2017.

By 2017, U.S. farm sector productivity was 108 percent above its 1970 level. Long-term TFP growth is mainly driven by technical change, which is primarily fueled by research and development investment from public and private sectors. It can also be enhanced by public infrastructure, extension, and technology spillover from other sectors or neighboring regions. Yet, in the short term, estimated TFP can fluctuate considerably from year to year, largely in response to transitory events such as bad weather and pest outbreaks or to changes in input use affected by macroeconomic activities or short-term policies. Eventually, TFP growth will return to its long-term trend following these temporary shocks[10].

1-2- Trends and compositional shift in agricultural outputs (1970 – 2017)

U.S. agricultural output has more than doubled since 1970. Yet, the growth trends in farm commodities differ, and the revenue shares of individual commodities in total farm output have shifted over time. From 1970 to 2017, aggregate output grew at an average annual rate of 1.75 percent, with the crop sector growing faster than the livestock sector. The growth of crops accelerated and surpassed the growth of livestock in the mid-1970s, due partly to faster growing foreign demand for crop exports relative to livestock exports. As a result, the crop revenue share of total farm production increased from 52 to 56 percent, the livestock share dropped from 47 to 39 percent, and the farm-related output share grew by 4 percentage points between 1948 and 2015. In general, crop production fluctuates more than livestock as it is more sensitive to adverse weather events[11].

By 2017, U.S. farm output was about 2.1 times its 1970 level. Aggregate input use increased only 0.1 percent annually over this time span. Therefore, the positive growth in farm-sector output was due almost entirely to growth in total factor productivity, which averaged 1.68 percent annually (table 2). Nevertheless, the input composition changed markedly, farms shifted to higher quality labor, mainly due to a more highly educated labor force. The U.S. farm sector used about 45 percent less labor input and 17 percent less farmland than in 1970. Increased labor quality made a positive contribution to output growth during the same period (defined by business cycles in accordance with fluctuations in the overall U.S. economy). On average, labor quality through changes in farm labor's educational attainment and other demographic characteristics contributed to output growth at 0.12 percentage points a year, offsetting part of the contraction in labor quantity. Still, over the entire period, the decline in overall labor input contributed negatively to output growth by nearly -1.40 percent per year. On the other hand, while the changes from durable equipment, service buildings, and inventory (capital, excluding land) made positive contributions to output growth in 9 of 12 sub-periods, shrinking land use still made overall contribution of aggregate capital (including land) to output growth of -0.32 percentage points per year. Growth in intermediate goods contributed positively to output growth in 9 of 12 sub-periods and accounted for about four-fifths of output growth for the entire period, offsetting negative contributions from labor and capital to output growth[12].

Table n°2: Sources of outputs growth (average annual growth rates, percent), 1970-2017.

year	Output growth	Sources of growth				
		Input growth				Total factor productivity
		Total inputs	Labor	Capital	Intermediate goods	
1970-1973	2.53	0.49	-1.84	-0.48	2.36	2,14
1973-1979	2.44	1.56	-1.06	0.96	2.76	0,75
1979-1981	2.59	-1.25	-1.39	0.15	-1.89	3,79
1981-1990	0.80	-1.28	-2.79	-2.23	-0.06	2,11
1990-2000	1.89	0.30	-1.04	-0.77	1.45	1,55
2000-2007	0.77	0.13	-1.47	-0.10	0.86	0,92
2007-2015	1.18	-0.03	-0.24	0.22	0.04	0,53

Source: USDA, Economic Research Service, Agricultural Productivity in the U.S. data product, 2017.

1-3- Trends and compositional shift in agricultural inputs (1970 - 2017)

Input growth has been the main source of economic growth for the U.S. aggregate economy and for most sectors, but the agricultural sector is different. While total farm output grew 111 percent from 1970 to 2017, total inputs used in agriculture grew by only 0.75 percent. Nevertheless, the input composition changed markedly (table 2), shifting from labor and land toward machinery and intermediate goods (including energy, agricultural chemicals, purchased services, and other materials). Between 1970 and 2017, labor and land inputs declined by about 45 and 17 percent respectively while intermediate goods and capital grew by 49.09 percent and 70.65 percent, respectively. Among the four major input categories labor, capital, intermediate goods, and land only capital and intermediate goods showed long-term positive growth, with average annual growth rates of 0.8 percent and 0.78 percent, respectively. In addition to being replaced by machinery and agricultural chemicals, over the last two decades, farm labor input has also been replaced by purchased contract labor services, which are included as part of purchased services in intermediate goods.

2- Methods and Materials:

2-1- Sample and data:

The data employed in this study are annual data covering the period 1986 – 2017. The main types of data are taken from OECD stat, United States Department of Agriculture (USDA), and from The Bureau of Economic Analysis *(*BEA*)* of the United States Department of Commerce.

2-2- Variables of the study:

The most important goal of this empirical study is to investigate the determinants of agricultural productivity. Data includes total factor productivity as indicator of agricultural productivity, agricultural research and development funding, agricultural service employees, farm sector debt, use of fertilizer, and government spending on transportation infrastructure. Variables with their symbols are given in table (3).

Table n°3: Variables of study

Variables	symbol	type
total factor productivity	(TFP)	Dependent
agricultural research and development funding	(ARDF)	Independent
agricultural service employees	(ASE)	Independent
farm sector debt	(FSD)	Independent
use of fertilizer	(FER)	Independent
government spending on transportation infrastructure	(GST)	Independent

3- Results and Discussion:

3-1- Order of Integration and Stationary of Serial:

Non-stationary in data time series can include the spurious correlation error into the econometric methodology. A chronological serial is stationary if not contain no trend and intercepts, so we must establish the order of variables integration, we say that variables are integrated in order p if her deference's in order p is stationary so we shall be checking are this variable got unit root or not. That means her deference's in order p is null growth. There are many tests permit to put on evidence the stationary of serial. In this study we use test of Phillips Perrons (PP) and augmented Dickey-Fuller test (ADF), in order to ensure that the variables are not I(2). The ADF and PP tests results for both level and first difference tests with their significance levels are presented in Table (4) below.

Table n°4: Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) Test Results

Variables		Test Equations					
		ADF			PP		
		With Intercept	With Intercept & Trend	With Out Intercept & Trend	With Intercept	With Intercept & Trend	With Out Intercept & Trend
LnTFP	At Level	-1.1901	-4.8063***	-3.3893***	-1.4802	-4.9576***	-3.3749***
	1st Difference	-7.9284***	-5.8619***	-10.7728***	-24.2055***	-27.0626***	-11.1540***
LnARDF	At Level	-1.4534	-1.9906***	2.9300***	-1.4454	-2.0724***	2.7340***
	1st Difference	-5.9766***	-5.9949***	-5.1431***	-5.9807***	-5.9925***	-5.1249***
LnASE	At Level	-1.8933	-1.6991	0.5388	-1.9975	-1.8149	0.4530
	1st Difference	-5.8410***	-5.9329***	-5.8584***	-5.8319***	-5.9329***	-5.8484***
LnFSD	At Level	1.7032	-2.7677	2.6866	1.7377	-2.8408	2.3099
	1st Difference	-5.1028***	-6.0788***	-1.2779***	-5.1032***	-6.2397***	-4.3006***
LnFER	At Level	-3.2642**	-4.1037**	0.2303	-3.1211**	-4.1245**	1.2859
	1st Difference	-7.3450***	-7.2685***	-7.3504***	-18.7636***	-24.1497***	-13.1358***
LnGST	At Level	-4.8690***	0.0759	0.4390	-13.1108***	1.5516***	5.3477
	1st Difference	-4.5003***	-7.6026***	-1.6122*	-4.2236***	-6.2068***	-2.7003***

Note: ** Significant at the 5% ; * Significant at the 1%.**

Source: Author computation using Eviews10.

The results depicted in table (4) revealed that the variables are stationary in first difference. On the based ADF and PP tests results, we select to use the ARDL technique to perform the long term and short-run analysis. The ARDL approach is preferable when variables have mixture of results at stationary in level I(0) and stationary in I(1). It is intimate that among the variables; no one is integrated of order two. Thus, our result is free of spurious regression.

3-2- ARDL Model Estimation:

In recent times, an emerging body of work led by Pesaran & Shin (1999) and further extended by Pesaran and al (2001), has introduced an alternative cointegration technique recognized as the Autoregressive Distributed Lag or ARDL bound test. The advantage of the ARDL model is flexible and provides both short- and long-run relationship. Table (5) provides if there is a short run relationship among variables or not.

Table n°5: ARDL Model Estimation:

Dependent Variable: LNTFP Method: ARDL Included observations: 31 after adjustments Maximum dependent lags: 1 (Automatic selection) Model selection method: Akaike info criterion (AIC)

Dynamic regressors (2 lags, automatic): LnARDF LnGST LnFER LnFSD LnASE
Fixed regressors: C
Selected Model: ARDL(1, 0, 2, 0, 1, 2)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LnTFP(-1)	-0.420973	0.165828	-2.538612	0.0200
LnARDF	0.272110	0.131486	2.069500	0.0524
LnGST	-0.251425	0.309386	-0.812658	0.4265
LnGST(-1)	-0.066190	0.448080	-0.147719	0.8841
LnGST(-2)	0.732384	0.294328	2.488325	0.0223
LnFER	0.123474	0.045888	2.690747	0.0145
LnFSD	-0.022307	0.100649	-0.221634	0.8270
LnFSD(-1)	-0.185508	0.098835	-1.876951	0.0760
LnASE	-0.034080	0.029462	-1.156769	0.2617
LnASE(-1)	-0.041345	0.035722	-1.157403	0.2615
LnASE(-2)	0.094778	0.026755	3.542487	0.0022
C	-2.450295	0.392910	-6.236276	0.0000
R-squared	0.979079	Mean dependent var		-0.119849
Adjusted R-squared	0.966968	S.D. dependent var		0.127179
S.E. of regression	0.023115	Akaike info criterion		-4.412064
Sum squared resid	0.010151	Schwarz criterion		-3.856972
Log likelihood	80.38699	Hannan-Quinn criter.		-4.231118
F-statistic	80.83604	Durbin-Watson stat		2.377169
Prob(F-statistic)	0.000000			

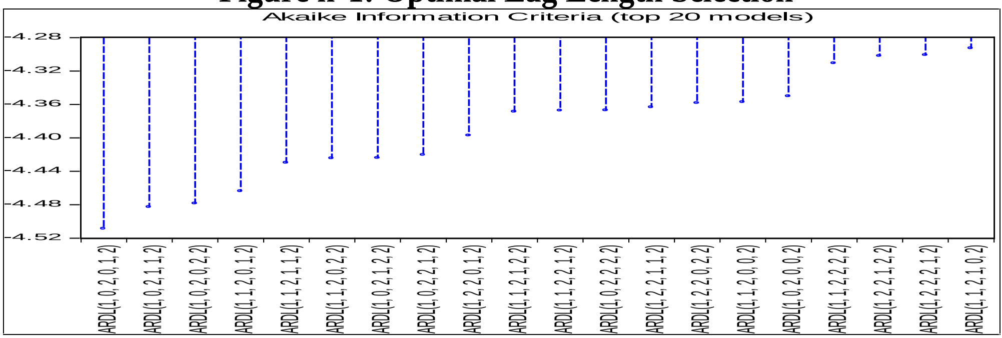
Source: Author computation using Eviews10.

The results of the model estimation show that some of agricultural productivity determinants affect it in different lag, which are LnTFP(-1), LnGST (-2), LnASE (-2), in addition to the constant and the variables LnFER and LnARDF, which mean that there is a short run from the independent variables to the dependent variable. The statistical tests of the regression equation indicate that the estimated model is good, as the coefficient of determination is equal to 0.9790, meaning that the model interprets 97.90% of the changes in the rate of agricultural productivity. Furthermore, the results indicate that the relationship between the dependent variable and the explanatory variables is not false; the value of F-statistics has a significant value of 80.83.

3-3- Optimal Lag Length Selection:

Before estimating the ARDL model, we must determine the optimum degree's delays for the model. For this purpose, the Akaike Information Criterion (AIC) was used to select the number of lags required in the cointegration test. The lag length chosen are showed in figure (1) below.

Figure n°1: Optimal Lag Length Selection



Source: Author using Eviews10.

The lag order of model based on Akaike Information Criterion (AIC) is: ARDL(1, 0, 2, 0,1, 2);
The ARDL model can be specified as:

$$\Delta LnTFP = C + \alpha_1 LnTFP_{t-1} + \alpha_2 LnARDF_{t-1} + \alpha_3 LnGST_{t-1} + \alpha_4 LnFER_{t-1} + \alpha_5 LnFSD_{t-1} + \alpha_6 LnASE_{t-1} + \beta_1 \Delta LnTFP_{t-1} + \beta_5 \Delta LnFSD_{t-1} + \sum_{i=1}^{2} \beta_{3i} \Delta LnGST_{t-1} + \sum_{i=1}^{2} \beta_{6i} \Delta LnASE_{t-1} + \varepsilon_t$$

Where:

Δ : the first-difference operator.

$\beta_1, \beta_3, \beta_5, \beta_6$: The coefficients of short–run relationship.

$u_1, u_2, u_3, u_4, u_5, u_6$: The coefficients of long- run dynamic relationship.

Ln: the natural logarithm

ε_t : stochastic error term.

C: Intercept of the function.

t shows time**.**

3-4- Bound Test for Cointegration:

To determine the existence of long run relationship among the variables of the study, the Pesaran, Shin & Smith (2001) Bound test procedure was used. Narayan (2004) tabulated two sets of critical values, the upper bound critical values refers to the I(1) series, meaning that there is cointegration among the variables and the lower bound critical values to the I(0) series, meaning that there is no cointegration relationship between variables . For some significance level, if the F-statistics falls outside the critical bound, a conclusive inference can be made without considering the order of integration of the explanatory variables. The bound test results were presented in Table (6) below.

Table n°6: ARDL bounds Test

ARDL Bounds Test			
Included observations: 31			
Null Hypothesis: No long-run relationships exist			
Test Statistic	Value	k	
F-statistic	7.226581	5	
Critical Value Bounds			
Significance	I0 Bound	I1 Bound	
10%	2.26	3.35	
5%	2.62	3.79	
2.5%	2.96	4.18	
1%	3.41	4.68	

Note: k is the number of regressor for dependent variable in ARDL model.

Source: Author computation using Eviews10.

The bound test results indicate that the F-statistic value is 7.226581, which is more than the upper bound critical value at all levels of significance. The bounds test results support the presence of cointegration relationship among the variables running from the independent variables to dependent variable.

3-5- Cointegration of long run relationship:

The two popular cointegration tests in applied time series modeling are the Engel & Granger (1987) cointegration test and the Johansen & Juselius (1990) cointegration test. The Engel & Granger cointegration test is adopted in cases of single equation models, while, the Johansen & Juselius cointegration test is used for system equation models. The autoregressive distributed lag (ARDL) model is based on single equation modeling Pesaran & al (2001). For the purpose of our study we chose the Autoregressive Distributed Lag. The long-run regression results are presented in table (7).

Table n°7: ARDL Cointegrating and Long Run Form

ARDL Cointegrating And Long Run Form Dependent Variable: LnTFP Selected Model: ARDL(1, 0, 2, 0, 1, 2) Sample: 1970 2017 Included observations: 31				
Cointegrating Form				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LnARDF)	0.272110	0.131486	2.069500	0.0524
D(LnGST)	-0.251425	0.309386	-0.812658	0.4265

D(LnGST(-1))	-0.732384	0.294328	-2.488325	0.0223
D(LnFER)	0.123474	0.045888	2.690747	0.0145
D(LnFSD)	-0.022307	0.100649	-0.221634	0.8270
D(LnASE)	-0.034080	0.029462	-1.156769	0.2617
D(LnASE(-1))	-0.094778	0.026755	-3.542487	0.0022
CointEq(-1)	-1.420973	0.165828	-8.568952	0.0000
Cointeq = LnTFP - (0.1915*LnARDF + 0.2919*LnGST + 0.0869*LnFER				
Long Run Coefficients				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LnARDF	0.191496	0.087423	2.190459	0.0412
LnGST	0.291890	0.027443	10.636162	0.0000
LnFER	0.086894	0.031452	2.762769	0.0124
LnFSD	-0.146249	0.035517	-4.117770	0.0006
LnASE	0.013619	0.013473	1.010826	0.3248
C	-1.724378	0.170731	-10.099972	0.0000

Source: Author computation using Eviews10.

As show the results in table above table (7), the error correction estimator is significant at 1%, which support the presence of long - run relationship between variables (ECT =-1.42), this means that when agricultural productivity (Measuring with total factor productivity) deviate from his equilibrium value in the short period (t-1), it corrects which was equivalent to 142 % of this deviation in the period (t). This ratio reflects the speed of return to the equilibrium position after the impact of any shock on the model as a result of the change in the determinants of agricultural productivity. Furthermore, the variables ARDF, GST, FER and FSD were statistically significant determinants of agricultural productivity in the United State of America.

The government spending on transportation has a very significant effect on agricultural productivity, as 1% increase in this variable will increase agricultural productivity by 29%, because a denser transportation network could enhance the benefits of public R&D investment and reduce production cost. That is, with higher road density, R&D investment has a larger impact on productivity growth in terms of cost reduction. and, thus, make new technology and extension more accessible and affordable to farmers. An increase in road density also helps to reduce production cost directly by lowering transportation costs for delivery of inputs and outputs and, therefore, enhances productivity growth.

Agricultural research and development funding has a very significant effect on agricultural productivity, as 1% increase in this variables will increase agricultural productivity by 19%. The positive relationship between agricultural R&D funding and agricultural productivity growth is as result of the role of agricultural research and development in fostering continuing series of biological, chemical, mechanical, and organizational innovations, which have themselves been the result of investments in public and private agricultural research, and also the advent of new technologies, innovations, and process improvements in the farm sector. These range from improved seed varieties, genetic enhancement in livestock, advanced machinery that comes equipped with global positioning systems, and robotics, among other innovations. On the other hand, the substantial increase in agricultural productivity can be attributed to the spillover effects of agricultural knowledge generated through agricultural research and development.

The Fertilizer utilization in agriculture is one of the major engines of agricultural growth, as an increase of 1% will increase the agricultural productivity by 8%, because fertilizers are biostimulant substances that influencing positively the physiological and biochemical processes of plants, improving both the absorption efficiency and the assimilation of nutrients. They provide a series of active substances with high biostimulant function, thus overcoming stress conditions and improving plants physiology, with abundant and sustainable yields and a minor use of non-renewable resources.

The farm sector debt has a negative impact on the growth of the agricultural productivity, because financial shocks - such as an drop in net farm income, higher rates of farm bankruptcies annually, the highest levels of debt burden on farmers and ranchers and a sudden jump in interest rates - affect the viability of highly leveraged farm businesses , and the increasing cost of servicing farm debt will squeeze profit margins that are already razor-thin, which has a negative impact on financial performance, technical efficiency and agricultural productivity.

3-6- Diagnostic tests:

Now, we perform some diagnostic tests to ensure that the model is best fit and the stability of the model.

- **Serial Correlation LM Test**: the serial correlation problems in the data were examined through the Breusch Godfrey serial correlation LM test. The results of autocorrelation test are not significant at the 5 percent level (table 8). This means there exists no serial correlation problem.

Table n°8: Breusch-Godfrey Serial Correlation LM Test

Breusch-Godfrey Serial Correlation LM Test:			
F-statistic	1.454249	Prob. F(2,17)	0.2612
Obs*R-squared	4.528893	Prob. Chi-Square(2)	0.1039

Source: Author computation using Eviews10.

- **Heteroskedasticity Test**: The Breusch Pagan-Godfrey test was applied to examine the problem of heteroskedasticity in the residuals. The examined results of heteroskedasticity indicate that no problem of heteroskedasticity exists in our data based on the calculated P-value of chi-square and fisher.

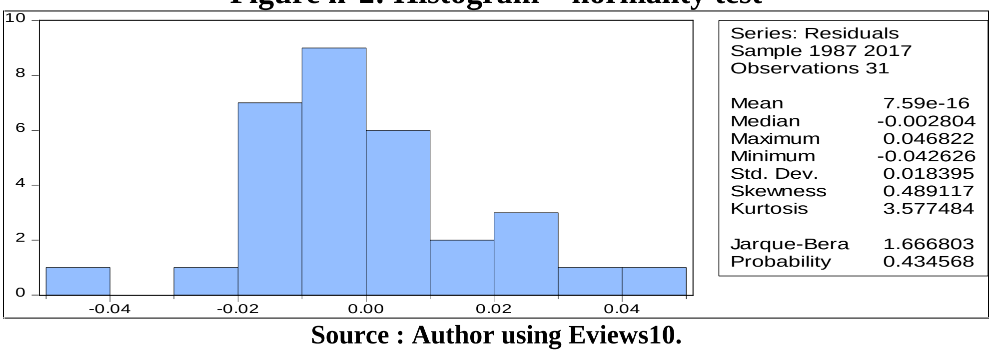
Table n°9: Heteroskedasticity Test

Heteroskedasticity Test: Breusch-Pagan-Godfrey			
F-statistic	0.687205	Prob. F(11,19)	0.7347
Obs*R-squared	8.823170	Prob. Chi-Square(11)	0.6382
Scaled explained SS	4.271442	Prob. Chi-Square(11)	0.9613

Source: Author computation using Eviews10

- **The test for normality:** The result of the test for normality in table figure 2 demonstrates that the error term is also proved to be normally distributed.

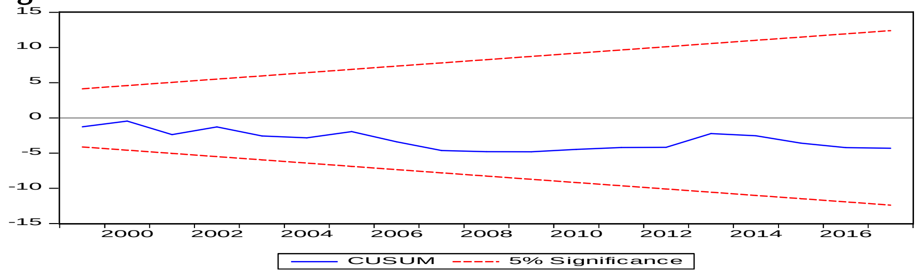
Figure n°2: Histogram – normality test



Source : Author using Eviews10.

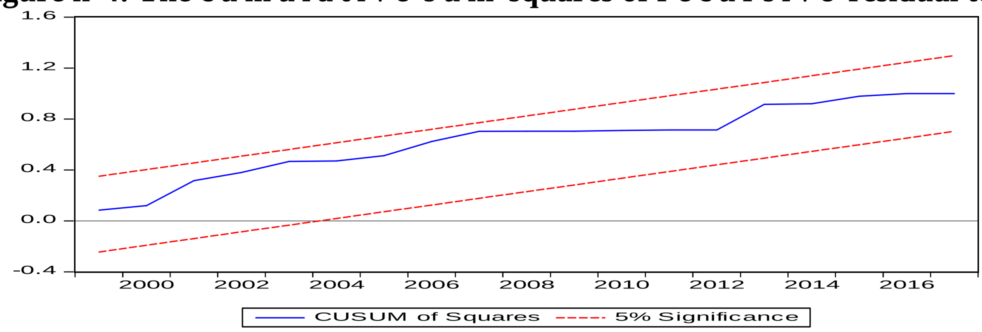
- **Test of parameters stability:** To make sure, that the data used in this study, does not contain any structural changes, we should use one of the appropriate tests CUSUM and CUSUM of squares, which developed in order to clarify the extent of stability and consistency of long-term parameters with short-term parameters. If the plot of CUSUM-SQ and CUSUM statistic stays within 5% significance level, then the estimated coefficients are said to be stable. A graphical presentation of this test for our ARDL model is provided in figures 3, 4 below.

Figure n°3: The cumulative sum of recursive residual test.



Source: Author using Eviews10.

Figure n°4: The cumulative sum squares of recursive residual test.



Source: Author using Eviews10

The results in the graphs show that the curve CUSUM within critical limits is 5%, as well as for the curve CUSUM OF SQUARES located within the critical area, which explains that the model is stable at 5%.

Conclusion

This study investigated the determinants of agricultural productivity in United State of America over the period of 1970 - 2017. We have applied ADF and PP unit root tests to test stationarity of the variables. Further, the ARDL bounds testing approach to cointegration was employed to investigate the long and short-run relationships between the variables. The results are:

- The success of the agricultural sector in United State of America depends on long-term TFP growth, which is mainly driven by transport infrastructure development, and technical change, which is primarily fueled by research and development investment from public and private sectors.
- The farm sector in United State of America has experienced significant shifts in both input use and output composition. These changes in the mix of outputs and inputs affect how the farm sector is organized and the sources of agricultural productivity growth.
- The most significant determinants of agricultural productivity are agricultural research and development funding, use of fertilizer, government spending on transportation infrastructure and farm sector debt.
- Transport infrastructure development has a larger impact on productivity growth in terms of cost reduction. and, thus, make new technology and extension more accessible and affordable to farmers. An increase in road density also helps to reduce production cost directly by lowering transportation costs for delivery of inputs and outputs and, therefore, enhances productivity growth.
- Agricultural research and development is an important factor in the growth of total production productivity in United States of America, given the role of agricultural research and development in fostering continuing series of biological, chemical, mechanical, and

organizational innovations, which have themselves been the result of investments in public and private agricultural research.

- Farm sector debt can negatively affect agricultural productivity, as in the case of the United States of America, due to the highest levels of debt burden on farmers and ranchers and a sudden jump in interest rates - affect the viability of highly leveraged farm businesses, and the increasing cost of servicing farm debt will squeeze profit margins.

In view of this, and for increasing agricultural productivity, we recommend:

- Using efficiently and effectively fertilizers - right source, right rate, right time and right place - which are the underpinning principles of fertilizer management, and adapting to all cropping systems to ensure productivity is optimized.
- The government should desist from borrowing short term loans to finance long term agricultural projects.
- The need to develop technologies and knowledge that will enable to maximize the productive potential of farms, thereby controlling costs and preserving their economic viability.
- Public investments in agricultural R&D are the foundation for the innovative technologies and practices, so they have to be encouraged for accelerating of new innovations in more efficient way.
- Macroeconomic policies should be targeted towards maintaining a low rate of interest as it would contribute to agricultural output growth in the country.

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