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Growth in Total Factor Productivity in the Egyptian Agriculture Sector: Growth Accounting and Econometric Assessments of Sources of Growth

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Abstract

This research aims to assess the Total Factor Productivity (TFP) of the whole agricultural sector in Egypt for the period 1961-2012 using Törnqvist index calculations. Particularly, it aims to investigate: (1) the most important factors explaining the TFP growth in the Egyptian agriculture (2) estimating changes in technical efficiency and technical change and determining the magnitude of their contribution to the overall TFP growth, and lastly, (4) based on these findings, providing policy implication and recommendations that allows enhancing and sustaining future growth of agricultural production in Egypt.

The currently analysis provided relevant results which might help us understanding the structural trend of the Egyptian agricultural sector, and understanding the most significant variables affecting this trend. Such results will have important policy implications for promoting further growth in the Egyptian agricultural sector. The empirical findings showed that rural development variables were found to significantly and negatively affect agricultural productivity. This demonstrates that agricultural activity is still a marginalized activity which is linked to low levels of income and is a source of employment for low productive labor. Moreover, a negative significant effect of the infrastructure variable on the productivity gains of the agricultural sector in Egypt was found which might indicates a form of low integration of farmers within large neighboring markets. These findings highlighted the decisions makers to take a deeper look at their rural infrastructure strategy, knowing that it may affect the productivity of the agricultural sector as whole.

Keywords: total factor productivity, agricultural growth, Tornqvist index, growth determinants, Egypt

1. Introduction

Growth of agricultural productivity is considered as backbone of sustainable growth poverty reduction in developing countries such Egypt. Trends of economic development of such countries show that differences in poverty reduction rates over the past decades have been closely related to differences in agricultural performance – particularly the rate of agricultural productivity growth.

Despite decades of investment in new agricultural technologies and rural development, hunger and poverty continue to plague large areas of Egypt. While increasing agricultural productivity perhaps remains the single most important determinant of economic growth and poverty reduction, serious doubts are emerging as to whether agricultural productivity in Egypt can be further increased and how. The role of policies, investments, resources constraints, and other related-factors in increasing agricultural productivity in Egypt is also questionable.

Growth of agricultural productivity is a prerequisite for achieving sustainable growth and significant reduction of poverty in developing countries. Development economists view productivity growth in the agricultural sector as critically important for growth of agricultural production and balance of food supply and demand. Trends of economic development in the Middle East and North African (MENA) countries show that differences in poverty reduction rates over the past decades have been closely related to differences in agricultural performance – particularly the rate of agricultural productivity growth

Despite decades of investment in new agricultural technology and rural development, hunger and poverty continue to plague large areas of the MENA region. While increasing agricultural productivity perhaps remains the single most important determinant of economic growth and poverty reduction in the rural areas of MENA countries, serious doubts are emerging as to whether agricultural productivity can be further increased and how.

Particularly, development experts need greater understanding of the links between agricultural productivity, employment implications and poverty – to what extent will farm productivity growth be labor-saving or employment generating Moreover, future agricultural growth in the region is likely to be severely constrained by limited water resources, population growth (especially youth) and the extreme weather volatility in addition to the political instability.

The objective of the current research paper is to provide an overview of the historical TFP growth of the Egyptian agricultural sector and to analyze its main determinants. The TFP calculation for Egypt is expected shed light on technical change and economic growth of this sector. The final aim of this research will be to provide guidance for future investments for the development of this sector in Egypt. For this purpose, a global dataset about agricultural inputs and outputs (values and volumes) in Egypt was constructed for the period 1961-2012. This data was used to calculate annual Törnqvist productivity indexes for the mentioned period, reflecting the TFP growth (change) of the Egyptian agricultural sector. Another set of variables was used to assess their relationship to the calculated Törnqvist indexes, through a log-linear econometric regression.

The remaining of the paper is divided into 5 sections. The next section presents a general overview of the Egyptian agriculture; the third and fourth sections present a theoretical discussion of TFP growth drivers and the methodology used for this research, respectively. Results are presented and discussed in the fifth section. A last section concludes.

2. Overview of the Agricultural Sector and Its TFP Growth in Egypt

The Egyptian economy has traditionally relied heavily on the agricultural sector for food, fiber and other products. The agricultural sector provides the livelihood for about 55% of the inhabitants and employment for about 34% of the total labor force. In addition, agriculture contributes with about 20% to the gross domestic product (GDP) and with about 20% of the total exports value. Crops production contributes with an average of 61.19 % to the agricultural GDP while livestock contributes with 30.87 % and fisheries with 7.93 %. The demand for agricultural products is increasing due to population growth and the need for more export earnings. Agriculture in Egypt has witnessed significant developments over the last two decades with direct effects on the role of the agricultural sector in national income formation and exports. Such developments have been also marked by farmers' delivery as related to the cropping structure, applied technology, levels of income, and farmers' response to market changes.

Agricultural growth rates in Egypt have been widely differed from one period to another due to the effect of the general economic conditions and to the different investment and development strategies implemented during the last decades. The 1981/1982 and 1986/1987 periods were at the forefront of the periods that achieved a higher growth of the agricultural GDP, estimated at an annual rate of 3%. The 1987/1988 and 1991/1992 periods were at the lower edge, with annual growth rate of around 2%. In the last decade there has been some improvement of this growth rates, reaching 3.3% in 2006/2007. At the beginning of the sixth development plan, 2007/2008 – 2011/2012, the projected rate of growth was estimated at 3.6%.A quick analysis of these figures shows that the structural changes experienced by the agricultural sector in Egypt during the 1990s were positively affecting the growth rates.

For a long period of time, Egyptian exports remained confined to cotton, rice, onion and citrus. Since mid-1970s, exports have witnessed a drastic change: diversification of the exported commodities, expanded export markets, and increased export returns. Total annual export value reached 1230 Million USD during the period 2005–2007, with the aforementioned four crops constituting some 50% of the total export value, while other crops such as vegetables, fruits, medicinal and aromatic plants are constituting the remaining share. On the other hand, export markets have not been confined to Arab and European markets but have been expanded to include African and South Eastern Asian markets, among others.

In spite of the fact that rates of agro-industrialization are still below expectations, the last two decades have witnessed a significant development in this regard. Many agro-industrial units using the latest techniques have been established, meeting world quality standards and capable of accessing several foreign markets. It is noteworthy that processing industry has not been limited to the direct processing of agricultural products but has also been expanded to include several inputs such as packaging material, fertilizers, pesticides, irrigation supplies, as well as other main agricultural inputs. These achievements have led to a significant increase of processed agricultural products. Agricultural activities' income levels in Egypt have been remarkably increasing during the last two decades, but remain low in average. Net returns per feddan (Note 1), have increased from an average of 684 EGP per year during 1980 – 1985 to about 1046 EGP per year in 2007.

A literature review of the TFP growth in the Egyptian agricultural sector reveals that empirical studies were focusing on analyzing TFP of specific agricultural commodities (Rodriguez & Elasraag 2015; Abou-Saad, 2012; Bahloul, 1999). Rodriguez and Elasraag (2015), decomposed the productivity growth of Egyptian cotton production using stochastic frontier approach, and were tracking the changes of the TFP composition over the period 1990–2008. They mainly showed that TFP of this production system does not increase in Egypt. According to their results, this is mainly due to the negative average contributions of changes in allocative efficiency and in the technical progress. Abou-Saad (2012) used Cobb-Douglass and *translog* function models for single-output multi-input stochastic production frontiers and a *translog* multi-output multi-input stochastic input distance function in order to measure the TFPs of four major crops in Egypt: wheat, maize, rice, and cotton. His both approaches provided similar results indicating high level of technical efficiency (TE) in grain production. Productivity growth was very low but the high TE indicates that such a growth needs to come from new technologies. The author also considers that there is a need to invest in research and development in order to reverse a continuous decline in technological progress (TP). Bahloul (1999) assessed the TFP of the overall agricultural sector in Egypt between 1975 and 1992, using the Törnqvist –Theil index. His results indicate an average TFP growth rate of 0.016% for the studied period. The results also indicate that the annual average wages affect the TFP growth negatively, while the number of agricultural workers and the number of tractors are among the factors which are positively and significantly affecting this growth rate.

3. Theoretical Discussion: Determinants of Agricultural Productivity Growth

Several factors have been identified in the specialized literature as sources of productivity change in the agricultural sectors. These are mainly related to the research and development, extension, education, infrastructure, government programs and policies, technology transfer and foreign R&D spillovers, health, structural change and resource reallocation, terms of trade, etc. The productivity measures itself do not provide any information about the separate role/effect of each of these factors. However, complementary econometric regressions can relate the calculated productivity changes to some of these variables in order to quantify the extent of their effect on the agricultural sector performances. We hereby provide a brief literature overview about the role and importance of some of these TFP growth determinants.

Agricultural Research & Development (R&D): Investments in R&D are in fact considered as main determinant of productivity growth in the agricultural sector. In fact, farmers are benefiting from new technologies, varieties, and breeding practices which are mostly developed through research channels and promoted through development ones. Moreover, agricultural research is not only required to increase the agricultural productivity, but also to prevent productivity fallings due to degradation and other overexploitation problems. In the most developed countries, investments in agricultural research and development can be divided into public and private investments, with clear dominance of private investments. However, this figure is completely different in the less developed countries, where mainly the public sector is investing in agricultural R&D. Another important R&D factor in the developing countries is the foreign R&D spillovers. Extension is also considered as part of R&D expenditures, which is actually due to its importance to enhance the scope and intensity of adoption of new technical innovations provided by different research systems and technology transfer channels. Agricultural extension systems aim to reduce the time lag between development of new technologies and their adoption. The sooner the benefits from research are received by farmers and consumers, the higher will be the rate of return to that research expenditure. This time lag between the development of the technology and its adoption by farmers is actually not only depending on the extension services performances but is also function of farmer's skills and level of education. For this reason, some variables reflecting farmer's levels of education and skills were also introduced in our analysis.

Education and Human Capital: Farmer's education is determining their cognitive capacity, ability to take rational decisions, openness for new learning and technologies, search for information, and managing available resources at their farm level. For this reason, an agricultural sector where most of the farmers are having high education level will certainly perform differently from and agricultural sector dominated by lowly skilled and educated farmers. Thus, education is an investment in "human capital" analogous to a farmer's investment in physical capital. Education also hastens the rate of development of new technologies by training scientists.

Another, though less obvious, effect of education is to help consumers better evaluate the potential risks posed by new products and technologies. The potential benefits of a new technology may not be realized if consumers do not appreciate it and purchase the final products.

Investments in agricultural infrastructure: Investment in public agricultural capital, (physical infrastructure in particular) accounts for the largest share of agricultural public budgets in many countries. The role of infrastructure is to expand the productive capacity by increasing resources and enhancing the productivity of private investments (Munnell, 1992). Many studies have found a significant positive relationship between investments in infrastructure and agricultural productivity (Gopinath & Roe, 1996; Yee et al., 2000). The most obvious example of how public investment in infrastructure might affect agricultural productivity is through investment in public transportation and in irrigation infrastructure. As an example, an improved highway system can allow for better market integration of farmers and can reduce costs of acquiring production inputs and of transporting outputs to market.

Level of trade openness in the agricultural sector: Terms of trade are defined as the export-import unit values ratio. In the literature, Agricultural exports expose the producers in a country to an international competitiveness which spurs efficient production technologies. Besides, agricultural imports are a sign of a problematic agricultural sector. An increase in terms of trade reduces inefficiency and consequently increases TFP. This implies that any increase of the export unit value (or equivalent any decrease of the import unit value) enhances TFP. A number of studies in the literature state that favorable agricultural terms of trade is a strategic necessity for enhancing technology adoption as well as mobilization of higher investment levels in transforming agriculture (Dantwala, 1976; De Janvry & Subbarao, 1986). An alternate body of opinion claims that non-price factors (mainly technology, infrastructure, research and extension) are more significant for sustainable agricultural growth in world economies where prices are used as a policy instrument for obtaining a desirable allocation of resources. Terms of trade are important source of information for policy-makers. Changes in inter-sectoral terms of trade cause redistribution of income not only among sectors but also among income classes. Such redistributive flows of income affect the saving, investment, and marketing capacities of farmers.

Other variables: Some other variables are also identified in the specialized literature as determining the agricultural productivity growth. In this study, we also considered variables such as: (i) the balanced territorial development reflected by the share of rural population (in the overall Egyptian population), (ii) the share of agricultural employment (iii) importance of the main strategic crop (wheat) in the total harvested areas, etc. Full definition of these variables as well as the proxies used to integrate them into our modeling of the TFP determinants will be presented in section 4.3 below.

4. Methodological Framework

4.1 TFP Definition and Conceptualization

The two most commonly used measures of productivity are single (partial) factor productivity (SFP) and total (multi) factor productivity (TFP). When multiple heterogeneous inputs are used in the production process, aggregation of these inputs may require the use of price indices. This implies that productivity can be affected by both changes in relative prices of inputs and by the input use per unit of output (Kathuria et al., 2011). TFP measures account for the use of a number of inputs in the production process and are therefore more suitable for performance measurement and comparison across firms and for a given firm over time (Coelli et al., 2005). In this context, TFP can be defined as a ratio of aggregate outputs relative to aggregate inputs used. This aggregation of inputs and outputs raises the problems of index number (i.e. How can we aggregate inputs and outputs without biasing our calculation?).

Three different views exist on what TFP means (Lipsey & Carlaw, 2002). The first conventional opinion considers TFP as the measure of the rate of technical change (see for example, Law, 2000; Krugman, 1996; Young, 1992 among others). The second view (Jorgensen & Griliches, 1967) considers that TFP only measures free lunches of technical change, which are mainly associated with externalities and scale effects. The third view is highly skeptical whether TFP measures anything useful (Metcalfe, 1987; Griliches, 1995). Kathuria et al. (2011) provides the following possibilities on what TFP growth means in literature:

TFP Growth = Output growth – Input growth

= Technical/Technological change/Progress

= Embodied (or endogenous) technical change + Disembodied (exogenous) technical change

= Changes in technical efficiency + Technological progress

Among these definitions, the later authors mention that the first one is the most commonly used. As per definition, TFP growth incorporates all the residual factors after accounting for input growth, and has also been hailed as an "index of ignorance" (Abramovitz, 1956).

4.2 TFP Measurements Methods

4.2.1 Frontier vs Non-Frontier Approaches for TFP Measurement

Measurement of TFP can be done using non-frontier and/or frontier approaches. Each of these approaches is further divided into parametric and non-parametric techniques. Non frontier approaches include growth accounting methods (or non-parametric index-based methods) and econometric parametric approaches. Frontier approaches include the non-parametric Malmquist index methodology and the stochastic production frontier method.

In frontier approach, the objective is to estimate the best obtainable positions based on the estimation of a bounding function, given inputs and prices levels. For example, a cost frontier traces the minimum attainable cost given input prices and output while a "production frontier" traces the set of maximum attainable output for a given set of inputs and technology. This approach is different from the parametric non frontier approaches where an average function is often estimated by the ordinary least square regression as the line of best fit through the sample data (Kathuria et al., 2011). Moreover, the frontier approaches identify the role of technical efficiency in overall firm performances while non-frontier approaches assume that firms are technically efficient. This difference results in different interpretation of TFP growth estimated from both approaches. TFP growth as obtained from frontier approach consists of two components: (i) outward shifts of the production function resulting from technological progress, and (ii) technical efficiency enhancement related to the movements towards the production frontier. On the other hand, the non-frontier approach only considers technological progress as a measure of TFP growth.

Both frontier and non-frontier approaches can be estimated through parametric and non-parametric techniques. Parametric estimations need the specification of a functional form for the frontier and parameters are estimated through econometric techniques using sample data and outputs. One important implication of this issue is that the accuracy of the derived estimates is sensitive to the specified functional form. In contrast, this latter point is the strength of the non-parametric methods (such as data envelopment analysis DEA, or other mathematical programming methods), which are parameters free and does not assume any functional forms. However, one shortcoming of the latter non parametric approaches is that no direct statistical tests can be carried out to validate the estimates.

4.2.2 Indexes for TFP Measurement: The Törnqvist Index

A common feature of the TFP index number is that the empirical estimation of different TFP indexes is based on different weighting methods of inputs and outputs. In most empirical studies, the Divisia, Solow, and the Törnqvist indexes are frequently used. Among index number methods, Törnqvist-Theil Index, which is an approximation to Divisia Index, was used in this study to construct aggregate output and aggregate input indexes. Explanation on theoretical properties and issues in measurement of the productivity through the Törnqvist Index can be found in Diewert (1980) and Coelli et al. (2005). The Törnqvist outputs, inputs and TFP indexes can be expressed under the logarithmic form as follows:

Output index:

$$\mathrm{Ln}\left(\frac{Q_t}{Q_{t-1}}\right) = {}^1\!/_2 \sum_j \left(R_{j,t} + R_{j,t-1}\right) \mathrm{Ln}\left(\frac{Q_{j,t}}{Q_{j,t-1}}\right) \tag{1}$$

Input index:

$$\mathrm{Ln}\left(\frac{X_t}{X_{t-1}}\right) = {}^1\!/_2 \sum_i \left(S_{i,t} + S_{i,t-1}\right) \mathrm{Ln}\left(\frac{X_{i,t}}{X_{i,t-1}}\right) \tag{2}$$

TFP index:

$$\mathrm{Ln}\left(\frac{TFP_t}{TFP_{t-1}}\right) = \mathrm{Ln}\left(\frac{Q_t}{Q_{t-1}}\right) - \mathrm{Ln}\left(\frac{X_t}{X_{t-1}}\right) \tag{3}$$

Where; $R_{j,t}$ is the share of output (j) in total revenue in time (t); $Q_{j,t}$ is the output (j) in time (t); $S_{i,t}$ is the share of input (i) in total input cost, and $X_{i,t}$ is the input (i) in time (t).

Compared to other methods for TFP calculation, the advantage of the Törnqvist index is related to its capacity to decompose TFP growth into outputs and inputs growth indexes. Moreover, the Törnqvist index also consider the inputs and outputs values (prices) which is not the case for other non-parametric indexes such as the Malmquist index.

4.2.3 Factors and Drivers Determining TFP Growth

At this level of the paper, the econometric estimation of the relationship between TFP growth and different factors has been conducted. The most important factors supposed to have an effect on the TFP growth of the Egyptian agricultural sector have been included. In a stylized form, the following regression model (with expected signs in parentheses) has been used:

$$TFP = f(BTD, IIC1, RR, TO, INF) \quad (4)$$

Where:

TFP = Annual Total Factor Productivity values of the Egyptian agricultural sector;

BTD (+) =Balanced Territorial Development Indicators expressed by the Rural GDP per capita (Current LE/Capita/Year);

IIC1 (+) = Index of Innovation Invention Capital- expressed by the number of scientist year;

RR (+) =Resources Reallocation expressed by the "agricultural employment share (%);

TO (+) =Trade Openness expressed by the following formula: (Import + export)/total production (%);

INF (+) =Infrastructure Investments, expressed by the "road density" (km /km2 agricultural land) - 1000 Km.

The log-linear form was considered as functional form for the Equation (4). The log-linear form allows for estimating coefficients that can be directly interpreted as elasticities. In addition, as pointed out in the pioneering work by Jud and Hyman (1974), Equation (4) contains a weak residual variance relative to other functional forms for the same data set and adjusts the data better than the linear specification for both forecasted parameter signs and statistical significance.

The standard Ordinary Linear Squared (OLS) method, if applied to non-stationary data series, can produce spurious regression. The OLS regression can give high R^2, low Durbin-Watson (DW) statistics, and significant t-values of the estimated coefficients, suggesting a significant relationship between dependent and explanatory variables, when in fact they are completely unrelated. Conventionally, the factors explaining TFP have been studied by expressing variables in logarithmic form. This is similar to the first differencing of variables in time series analysis. Provided the original series are integrated of order 1, as is normally the case, expressing the variables in logarithmic terms ensures a stationary data series and means that the OLS method can safely and directly be used (Hendry, 1995).

4.3 Data Description and Statistical Analysis

The data used in this study was collected from different sources. FAO's annual time series (from 1961 to 2012) of Egyptian agricultural (including crops and livestock) production, total cultivated area, total labor employed in the agricultural sector, machinery deployed in the agricultural activities, animal capital, and fertilizer consumption are used to construct the Törnqvist index. The FAO data is complemented, when needed, with data from national statistical agencies, especially when such alternative data is more accurate or up to date. Data from FAO was continuously cross checked with the available (sometimes limited) data from national sources. The following Table 1 presents the list of the variables used in the empirical model (TFP growth measurement). Therefore, the TFP determinant variables where primarily collected from national sources, while some of them were also collected from international databases, as it is for the UNDP-human development index, and the road density.

Summary statistics of the variables (average inputs values) used in the empirical model, including mean, minimum and maximum values and standard deviations and the inefficiency variables are summarized in Table 2. The figures from this table shows that average labor value (1961-2011) is the highest among other inputs. Labor input is followed by the natural resources value (residual), animal feed, capital stock, and fertilizers, respectively.

Table 1. List of Inputs and outputs variables used for the Egyptian agricultural TFP calculation

Variables	Description	Source
Inputs/outputs variables		
Total Agricultural Output (in value)	This variable is representing the total annul value (in current local currency) of the agricultural production in Jordan. This variable is also disaggregated into crops and livestock outputs.	FAO Database
Labor (in quantity and value)	Labor is an agricultural input. This variable is representing the annual quantity (number of active persons) and value (in current local currency: LCU (Note 2)) of labor used in the agricultural sector. The total value is calculated based on average wages in Egypt.	Ministry of Planning (MOP)
Seeds (in quantity and value)	This variable is describing the aggregated annual quantities (in tons) and values (LCU) of all crops seeds used in the agricultural sector. This is not taking into consideration the seedlings and saplings.	FAO database
Machinery (in quantity and value)	The machinery variable is reflected by the annual number and value (LCU) of new tractors in use. Other machineries were not considered in this input vector.	FAO database
Pesticides (in quantity and value)	Pesticide variable is describing the overall annual quantities (in Tons) and value (LCU) of pesticides and other treatment products used in the agricultural sector for different cropping activities.	FAO database
Animal Feed (in quantity and value)	The feed variable is describing the annual quantity (in tons) and value (LCU) of animal feeds used for the livestock activity in Jordan.	FAO database
Capital Stock (in quantity and value)	Capital stock is an important variable representing the annual value (LCU) of fixed inputs (land, live head of livestock, tree plants, livestock infrastructure, etc.). For the quantity of this variable, we used an aggregated normalized index regrouping the annual values of the most important among these fixed capital assets.	FAO database
Natural Resources (water/land) (in quantity and value)	Natural resource input vector is regrouping the rest of inputs which are hard to account for. It is usually including land and water resources used for the agricultural activities. The value of this input corresponds to the residual difference between the overall agricultural output value and the value of all the previous input vectors.	FAO Database + CAPMAS

Source: Own elaboration (2014).

Table 2. Descriptive statistics of the input and output variables, calculated over the period 1961-2011

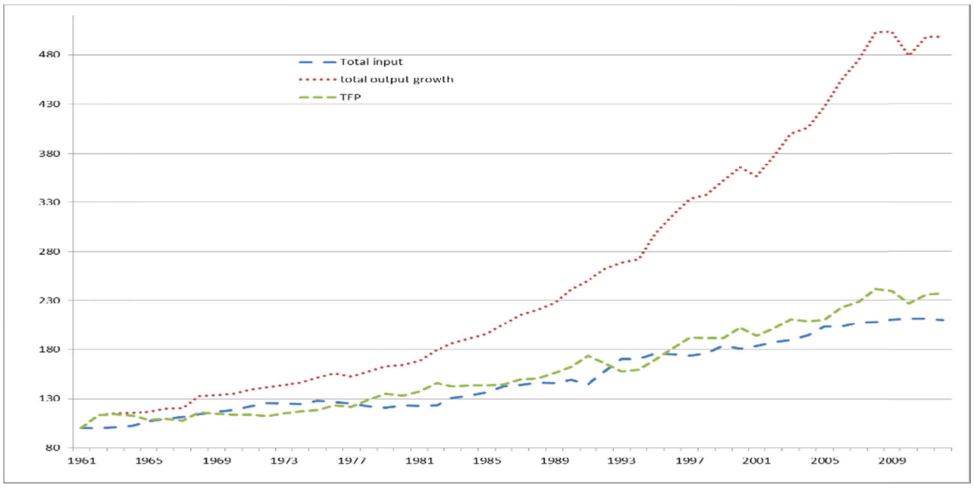
Inputs and outputs	Unit	T	Minimum	Maximum	Mean	S. Deviation
Quantity of Labor	Thousand Workers	52	3600.0	6965.0	4928.4	958.8
Labor Value	Million LE	52	99.0	13165.9	3717.8	3903.6
Fertilizers Quantities	1000 Tons	52	238.9	1472.4	844.1	403.4
Fertilizers Values	Million LE	52	4.7	16604.7	2749.1	4690.6
Total Seeds Quantities	1000 Tons	52	402.8	1079.7	676.2	180.8
Value (Current million LE)	Million LE	52	7.5	4554.8	1258.7	1435.1
Number of Tractors		52	12837.0	103188.0	55149.3	33431.3
Depreciated Tract Value	Million LE	52	0.1	56.9	14.9	18.1
Pesticides Quantities	Tones	52	1859.3	13213.0	7075.1	3246.8
Pesticides Values	Million LE	52	4.7	1398.7	161.3	297.3
Total Animal Feed Quantities	1000 Tons	52	27310.7	71372.	48643.8	12285.3
Total Animal Feed Value	Million LE	52	238.8	24082.8	3996.3	5605.3
Capital Stock Quantity		52	300.0	2517.5	924.1	674.7
Capital Stock Value	Million LE	52	15.3	8242.6	2059.3	2510.4
Total Agricultural Output	Million LE	52	753.0	188832.0	36089.3	49878.6

Source: Own elaboration (2014) based on FAOSTAT (2013) and other sources.

5. Results and Discussion

5.1 Agricultural TFP Growth of Egypt

The trends of the output, inputs and TFP indexes are presented in Figure 1. The three indexes trends are going up slowly and smooth during the 1966 – 1982 period. The dominance of the irrigated agriculture in Egypt might explain the steady levels of agricultural outputs, inputs use and productivity. Irrigation creates in fact lower dependence to climate volatility and makes the levels of outputs less volatile among years. The privatization and economic liberalization of the agriculture sector have been started since 1981. The structural adjustment plan (SAP) of Egypt also started in the early 90s. The estimation of the Equations (1), (2) and (3) for the Egyptian agricultural sector are presented in the following Figure 1 and Table 3.



Source: Elaboration by the authors (2014)

Figure 1. Trends of the output, inputs, and TFP indexes calculated (base 100 for 1966)

Furthermore, our results for the Egyptian case show that trends of agricultural, crop and livestock output values have been increased faster since 1999-2000. The trends of labor, fertilizers, capital stock and seeds values have been strongly increased since 1990. The crops revenue shares in the agricultural revenue were fluctuating during 1961 – 2011. It decreased from 69.4% in 1961, to 61.6% in 1982, to 55.6% in 1984 and then increased to 71.5% in 1992. The shares of livestock revenue in total agricultural revenue were also fluctuating during the same period. It increased from 30.7% in 1961, to 38.4% in 1982, to 44.4% in 1984 and then decreased to 28.6% in 1992. These fluctuations justify the variability on the annual growth rates of the selected agricultural inputs and outputs.

Table 3. Normalized (base 100 for 1962) Values of Output, Input and TFP Indexes for the Egyptian agricultural sector calculated based on the Tornqvist-Theil method

	Normalized Output Index	Normalized Input Index	Normalized TFP Index
1962	100	100	100
1970	120.31	108.11	13.55
1975	144.37	125.07	19.29
1980	158.51	123.57	34.94
1985	184.17	129.21	54.95
1990	222.33	145.56	76.77
1995	270.29	163.66	106.63
2000	341.09	177.92	163.17
2005	393.48	191.52	201.96
2010	482.80	208.05	274.74
2011	498.16	211.21	286.95

Source: Elaboration by the authors (2014).

The annual growth rates of the studied inputs and outputs variables are ranging between 0.7% (e.g., natural resource quantity) and 18.2% (e.g., fertilizers values). The increase of agricultural output resulted from an increased use of traditional inputs: These were mainly cultivated areas and growth in TFP. On average, modern inputs (fertilizers and machinery) contributed little to the agricultural output growth and the difference between growth in output and the sum of total contributions by factor inputs and TFP is nearly equal to growth in efficiency, which on average made the lowest contribution to growth in output.

5.2 Factors Determining TFP Growth

Concerning the TFP determinant, Equation (4) was estimated using the SPSS statistical package. As mentioned in the methodological section, the log linear form of the equation was considered in this econometric estimation. Results of the estimation reveal some significant variables affecting the productivity growth of the agricultural sector in Egypt. Table 4 presents the results of this estimation. The estimated relationship between the TFP and the TFP determinants and the estimated parameters are not significant. This is due mainly to the obvious fluctuations in the values of the TFP determinants during the studied period.

Table 4. TFPG determinants in the Egyptian agricultural sector (1980–2011)

	Dependent variable $LnTFP_t$		
Parameters	**Estimated coefficients**	**t-ratios**	**p-value**
Constant	-0.12	-0.17	0.86
$LBTD_t$ (Balanced Territorial Development Indicators)	-0.07**	-1.35	0.18
$LIIC1_t$ (Index of Innovation Invention Capital- IIC - # scientists-year)	0.09	0.36	0.71
LRR_t (Resources Reallocation: Agricultural employment share)	0.005	0.01	0.99
LTO_t (Trade Openness)	0.04	0.65	0.51
$LINF_t$ (Infrastructure)	-0.05**	-1.60	0.12
T	33		
R^2	0.41		
F-statistic	0.81 ($p<0.51$)		
Log likelihood	66.65		

Source: Author's calculation based on coefficient estimates of the linear regression model (2014).
*Note: ** Significant at 10% level.*

The indicators for the estimation performance are quite satisfying. The R^2 is equal to 0.41, showing that 41% of the TFP variations in Egypt, over the period of analysis, are explained by the regressed variables considered in our analysis. Concerning TFP determinants for the agricultural sector in Egypt, many important issues can be raised: First, rural development variables were found to significantly and negatively affect agricultural productivity. Put differently, when the rural GDP per capita increases, the agricultural productivity growth of the agricultural sector decreases. This demonstrates that agricultural activity is still a marginalized activity which is linked to low levels of income and is a source of employment for low productive labor. This type of structural problem cannot be handled solely within the framework of an agricultural development strategy but implies a wider vision of integrated rural development where agriculture is developed in parallel/synergy with other economic sectors.

A second issue related to TFP determinants is the negative significant effect of the infrastructure variable on the productivity gains of the agricultural sector in Egypt. Based on specialized literature, if the coefficient of this variable was negative, this might indicate a form of low integration of farmers within large neighboring markets. However, the positive sign of this variable could indicate the high level of fragmentation of agricultural lands due to the development of more roads and unpaved rural roads (Dhehibi et al., *2014*). It is again important that policy makers take a deeper look at their rural infrastructure strategy, knowing that it may affect the productivity of the agricultural sector as whole.

6. Concluding Remarks and Policy Implications

The aim of this study was to calculate the TFP growth of the agricultural sector in Egypt and to assess its determinants. The Törnqvist index methodology was used to calculate the TFP growth and was complemented by an econometric regression of the obtained TFP scores on a set of potentially explicative variables.

Results indicated that the trends of agricultural, crop and livestock output values have been increasing rapidly in Egypt since 1999-2000, while trends of labor, fertilizers, capital stock and seeds uses have been dramatically increasing since 1990. The crops revenue shares in the agricultural revenue have been quite fluctuated during 1961 – 2011. It's decreased from 69.4% in 1961, to 61.6% in 1982, to 55.6% in 1984 and then increased to 71.5% in 1992. In addition the livestock revenue shares in agricultural revenue have been relatively fluctuated during the same period. It increased from 30.7% in 1961, to 38.4% in 1982, to 44.4% in 1984 and then decreased to 28.6% in 1992.Results also show that the Törnqvist-Thiel Indexes for agriculture, crops and livestock have been gradually increased during 1961 – 2011, with respective normalized values of 114, and 498, in 1962 and 2011.

Furthermore, results of the analysis of the TFP growth determinants in Egypt shows the existence of major structural problems within the agricultural sector. In fact, the level of rural GDP per capita was surprisingly found to be negatively related to the TFP growth, indicating that the agricultural activity remains marginalized and synonym of low income levels. This also means that capital accumulation in the agricultural sector will be low, thus affecting the investment levels. Investments in infrastructures (in our case roads density used as proxy) was also found to be negatively correlated to the TFP growth, indicating that these investments have not been targeting the rural areas where most of the agricultural activities are located.

Increased productivity together with the sources of growth implies that the Egyptian government's effort on formulating and implementing a comprehensive strategy that strengthens public and private sectors linkages in helping to facilitate adoption of new technologies and improved management of resources that will contribute to the TFP growth of agriculture; such a strategy is more likely to yield better results in terms of employment, income generation and hence poverty alleviation. Thus, the measurement of productivity and the analysis of agricultural sector performance in this country is an essential steps in a systematic study of the relationship between agricultural-sector productivity, growth in per capita income and real GDP and the incidence of poverty.

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Notes

Note 1. 1 feddan=0.42 hectares.

Note 2. 1 Egyptian pound = 0.13 US$.