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# Approaches to Total Factor Productivity Measurements in the Agriculture Economy

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Food security and better livelihoods
for rural dryland communities

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# 1. Introduction: Definition of Productivity

Productivity is defined as the efficiency of a production system, and as such would be a ratio of units of output per unit of input to the system (James and Carles, 1996). It is also defined as the production value (or quantity) divided by the amount of factors consumed in the production process (Pepitone, 2000). Generally, productivity is the relationship between the quantity of output and the quantity of input used to generate that output. It is a ratio of output to input (Productivity = Output/Input).

The output used for productivity calculation could be of different forms. It can be in a form of produced goods or provided services. Outputs may be expressed in physical (quantities) or financial (value) terms. Inputs are resources used to produce outputs. Most common forms of inputs are labor, capital, and intermediate inputs.

Productivity has an effect on organizations/economies/sectors growth. In fact, higher productivity results in performances enhancement (production increases) and higher profits (minimal factors costs, better selling prices, marketing capacities, etc.). Enhanced skills in transforming inputs to outputs play critical role in enhancing productivity and competitiveness. In fact, with the same amount of inputs, some farmers can produce more than others, depending on their skills, knowledge level, and cognitive capacities.

The two most commonly used measures of productivity are single (partial) factor productivity (SFP) and total (multifactor) factor productivity (TFP). When multiple inputs of heterogeneous nature 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). Precise definitions of partial and total factor productivity will be presented in this working paper. However, main focus will be on the total factor productivity, since it is the method we are using in the APWEC-MENA project in order to account for agricultural sector growth in Tunisia, Jordan and Egypt.

Measurement of TFP can be done using non-frontier and/or frontier approaches. 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; which is a parametric approach. The presentation of these different methodologies will be provided in this working paper.

## 1.1. Difference between productivity and competitiveness

There is usually confusion between the concept of productivity and other close concepts such us “competitiveness”, “efficiency”, etc. Hereby we provide an explanation of the differences between these concepts. In fact, as defined earlier, productivity is a ratio of production value divided by the amount of factors consumed in the production process. It is expressing the value of output produced by a unit of input (in case of partial productivity); or the value of output produced by a unitary combination of inputs (in the case of TFP). Higher productivity implies better competitiveness of the enterprise (sector, etc). Productivity of a sector is also an indicator of its competitiveness.

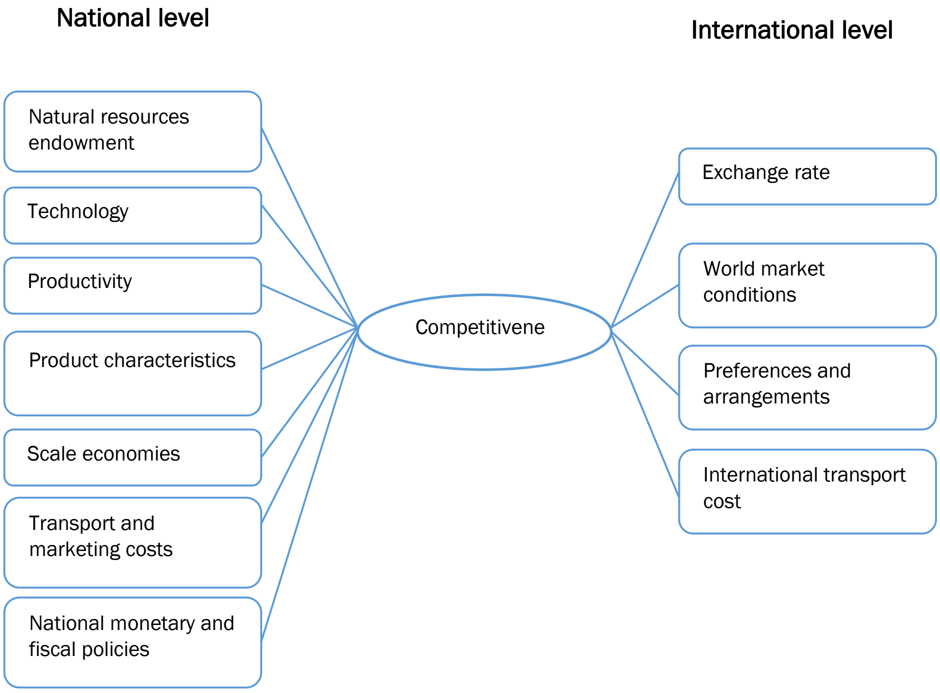
Competitiveness is however not only related to the productivity. It is in fact very difficult to give a unique definition of the concept of competitiveness. The divergent approaches to competitiveness have produced many different definitions. It is a very general and multifaceted concept and has a multidimensional nature linked to the optimal use of resources and geared to capturing development perspectives (Biggeri, 2007).

Porter considered the following definitions of competitiveness:

- For firms (at micro level), competitiveness is the ability to provide products and services more effectively and efficiently than relevant competitors and to generate, at the same time, returns on investment for stakeholders;
- For national (and regional) economic sectors and clusters of firms (at meso-level), competitiveness is the ability of firms to achieve sustainable success against their competitors in other countries, regions or clusters.

More precisely, Lachaal (2001) provides a comprehensive assessment of what can be considered as determinants of competitiveness (see Fig 1). As we can see in the Figure 1 below, productivity is considered as one of national (domestic) determinants of competitiveness.

Figure 1: The determinants of competitiveness




Source: Lachaal *et al.*, 2001.

Biggeri (2007) considers that measures of competitiveness at economic sector level include the overall profitability of one nation's firms in the sector, the trade balance in the industry, the balance of outbound and inbound foreign direct investment, and direct measures of cost and quality at industry level. In line with this statement, Lachaal (2001) states that measures of the competitiveness may include different types of indicators such as:

- Measures related to the production costs (comparative advantages/relative costs/absolute costs, etc),
- Measures related to the factor productivity,
- Measures of trade performances,

### 1.2. Differences between productivity and efficiency

The difference as well as the interdependencies between productivity (rate of production) and efficiency (level of production in comparison with resources and costs) is also ambiguous. They are too close but different concepts.

Efficiency is determined by the amount of resources which are necessary to obtain certain results. It is comparing our current level of production with a potentially target level. In order to meet our production target, we commit a specific combination of factors and skills. For example, if we are able to meet our targeted production with fewer resources; then we have operated more efficiently.

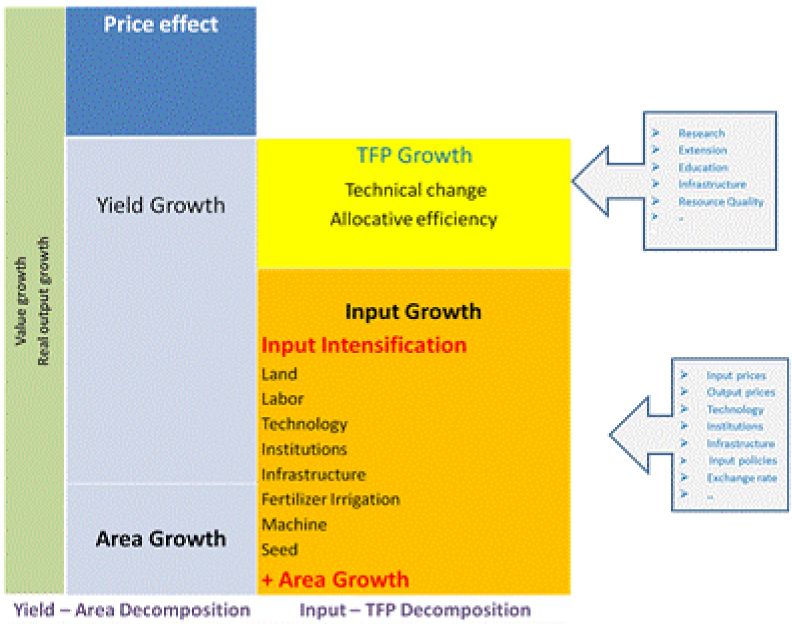
However, productivity is calculated as a static measure of production performance by looking inside the enterprise/sector. Efficiency is calculated based on other peers sectors or firms, and shows us how we can produce more comparing to other targets. Then, we can say that efficiency is a measure of waste in a system while productivity is a measure of the output produced by unit of input.

A firm or sector is considered efficient if it can produce more with the available inputs; this means that the enterprise is not located on the curve of production possibilities, but below it. Productivity reports the output production volume to an input quantity, independently from their efficiency use level.

### 1.3. Economic growth decomposition: The central role of factors productivity

The agricultural output growth is usually due to three types of factors: area growth, yield growth, and prices change (figure 2, and 3). Area growth induces a growth in the quantity of input use in addition to land use. On the other side, the yield growth is generated by both input use growth and productivity (TFP) growth. Then, the TFP growth is the result of both technical change and better allocative efficiency of the used factors.

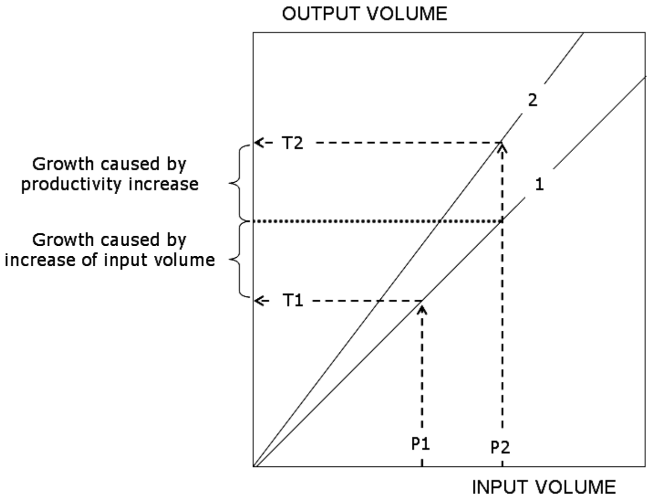
Figure 2: Economic decomposition of output growth




Source: Own elaboration (2013).

The change of the production function from (1) to (2) (in figure 3), is due to growth in the input level (from P1 to P2) in addition to a growth caused by productivity increase. Total output growth from T1 to T2 (figure 3) is then considered as the sum of both growth indicators.

Figure 3: Decomposition of output growth




Source: Own elaboration (2013).

## 2. Partial Factor Productivity

Productivity measure is quite simple when a single output is produced by a single input. In this case, the output per unit of input is a measure of the productivity level. This measure can be used in comparing performances between firms or sectors. In reality, this latter case is very rare. Usually, at least labor and capital are needed for any simple investment. When multiple outputs are produced using multiple inputs, productivity can often be assessed using *partial productivity measures* or multifactor of *total factor productivity*. Partial productivity refers to the measure of produced output per unit of each input used. This indicator is caculated for each input separatly, such as output per worker or per hour worked, or output per ha of land. Though commonly used, partial productivity measures are of limited use and can potentially mislead and misrepresent the performance of a firm (Coelli *et al.,* 2005). In fact, when the proportion in which the factrs of production are combined (e.g., labor and capital) undergoes a change, partial measures of productivity provide a distorted view of the contribution made by these factors in changing the level of production (Kathuria et al 2011).

## 3. Total factor productivity (TFP)

Total factor productivity measures account for the use of a number of factor inputs in production and, therefore, are more suitable for performance measurement and comparisons 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 output produced relative to aggregate input used. This aggregation of inputs and outputs raises the problems of index number. In another term, how can we aggregate inputs and outputs without biasing our calculation?

Three different views exist on what TFP means (Lipsey and 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 and Griliches, 1967) regards that TFP measures only 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).

### 3.1. Measures of the TFP growth

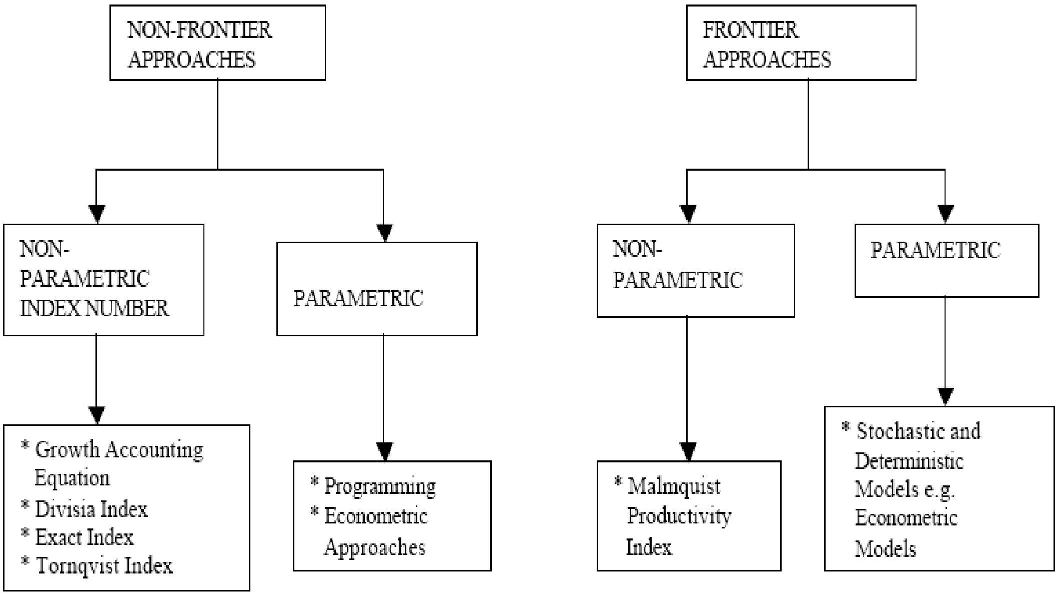
There are basically two approaches to measure the TFP growth - the frontier and non-frontier approaches (figure 4). Each of these approaches is further divided into parametric and non parametric techniques. In frontier approach, the objective is to estimate the best obtainable positions based on the 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 (Kathuria, 2011). 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 related to the movements towards the production frontier. On the other hand, the non frontier approach 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.

Figure4: Different approaches to Total Factor Productivity measurements




Source: authors' elaboration adapted from Mahadevan (2004).

## 3.2. Non frontier approaches

### 3.2.1. Non-parametric techniques (TFP index numbers)

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 Tornqvist indexes are frequently used.

#### *3.2.1.1. Solow index*

Solow uses a Cobb-Douglas production function (PF) in order to calculate the TFPG. For the estimation of this PF, he assumes a constant return to scale, autonomous Hick's neutral technical change, and that the factor payments are equal to their marginal products. The production function is then under the following form:

$$Q = A(t)F(K, L)$$

Q, K, and L, respectively represent the output, capital, and labor. A(t) is a multiplicative factor accounting for the shift of the production function between two time periods (at given levels of capital or labor). Solow then addressed the key question of measuring A(t)using index number approach. The solution is based on the logarithmic differential of the production function.

$$\frac{\dot{Q}_t}{Q_t} = \frac{\partial Q}{\partial K}\frac{K_t}{Q_t}\frac{\dot{K}_t}{K_t} + \frac{\partial Q}{\partial L}\frac{L_t}{Q_t}\frac{\dot{L}_t}{L_t} + \frac{\dot{A}_t}{A}$$

The equation above indicates that the output growth (left hand side) is divided into growth in capital and labor (inputs) both weighted by their output elasticities, and the growth in the Hicksian efficiency index (A(t)). Assuming that each input is acquired by a value which corresponds to its marginal product, and then we will have:

$$\frac{\partial Q}{\partial K} = \frac{r_t}{p_t}$$

and

$$\frac{\partial Q}{\partial L} = \frac{w_t}{p_t}$$

Consequently, the unobservable eslaticities will be converted into observable income shares $S^K$ and $S^L$. The Solow index will be calculated as:

$$R_t = \frac{\dot{Q}_t}{Q_t} - s_t^K \frac{\dot{K}_t}{K_t} - s_t^L \frac{\dot{L}_t}{L_t} = \frac{\dot{A}_t}{A}$$

#### 3.2.1.2. DIVISIA index

A Divisia index can be defined as a theoretical construct to create index number series for continuous-time data on prices and quantities of goods exchanged. It is designed to incorporate quantity and price changes over time from subcomponents which are measured in different units (labour hours and equipment in currency).

A Divisia quantity index has a rate of growth equal to a weighted average of rates of growth of its component quantities. Similarly, a Divisia price index has a rate of growth equal to a weighted average of rates of growth of its component prices. The weights in either case are the relative value shares of each component in total value.

In a single output case, TFP growth ($T\dot{F}P$) is defined as:

$$T\dot{F}P = \dot{Y} - \sum_j S_j \dot{X}_J,$$

where Y is the output, $X_j$ is a vector of inputs (*j=1,2,…,J*),. A dot over a variable indicates its rate of change between two time periods (annual change). In case of multiple outputs, the TFP growth will be defined as:

$$T\dot{F}P = \sum_m R_m \dot{Y} - \sum_j S_j \dot{X}_J$$

Where;

- $R_m$ is the output value share: $R_m = P_m Y_m / \sum_m P_m Y_m$,
- $P_m$ is the price of the output $Y_m$

#### 3.2.1.3. Tornqvist Index

Among index number methods, Tornqvist-Theil Index, which is an approximation to Divisia Index, is to be used in the APEWC-MENA project for constructing the aggregate output index and aggregate input index. Explanation on theoretical properties and issues in measurement of the productivity through the Tornqvist Index can be found in Diewert (1978, 1980); Christensen (1975); Capalbo and Antle (1988) and Coelli *et al.,* (2005). The Tornqvist output, input and TFP index in logarithm for can be expressed as follows:

Output index:

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

Input index:

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

TFP index:

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

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),*

The TFP index (last equation) measures TFP changes by calculating the weighted differences in the growth rates of outputs and inputs. The growth rates are in log ratio form, and the weights are revenue and cost shares for outputs and inputs, respectively.

The TFP index as defined in the last equation can be used as an approximation of technological progress, assuming that producers behave competitively, that the production technology is input-output separable, and that there is no technical inefficiency (Antle and Capalbo, 1988).

### 3.2.2. Parametric methods

As shown in figure 4, both frontier and non-frontier approaches can be further divided into parametric and non-parametric methods. The non frontier two main approaches in non-frontier methods for the estimation of growth in TFP are the production function approach (also called parametric approach), and the growth accounting approach (also called non-parametric index number method). Both parametric and non parametric approaches of the non-frontier method se the production function as starting point.

Consider:

$$Y = A(t)f(Xx) \text{ and } V = A(t)f(x')$$

Where Y is a single homogenous output, A(t) is an index of technological change or of TFP, f(X) is the functional for of the production function.

on used specifying the type of the relationship between Y and X (inputs : labor and capital), V is the real value added, f(X') is the functional form of the relationship between V and (X': input vector)

The non parametric approach makes reference to the production function estimation, which involves the specification of the functional forms for A(t), f(X) and f(X'). The functional form which is most often used for A(t) is given as (Kathuria *et al.,* 2011) :

$$A(t) = A_0\, e^{\gamma_t}$$

The equation above implies that technological progress occur at a constant rate of γ.

A part from specifying a functional from for the technological change, f(X) and f(X') also need to be specified. Three major forms of production function are the most used in literature for TFP change measurement: (i) Cobb-Douglas production function; (ii) CES (Constant Elasticity of Substitution) production function and; (iii) TL (Transcendental Logarithmic) production function. Hereby the functional form corresponding to the CD production function (which is the most used among the previous forms):

$$\log\left(\frac{V_i}{L_i}\right) = a + (\alpha + \beta - 1)\log(L_i) + \beta \log\left(\frac{K_i}{L_i}\right) + \gamma t + \mu_i$$

Where V, L, K, and t are real value added, labor, capital, and time respectively.

γ, α's and β's are constants and denote the rate of technical progress, partial elasticity of output with respect to labor, and partial elasticity of output with respect to capital, respectively. By estimating this production function empirically, we can obtain (i) a measure of growth of TFP (or the rate of technical change γ); and (ii) exact information on returns to scale (Kathuria *et al.,* 2011). In fact, if (α + β -1) is not significantly different from 0, the assumption of CRS (constant returns to scale) hold true. Depending on this magnitude, we can also find out if we are faced to increasing or decreasing returns to scale conditions.

### 3.3. Frontier approaches for TFP calculation

Frontier approaches for estimation of TFP growth assume the existence of a production function corresponding to the set of maximum attainable output levels for a given input combinations. The advantage of this approach is that it decomposes the changes in TFP into technological progress and technical efficiency changes; the former associated with changes in the best-practice production frontier, and the latter with other productivity changes, such as learning by doing, improved managerial practices, and changes in the efficiency with which a known technology is applied (Kathuria *et al.,* 2011). The two main approaches in the estimation of TFP growth using frontier methods are the Malmquist (nonparametric approach) and the stochastic frontier (parametric) approaches.

#### 3.3.1. Parametric approaches (based in Econometric models)

The stochastic frontier method (Aigner *et al.,* 1977) estimated used cross sectional data of N observed firms. It assumes that a firm (i) uses inputs $X_i$ (i = 1, ...,N) to produce an output $Y_i$, and the function can be written as follows:

$$Y_i = f(X_i, \beta)e^{(\delta_i - u_i)}$$

The particularity of this model is that the error term is divided into two main components. These are the usual random noise component ($\delta_i$) and the inefficiency component ($u_i$). The noise component is measuring measurement errors and other random errors which are beyond the firm capacity. This error term is normally distributed with a mean 0, and constant variance$\sigma_\delta^2$. ($u_i$) are assumed to be independently and identically distributed, they are also assumed to be non negative. U takes a value of 0 when the firm is fully efficient (technical efficiency equal 1), and a value lower than 0 when the firm faces some technical inefficiencies. Thus, the value of u measures the firm efficiency level which is also expressing how far a firm's given output is from its potential output compared other firms of the sample.

#### 3.3.2. Non parametric approaches (DEA and the Malmquist index)

This research methodology is similar to the stochastic frontier approach with the unique difference of non-requirement for parameters estimation for the farmers' production technology description. Instead, the technology of the best performing farmers is considered as benchmark, and the efficiency of the rest of farmers in the sample will be measured accordingly. The Use of DEA approach aims to provide measures of the efficiency and productivity of firms.

For the DEA approach, data requirement are the same than for the SFA modelling approach. The same type of input-output matrix is needed in order to be able to calculate firm's TFP and efficiency. Panel data is also possible and suitable to use in DEA.

Unlike the parametric estimation, the deterministic estimation has a single one sided error component where u is greater than 0 represent technical inefficiency (Kathuria *et al.,* 2011). The shortcoming of the DEA approach is that all deviations from the frontier are considered as technical inefficiencies. TFP change in DEA approach is estimated through changes in Malmquist productivity index.

The Malmquist productivity index was first introduced by Caves et al (1982). The non parametric estimation of this Index was initiated by Färe et al, (1994). Färe *et al.,* (1994) showed that comparing each firm to the best practice frontier provides a measure of its efficiency and a measure of shift in the frontier (from one period to another) which is also similar to the technological progress. The Malmquist index measuring the TFP change is then a product of the latter both components. It is defined through a distance function measuring the TFP growth between two time periods by calculating the ratio of the distances of each data point relative to a common technology (Kathuria *et al.,* 2011). It is decomposes productivity into technical change and technical efficiency change (Coelli, 2008). Based on Färe *et al.,* (1994), the Malmquist index can be written as:

$$m_0(y_{t+1}, x_{t+1s}, y_t, x_t) = \left[\frac{d_0^t(y_{t+1}, x_{t+1})}{d_0^t(y_t, x_t)} \times \frac{d_0^{t+1}(y_{t+1}, x_{t+1})}{d_0^{t+1}(y_t, x_t)}\right]^{1/2}$$

Where (t) is the initial (reference) time period and (t+1) is the final period. $d_0^t(y_t, x_t)$ represents from the period t observation to the period (t+1) technology. $m_0$ higher than 1 indicates a TFP growth between both periods while a value of m0 lower than 1 indicates a TFP decline. The Malmquist in equation below is representing the productivity of the production point ($x_{t+1}$, $y_{t+1}$) relative to the production point ($x_t$, $y_t$). This index is in fact a geometric mean of two output-based Malmquist TFP indices; one index uses the period (t) technology and the other period (t+1) technology. To calculate this index we then need to calculate the four component distance functions, which will involve 4 linear programs (similar to thee conducted in calculating the Farrell technical efficiency measures) (see Coelli, 2008 for more information).

## 4. Factors Affecting Total Factor Productivity

### 4.1. TFP Determinants

Several factors have been identified in the social science literature as the most important sources of productivity change in the agricultural sector: 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, among others. Productivity measures do not provide any information about the separate role of each of these factors. However, an understanding of the potential sources of productivity growth is important for formulating appropriate policy decisions to increase productivity and social welfare.

#### Research and Development (R&D)

The results of agricultural research include higher yielding crop varieties, better livestock breeding practices, more effective fertilizers and pesticides, and better farm management practices. Agricultural research is required not only to increase agricultural productivity, but to keep productivity from falling. For example, yield gains for a particular plant variety tend to be lost over time because pests and diseases evolve that make the variety susceptible to attack. Thus, a large share of agricultural research expenditures is devoted to maintenance research.

Farmers benefit from agricultural research in the short run because of lower costs and higher profits. However, the long run beneficiaries of agricultural research are consumers who pay lower food prices. Agricultural research also helps maintaining competitiveness of a given country in world markets. Agricultural research can also reduce inequality in incomes and living standards because lower food prices benefit low-income people more than high-income people (Low-income people spend a larger share of their income on food than do high-income people.) Moreover, the major portion of public agricultural research is paid for by taxes from middle-income and high-income people.

Private agricultural research is mainly performed by manufacturers of farm machinery and agrochemicals, and by food processors. Public agricultural research is performed in national agricultural experiment stations and other universities.. Both public and private research has positive effects on agricultural productivity, with public research having a greater impact than private research.

### Extension (EXT)

Agricultural research expenditures affect productivity after a time lag. First, a particular research project may take several years to complete. Second, it takes time for farmers to learn and adopt the innovation. The sooner the benefits from research are received by farmers and consumers, the higher will be the rate of return to that research expenditure. Agricultural extension system aims to reduce the time lag between development of new technologies and their adoption. Extension agents disseminate information on crops, livestock, and management practices to farmers and demonstrate new techniques. They also directly consult with farmers on specific production and management problems. Unlike research, it is reasonable to assume that extension has an immediate effect on productivity.

### Education - Human Capital (ED)

Education provides individuals with general skills to solve problems. Education is thus an investment in “human capital” analogous to a farmer’s investment in physical capital.

Education hastens the rate of development of new technologies by training scientists. Education also speeds the rate of adoption of new technologies among farmers. Better educated farmers are more able to assess the merits of innovative technologies, and adopt them quicker than non-educated farmers, of and successfully adapt a new technology to their particular situations.

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 buy products. Meat with livestock growth hormones, food products with high levels of chemicals, and genetically modified varieties are cases in point. Firms may be hesitant to develop a new technology if regulatory approval or consumer demand for products using the technology is uncertain.

### Infrastructure (INF)

Investment in public capital, in particular, physical infrastructure, accounts for the largest share of budgets in many countries. The role of infrastructure is to expand the productive capacity by increasing resources and enhancing the productivity of private invested capital (Munnell, 1992). A few studies have found a significant positive relationship between infrastructure and agricultural productivity (Gopinath and Roe, 1998; 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.

### Government Programs and Policies (GPP)

The role of government (at macro and micro level) in the agricultural sector is pervasive. Government programs affect productivity through enhancing both resource allocation and output distribution through control of its prices. Government farm programs are the most common example of government involvement in agriculture. But other examples are numerous: Tax policy may be used to encourage private firms to invest in the development of innovations and farmers to adopt the innovations. Enhanced intellectual property rights protection may increase the incentives for private firms to engage in private agricultural research. Regulatory policies affect the rate at which new fertilizers and farm chemicals reach the market place. Although relatively little research has investigated the impact of government farm programs on agricultural productivity, some of the few studies found a significant positive relationship (Huffman and Evenson, 1993). For example, direct government payments may encourage substitution of improved capital inputs for labor and increase the rate of new technology adoption (Makki et al., 1999).

### Technology Transfer: Foreign R& D Spillovers (TT)

Isaksson (2007) indicated that knowledge is created by a small number of leader countries in technological terms. Because most countries do not produce state-of the-art technology themselves, it must be acquired from elsewhere. There are several ways knowledge can cross national borders. For instance, technology is often embodied in goods (e.g., Irrigated material, Mechanization, etc.). Thus, imports of relatively high knowledge content can be exploited. Trade, in general, increases international contacts and can be a source of learning. Foreign R & D spillovers in the form of a research (new technologies and funding) in a foreign country can also entail technology transfers. Trade and foreign R & D spillovers, as carriers of knowledge, should probably be seen as having indirect effects on TFP, as the better they work, the stronger their impact, albeit with no intrinsic direct effect on their own.

### Health – Human Capital (HE)

Health influences TFP growth directly through household income and wealth, and indirectly through labor productivity, savings and investments and demography, by reducing various forms of capital and technology adoption. Healthy workers are more productive, all else being equal (Isaksson, 2007).

Cole and Neumayer (2003) investigate the impact of poor health on TFP based on 52 developed and developing countries over the (maximum) time period – from 1965 to 1996. They argue that, although other researchers have studied the effect of poor health on output growth, this effect is probably inaccurately measured because it is only indirect – it runs through its effects on the efficiency of labor and physical and human capital. The authors' contribution is to study the direct impact of poor health on cross-country aggregate productivity levels. Three health indicators are considered: (1) the proportion of undernourished within a country (which mainly affects the workforce), (2) the incidence of malaria and other waterborne diseases (which reduces labor productivity and human capital), and (3) life expectancy. As expected, the general result was that poor health has a negative effect on TFP.

Moreover, Bloom *et al.,* (1999), Gallup et al., (1999), and Bloom *et al.,* (2004) investigate the relationship between life expectancy at birth and economic growth. Taking the latter study as an example, the authors include life expectancy in an aggregate production function in an attempt to establish whether health influences labor productivity and TFP.

Using panel data covering the period 1960 to 1990 for 104 countries, they find out that increased life expectancy has a positive effect on growth. A one-year improvement in the population's life expectancy contributes to an output increase of 4 per cent. In addition, their estimates based on aggregated data corroborate those using micro data. This established a direct health effect on growth, although there are also indirect effects to be considered. Among them, for example, is the extent to which health influences life cycle savings that, the authors speculate, may also have an effect on capital accumulation.

### Structural Change and Resource Reallocation (RR)

Chanda and Dalgaard (2003) attempt to show that aggregate TFP is greatly influenced by the structure of the economy and here institutions are important for how the structure develops. Their main contention is that the correlation between institutions and TFP arises because the former determines the agricultural/non-agricultural composition of the economy. In economies where institutions are weak less funds are available for investment and, hence, capital accumulation.

This in turn affects the output composition, since capital-intensive non-agricultural activities could offer higher wages and thereby attract labor from agriculture.

Here is the human capital that enters the scene. As long as human capital increases the marginal product of labor in the non-agricultural more than in the agricultural sector, labor will be diverted from the latter sector. Furthermore, as long as the relative productivity in agriculture is lower than that of the non-agricultural sector, aggregate output per worker will increase. To the extent that human capital extends to health capital, assuming the latter is influenced by geography, TFP will be determined by geography independent of institutions.

### Terms of Trade (TT)

In literature number of studies claimed 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 and 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. Sectoral terms of trade are important source of information for policy-making authorities. Changes in inter-sectoral terms of trade cause redistribution of income not only in sectors but also among income classes. Such redistributive flows of income affect the capacity for savings and incentives to invest, produce and sell.

Terms of trade is defined as the export-import unit values ratio. In the literature, agriculture exports and irrigation were found to have the greatest effects on technical inefficiency reduction (Ben Jmeaa and Dhif, 2005). 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.

### Other Determinants (OD)

Other indicators that can affect positively the TFP growth could be summarized as follows:

- Sustainable management: Share of agriculture in water use.
- Share of the main crop area compared to total cropland harvested.
- Balanced territorial development: Rural GDP per capita.
- Share of irrigated land / total agriculture land.

## 4.2. TFP Determinants Models

In order to examine how these determinants may have contributed to agricultural TFP growth, in the empirical literature, multivariate regression analysis have been used. The empirical analysis considers the following formula:

$$TFP = F\,(R\&D, EXT, ED, INF, GPP, TT, HE, RR, OD)$$

Where;

- TFP = Index of Agriculture Total Factor Productivity
- R&D: Research and Development Indicator
- EXT: Extension Indicator
- ED: Education (Human Capital) Indicator
- INF: Infrastructure Indicator
- GPP: Government Programs and Policies Indicator
- HE: Health Indicator
- RR: Structural Change and Resource Reallocation Indicator
- TT: Terms of Trade Indicator

- OD: Other Determinants
    - Sustainable management: Share of agriculture in water use.
    - The main crop share of total cropland harvested.
    - Balanced territorial development: Rural GDP per capita.
    - Share of irrigated land / total agriculture land.

## 5. Estimates the Rates of Return to Public Investment in Agriculture

Measuring the social rate of return on agricultural research investment has been a standard practice accompanying agricultural research studies. This is important for developing countries where research investment is primarily a public sector activity. Government budgets are limited and there are many competing public investment alternatives. The measured rate of return can provide guidance on funding decisions and possibly research policy implications. It is of public interest to determine the payoffs to society from past investment on public agriculture research in assessing whether additional investment is likely to worthwhile.

In practice, the social rate of return on R&D is computed based on the estimated coefficients of the level terms of the public research variable or the long term TFP elasticities with respect to the public research variable. This regression based rate of return is the marginal internal rate of return (MIRR), calculated as the discount rate **r**, such as:

$$\sum_{t=1}^{\infty}\left[VMPt\frac{1}{(1+r)^{t}}\right]-1=0$$

The MIRR is the discount rate that equates a stream of discounted benefits from an initial investment of 1 monetary value (MV) such as one Jordanian Dinar (JD); Tunisian Dinar (TD) or Egyptian Pound (EGP), to exactly 1 MV. A standard methodology for estimation the MIRR to research & extension expenditure is widely used in the literature: Knutson and Tweeten (1979); Thirtle and Bottomley (1989); Nagy (1991); Evenson *et al.,* (1999), Rao *et al.,* (2012).

Let's assume that the relationship between productivity growth and research and extension investment is explored with the following Cobb-Douglas specification like in Lu *et al.,* (1978); Norton and Davis (1981); Thirtle and Bottemley (1989); Nagy (1991):

$$TFP = A\prod_{i=1}^{n} E_i^{\theta i}\prod_{j=0}^{k} R_{t-j}^{\alpha j}\ e^{\epsilon}$$

Where:

- TFP is the total factor productivity index of the agriculture output;
- E is vector of the other TFP determinants variables;
- $R_{t-j}$ is the expenditure on the Agricultural Research;
- $\alpha_j$ are the partial productivity coefficients of research in the $j^{th}$ year; and θs are the productivity coefficients for the other variables, and
- ε is the error term.

According to Alston *et al.,* (1995), in general, the research adoption process in agriculture involves following types of time lags:

(1) Research lag between initiation of research and generation of pre-technology knowledge;

(2) Development lag, which results from pre-technology research;

(3) Adoption lag between the release of agricultural technology and its optimal adoption by farmer producers.

Given this, the average lag between availability of technology and its adoption is generally considered to be about 8-12 years. Thus, the estimation of the MIRR is based on the following formula:

$$VMP_{t-i} = \frac{\Delta Y_t}{\Delta R_{t-i}} = \alpha_i \frac{TFP}{R_{t-i}} \frac{\Delta Y_t}{\Delta TFP_t}$$

Where;

- $VMP_{t-i}$ is the value marginal product of research in period (t-i);
- $\Delta Yt$ and $\Delta TFPt$ calculated as averages of output and TFP;

Using $\alpha_i$ (that varies over the lag period) provides a series of marginal value products resulting from a unit change in research expenditure. The MIRR can be obtained, at the discount rate r, from these annual flows of benefits from a unit change in real expenditure with the following standard formula:

$$\sum_{i=1}^{n} \left[ VMP(t-i) \frac{1}{(1+r)^i} \right] - 1 = 0$$

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