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NON-PARAMETRIC APPROACH TO MALIAN AGRICULTURAL PRODUCTIVITY

APPROCHE NON PARAMETRIQUE DE LA PRODUCTIVITE AGRICOLE AU MALI

1. **Dr Boukary KASSOGUÉ,** IPR/IFRA de Katibougou, boukary.kassogue@ipr-ifra.edu.ml, Tel: +223 79190358

2. **Pr Issa SACKO,** USSGB-FSEG-Bamako, i_sacko@yahoo.fr, Tel: +223 66738376

3. **Pr Amadou NDIAYE** UGB-Sénégal amadou.ndiaye@ugb.edu.sn, Tel :221 773560342

4. **Pr Mamadou Abdoulaye KONTE**, UGB-Sénégal, e-mails : mamadou-abdoulaye.konte@ugb.edu.sn Tel : + 221 77 622 13 50

5. **Pr Bouréma KONÉ**, Écofil /IER, kone_b@yahoo.fr,

Tel : +223 63132525

ABSTRACT

This article aims to examine the total factor productivity of agriculture in Mali because agriculture occupies a prominent place in the economy of each nation in general and also of Mali in particular. To achieve this, we used a linear programming model to examine the sources of agricultural productivity growth from the nonparametric approach of the Sten Malmquist index of productivity. This programming was mainly focused on 3 agricultural sectors, namely cotton, rice and millet for reasons of the specificity of production, trade and their weight in the agricultural economy of Mali. Data processing was done under R software version 3.4.4 (2018-03-15), RStudio-1.1.453 built from FAO, Countrysat, OECD and World Bank databases from 1990 to 2016. At the end of the results obtained, the Malmquist index

is 2.4912 higher than that (1.9291) of Africa due mainly to technological efficiency (2.4912) that technical equal to 1 (Kassogue B., 20220). Further, the decomposition of this index into technical efficiency revealed a pure inefficiency of 0.9999 and a scale inefficiency of 1.0000 by an ineffective decision-making unit at the threshold of 76.663 following a bad combination of the production factors.

Keywords: Total factor productivity, Malmquist index, Technical efficiency growth, technological efficiency, scale efficiency.

1.GENERAL INFORMATION ON THE GROWTH OF THE MALIAN AGRICULTURAL SECTOR

Agriculture occupies a prominent place in the economy of every nation. From this, the Physiocrats concluded that all sectors are sterile except the agricultural sector. The proof is that the development of agriculture provides raw materials to industry, which in turn allows the development of services. Thus, agriculture is considered the backbone of the economies of West African countries in general and Mali in particular. In Mali, agriculture occupies 70% of the main economic activities and 18% of the auxiliary economic activities and contributes on average 35% to the formation of the gross domestic product (GDP) or 40% in terms of currency (World Bank, 2016). However, the question of agricultural productivity in West African countries is a major problem. It is about productivity beyond natural constraints, that is to say the perfect mastery of the combination of inputs for a better obtaining of outputs. To this end, the adoption and implementation of agricultural policies is essential, but it constitutes a difficult test with often little success. Overall, there is the natural tendency which demonstrates that agriculture is under climatic constraint and the technological tendency which demonstrates that ethnological progress is essential for obtaining a better output. Some wrongly accuse the first, others support the second vice versa. Namely, for our part, we are ignoring here productivity and therefore the use and perfect mastery of production techniques and technological innovations. The contribution of the agricultural sector to GDP represented 40.96% on average over the 2015 period (BM, 2015). It plays an important role in GDP according to the annual trend of the sub-sectors that compose it. Thus, between 2005 and 2010, the GDP of the crop production sub-sector (agriculture) increased overall by 12.12% against 9.15% (2010-2017). There

is a decrease of 18.18% for livestock against an increase of 13.23% (2010-2017). There is also a decrease of 27.27% for forestry against a decrease of 23.12% (2010-2017). We observe 0% for fishing against an increase of 4.35% (2010-2017) (Kassogué B., 2020 cited by BM, 2012; Africa database and INSTAT, cited by PNISa, Dabitao and Dembélé, 2011; PNISA, 2014). The contribution of the agriculture sector to Mali's gross domestic product is constantly fluctuating, which sometimes slows down the performance of its economy. However, according to several authors, namely Cette G. (2007), Kahneman D. and Alan B. Krueger (2006), McGillivray & Shorrocks (2005), Obsberg & Shape (2005) […] agree that the gross domestic product is the indicator most often used to apprehend the level of development of a country and the activity sectors of nations. In this difficult context, the gross domestic product in Mali, in real terms, recorded zero growth (0.0%) in 2012. On the other hand, agricultural GDP in 2017 was 40.7% (World Bank, 2017). In 2014, the Malian economy experienced a performance of 7.2% against 1.7% of real GDP in 2013, attributable to a rebound in growth in the primary sector. Thanks to favorable rainfall and the introduction of agricultural inputs at the start of the campaign, agricultural production increased by nearly 15%. During the same period the real GDP of the secondary sector recorded a growth of 9% higher than that of the tertiary sector approximately 4%. Despite this performance recorded in 2014, the performance of the Malian economy over the 2012-2014 period was well below the average for WAEMU countries, with average real growth of 3.0% against 6.3% for WAEMU. From 2015 to 2018, the GDP of the agricultural sector experienced an overall increase of approximately 4.6% on average (IMF, 2017), i.e. a growth rate of 11.9% per year, which exceeds the objective of budget allocation to the agricultural sector of 10% of NEPAD. This trend is part of Mali's vision of 2060 to devote 15% or 34.3 billion FCFA/year (Ministry of Economy and Finance, 2016) of the state budget to agriculture with a view to make Mali a net exporting agricultural power. From 1992 to 2017, Malian agriculture was financed through expenditure by the government and development partners and this budget reached an average of 15% of the national budget (adapted from the results of the agricultural sector: review of policies, strategies and agricultural financing programs).

2. Real problem of Malian agricultural

The good growth of the Malian agricultural sector at times should not hide the productive weakness of this sector. First of all, according to the Ministry of the

Environment and Sanitation (MEA, 2011), Malian agriculture is extensive and not very productive resulting from a number of factors, in particular: dependence on climatic hazards and rainfall in down 30% over the past 30 years. For Fané (2016), droughts and floods as well as regular locust invasions weaken the productivity of Malian agriculture. A group of Malian researchers is studying the potential of agroindustrial poles and places the lack of adequate production infrastructure in particular as a major problem followed by the low level of irrigation in production pockets (Agropole, 2013). According to the national plan for investment in the agricultural sector (PNISA, 2011), the low productivity of Malian agriculture is linked to difficulties in accessing inputs (land, fertilizer) and credit, thus blocking agricultural investments. The monitoring of agricultural and food policies in Africa (SPAAA, 2013) highlights the low level of education of producers. For the "Monitoring African Food and Agricultural Policies project methodology: concept paper" (FAO, 2016), notes that agricultural extension and research very often do not reach the actors of the sector before emphasizing the high cost mechanism transport, loss during the transaction and packaging of agricultural products. According to the statistical planning unit of Mali (CPS, 2011), the low productivity of Malian agriculture is linked to poverty and the fragility of the soil, which leads to a general deterioration of natural resources. As for Diakité L & Koné B (2010), the vulnerability of this agriculture faces price volatility on the domestic and international market. According to NEPAD (2006, 2008); World Bank (2008), low agricultural productivity in Africa in general and in Mali in particular is characterized by low public spending in the sector in general, particularly investment spending (for unsuitable support from subsidies) and by the poor organization of actors in the sector. In conclusion, the Malian economy is highly dependent on agricultural activities, the levels of production and agricultural productivity of which are still globally dependent on several hazards. However, although agriculture is the engine of the Malian economy, many production difficulties reduce the efficiency of this sector. “Such a face of the economy in the presence of a rapidly growing rural population is mainly reflected in strong fluctuations in GDP and increased impoverishment of the population” (SPAAA, 2013).

Table 1: Overall increase in production of the entire agricultural sector

	Overall increase from 2005-2010	Overall increase from 2010-2017
Vegetable production	12,12 %	9,15 %
Breeding	-18,18 %	13,23 %
Forestry	27,27 %	23,12 %
Sin	0 %	4,35

Source: Constructed by the author using data from FAO, Countrysat, WB (2016).

3.LITERATURE REVIEW ON AGRICULTURAL PRODUCTIVITY

The economic literature teaches us that the issue of agricultural productivity is at the center of current debates on food security in the world in general and in Mali in particular. Therefore, we will seek to know the origin of the word productivity and its usefulness which lend themselves to the context of this thesis. Initially, we expose the definitions and the contours of the concept of the productivity, then we will present in the second place, the factors which support and limit the agricultural productivity.

3.1 Productivity, from physiocratic theory to neoclassical theory

The notion of productivity began to take shape with the work of physiocrats such as Quesnay (1694-1774). This pioneering author, himself a landowner, noted that by incurring higher costs (purchase of oxen, horses, plow, and manure) the land is better cultivated with less work and gives its owner a greater product. Later, he deduced from this reasoning what he called the "agricultural surplus theory". At the same time, Turgot establishes, on the contrary, that the land provides diminishing returns as less fertile land is cultivated. However, Malthus takes up this argument in parallel in the same logic as Turgot when speaking of the "limited productive power of the earth" in his "Essay on the principle of population" in 1798. For the English classics, in particular Adam Smith in 1776 introduces the notion of labor productivity, to designate the physical output of labor "research on the causes of the wealth of nations" opens with a first book relating to the "causes which have perfected the productive faculties of labor". In this context, he defines the productive power of labor as the "quantity of work that the same number of arms is able to provide" and develops the idea that this can be improved

thanks to the "division of work ". Thus, the resulting gains in labor productivity benefit employees by promoting a reduction in the prices of manufactured products. The theory of agricultural surplus establishes above all the role of advances in capital in the increase in agricultural production, and therefore in the increase in national income, then it considers agriculture as the only source of wealth. The marginalist school operates a complete reversal of the problem, taking advantage of the work of Say J.B. (1828-1829). This last author thinks that production brings into play the productive services of three elements: the industry of man (in the current sense of work), capital, and natural agents. He observes empirically that whoever owns one of these elements useful for production can demand remuneration when he sells its use (Destais and Gillot-Chappaz, 2000). However, Say does not address the question of the quantification of this remuneration or that of its theoretical justification, which will later lead Von Böhm Bawerk to qualify it as “the founder of the naive theory of productivity”. Jevons (1871), pioneer of the English marginalist school, laid the foundations of a theory of capital. It specifies that productivity still remains a quantity attached to work, since it defines the degree of productivity by quantity produced in exchange for a certain amount of wages and a productivity indicator corresponding to the inverse of a cost of unit production at a fixed rate of return. Jevons goes further in the analysis of capital income based on the idea of linking the remuneration of the means of production and their marginal contribution to production. His successors within the neoclassical school developed an analysis of the marginal returns to capital and the marginal productivity of labor and made them tools for distributing total income among the factors of production. Neoclassical economists according to the distribution theory believe that it is not only the land, but also all the factors of production which receive a remuneration equal to their marginal productivity at the optimum. Thus, the American economist John Bates Clark (1847-1938) developed the product exhaustion theorem. This theorem states that, when the production function is homogeneous of degrees 1 and when the factors are remunerated at their marginal productivity, then the income from production is entirely absorbed by the factors.

3.2 The main factors that promote agricultural productivity

The literature gives us a number of factors that promote productivity growth. According to Cette B. (2007), these factors are of two types, institutional factors and non-institutional factors. According to Cette B. (2007), the non-institutional factors

likely to increase agricultural productivity are threefold. The first concerns major long-term technological innovations; the second is investment in research and development, public investments in education and infrastructure in the short term, the third concerns the accumulation of capital, the dissemination of techniques, the organizational aspects in the medium term. In addition to these factors, Cette G. (2007) considers that changes in economic structures are also non-institutional factors that are likely to influence changes in productivity. Some authors like Belorgey (2003), Lecat and Maury (2004,2006); consider that the differences in standard of living and productivity per worker are factors that explain the productivity of nations. Differences in living standards between countries are linked to the development of public infrastructure, school enrollment rates and above all macroeconomic variables of the employment rate, credit to the private sector and inflation. As for productivity per worker, it essentially includes working hours, the employment rate, the importance of the production and distribution of ICTs, the investment rate and the position of the cycle, i.e. say the production capacity utilization rate. At the institutional level, the factors that promote productivity are addressed by two major theses. The first is the thesis that the production techniques and the form of organization of the actors promote the productivity of nations (Aghion and Howitt, 2006; Crafts, 2006). The second thesis consists in proving that the services in charge of agriculture, the protection, the labeling, the standardization of agricultural products are more conducive to ensuring better growth in agricultural productivity.

4 METHODOLOGICAL APPROACH

4.1 The model according to the Sten Malmquist index

Defined as the Output/Input ratio, total productivity varies both according to the efficiency of the production process and by the type of technology used. In addition, measuring the growth of agricultural productivity between two or more periods amounts, according to Malmquist, to breaking this notion down into two essential components. The first is the change in the level of technical efficiency and the second is the technological change, which together constitute the measure of total factor productivity of the Malmquist index. But we highlight technical efficiency which breaks down into two notions of measurement, pure efficiency and scale efficiency, for which the data envelopment analysis method would be the best suited and appropriate to identify these two measurements.

Indeed, the Malmquist index (M or malm or Malm) measures the change in total factor productivity by distinguishing the change in efficiency over time from technical progress (Färe, Grosskopf, Lindgren, Ross, 1994) based fundamentally on linear programming. This index is calculated empirically in terms of a distance function and compares the output obtained in period t with the inputs of this period to the output obtained in t with the inputs of period t+1. The breakdown of this index would thus allow the units to keep pace with the leading production units in terms of innovation and improvement of technical efficiency over time, for example, i.e. two sets of production according to the authors above:

$$\boldsymbol{s^t} = \{(\boldsymbol{x^t}, \boldsymbol{y^t}): x^t \; \boldsymbol{can\ produce}\ \boldsymbol{y^t}\ )\}\boldsymbol{et}\ \boldsymbol{s^{t+1}}$$
$$=\{(\ \boldsymbol{x^{t+1}}, \boldsymbol{y^{t+1}}): x^{t+1}\ \boldsymbol{can\ produce}\ \boldsymbol{y^{t+1}})\}, \qquad [1]$$

$\boldsymbol{o}$ü ($\boldsymbol{x^t}, \boldsymbol{y^t}$) $\boldsymbol{et}$ ($\boldsymbol{x^{t+1}}, \boldsymbol{y^{t+1}}$) represent respectively the quantities of inputs and outputs at the two periods t and t+1. These quantities are defined in$\boldsymbol{R^n_+}$ et t = 1…t. Four output-oriented distance functions can be determined by combining the boundaries at t, and t+1 on the one hand, and the quantities of inputs and outputs at t and t+1 on the other.

4.1.1 Output-oriented Malmquist productivity indices

According to Shepard (1970) and Färe (1988), the output-oriented distance function at period t and constant returns to scale technology is defined as follows.

$$\boldsymbol{d^t_{o,crs}}(\boldsymbol{x^t_i}, \boldsymbol{y^t_i}) = \boldsymbol{min}\left\{\boldsymbol{\theta}: \left(\boldsymbol{x^t_i}, \frac{\boldsymbol{y^t_i}}{\boldsymbol{\theta}}\right) \boldsymbol{\epsilon s^t_{crs}}\right\} \qquad [2]$$

$$=[\mathbf{max}\{\boldsymbol{\theta}: (\boldsymbol{x^t_i}, \boldsymbol{\theta y^t_i})\boldsymbol{\epsilon S^t_{crs}}\}]^{-1} \qquad \mathbf{(2.1)}$$

$$=[\boldsymbol{f^t_o}(\boldsymbol{x^t_i}, \boldsymbol{y^t_i})]^{-1} \qquad \mathbf{(2.2)}$$

$\boldsymbol{f^t_o}(.)$ represents in (1), Farrell's measure of technical production efficiency (1957). The term $\boldsymbol{d^t_{o,crs}}(\boldsymbol{x^t_i}, \boldsymbol{y^t_i}) \leq \ \mathbf{1}$ if and only if $(\boldsymbol{x^t_i}, \boldsymbol{y^t_i})\ \boldsymbol{\epsilon}\ \boldsymbol{s^t_{crs}}$ and $\boldsymbol{d^t_{o,CRS}}(\boldsymbol{x^t_i}, \boldsymbol{y^t_i}) = \mathbf{1}$ if and only if $(\boldsymbol{x^t_i}, \boldsymbol{y^t_i})\ \boldsymbol{\epsilon}\ \boldsymbol{S^t_{crs}}$ is the production frontier.

Indeed, let us recall that the Malmquist index was exposed for the first time by Caves, Christensen and Diewert (1982) as a theoretical index called the Malmquist productivity index. However, Sten Malmquist would have shown how to construct quantity indices as a ratio of distance functions based on the work of Färe, R., S. Groskopf, M. Norris and Z. Zhang (1994), the synthetic index of productivity of Malmquist is defined as follows:

$$\boldsymbol{m_o}(\boldsymbol{x^{t+1}_i}, \boldsymbol{y^{t+1}_i}, \boldsymbol{x^t_i}, \boldsymbol{y^t_i}) = \left[\frac{\boldsymbol{d^t_{o,\mathrm{crs}}}(\boldsymbol{x^{t+1}_i}, \boldsymbol{y^{t+1}_i})}{\boldsymbol{d^t_{o,crs}}(\boldsymbol{x^t_i}, \boldsymbol{y^t_i})} \times \frac{\boldsymbol{d^{t+1}_{o,\mathrm{crs}}}(\boldsymbol{x^{t+1}_i}, \boldsymbol{y^{t+1}_i})}{\boldsymbol{d^{t+1}_{o,\mathrm{crs}}}(\boldsymbol{x^t_i}, \boldsymbol{y^t_i})}\right]^{1/2} \qquad [3]$$

These authors consider that the technology at period t is the reference in this formulation. It is a function of distance that measures the maximum proportional change in output required to render ($\boldsymbol{y^{t+1}}$, $\boldsymbol{x^{t+1}}$) operational relative to the technology of period t. It calculates the distance that separates an observation from the technological frontier. Moreover, as for the second equation (3), it conceptualizes the Malmquist total productivity index. It is a synthetic Malmquist index which represents the geometric mean of the two indices as defined by Caves, Christensen and Diewert (1982) so as not to choose a particular reference, i.e.:

$$\boldsymbol{M_{ccd}^{t}} = \frac{\boldsymbol{d_{o,\mathrm{crs}}^{t}(x_i^{t+1}, y_i^{t+1})}}{\boldsymbol{d_{o,\mathrm{crs}}^{t}(x_i^{t}, y_i^{t})}} \quad [\mathbf{4}]$$

and

$$\boldsymbol{M_{ccd}^{t+1}} = \frac{\boldsymbol{d_{o,\mathrm{crs}}^{t+1}(x_i^{t+1}, y_i^{t+1})}}{\boldsymbol{d_{o,crs}^{t+1}(x_i^{t}, y_i^{t})}} \quad [\mathbf{5}]$$

As for the term of equation (5), it has a capital characteristic of composing this index into two components independent of each other, namely the change in terms of efficiency ($\boldsymbol{ECH_i^t}$) and technological progress($\boldsymbol{TCH_i^t}$) as following:

$$\boldsymbol{ECH_i^t} = \frac{\boldsymbol{d_{o,\mathrm{crs}}^{t+1}(x_i^{t+1}, y_i^{t+1})}}{\boldsymbol{d_{o,crs}^{t+1}(x_i^{t}, y_i^{t})}} \quad [\mathbf{6}]$$

$$\boldsymbol{TCH_i^t} = \left[\left(\frac{\boldsymbol{d_{o,\mathrm{crs}}^{t}(x_i^{t+1}, y_i^{t+1})}}{\boldsymbol{d_{o,\mathrm{crs}}^{t+1}(x_i^{t+1}, y_i^{t+1})}}\right)\left(\frac{\boldsymbol{d_{o,\mathrm{crs}}^{t}(x_i^{t}, y_i^{t})}}{\boldsymbol{d_{o,\mathrm{crs}}^{t+1}(x_i^{t}, y_i^{t})}}\right)\right]^{\mathbf{1/2}} \quad [7]$$

The sixth equation (6) is defined as the ratio of Farrell's technical efficiency at period t+1 divided by Farrell's technical efficiency at period t, while equation (7) translates the geometric mean of the technological evolution observed at the input level$\boldsymbol{x^{t+1}}$ and the assessed technological evolution of the inputs $\boldsymbol{x^t}$. Finally, the previous equation (2) can be reformulated as followst:

$$\boldsymbol{M_o(x_i^{t+1}, y_i^{t+1}, x_i^t, y_i^t)} = \boldsymbol{MALM_i^t} = (\boldsymbol{ECH_i^t}) \times (\boldsymbol{TCH_i^t}) \quad [8]$$

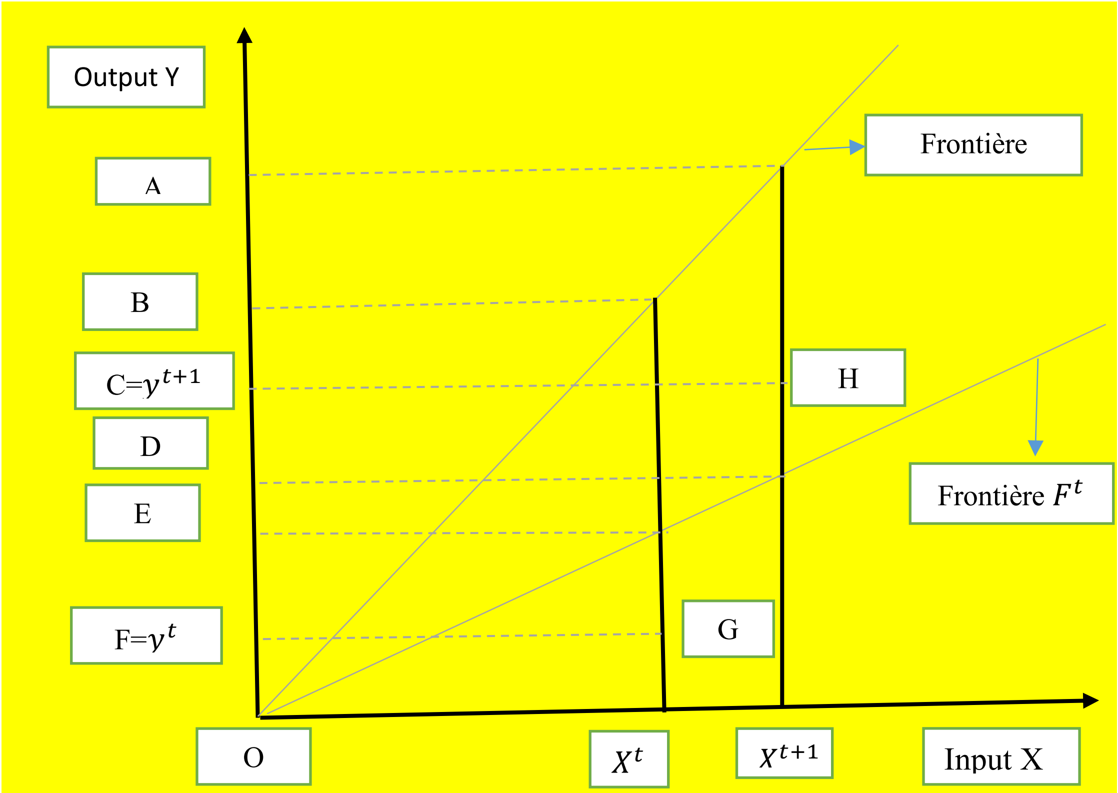
Let the following equation (8), corresponding to equation (7) of the previous chapter, be reformulated as follows:

$$\boldsymbol{M_i(x_i^{t+1}, y_i^{t+1}, x_i^t, y_i^t)} = \left[\frac{d_{i,crs}^{t}\boldsymbol{(x_i^{t+1}, y_i^{t+1})}}{\boldsymbol{d_{i,crs}^{t}(x_i^{t}, y_i^{t})}}\right]\left[\left\{\frac{\boldsymbol{d_{i,crs}^{t}(x_i^{t+1}, y_i^{t+1})}}{\boldsymbol{d_{i,crs}^{t+1}(x_i^{t+1}, y_i^{t+1})}}\right\}\left\{\frac{\boldsymbol{d_{i,\mathrm{crs}}^{t}(x_i^{t}, y_i^{t})}}{\boldsymbol{d_{i,\mathrm{crs}}^{t+1}(x_i^{t}, y_i^{t})}}\right\}\right]^{\mathbf{1/2}} \quad [\mathbf{9}]$$

ECH TCH

The first term of equation (9) represents the change in technical efficiency, i.e. a move towards or away from the frontier of best practices. However, based on constant returns to scale (CRS), Färe et al. (1994) decompose technical efficiency into pure technical efficiency and scale efficiency like Farrell (1957). Scale efficiency refers to the size of the production unit while pure technical efficiency refers to the optimal use of resources by the managers of the production unit. As for the second term of equation (9), it reflects technological change or innovations represented by a shift in the production frontier at period t+1. It is thus possible to calculate for each production unit i the trajectories over time of productivity, of the change in technical efficiency and of technical progress. However, a value of ECHit and TCHit greater than 1 reflects respectively an improvement in technical efficiency and technical progress between the two periods. From the above assumption if we consider that $\boldsymbol{x^t = x^{t+1} et\ y^t = y^{t+1}}$, the total productivity index Mo (.) = 1. Consequently, a value of Mo (.) greater than 1 reflects a gain in productivity. To further illustrate this formulation by the approach of the frontier of determination of the Malmquist productivity index, we are inspired by the works of the authors (Charnes, A., Cooper, W., Lewin, A.Y., and Seiford, L.M., 1994) represented by the graph above.

Chart 1 Output-oriented Malmquist productivity index



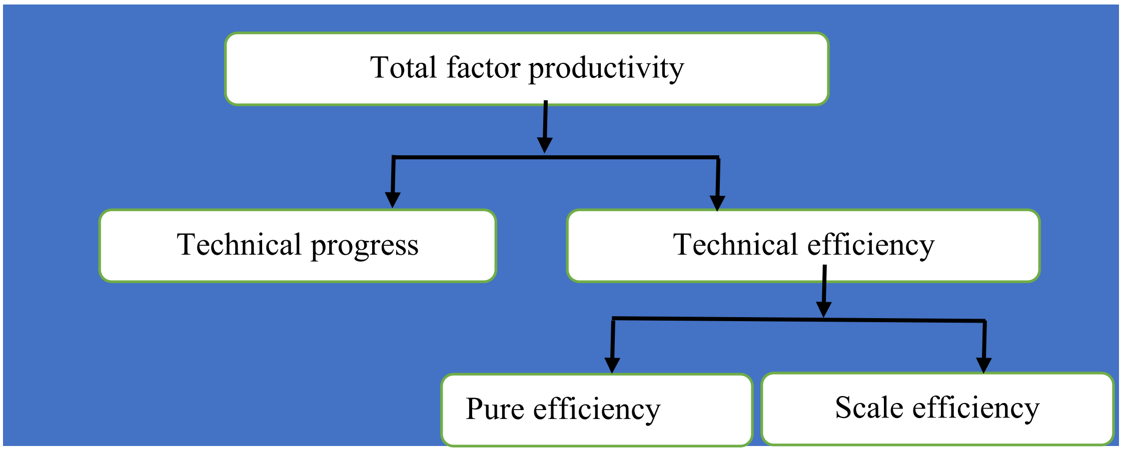
Source : Charnes, A., Cooper, W., Lewin, A.Y, Seiford, L.M (1994)

According to these authors, the graph above thus makes it possible to demonstrate the technical efficiency at periods t and t+1, the data of which are represented respectively by the figure OF/OE and OC/OA. Indeed, for the productivity growth rate, we consider to as the ratio and $\boldsymbol{To} = (\boldsymbol{OC}/\boldsymbol{OX^{t+1}})/\,(\boldsymbol{OF}/\boldsymbol{OX^{t}})$. Alternatively, this expression can be further rewritten as follows: To= {(OC/OA) / (OF/OE)} × $\{(\boldsymbol{OA}/\boldsymbol{OX^{t+1}})/\,(\boldsymbol{OE}/\boldsymbol{OX^{t}})\}$. The first term is the ratio of technical efficiency in period t+1 to period t and the second term is the ratio of frontier productivity in t+1 to frontier productivity in t. However, the measure of productivity growth per To can result either from an improvement in efficiency or from a favorable movement of the production frontier. This is what was previously developed above. From a graphical point of view, the components of the distance function are of four orders and are calculated as follows: $\boldsymbol{D_o^t}\,(\boldsymbol{y^t},\boldsymbol{x^t}) = \frac{\boldsymbol{OF}}{\boldsymbol{OE}}$. This is the distance that would measure the relative efficiency of production in G compared to the frontier of the period t. $\boldsymbol{D_o^{t+1}}(\boldsymbol{y^{t+1}},\boldsymbol{x^{t+1}}) = \frac{\boldsymbol{OC}}{\boldsymbol{OA}}$, corresponds to the distance that measures the relative efficiency of production in H compared to the frontier of period t+1. Function

$D_o^t(y^{t+1}, x^{t+1}) = \frac{OC}{OD}$ is the measurement distance of the relative efficiency of production in H compared to the frontier of period t. finally, $D_o^{t+1}(x^t, y^t) = \frac{OF}{OD}$ is the distance function that corresponds to the measure of the relative efficiency of production in G compared to the frontier t+1. In addition, $F^t and\ F^{t+1}$ represent the sets of productions relating to periods t and t+1. However, if a production unit is below the border F^t for example, any movement with the aim of getting closer to this border is called "technical efficiency". On the other hand, if the border itself moves, going from F^t F à F^{t+1}, we consider it to be the result of technological progress. Therefore, best practice technologies should be used by production units to follow the leaders that would allow them to be on the frontier. However, Griefell, Tatjé and Lovell (1995) dispute the ability of the output-oriented indices of Caves et al. to account for productivity gains in the presence of a technology with variable returns. These observations are also valid for an input-oriented technology.

According to Coelli et al., decomposing technical efficiency into pure efficiency and scale efficiency imposes the constraint of convexity (N1'λ) to account for varying returns to scale. The process of total factor productivity decomposition is summarized in diagram 1 below.

Diagram 1 Decomposition of total factor productivity



Source: Constructed by the author from the literature review

In general, the Malmquist productivity index has been the subject of several empirical studies. In what follows, we will examine the instruments for analyzing productive efficiency.

5.TOTAL AGRICULTURAL PRODUCTIVITY RESULT IN MALI

Furthermore, we assume that the countries do not all have the same technological availability or the same ability to combine production factors, so they would have contributed to the improvement of the total factor productivity of the region in a very dispersed way. This is why we analyze the total factor productivity of each country separately below. The model is always the same, the only particularity is the interest for us to deal with total factor productivity to make a notable observatory in order to suggest the levers on which each country should rely to improve the production of its nation. The study focuses on the agricultural productivity of 7 West African countries (Benin, Burkina, Côte D'Ivoire, Mali, Nigeria, Senegal and Togo) with 3 agricultural production sectors including the production sector food crop: cereals (millet and rice) and the cash crop sector (cotton) over 26 years from 1990 to 2016, i.e. 228 resolved linear programs [3(3*26-2)] per country for a data of 27 observations and 16 variables. As mentioned earlier, the Malmquist total factor productivity index and its two components, technical progress and total technical efficiency, were calculated from 1990 to 2016 for the 3 agricultural speculations by the distance to the border using the distance functions. According to (Färe R. et al. 1994; Coelli T.J. et al. 1998), technical progress indices are obtained by comparing the boundaries of two periods when panel data are available. The Malmquist productivity index and its components (based on inputs) between a base period (t) and a period (t+1) are calculated following the method developed by (Färe R. et al. 1994; Coelli T., J. et al.1998). The description of the data and the definition of the variables, the methodology and the use of the processing interface are the same as before.

5.1 Malian total agricultural productivity result

Table 2 Shephard distance function estimates (summary) of Mali

c111o	c100o	c011o	c000o	c110o
Min. : 1	Min. : 0.8889	Min. : 0.984	Min. : 1	Min. : 0.7389
1 st Qu. : 1	1st Qu. : 1.1330	1st Qu. : 1.201	1st Qu. : 1	1st Qu. : 0.9947
Median :1	Median: 1.5396	Median: 1.422	Median :1	Median: 1.1203
Mean :1	Mean: 4.3277	Mean : 84.931	Mean :1	Mean : 1.2020
3rd Qu. : 1	3rd Qu. : 1.9619	3rd Qu. : 2.036	3rd Qu. :1	3rd Qu. : 1.3311
Max. : 1	Max. : 43.7184	Max. : 2119.720	Max. : 1	Max. : 1.9544
c010o	v111o	v000o		

Min. : 0.9804	Min. : 1	Min. : 1
1 st Qu. : 1.0148	1st Qu. : 1	1st Qu. : 1
Median : 1.0902	Median :1	Median : 1
Mean : 80.9611	Mean :1	Mean : 1
3 rd Qu. : 1.3919	3rd Qu. : 1	3rd Qu. : 1
Max. : 2036.1407	Max. : 1	Max. : 1

Source: built by the author, extracted from linear programming under R studio version 3.4.4 (2018-03-15) using data from FAO, Countrysat, BM, OECD.

In short, the improvement in the total factor productivity of the Malmquist index achieved in Mali is 2.4912 on average mainly due to the adoption of the best technology, otherwise in terms of production technique it stabilizes on average. equal to 1. Table 2, 3 below, histography 1,2,3,4,5; Figure 1 explain the effectiveness of the Malmquist index and its two components.

Table 3: Malmquist productivity index results (summary) of Mali

Malmquist	effch	tech	obtech	biotech
Min. : 0.1751	Min. : 1	Min. : 0.1751	Min. : 1.019	Min. : 1.038
1 st Qu. : 0.7594	1st Qu. : 1	1st Qu. : 0.7594	1st Qu. : 1.103	1st Qu. : 1.086
Median : 1.0604	Median :1	Median : 1.0604	Median :1.182	Median : 1.354
Mean : 2.4912	Mean :1	Mean : 2.4912	Mean :1.217	Mean : 3.650
3 rd Qu. : 1.3511	3rd Qu. : 1	3rd Qu. : 1.3511	3rd Qu. : 1.298	3rd Qu. : 2.195
Max. : 33.6024	Max. : 1	Max. : 33.6024	Max. : 1.510	Max. : 46.960

matech	pure.out.effch	out.scalech
Min.: 0.02287	Min.: 1	Min.: 1
1 st Qu.:0.51003	1 st Qu.:1	1 st Qu.:1
Median :0.64962	Median : 1	Median : 1
Mean :0.64071	Mean : 1	Mean : 1
3 rd Qu. : 0.88265	3rd Qu. : 1	3 rd Qu. : 1
Max. : 1.12501	Max. : 1	Max. : 1

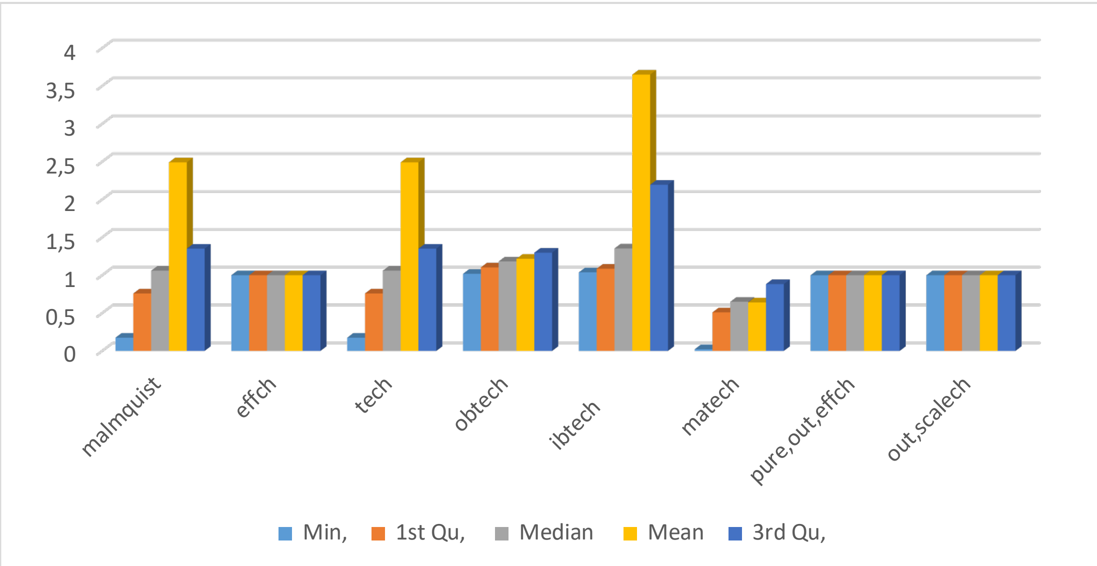
Source: built by the author, extracted from linear programming under R studio version 3.4.4 (2018-03-15) using data from FAO, Countrysat, BM, OECD.

Table 4: Simplified representation Malmquist productivity index results (summary) of Mali

	malmquist	effch	Tech	obtech	biotech	matech	pure.out.effch	out.scalech
Min.	0.1751	1	0.1751	1.019	1.038	0.02287	1	1
1 st Qu.	0.7594	1	0.7594	1.103	1.086	0.51003	1	1
Median	1.0604	1	1.0604	1.182	1.354	0.64962	1	1
Mean	2.4912	1	2.4912	1.217	3.650	0.64071	1	1
3 rd Qu.	1.3511	1	1.3511	1.298	2.195	0.88265	1	1
Max.	33.6024	1	33.6024	1.510	46.960	1.12501	1	1

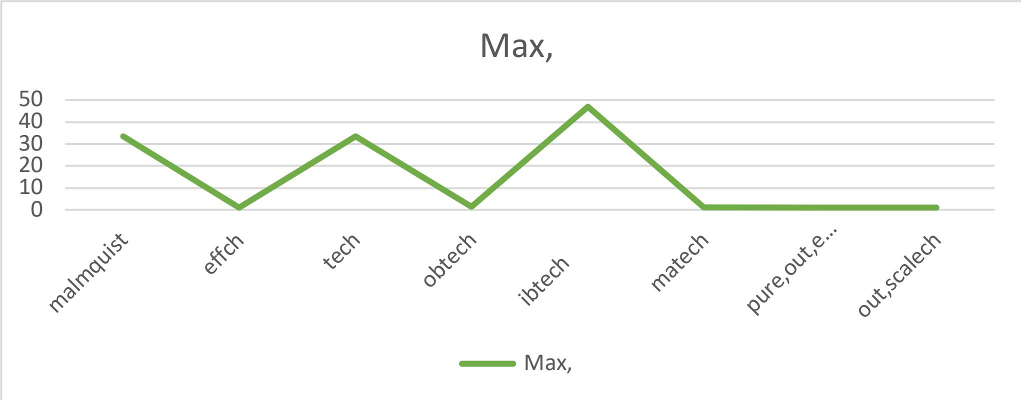
Source: built by the author, extracted from linear programming under R studio version 3.4.4 (2018-03-15) using data from FAO, Countrysat, BM, OECD.

Histogram 1 Malmquist productivity index results (summary)



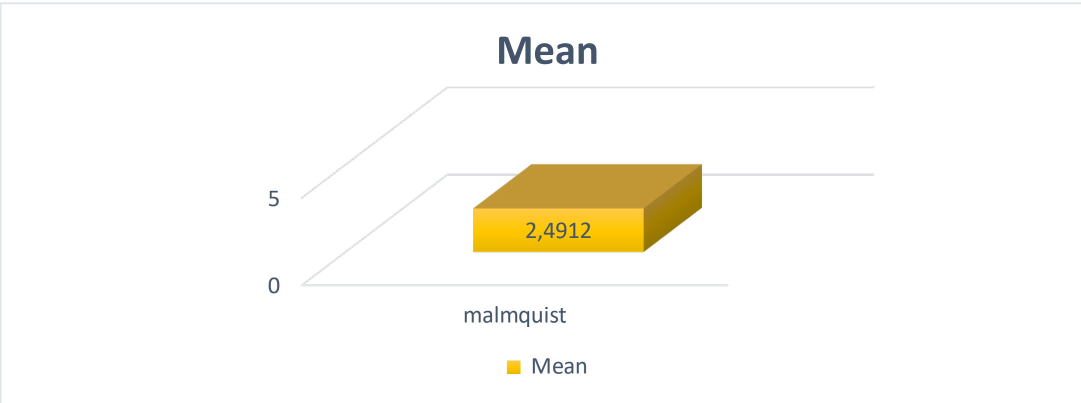
Source: built by the author, extracted from linear programming under R studio version 3.4.4 (2018-03-15) using data from FAO, Countrysat, BM, OECD.

Graphique 21 Malmquist productivity index results (summary) Max



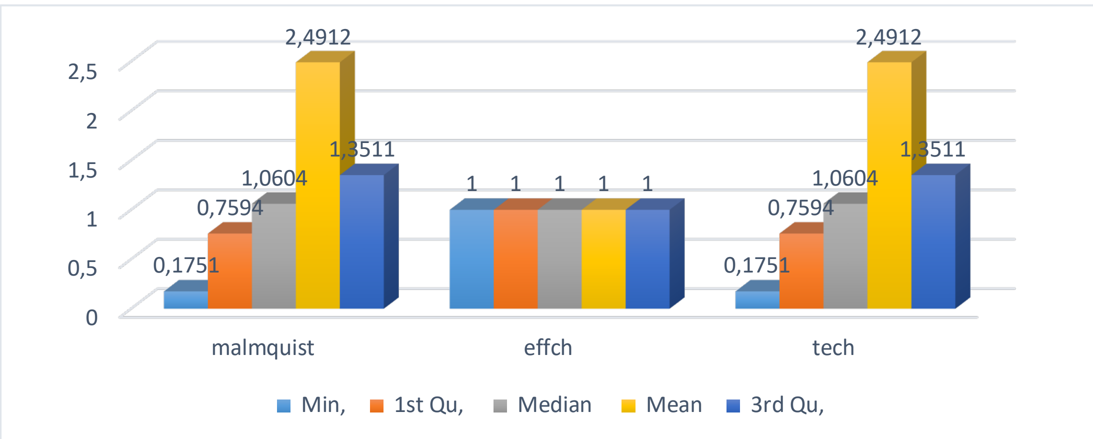
Source: built by the author, extracted from linear programming under R studio version 3.4.4 (2018-03-15) using data from FAO, Countrysat, BM, OECD.

Histogram 2 Average Malmquist Productivity



Source: built by the author, extracted from linear programming under R studio version 3.4.4 (2018-03-15) using data from FAO, Countrysat, BM, OECD.

Histogram 3 Malmquist and its components1



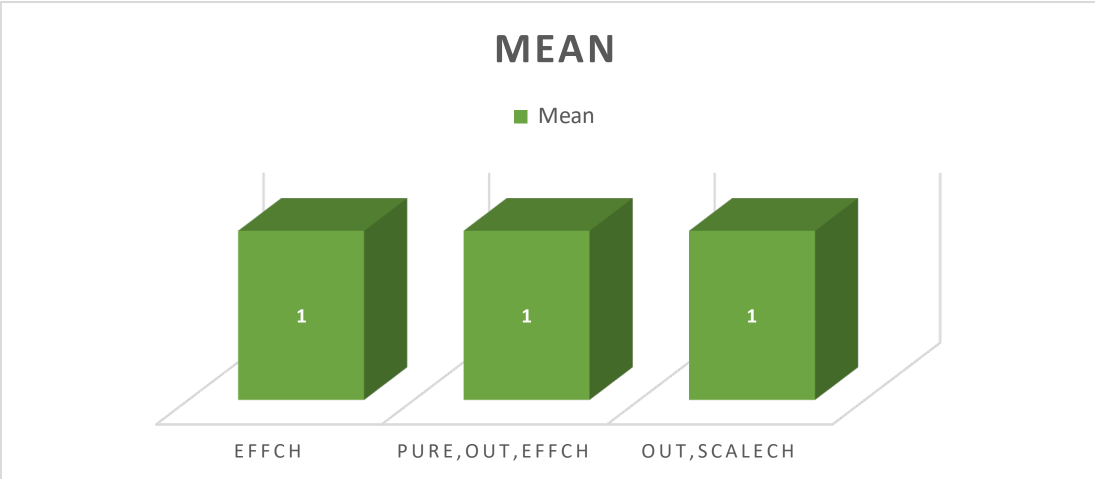
Source: built by the author, extracted from linear programming under R studio version 3.4.4 (2018-03-15) using data from FAO, Countrysat, BM, OECD.

5.1.1 Measuring technical efficiency: an application of the Data Envelopment Analysis (DEA) method from Mali

Components of technical efficiency

The histogram below shows that Mali's average total technical efficiency index is stationary. This result means that on average, under the assumption of constant returns to scale, the technical efficiency of Mali is constant, the combination of inputs is neither less nor more in obtaining maximum outputs. This means that there are not enough gaps in the management of resources from a global point of view and in relation to the availability of the production process such as agricultural education which makes it possible to boost agricultural productivity by best production techniques. The interpretation that could have been given to the stationarity of the two components of efficiency: pure and scale would be a poor use of inputs unsuited to the size of farms. This means that there is a negative relationship between farm size and the ability of farmers to combine inputs and outputs (histogram 4).

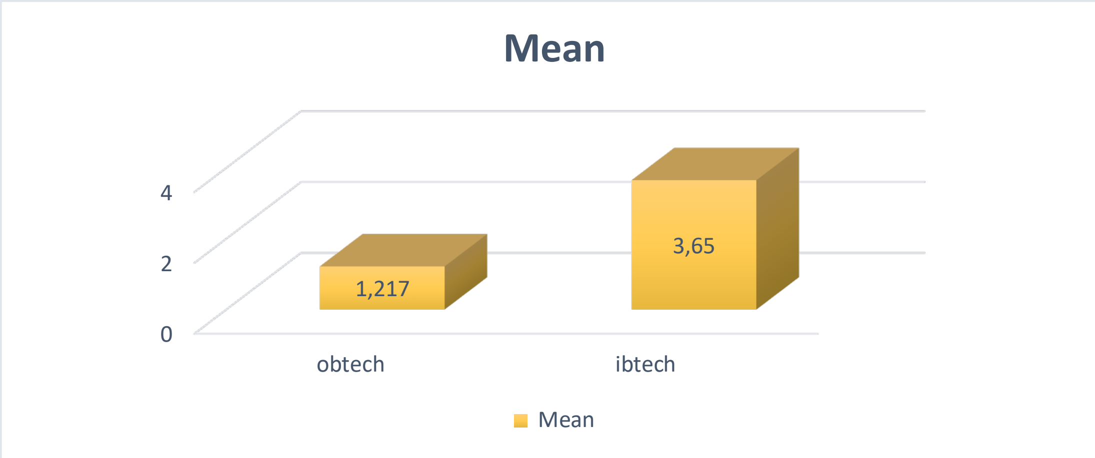
Histogramme 4 Productivité moyenne des composantes d'efficacité techniques



Source: built by the author, extracted from linear programming under R studio version 3.4.4 (2018-03-15) using data from FAO, Countrysat, BM, OECD.**5.1.2 Change in total factor productivity**

The obtaining of maximum outputs as a result of a judicious use of inputs is comparable to that of Burkina and the Ivory Coast for a difference of 2.433 more units of inputs which makes it possible to obtain a unit of optimal output (Kassogué B. 2020).

Histogram 5 Changes in inputs and outputs



Source: built by the author, extracted from linear programming under R studio version 3.4.4 (2018-03-15) using data from FAO, Countrysat, BM, OECD.

CONCLUSION

Mali's malmquist index is 2.4912 higher than that of West Africa (1.9291) mainly due to technological (2.4912) and technical (1) efficiency. Further, the decomposition of this index into technical efficiency revealed a pure inefficiency of 0.9999 and a scale inefficiency of 1.0000 by an ineffective decision-making unit at the threshold of 76.663 following a bad combination of the production factors.

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