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The Paradigm of Agricultural Efficiency and its Implication on Food Security in Africa: What Does Meta-analysis Reveal?☆

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Summary. — The study investigates whether African agricultural efficiency levels have been improving or not and what drives them over the years based on 442 frontier studies using meta-regression analysis. The results show that the mean efficiency estimates from studies decrease significantly as year of survey in the primary study increases. Also studies published in Journals, with parametric specification and with panel data produced significantly higher efficiency estimates, while those with a focus on grain crops reported significantly lower efficiency estimates. Other results show that education, followed by experience, extension, and credit are the major drivers of agricultural efficiency levels in Africa.

Key words — agriculture, efficiency, meta-analysis, food security, fractional regression, Africa

1. INTRODUCTION

Agriculture remains the main trust of many countries in Africa, as the principal source of food and livelihood, making it a critical component of programs that seek to reduce poverty and attain food security in the continent. But in recent years, food insecurity has become a serious concern in Africa, especially in sub-Saharan Africa (SSA), which is reminiscent of the same issue in Asia for decades earlier (Otsuka, 2013). The key to boosting food security in the region cannot be divorced from agricultural total factor productivity (TFP) growth. As noted by Brümmer (2006), improvement in the efficiency levels of agriculture and food production has always been identified as a major component of total factor productivity (TFP) growth that needs to be explored to effectively address food insecurity problem in the developing economies.

Although, no country has successfully reduced poverty and food insecurity through agriculture alone as institutional and industrial development are often needed, but almost none has achieved it without first increasing its level of agricultural productivity and efficiency (POSTnote, 2006). In other words, the study of agricultural efficiency is important to all economies; developed and developing. And, this underscores why analysis of efficiency in agriculture and food production and the role of efficiency in increasing agriculture and food production, has received particular attention by researchers and policy makers alike as an important input for better informed policy decisions around the globe (Ogundari, Amos, & Okoruwa, 2012; Thiam, Bravo-Ureta, & Rivas, 2001).

According to Gallup, Radielet, and Warmer (1997), increase in the efficiency and productivity of agricultural enterprises is likely to enhance smallholder (or subsistence) farmers opportunities to produce more, which in turn could lead to increase in their food security and income levels. This is because improvement in agricultural efficiency levels provides opportunities for farmers to produce more at same level of resources, while productivity and efficiency affect agriculture and food production directly by increasing the available supply of food and indirectly by increasing household income. For example, study by Gallup *et al.* (1997) has shown that 1% rise in per capita agricultural output (or TFP growth) could lead to a 1.6% rise in income of the poorest. Likewise, Martin (2013) argued that the poverty impact of increase in agricultural productivity growth is much larger than for industry or services sector.

The popularity of frontier efficiency studies in the last three decades has received attention among researchers and policy analysts and this is evidenced by the proliferation of the methodology and its application across the globe (Thiam *et al.*, 2001). Meanwhile, recent empirical findings by Thiam *et al.* (2001), Bravo-Ureta *et al.* (2007) and Ogundari and Brümmer (2011) have shown that the mean efficiency estimates of agricultural and food production reported in the primary studies differ across many study attributes (or dimensions) such as methodology, data type, model specification, and location among others.

In addition, two recent cross-country analyses of agricultural productivity growth in Africa based on FAOSTAT data by Alene (2010) and Yu and Nin-Pratt (2011) provided evidence that change in efficiency levels over time contributed negatively to the TFP growth of the sector over the years. Subsequently, both authors concluded that the decline in efficiency levels is a major cause of poor TFP growth in African agriculture and food production, while both studies also identified

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☆ The most valuable of all capital is investment in human beings–Alfred Marshal, (1920).

technical progress (technological change) as main driver of agricultural TFP growth in the region. [1] This observation contradicts Fugile and Wang's (2012) argument that the future challenge to the global food security as in the past does not appear to be related to technical constraints, but rather to uneven access to resources (i.e., poor resource use efficiency level).

Furthermore, recent study by Ogundari (2013) has shown that there are a substantial number of efficiency studies that have been used to raise policy debates on the performance of African agriculture and food production over the years. In this respect, it will be interesting to understand what literature revealed about the trends (or development) in the African agricultural efficiency levels and what drives the efficiency levels over the years as an important input in agricultural policy decisions in the region. In other words, could similar findings obtained from existing cross-country studies on agricultural productivity be distilled from synthesized literature on efficiency of African agriculture over the years? As noted by Ogundari *et al.* (2012), lessons/policy implications drawn from previous studies on agriculture and food production, could be very useful as guides to agricultural policymakers in designing effective food security programs and policies. Thus, arising from the foregoing, the present study addresses the following research questions:

RQ1. How did the relationship between reported mean efficiency estimates and year of survey from the selected frontier studies develop (i.e., rise or decline) over the years?

RQ2. Are there differences in reported mean efficiency estimates driven by study-specific attributes such as methodology used, model specification, publication outlet, data type, location etc. from the selected frontier studies?

RQ3. What factors (policy variables) have driven agricultural efficiency levels most over the years from the selected frontier studies?

The present study builds on the earlier works by Thiam *et al.* (2001), Bravo-Ureta *et al.* (2007), and Ogundari and Brümmer (2011) that utilized meta-analysis to investigate how the mean efficiency scores from primary studies on agriculture and food production differ across study attributes such as methodology used, data type, model specification etc. While Thiam *et al.* (2001) focused on farm-level efficiency estimates from the developing agriculture using just 2 studies from Africa, Bravo-Ureta *et al.* (2007) examined efficiency estimates from both the developing and developed agriculture using 14 studies from Africa, and Ogundari and Brümmer (2011) focused exclusively on efficiency estimates from Nigeria with 124 studies involved.

The present study contributes to existing literature in three ways. *First*, unlike previous studies that include few numbers of observations from Africa, the present study focuses exclusively on the efficiency estimates from Africa with broader geographical coverage that would produce a better understanding of the link between these estimates in African agriculture and attributes of studies reporting these estimates in the region. *Second*, unlike previous studies that used Tobit, OLS, and truncated regressions, believed to yield biased result as argued by McDonald (2009) and Ramalho, Ramalho, and Murteira (2011), the current study makes a significant contribution in terms of methodology employed by using fractional regression model for the meta-regression analysis (MRA). *Third,* unlike previous studies with the exception of Ogundari and Brümmer (2011), we extend our discussion to include drivers of agricultural efficiency level over the years in Africa.

The paper is structured as follows. The next section provides overviews of frontier efficiency and meta-analysis. Section 3 provides detailed description of the meta-dataset used for the analysis. In Section 4, meta-regression model specification is provided. Section 5 presents the results and discussion, while conclusions are provided in Section 6.

2. AN OVERVIEW OF FRONTIER EFFICIENCY AND META-ANALYSIS

(a) *An overview of frontier efficiency*

Efficiency refers to how well a system or unit of production performs in the use of resources to produce outputs, given available technology relative to a standard (frontier) production (Fried, 2008). The efficiency of a decision-making unit (DMU) can be assessed as technical, cost or profit or allocative efficiency. When producers face input–output mix, efficiency of DMU, called technical efficiency, is measured relative to production frontier, using primal technology specification (i.e., production function). Also, when producers face input price mix and output price mix, efficiency of DMU is measured relative to cost and profit frontiers, respectively. In this regard, cost and profit efficiencies are estimated using dual technology specification (referred in the literature as alternative representation of the production function) such as cost and profit functions, respectively. Since, the measure of cost or profit efficiency can be decomposed into technical and allocative efficiencies (see for detail, Coelli, Rao, O'Donnell, & Battese, 2005; Kumbhakar & Lovell, 2000), allocative efficiency is derivable from the combination of either the production and cost frontiers or production and profit frontiers estimates. [2] Thus, following Farrell's (1957) definition, technical efficiency is defined as the ability of a DMU (e.g., a farm) to produce maximum output given a set of inputs, while allocative efficiency is the ability to produce a given level of output using cost-minimizing input ratios – in recognition that a technically efficient producer could choose an inappropriate input mix given the input prices it faces. But profit efficiency is viewed as the highest possible profit achieved by DMU relative to the frontier profit, given the optimum combination of output and factor prices (Kumbhakar & Lovell, 2000).

Meanwhile, economic theory offers numerous procedures for evaluating efficiency of a DMU (Hoff, 2007), as methodologies employed in estimating efficiency level of agriculture and food production have evolved over the years. This however, ranges from when simple indexing method and mathematical programing (or nonparametric method-Data Envelopment Analysis – DEA) were used, the use of simple and sophisticated econometrics (or parametric method such as stochastic frontier analysis – SFA), the introduction of theoretically consistent functional forms, the introduction of dynamic and spatial econometrics and systems of equations, use of multi-output technology estimation to the introduction of meta-frontier technology among others (for detail discussion see, Kumbhakar & Lovell, 2000 and Coelli *et al.*, 2005). [3]

Another major extension in efficiency measurement is recent advances in panel data methodologies, which led to the incorporation of efficiency into TFP growth decomposition process similar to the Solow Growth model. As noted by Kumbhakar and Lovell (2000), a major feature of panel data is the ability to decompose TFP growth into four distinct components such as technical change or technological change (which could be outward or inward shift of production frontier) and efficiency change (which could be movement toward (catching up) or away from (lagging behind) the production frontier and until lately into scale efficiency change (change in variety of inputs