Agricultural Productivity and Policies

in Sub-Saharan Africa

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Selected Paper prepared for presentation at
the Agricultural & Applied Economics Association's
2011 AAEA & NAREA Joint Annual Meeting,
Pittsburgh, Pennsylvania, July 24-26, 2011

Abstract

We analyze the evolution of Sub-Saharan Africa's agricultural total factor productivity (TFP) over the past 45 years, looking for evidence of recent changes in growth patterns using an improved nonparametric Malmquist index. Our TFP estimates show a remarkable recovery in the performance of Sub-Saharan Africa's agriculture between 1984 and 2006 after a long period of poor performance and decline. That recovery is the consequence of improved efficiency in production resulting from changes in the output structure and an adjustment in the use of inputs. Policy interventions, including fiscal, trade and sector specific policies, appear to have played an important role in improving agriculture's performance. Despite the improved agricultural performance, SSA economies face serious challenges to sustain growth. Among these are the small contribution of technical change to TFP growth in the past, the large tax burden imposed by remaining distortions, and the challenge of population growth.

Key words: agriculture, efficiency, Malmquist index, total factor productivity, technical change, Sub-Saharan Africa, policy

JEL Codes: O3, Q1

Agricultural Productivity and Policy Changes in Sub-Saharan Africa

1. Introduction

Sub-Saharan Africa (SSA) is the most important development challenge of the 21st century. This region has been lagging behind the rest of the developing world in terms of economic growth and poverty alleviation, widening the gap between SSA and emerging developing countries. GDP per capita was only $612 (constant 2000 value) in 2009, which is only less than one-third of the level in developing East Asia. As a result, 29 out of the 40 low income countries are in this sub-continent, and countries with the highest rates of malnutrition can be found in SSA.

Economies in sub-Saharan Africa (SSA) have exhibited impressive performance in recent years, growing at 6 percent per year. This brings widespread optimism among researchers and policy makers, fueled by the end of several civil wars, a wave of democratization in several countries (which made possible the creation of the New Partnership for Africa's Development, or NEPAD, and a new agenda for development), the acceleration of economic growth, and significant improvements in the performance of the agricultural sector across Africa during the 1980s and 1990s.

Agricultural sector is predominant in most SSA economies, contributing more than one-third of the regional GNP and employing more than two-thirds of the labor force (World Bank, 2010). Agriculture is also one of the major sources of foreign exchange earnings. In spite of its central role in the region's economy, agricultural performance has not been as encouraging as in other developing countries, represented by the low cereal yield and high reliance on grain imports. On the other hand, low inherent soil fertility together with increased population pressure has caused soil degradation and nutrient depletion across much of the continent.

In the long run, sustainable agricultural growth can only be achieved through increased total factor productivity (TFP), the amount of output per unit of total factors used in the production process (Winters et al. 1998). A more efficient use of resources becomes increasingly important as countries begin to face resource constraints. Despite

evidence of improved performance in the past 10 years, there are only a few studies that have attempted to analyze SSA's agricultural productivity changes and the factors explaining those changes. Most studies have shown evidence of recovery in Africa. However, estimates of the magnitude of productivity growth vary depending on the analytical methodology and sample.

Block (1995) finds agricultural productivity growth rates during the 1970s is disappointing, but 39 SSA countries grew at approximately 1.6 percent per year from 1983 to 1988. Lusigi and Thirtle (1997) suggest that average growth in productivity for 47 African countries is 1.27 percent per year in 1961–1991. No signs of sustained growth in productivity are found during the 1960s and 1970s and productivity growth picks up after 1984, Fulginiti et al. (2004) report total gains of 0.83 percent for 41 SSA countries between 1960 and 1999. However, between 1985 and 1999 productivity rose by 1.9 percent per year. They also found evidence of fairly strong growth during the 1980s and 1990s, with annual growth rates of 1.29 and 1.62 percent, respectively.

In contrast, Trueblood and Coggins (2003) claim that although selected countries show signs of recovery in the 1980s, the SSA regional aggregate productivity has declined by an average of 0.9 percent. They attribute those losses to, among other things, the choice of the technology frontier, which is defined by the most efficient countries in the sample. Instead of using SSA countries as reference like Fulginiti et al. (2004), Trueblood and Coggins use a global average. Similarly, based on a global sample, Coelli and Prasada Rao (2005) report that 6 out of 18 African countries have productivity growth rate above 2 percent during the 1980–2000 period.

Recently, Evenson and Avila (2007) estimate the average TFP growth for Africa (including North Africa) at 1.68 percent per year in 1981-2001, higher than what they find for the 1961–1980 period (1.20 percent). Following the same fixed input cost shares, a slightly lower productivity growth rate of 1.2 percent is reported by Fuglie (2008) for SSA since 1990. Alene (2010) finds that SSA agricultural productivity grew at 1.6 percent per year1970–2004, based on a sequential technology frontier approach. In a recent paper Block (2010) revisits agricultural productivity growth in SSA and finds that total factor productivity growth has increased rapidly since the early 1980s following a period of nearly 20 years of declining rates of TFP. Block associates this

improved performance with expenditures on agricultural R&D, along with the reform of macroeconomic and sectoral policies that enhanced agricultural incentives

In addition, researchers have examined whether the source of growth is technical change or purely gains in efficiency. Lusigi and Thirtle (1997) argue that the majority of countries with higher labor-to-land ratios experience higher gains in technical progress while most countries with lower labor/land ratios experience more improvement in efficiency scores. Nin-Pratt and Yu (2008) indicate that productivity recovery is the consequence of improved efficiency in production, resulting from changes in the output structure and an adjustment in the use of inputs, including an overall net reduction in fertilizer use but increased fertilizer use in most of the best-performing countries. In contrast, Alene (2010) finds that technical progress, rather than efficiency change, is the principal source of productivity growth in SSA.

Empirical evidence on factors explaining the recovery of African agricultural productivity is sparse, with most studies looking at the relationship between productivity and policy reforms. Block (1995) finds that almost two-thirds of TFP growth can be explained by macroeconomic policy changes. Similarly, Nin-Pratt and Yu (2008) find that policy changes implemented in the mid-1980s and the second half of the 1990s, combined with technological innovations available at that time, appear to have played an important role in improving agriculture's performance.

Investment in agricultural R&D also made a significant contribution to productivity growth according to both Block (1995) and Lusigi and Thirtle (1997). This is confirmed by Alene (2010), who finds that agricultural R&D and improved weather together with policy reforms, contributed to the recovery of agricultural productivity. Other factors associated with productivity growth include institution (Fulginiti et al., 2004) and population pressure (Lusigi and Thirtle, 1997).

Generally speaking, negative productivity growth rates are observed during the 1960s and 1970s. Agricultural productivity rises since the mid-1980s, with growth rates in total factor productivity (TFP) ranging between 0.5 and 2 percent per year, a clear improvement from growth rates observed in the earlier years. Possible factors that explains TFP growth includes policy and agricultural R&D.

This study focuses on the analysis of policy changes and investments behind the recovery of SSA's agricultural sector answering the following questions: Which policy changes were behind SSA's agriculture recovery? Which policies and investment are needed to sustain agricultural TFP growth in the coming years? We examine the impact of macro and sectoral policies on agricultural productivity growth, and also the role of trade policies in SSA's export diversification and insertion in world markets. First we estimate a nonparametric Malmquist index and its components (efficiency and technical change). Instead of fixed input cost share used by other researchers, we constrain the shadow input shares in the estimation of distance functions to rule out the possibility of zero input shadow prices. Next, we update the study by Nin-Pratt and Yu (2008) by using a group of policy indicators to determine the contribution of policies to the improved performance of SSA's agricultural sector.

We make several contributions to the literature of agricultural productivity in SSA. First, this paper expands the existing literature by bringing new evidence to investigate the factors behind the dynamism of agriculture and the possible linkage between agricultural growth and policy changes. Second, we confirm the improved performance of SSA's agriculture since the mid-1980s measured in terms of TFP growth. Third, we are able to quantify the impact of various policies on productivity, suggesting that more favorable policy environment contribute to the recent recovery in agriculture.

The paper is organized as follows. The next section presents the methodology employed and the data used to estimate agricultural TFP. Section 3 presents productivity estimates and discussion of results, while main findings from the literature on SSA's policies in past decades are presented in section 4. This is followed by results of the estimation of an econometric model relating agricultural TFP series with measures of policies in section 5. The last section summarizes main findings and concludes.

2. Productivity Measures and Methodology

Productivity change is defined as the ratio of change in output to change in input. In the hypothetical case of a production unit using one input to produce one output, the measure of productivity is fairly simple to derive. However, production units can use

multiple inputs to produce one or more outputs, and under such circumstances the primary challenge in measuring TFP rises from the need to aggregate different inputs and outputs. The aggregation of inputs and outputs is both conceptually and empirically difficult. Several methods to aggregate inputs and outputs are available, resulting in different approaches to measuring TFP. Such methods can be classified into four major groups: (a) econometric production models; (b) total factor productivity indices; (c) data envelope analysis (DEA); and (d) stochastic frontiers.

The Malmquist index, pioneered by Caves, Christensen, and Diewert (1982) and based on distance functions, has been extensively used in the measure and analysis of productivity after Färe et al. (1994) showed that the index can be estimated using DEA, a nonparametric approach. The nonparametric Malmquist index has been especially popular because it is easy to compute and does not require information about input or output prices or assumptions regarding economic behavior, such as cost minimization and revenue maximization. This is especially attractive in the context of African agriculture, where input market prices are either nonexistent or insufficiently reported to provide any meaningful information for land, labor, and livestock. Malmquist index approach is chosen for its ability to decompose productivity growth into two mutually exclusive and exhaustive components: changes in technical efficiency over time (catching up) and shifts in technology over time (technical change).

The Malmquist TFP Index

The Malmquist index measures the TFP change between two data points (e.g., those of a country in two different time periods) by calculating the ratio of the distance of each data point relative to a common technological frontier. Following Färe et al. (1994), the Malmquist index between period t and $t + 1$ is given by

$$M = \left[M^t \times M^{t+1}\right]^{1/2} = \left[\frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \times \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)}\right]^{1/2} \tag{1}$$

This index is estimated as the geometric mean of two Malmquist indices, one using as a reference the technology frontier in t $\left(M^t\right)$, and a second index that uses the frontier in

$t + 1$ as the reference $\left(M^{t+1}\right)$. The distance function $D^t(x^t, y^t)$ measures the distance of a vector of inputs (x) and outputs (y) in period t to the technological frontier in the same period t. On the other hand, $D^{t+1}(x^t, y^t)$ measures the distance between the same vector of inputs and outputs in period t, but in this case to the frontier in period $t + 1$. The other two distances can be explained in the same fashion.

Färe et al. (1994) showed that the Malmquist index could be decomposed into an efficiency change component and a technical change component, and that these results applied to the different period-based Malmquist indices. It follows that

$$M = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \times \left[\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})} \times \frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)} \right]^{1/2} \tag{2}$$

The ratio outside the square brackets measures the change in technical efficiency from period t to $t + 1$, or how far the observed production is from maximum potential production. The expression inside the brackets measures technical change, capturing the shift of technology frontier between the two periods. If the efficiency change index values greater than one, it means that the production unit is closer to the frontier in period $t + 1$ than it was in period t, in other word, the production unit is catching up to the frontier. A value less than one indicates efficiency regress. The same holds for the technical change component of total productivity growth, signifying technical progress when the value is greater than one and technical regress when the index is less than one. However, as in Nin et al. (2003), the DEA approach used to estimate distances defines the frontier as a sequential frontier, ruling out the possibility of technical regress. The method has been extensively applied to the international comparison of agricultural productivity.

To define the input-based Malmquist index, it is necessary to define and estimate the distance functions D, which requires a characterization of the production technology and production efficiency. Following Kuosmanen et al. (2004), we formally defining technology and efficiency and relating this measure with allocative efficiency and an economic measure of performance. This approach allows us to highlight the importance

of shadow prices in the nonparametric estimation of distance functions and to be able to introduce new information in the estimation of distance functions to avoid the bias caused by zero shadow prices.

Technology and Distance Functions

We assume, as in Färe et al. (1994), that for each time period $t = 1,...., T$ the production technology describes the possibilities for the transformation of inputs x^t into outputs y^t, or the set of output vectors **y** that can be produced with input vector **x**. The technology in period t with $y^t \in R_+^m$ outputs and $x^t \in R_+^n$ inputs is characterized by the production possibility set as follows:

$$L^t = \{(y^t,x^t): \text{such that } x^t \text{ can produce } y^t \}. \tag{3}$$

The technology described by the production possibility set L^t satisfies the usual set of axioms: closedness, nonemptiness, scarcity, and no free lunch. The frontier of the production possibility set for a given output vector is defined as the input vector that cannot be decreased by a uniform factor without leaving the set.

The nonparametric distance functions can be defined in either the envelope form and a dual equivalent approach that can be derived from the envelope or primal form (see Kuosmanen et al. 2004). The envelope approach is normally the one preferred in the literature to estimate distances. On the other hand, the dual form has the advantage of a more intuitive specification, offering an economic interpretation of the problem. It also allows an explicit estimation of input and output shadow prices and the possibility of imposing bounds to those prices. Hence we focus here on the dual form for this study.

The dual linear program measures efficiency as the ratio of a normalized weighted sum of all outputs. The weights are obtained by solving the following problem (Coelli and Prasada Rao 2001):

$$\max_{\rho,\omega} \sum_{k=1}^{m} \rho_k\, y_{ik}$$

s.t.

$$\sum_{j=1}^{n} \omega_j x_{ij} = 1 \tag{4}$$

$$\sum_{k=1}^{m} \rho_k\, y_{ik} - \sum_{j=1}^{n} \omega_j x_{ij} \le 0 \qquad i = 1,...,r$$

$$\rho_k, \omega_j \ge 0 \qquad\qquad k = 1,...,m;\ j = 1,...,n$$

where the optimal weights ρ_k and ω_j are respectively output k and input j shadow prices.

Kuosmanen et al. (2004) generalize the dual interpretation of the distance function to the case of closed, nonempty production sets satisfying scarcity and no free lunch, showing that the distance has the following dual formulation:

$$D_0^t(x^t, y^t) = \max \left\{ \frac{\rho y^t}{\omega x^t} : \frac{\rho y^t}{\omega x^t} \le 1 \forall (y^t, x^t) \in L^t \right\} \tag{5}$$

.

They interpret this distance function as "the return to the dollar,[1] at the 'most favorable' prices, subject to a normalizing condition that no feasible input-output vector yields a return to the dollar higher than unity at those prices." There exists a vector of shadow prices for any arbitrary input-output vector; however, these prices need not be unique. Kuosmanen et al. (2004) define the set of shadow price vectors as

$$V^t(y^t, x^t) = \left\{ (\rho, \omega) \in R_+^{n+m} : \frac{\rho y}{\omega x} = D^t(y, x); \frac{\rho y^t}{\omega x^t} \le 1 \forall (y^t, x^t) \in L^t \right\} \tag{6}$$

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and contend in the spirit of the theory of revealed preferences (Varian 1984) that "the observed allocation of inputs and outputs can indirectly reveal the economic prices underlying the production decision." Based on this, they assume that decision-making units allocate inputs and outputs to maximize return to the dollar. Such prices are well

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[1] *Return to the dollar* is an economic criterion to evaluate performance. It measures the ability of producers to attain maximum revenue to cost (introduced by Georgescu-Roegen 1951 and referred to in Kuosmanen et al. 2004). The assumption of allocative efficiency depends on the specified economic objectives of the firms through the shadow price domain (Kuosmanen et al. 2004).

defined and are observed by decision makers but are not known by the productivity analyst. Assuming that decision-making units allocate inputs and outputs to maximize return to the dollar, Kuosmanen et al. (2004) define that the production vector (y^t, x^t) is allocatively efficient with respect to technology L^t and prices (ρ^t, ω^t) if and only if (ρ^t, ω^t) $\in V^t(y^t, x^t)$. Allocative efficiency is a necessary but not sufficient condition for maximization of return to the dollar given that it allows for technical inefficiency (production in the interior of the PPS). This dual approach to the problem of efficiency and input allocation will be used below to analyze the plausibility of shadow prices obtained when estimating efficiency and eventually to correct those prices, introducing exogenous information into the linear programming problem.

Introducing Bounds to Shadow Input Shares

The lack of prior price information for inputs was pointed out as the prime motivation for estimating nonparametric Malmquist indices for the analysis of TFP change in SSA. If we do not constrain the linear programming problem used in DEA to determine efficiency, we allow total flexibility in choosing shadow prices. Because of the lack of price information already mentioned, in most of the literature on efficiency and nonparametric TFP analysis, flexibility has been considered to be one of the major advantages of DEA when comparing it with other techniques used to measure efficiency or productivity (Pedraja-Chaparro et al. 1997). However, total flexibility for the weights has been criticized on several grounds, given that the weights estimated by DEA can prove to be inconsistent with prior knowledge or accepted views on relative prices or cost shares.

Pedraja-Chaparro et al. (1997) stress two main problems with respect to allowing total shadow price flexibility. First, by allowing total flexibility in choosing shadow prices, inputs considered important a priori could be all but ignored in the analysis or could end up being dominated by inputs of secondary importance. Such is the case when linear programming problems assign a zero or close to zero price to some factors because of the particular shape of the production possibility set. Second, the relative importance attached to the different inputs and outputs by each unit should differ greatly. Although some degree of flexibility on the weights may be desirable to reflect each

decision-making unit's particular circumstances, it may often be unacceptable to have weights varying substantially from one decision-making unit to another. Another argument used against total flexibility of shadow prices (Kuosmanen et al. 2006) is that in some cases, a certain amount of information regarding the input and output prices or shares might be available. In that case, the analysis can be strengthened by imposing price information in the form of additional constraints that define a feasible range for the relative prices. Therefore, a strong case seems to exist for the analysis of shadow prices obtained from DEA when estimating efficiency and TFP, and eventually for considering the introduction of restrictions on shadow prices or cost shares, setting limits between which prices or shares can vary.

To define suitable limits to the value that input shares take, we set an upper and a lower bound (a_i, b_i) to the input share in problem (4). We define the standard distance function where ρ and ω are respectively the output and input shadow prices and $\omega_i^t \times x_{io}^t$ (the input shadow prices multiplied by the input quantities) is equal to the implicit input shares as shown in Coelli and Prasada Rao (2001):

$$D^t(y_k^t, x_k^t) = \underset{\rho, \omega}{Max} \sum_{r=1}^{s} \rho_r y_{ro}^t ,$$

s.t. (7)

$$\sum_{i=1}^{m} \omega_i^t x_{io}^t = 1 ,$$

$$\sum_{r=1}^{s} \rho_r^t y_{rj}^t - \sum_{i=1}^{m} \omega_i x_{ij}^t \leq 0 ,$$

$$a_{io}^t \leq \omega_i^t x_{io}^t \leq b_{io}^t \quad i = 1, ..., m ,$$

$$\rho, \omega \geq 0 .$$

Note that the introduction of bounds on shadow input shares constitutes additional constraints to the original formulation. Restricted and unrestricted models will provide the same results only if all the additional restrictions imposed are nonbinding. In general, the narrower the imposed bounds, the larger the expected differences between model results.

To define the bounds for the input shares, we introduce information on the likely value of the shares of the different inputs from Evenson and Dias Avila (2007). In that

paper, the authors estimate crop input cost shares for 32 SSA countries by adjusting carefully measured share calculations for India. Cost shares of SSA countries were calculated by scaling India's input shares comparing India's input/cropland ratio to those ratios of the particular SSA country. Given that inputs used in the study by Evenson and Dias Avila (2007) are similar to those used here, we use information from that study to determine the maximum and minimum share values for each input among all countries and use those estimated shares as a rough reference to set the limits between which input shares in DEA estimates for SSA countries can vary. By setting these general limits for all countries, we allow input shares to vary, keeping flexibility and uncertainty about the true value of such shares and contemplating differences in the unique circumstance of each individual country. With the imposition of share bounds, the linear programming program can no longer disregard the less favorable inputs, and we ensure that the most important outputs and inputs are attached higher weights than the ones considered less important. A more thorough discussion of the bounds imposed and a comparison of the results of the constrained and unconstrained problems used in the estimation of distance functions can be found in Nin-Pratt and Yu (2010).

Data and Countries Included in This Study

To estimate TFP growth in SSA, the only internationally comparable database available to us is that of the Food and Agriculture Organization of the United Nations (FAO). It provides national time-series data from 1961 to 2006 for the total quantity of different agricultural inputs and output volumes measured in international dollars. We use one output (agricultural production) and five inputs (labor, land, fertilizer, tractors, and animal stock) for 98 countries, including 26 SSA countries, to estimate TFP.[2] Agricultural output is expressed as the quantity of agricultural production measured in millions of 1999–2001 "international dollars." Agricultural land is measured as the number of hectares of arable and permanent cropland; labor is measured as the total economically active agricultural population; fertilizer is the metric tons of nitrogen,

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[2] We combine a dissimilarity index developed by Fox et al. (2004) and a modification to the DEA model suggested by Andersen and Petersen (1993) to identify outliers. The dissimilarity index provides bilateral comparisons of the input-output vector of all countries with a reference input-output vector defined as the mean of all countries, showing how different each country is from the mean. The method by Andersen and Petersen measures the influence that some observations have on efficiency estimates of other observations.

potash, and phosphates used measured in nutrient-equivalent terms; livestock is the total number of animals (cattle, buffalo, sheep, goats, pigs, and laying hens) measured in cow equivalents.

Output growth in Sub-Saharan Africa (SSA) from 1964 to 1983 was on average 1.80 percent, with the worst performance occurring between 1972 and 1983 below the rate of increase in the use of inputs in agriculture (1.2 percent). The recovery of SSA's agriculture resulted in output growth rates of 3.2 percent per annum between 1984 and 2003, slightly surpass the population growth rate of 2.6 percent over the same period. However, despite the recent recovery, output per capita in 2003 was only close to its level in the 1960s.

3. Agricultural TFP growth, 1961–2006

The overall performance of agriculture in SSA was poor between 1961 and 2006. A simple average of TFP measures at the country level for a sample of 26 SSA countries shows that annual growth in that period was almost zero (0.02 percent). This average, however, hides significant variations across time, where two periods with contrasting results can be distinguished (Figure 1 and Table 1). The first period is characterized by poor performance and negative productivity growth (-1.33 percent per annum) stretches from the mid-1960s to the mid-1980s. Recovery starts in 1984–1985 and extends to 2006, with agricultural TFP growing at 1.37 percent per year. What more important, the growth has been accelerating: annual growth rate is 1.25 percent in 1984–1995 and this rate is boosted to 1.43 percent in 1996-2006.

The decomposition of SSA's TFP growth into efficiency and technical change shows that most TFP growth of the last 20 years is the result of SSA catching up to the frontier after falling behind during the 1970–1983 period (Table 1). It is clear from the table that between 1984 and 2006 the region was only catching up with efficiency levels of the early 1960s.

The TFP performance of individual countries varies depending on the period considered. Between 1984 and 1993, two countries explain most of agricultural TFP growth: Nigeria and Ghana, contributing 61 and 17 percent, respectively, to total TFP growth in the region. Other countries with a relatively significant contribution to TFP

growth during that period are Sudan and Tanzania (Figure 2a). Those four countries together explain 94 percent of total TFP growth in our sample over the period of 1984-1993. The number of countries contributing to total TFP growth increases significantly between 1994 and 2006, with nine countries explaining 90 percent of TFP growth during that period. In addition to the four major contributors in 1984-1993, Ethiopia, Ivory Coast, Mali, Kenya, and Cameroon also fuel the acceleration of TFP growth in 1994-2006 (Figure 2b).

Looking at agricultural TFP growth rates for individual countries between 1984 and 2006, we observe that TFP grew above 1.5 percent per annum in 10 of the 26 countries in our sample (Table 2). Angola leads the group in terms of productivity performance, growing at 4 percent annually (average index of 1.04). Nigeria and Ghana also rank high in the sample, with growth rate reach 3.4 and 3.0 percent, respectively. Tanzania and Sierra Leone also show remarkable growth and average TFP growth rates top 2 percent.

This ranking changes if we focus on most recent years between 1995 and 2006. As shown in the last six columns of Table 2, Angola is still the country with the fastest growing agricultural TFP, but Mozambique, Tanzania, and Burkina Faso rises with impressive growth in agricultural sector. Nigeria and Ghana are still among the best SSA performers, although the average TFP growth slows slightly in 1995-2006 period. Mali, Zambia, Madagascar and Ethiopia also improved their performance significantly.

Decomposition of TFP growth into its components in Table 2 shows that in general, most of TFP growth is explained by efficiency gains, which corresponds to the fact that most countries are recovering from periods of negative productivity growth and reduction in efficiency. For instance, fast TFP growth in Angola is the result of catching-up after an extended period of civil war, which is reflected in zero growth rate of technical change (index=1). Likewise, TFP growth in Nigeria and Ghana is also mainly explained by efficiency growth instead of technology advances. In the case of other countries in Coastal West Africa, only Benin shows significant contribution of technical change to TFP growth. A similar result is obtained in East Africa. In Southern Africa, the contribution of technical change to TFP appears to be important in the case of

Swaziland and Zimbabwe, but performance of agriculture in these countries was generally poor due to growing inefficiency.

To better understand TFP, partial productivity measures, namely labor and land productivity, are examined. These two indicators capture changes in the labor/land ratio, which is affected by increased rural population (or agricultural labor force) and the incorporation of arable land to crop production. Rural living standard will deteriorate if rural population grows faster than yields (Block 1995). Table 3 lists the 9 top performers of TFP growth in SSA during the period of improved performance in 1995-2006. These countries show on average high TFP growth, slow or negative growth of workers per hectare (with the exception of Angola), and increased labor and land productivity. They are more likely to have increased rural living standards through increased labor income in agriculture. A caveat to these results is that in many of these countries labor per hectare increased slowly because they were still able to incorporate more land into crop production, given that the rural population is still showing significant growth. If the availability of land decreases in the coming years, yields will need to increase faster to compensate for growth in rural population and improve rural income.

4. Policy changes and growth in agriculture

According to Anderson and Masters (2008), most African countries gain independence in the 1960s at a time when central planning was widely seen as a promising strategy for economic development. In this environment, elected governments across Africa typically kept the marketing boards and other instruments for intervention that had been developed by previous administrations, expanding their mandate and increasing public employment, in many cases as a mean for electoral politics. In the 1970s, growing fiscal deficits, current account imbalances and overvalued exchange rates were supported by project aid and loans at a time of zero or negative real interest rates as governments chose to ration credit and foreign exchange rather than expand the money supply. The result of growing government intervention was political instability and weak market institutions.

African governments faced mounting pressures for public-sector reform with the rise in world real interest rates, combined with global recession that worsened Africa's

terms of trade during the 1980s. These changes made it increasingly difficult for governments to finance the growing fiscal deficits associated with intervention. The World Bank, IMF, and USAID as lenders of last resort, made their aid conditional on devaluation, deregulation, privatization and retrenchment. As a result, trade policy reforms in the 1980s and 1990s were heavily influenced by structural adjustment programs (SAPs) sponsored by the World Bank and the IMF. Loan conditions were often blamed for the economic stresses which accompanied them, but the actual implementation of reforms was typically slow and often subject to reversal or offsetting policy changes (Anderson and Masters 2008).

As Anderson and Masters conclude, Africa's larger countries have had relatively interventionist governments followed by reform and a degree of recovery. Although the differences in the process of policy reform followed by these countries are frequently emphasized, there are also clear patterns across countries and clear trends in policy choices.

In order to "assess how much policy reform has taken place in Africa, how successful it has been, and how much more remained to be done", World Bank (1994) concludes that progress has been made, but reforms remain incomplete. It also stresses that poor macroeconomic and sectoral policies were the main factors behind the poor performance of SSA's economy between the mid-1960s and the 1980s. These poor-designed policies resulted in overvalued exchange rates, prolonged budget deficits, protectionist trade policies and government monopolies, which reduced competition, affected productivity negatively and imposed heavy taxation on agricultural exports. Food markets were controlled by state enterprises, which also monopolized the import and distribution of fertilizers and other inputs, which were often supplied to farmers at subsidized prices and on credit. The prices farmers received were generally low because of taxation or high costs incurred by state enterprises. The negative impact of such policies on agricultural prices was particularly significant in the case of export crops. During this period, African governments followed a development strategy that prioritized industrialization, with a clear bias against agriculture (Kherallah et al. 2000).

As emphasized by Kherallah et al. (2000), one of the most fundamental shifts in the development strategy for Africa was to view agriculture not as a backward sector but

as the engine of growth, an important source of export revenues and the primary means to reduce poverty. The idea behind the structural adjustment programs was that reducing or eliminating state control over marketing would promote private-sector activity and that fostering competitive markets would lead to increased agricultural production.[3]

Policy reforms have been uneven across sectors and/or across countries and occurred in two major waves. The first wave of reforms started in 1984–1985. Almost two-thirds of African countries managed to put better macroeconomic and agricultural policies in place by the end of the 1980s. Improvements in the macroeconomic framework also enabled countries to adopt more market-based systems of foreign exchange allocation and fewer administrative controls over imports (World Bank, 1994). The second wave of reforms came when many countries made major gains in macroeconomic stabilization, particularly since 1994. The devaluation of the CFA franc significantly improved the performance of the economy and of the agricultural sector in several West African countries. According to the World Bank (2000), by the end of the 1990s, the combination of sustained reforms and financial assistance was associated with better economic performance, at least at the aggregate level. Most prices have been decontrolled and marketing boards eliminated (except in some countries for key exports such as cotton and cocoa). Current account convertibility has been achieved; trade taxes have been rationalized from high average levels of 30 to 40 percent to trade-weighted average tariffs of 15 percent or less. Trade-weighted tariffs are now below 10 percent in more open countries such as Uganda and Zambia. Arbitrary exemptions, although still numerous, have also been rationalized.

In the case of agriculture reform, most policy changes took place after 1986–1987, and significant progress was achieved. Most countries lowered export taxes, raised administered producer prices, reduced marketing costs (usually by deregulation and de-monopolization of export marketing), and depreciated the exchange rate of the domestic

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[3] The reforms included four types of measures as summarized by Kherallah et al. (2000): (a) liberalizing input and output prices by eliminating subsidies on agricultural inputs and bringing domestic crop prices in line with world prices; (b) reducing overvalued exchange rates; (c) encouraging private-sector activity by removing regulatory controls in input and output markets; and (d) restructuring public enterprises and restricting marketing boards to activities such as providing market information.

currency (Cleaver and Donovan 1995). According to the World Bank (2008), the average net taxation of agriculture in SSA was more than halved between 1980–1984 and 2000–2004. During the same period, agriculture-based countries (mostly African countries) lowered protection of agricultural importables, from a 14 percent tariff equivalent to 10 percent, and reduced taxation of exportables, from 45 percent to 19 percent. Most of the decline in taxation is the result of improved macroeconomic policies (World Bank 2008).

As a result of these changes in the first years of the reform, two-thirds of the adjusting countries were taxing their farmers less, and policy changes increased real producer prices for agricultural exporters. Most of the governments that had major restrictions on the private purchase, distribution, and sale of major food crops before adjustment have withdrawn from marketing almost completely. On the other hand, governments sold only a small share of their assets, although governments have stopped expanding their public enterprise sectors (World Bank 1994).

Market reforms were more comprehensive in food markets than in export crop or input markets. Kherallah et al. (2000) explain progress in food market reforms by the losses that those markets brought to governments, whereas in contrast, the purchase and sale of export commodities brought considerable revenue to many governments. Also, major restrictions on the purchase and sale of agricultural commodities were eliminated: Benin (tubers); Ethiopia (teff, maize, wheat); Mali (millet, sorghum); Tanzania (maize); Malawi and Zambia partially (maize) (Kherallah 2000).

Anderson and Masters (2008) estimate nominal and relative rates of assistance (NRA and RRA respectively) to measure the effect of government policies on returns to farmers in SSA.[4] We highlight here some of their main conclusions from the analysis of changes in rates of assistance to agriculture:

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[4] NRA is defined as the percentage by which government policies have raised gross returns to farmers above what they would be without the government's intervention and are based on estimates of assistance to individual industries at the farm gate. As farmers are affected not only by the prices of their own outputs, but also by the incentives nonagricultural producers face affecting mobile resources engaged in other sectors, Anderson and Masters (2008) also estimate NRAs for the nonfarm sector to capture the effect that policies had on agriculture through their effect on nonfarm activities. RRAs are then calculated as the ratio of farm and nonfarm NRAs. See Anderson and Masters for details on these estimates.

- At present, African governments have removed much of their earlier anti-farm and anti-trade policy biases, and most of these changes have come from reduced taxation of farm exports.

- Substantial distortions remain and still impose a large tax burden on Africa's poor. In constant 2000 US dollar terms, the transfers paid by farmers were reduced to an average of $41 per person working in agriculture from a peak value of $134 in the late 1970s. However, this lower amount is still appreciably larger than in other regions, given that in both Asia and Latin America, the average agricultural NRAs and RRAs reached zero by the early 2000s.

- Trade restrictions continue to be Africa's most important instruments of agricultural intervention. Domestic taxes and subsidies on farm inputs and outputs, and non-product specific assistance, are a small share of total distortions to farmer incentives in Africa. As a result, policy incidence on consumers tends to mirror the incidence on producers, with fiscal expenditures playing a much smaller role than in more-affluent regions.

5. Linking Policy Reforms with TFP Growth in Agriculture

Since the implementation of structural adjustment programs, policymakers and academics have argued about the causes of and the solutions to the African crisis and the impact of the structural adjustment promoted by the international financial institutions in the 1980s and 1990s (see, for example, Arndt et al. 2000; Boratav 2001; Mkandawire 2005). As discussed above, agricultural productivity in SSA was affected by distortions to agricultural incentives through macroeconomic, sectoral policy and trade measures. Importantly, the total effect of distortions on the agricultural sector depends not only on direct agricultural policy measures, but also on policy measures altering incentives in non-agricultural sectors. It is therefore important to link a comprehensive package of government assistance with producers' performance.

We use some broad indicators to capture policies that could potentially affect agricultural productivity. We group these indicators in four major groups. The first set of indicators captures macroeconomic policy: money supply, inflation, real exchange rate and valuation of local currency. Following Rodrik (2008), the real exchange rate is

defined as exchange rate measured in purchasing power parity (PPP) terms to allow cross country comparison. When real exchange rate is greater than one, the value of the local currency is lower (or more depreciated) than it is in PPP terms. The real exchange rate is corrected to take into account the Balassa-Samuelson effect: as poor countries grow, the labor productivity of their traded-goods sector will rise, spilling over to wages and prices in producing non-traded goods, and so their price structures should become more like those of developed countries. We obtain the index of undervaluation as the difference between actual and adjusted real exchange rate. If the undervaluation index is above one, the local currency is undervalued.

The second set of indicators is used to describe support to the agricultural sector, and includes nominal protection coefficients (NPC) and nominal rates of assistance (NRA). NPC measures the ratio between the average price received by producers at the farm gate (including payments per tonne of current output), and the border price, measured at the farm gate. An NPC value greater than one suggests that producers are being protected, while an NPC value below one means that agricultural producers are being taxed. If producers' share in border price increases, NPC value increases, suggesting that explicit taxation is decreasing. The Nominal Rate of Assistance (NRA) is computed (Anderson and Valenzuela 2009) as the percentage by which government policies have raised gross returns to farmers above what they would be without the government's intervention (or lowered them, if NRA<0). The higher NRA value, the larger price distortion is. Average NRA defines the delivered rates of distortion to domestic prices for food and export products from policy interventions. Support to agricultural sector can also come in the form of investment in agricultural R&D and government spending in agriculture, which is proxied by agricultural R&D per researcher and share of agriculture in total government spending, respectively.

The third set of variables focuses on the terms of trade of agricultural sector, including real producer price (RPP, calculated at the farmgate price divided by CPI), as well as relative price of agricultural products to nonagricultural products and relative price of agricultural products to industrial products (expressed as the ratio of agricultural GDP deflators to nonagricultural and industry GDP deflators, respectively). These

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variables not only inspect the price support to agricultural products, but also take into account assistance to producers of non-agricultural tradables.

The last set of variables measures the trade openness as the ratio of trade to GDP: openness of agricultural sector (ratio of agricultural trade to agricultural GDP). We calculate the dependence on agricultural imports as ratio of agricultural import to agricultural GDP and the importance of international markets for agricultural output as ratio of agricultural export to agricultural GDP. Table 4 summarizes the variables, sources, coverage and expected impact on TFP.

In order to measure the effect of policy interventions on agricultural TFP, the analytical model of the constrained agricultural TFP growth rate is expressed as a function of policies variables including macro policy, support to agriculture, agriculture term of trade and agriculture trade. Since many variables are expressed in indexes, we construct an unbalanced panel dataset of growth rates starting at 1971. Evidence from panel unit root test indicates that growth rate variables are stationary, suggesting that the series considered as our panel are stationary and our parameter estimates are valid. Although Panel vector autoregression does not report serious endogeneity problem, past literature suggest that ignoring endogenous trade variables could produce biased and inconsistent estimators (Rodriguez and Rodrik, 2001). At present, instrumentation with geography is still the most promising way to solve the endogeneity problem (Irwon and Tervio, 2002; Noguer and Siscart 2005). This paper will take this approach to address the endogeneity issue.

Following Frankel and Romer (1999), the empirical regression adopts a two-stage approach. In the first stage, we derive an instrument of trade openness by estimating a gravity model of bilateral trade. The gravity model is defined as

$$\ln\left(\frac{trade_{ij}}{GDP_i}\right) = \alpha_0 + \alpha_1 lnD_{ij} + \alpha_2 lnN_i + \alpha_3 lnA_i + +\alpha_4 lnN_j + \alpha_5 lnA_j + \alpha_6 L_i + \alpha_7 L_j +$$
$$\alpha_8 B_{ij} + \alpha_9 B_{ij} lnD_{ij} + \alpha_{10} B_{ij} lnN_i + \alpha_{11} B_{ij} lnA_i + +\alpha_{12} B_{ij} lnN_j + \alpha_{13} B_{ij} lnA_j +$$
$$\alpha_{14} B_{ij} L_i + \alpha_{15} B_{ij} L_j + \alpha_{16} SSA_j + \varepsilon_{ij} \tag{8}$$

Where $ln\left(\frac{trade_{ij}}{GDP_i}\right)$ is the share of trade between country i and country j on country i's GDP, D_{ij} is the distance between the countries, the trading partners size is measured in population N and area A, L is a dummy for landlocked countries, and B is a

dummy for a common border between country *i* and *j*, *SSA* is a dummy indicating country *j* is also located in sub-Saharan Africa, ε is the error term.

Bilateral trade is calculated as the sum of the value of exports and imports between country *i* and *j*, and is drawn from the UN Comtrade database. The matrix of geographic distance between two countries, being landlocked, land area, sharing a common border (contiguity) are extracted from the Centre d'Etudes Prospectives et d'Informations Internationals (CEPII) database, as described in Head, Mayer, and Ries (2010). The distance is calculated using the great circle formula between two countries. GDP and population data comes from the World Bank's World Development Indicator database (World Bank, 2010). The bilateral trade data covers 161 countries in 1962-2005.

The gravity model results are shown in Table 5, which are generally consistent with our expectation and results in the gravity model literature. Distance between two countries is negatively associated with bilateral trade. Trade between country *i* and country *j* decreases in country *i*'s population and both countries' area, confirming the inverse relationship between countries' trade share and their sizes. In addition, trade increases in country *j*'s population. Trade could fall by as much as 35 percent if country *i* is landlocked, and drop even more if country *j* is also landlocked. Substantially lower trade volume is reported if the trading partner (country *j*) is located in sub-Saharan Africa, but this is not necessarily the case if country *i* is a SSA country. Although the presence of contiguity (common border) does not increase trade, the impacts of other geographic factors on trade are changed as the interaction terms between border and other variables are mostly significant. For instance, distance is no longer a deterrent if two countries share a border. Sharing a common border can facilitate flow of commodities in landlocked countries. The statistical significance is very high for all variables with the exception of some interaction terms, indicating that only a small fraction of country pairs in the sample share a common border (Ferrarini, 2010). Similar to Frankel and Romer (1999), our panel results verify that geographic variables are one of the major contributors of trade with an R-square of 0.36.

Next, the fitted value from the gravity model of bilateral trade is aggregated across trade partners to generate the trade instrument variable (Frankel and Romer,

1999). The constructed trade share in GDP of country *i* that is attributable to geographic factors is expressed as

$$\widehat{T}_i = \sum_{j \neq i} \exp \left[\ln \left(\frac{\text{trade}_{ij}}{\text{GDP}_i} \right) \right] \qquad (9)$$

The quality of the instrument is evaluated by examining the resemblance of the instrument, estimated trade share $\widehat{T}$, with the actual share T. Both Pearson and Spearman correlation report high correlation coefficients above 0.5, slightly lower than 0.57 reported by Ferrarini (2010). The correlation coefficient is 0.68 when applied to 127 countries in 1985, higher than the correlation of 0.62 found by Frankel and Romer (1999) in 150 countries. Similarly, a visual presentation of the relationship between the estimated and actual ratio prove that a major portion of the variation in overall trade can be explained by the geographic variables (Figure 3).

Agricultural products are a large part of total trade for many SSA countries. On average agricultural commodities account for 31 percent of export revenue and 21 percent of imports in 2000-2005. This ratio can reach more than 70 percent in some West African countries like Benin, Burkina Faso, and Guinea-Bissau. Therefore, we also introduce two alternative variables as instruments for exports and imports to reflect the share of agricultural export and import in GDP.

In the second stage of analysis, we regress agricultural TFP on the four sets of policy variables, namely, macroeconomic policy, support to agriculture, agricultural terms of trade and agricultural trade openness. Since many variables within the same set are highly correlated and have different country and time coverage, we examine different variable combinations for result robustness. Table 6 presents the results of panel and instrumental variable (IV) regressions. We expect the coefficient of money supply to be positive as higher money supply implies more active economic activities and a more productive agricultural sector. Higher inflation increases uncertainty over future relative prices, high price volatility, discourages investment and savings, and eventually might lead to lower economic growth. The coefficients of agricultural support are expected to be positive as support should motivate producers to invest, increase the use of inputs and the adoption of new technology. The estimated coefficients from the panel fixed effect model are reported in the first column of Table 6. The coefficients of money supply and inflation are significant and of the expected sign. Interestingly, we find agricultural

sector support and openness of agricultural trade negatively associated with productivity growth.

In order to better understand the effect of agricultural trade and the negative sign of agricultural trade openness in Table 6, we disaggregate trade into agricultural export and agricultural import. The last five columns in Table 6 describe the IV estimation results using different instruments for agricultural trade openness. IV analysis does not yield statistically significant results when using the share of trade, agricultural trade, or agricultural export in GDP (columns 2-4 in Table 6). However, estimated coefficients based on the share of agricultural import in GDP (columns 5 and 6 in Table 6) are almost identical to that of panel fixed effect, which confirms the panel VAR results of no significant endogeneity among agricultural trade openness and other policy variables.

In order to examine the robustness of the trade variable, we replace the trade openness variable used in the regressions reported in Table 6 with two separate trade variables: the share of export and import in GDP, instrumented with their corresponding predicted values produced in the first stage of gravity model regression. This disaggregation also allows us to pinpoint the relative importance of export and import in promoting agricultural productivity. Table 7 summarizes the results using alternative trade indicators. The coefficients of money and inflation under fixed effect models are unchanged from the original trade openness model definition. However, only the coefficients of agricultural imports remain significant despite different instruments. The results echo our finding in Table 6, suggesting that growth in agricultural productivity is mainly driven by agricultural imports rather than exports. The negative sign suggests that high dependence on agricultural imports is associated with productivity slowdowns. That is, import of agricultural commodities has a depressing effect on domestic productivity in SSA countries.

Instead of supporting policies for agricultural sector in general, we also zoom in to examine the impact of subsector specific policies on agricultural TFP. Table 8 reports three sets of agricultural supporting policies: protection coefficient (NPC) and real producer price (RPP) for agriculture, agricultural export crops, and cereals. Again, the only significant coefficient is for agricultural imports.

When we apply nominal rate of assistance of cereal and cash crops to a smaller sample of nine countries (not reported in Table 9), the beneficial effect of relative price is pronounced and consistent across all model definition, while improved terms of trade for agricultural commodities life productivity with a considerable elasticity of 0.1.

Our last group of agricultural support variables includes agricultural R&D and government expenditure, which are only applied to a smaller sample due to data availability. Table 9 shows that although the coefficients of agricultural R&D are not significant under model specification, the coefficients of money supply, inflation, sectoral support and trade openness are all significant and greater than in the large sample. If the sample is further narrowed down to five major agricultural producers (Nigeria, Ghana, Cote d'Ivoire, Sudan and Kenya), none of the policy variables proves relevant to agricultural productivity (right panel of Table 9). Estimation results remain unchanged when relative price between agricultural and nonagricultural products is replaced with real producer price to include other important countries like Ethiopia. The results not only further confirm the relationship between agricultural productivity and policies, but also highlight the robustness of the relationship under different definition of agricultural terms of trade.

Public expenditure in agricultural sector indicates the importance of agriculture in government policy agenda (Table 10). Parallel to the results above, the small sample of eight SSA countries corroborates our findings, showing positive correlation between improved terms of trade for agricultural products and enhance TFP performance. Lower TFP scores could be driven by high inflation or lower protection of imports.

Instead of using money supply and inflation, Table 11 and Table 12 show regression results using the real exchange rate and the index of currency undervaluation as alternative measures to represent macroeconomic policy, respectively. Trade theory predicts that undervalued currency (low real exchange rate in Table 11 and high index of currency undervaluation in Table 12) suggest a depreciation of local currency, which encourage export and discourage imports. If the real value of local currency decreases and the depreciation is passed back to domestic farmers, productivity should increase. Our results in Table 11 and Table 12 showcase the relationship. The effects of other variables are consistent with previous model using fiscal policies: higher dependence on

import openness appears to dampen productivity and favorable prices for agricultural products provide considerable incentives for farmers to improve performance.

In summary, our two-stage approach shows that geographic factors account for a major part of variation in trade performance. Fiscal policies and exchange rates do have impact on agricultural TFP growth. We find a positive impact of money supply on productivity, and also that inflation had a detrimental effect on agricultural TFP. Government's policy can also boost TFP through the channel of local currency depreciation. In addition, the impact of trade is mainly channeled through imports of agricultural products, which discourage domestic production. In addition, our results are consistent under different model specifications using various agricultural policy combinations, proving the robustness of our results.

6. Conclusions

In this study we analyze the evolution of SSA's agricultural TFP between 1961 and 2006 looking for evidence of recent changes in growth patterns using an improved nonparametric Malmquist index and its components, efficiency and technical change indices, for 37 SSA countries. Unlike previous studies using this methodology, we constrain the linear programming problem used to estimate distance functions for the Malmquist index to rule out the possibility of zero input shadow prices. We also look at the contribution of different countries to total TFP growth in SSA and analyze changes in the composition of outputs and inputs. Finally, we estimate an econometric model relating TFP growth to policy interventions in agriculture and trade.

Results of our TFP estimates show a remarkable recovery in the performance of SSA's agriculture starting in the mid-1980s and early 1990s after a long period of poor performance and decline, which is mostly attributable to the catching up of technological frontier. Results of our econometric analysis point to policy changes in SSA countries as one of the major factors determining the agricultural sector's improved performance.

The favorable impact of policy changes show that policies applied by many SSA countries after independence imposed a heavy burden on agriculture, and that the structural adjustment implemented in the region brought a more favorable fiscal and sectoral policy environment for agriculture. This more favorable policy environment

resulted in improved allocation efficiency and increased production, a more efficient use of inputs, and as a consequence of those, increased productivity. We also obtain a non-significant impact of agricultural R&D investment on TFP, which is likely reflecting the lack of technical progress experienced by SSA's agriculture in recent years and the strong relationship between TFP performance and policy during the analyzed period.

Output growth and changes in the relative use of inputs resulted in a significant increase in output per hectare, after several years of little or no growth. Considering TFP growth together with balanced growth in land and labor productivity as indicators of good agriculture performance, we find nine countries (Angola, Nigeria, Ghana, Mozambique, Guinea, Cameroon, Mali, Zambia and Ethiopia) with relatively high TFP growth and sustained growth in labor and land productivity from 1995 to 2006.

Despite improved agricultural performance between 1985 and 2006, several warning signs still exist, calling for more efforts to sustain TFP growth in the coming years. First, the decomposition of TFP growth into efficiency and technical change shows that most TFP growth in the last 20 years is the result of SSA catching up to the frontier after falling behind between 1970 and 1984.. Without increases in the rate of growth of technical change, TFP growth is expected to slow down in the coming years as countries catch up with efficiency levels at the production frontier. According to our estimates, a slowdown in TFP growth is already apparent in the cases of Nigeria and Ghana, the leaders of the recovery of SSA's agriculture in the mid-1980s. Second, substantial distortions remain that still impose a large tax burden on Africa's poor, and are much larger than those in other developing regions as shown by Anderson and Masters (2008). Third, sustained growth in labor productivity faces the challenge of population growth and related increases in agricultural labor per hectare. In many countries, expansion of labor productivity was possible because those countries were still able to incorporate more land into crop production. If the availability of land reduces in the coming years, yields will need to increase faster to compensate for growth in rural population and improve rural income.

References

Alene, A.D. 2010. Productivity growth and the effects of R&D in African agriculture. *Agricultural Economics,* 41: 223–238

Andersen, P. and N.C. Petersen, 1993. "A procedure for Ranking Efficient Units in Data Envelopment Analysis." *Management Sciences* 39(10): 1261-1264.

Anderson, K. and W. Masters 2008. Distortions to Agricultural Incentives in Sub-Saharan and North Africa. Agricultural Distortions Working Paper 64, The World Bank: Washington D.C.

Anderson, K. and E. Valenzuela. 2008. *Global estimates of distortions to agricultural incentives, 1955 to 2007*. Available at: ww.worldbank.org/agdistortions. Date accessed: February 2010.

Arndt, C., H. Tarp Jensen, and F. Tarp. 2000. Stabilization and structural adjustment in Mozambique: An appraisal. *Journal of International Development* 12: 299–323.

ASTI (Agricultural Science and Technology Indicators). 2010. Washington, D.C.: International Food Policy Research Institute. http://www.asti.cgiar.org/, last accessed March 2011.

Block, S., 2010. The Decline And Rise Of Agricultural Productivity In Sub-Saharan Africa Since 1961, National Bureau Of Economic Research (NBER), Working Paper 16481, October.

Block, S. A. 1995. The recovery of agricultural productivity in Sub-Saharan Africa. *Food Policy* 20: 385–405.

Boratav, K. 2001. Movement of relative agricultural prices in Sub-Saharan Africa. *Cambridge Journal of Economics* 25: 395–416.

Caves, D. W., L. R. Christensen, and W. E. Diewert. 1982. The economic theory of index numbers and the measurement of input, output, and productivity. *Econometrica* 50: 1393–414.

Cleaver, K. M., and W. G. Donovan. 1995. Agriculture, poverty, and policy reform in Sub-Saharan Africa. World Bank Discussion Papers, Africa Technical Department Series, No. 208, World Bank, Washington, D.C.

Coelli, T. J., and D. S. Prasada Rao. 2001. Implicit value shares in Malmquist TFP index numbers. Centre for Efficiency and Productivity Analysis, Working Papers, No. 4/2001, School of Economic Studies, University of New England, Armidale.

Coelli, T. J., and D. S. Prasada Rao. 2005. Total factor productivity growth in agriculture: A Malmquist index analysis of 93 countries, 1980–2000. *Agricultural Economics* 32 (s1): 115–34.

Evenson, R. E., and A. F. Dias Avila. 2007. FAO data-based TFP measures. In ch. 31of *Handbook of agricultural economics,* vol. 3., *Agricultural development: Farmers, farm production, and farm markets,* edited by R. E. Evenson, P. Pingali, and T. P. Schultz. Amsterdam North Holland.

FAO (Food and Agriculture Organization of the United Nations). 2007. FAOSTAT database. http://www.fao.org/. Accessed May 5.

Färe, R., S. Grosskopf, M. Norris, and Z. Zhang. 1994. Productivity growth, technical progress, and efficiency change in industrialized countries. *American Economic Review* 84: 66–83.

Ferrarini, B. 2010. Trade and income in Asia: Panel data evidence from instrumental variable regression. Economics Working Paper No. 234. Manila, Philippines: Asian Development Bank.

Fox, K.J, R.J. Hill, and W.E. Diewert, 2004. "Identifying Outliers in Multi-Output Models." Journal of Productivity Analysis, 22: 73-94

Frankel, J. A. and D. Romer. 1999. Does trade cause growth? *American Economic Review* 89(3): 379-399.

Fuglie K., 2008. Is a slowdown in agricultural productivity growth contributing to the rise in commodity prices? *Agricultural Economics* 39: 431–441.

Fulginiti, L. E., R. K. Perrin, and B. Yu. 2004. Institutions and agricultural productivity in Sub-Saharan Africa. *Agricultural Economics* 4: 169–80.

Head, K., T. Mayer, and J. Ries. 2010. The erosion of colonial trade linkages after independence. *Journal of International Economics* 81(1):1-14.

Irwin, D. A. and M. Tervio. 2002. Does trade raise income? Evidence from the twentieth century. *Journal of International Economics* 58(1): 1-18.

Kherallah, M., C. Delgado, E. Gabre-Madhin, N. Minot, and M. Johnson. 2000. The road half traveled: Agricultural market reform in Sub-Saharan Africa. Food Policy Report, IFPRI, Washington D.C.

Kuosmanen, T., L. Cherchye, and T. Sipiläinen. 2006. The law of one price in data envelopment analysis: Restricting weight flexibility across firms. *European Journal of Operational Research* 127 (3): 735–57.

Kuosmanen, T., T. Post, and T. Sipiläinen. 2004. Shadow price approach to total factor productivity measurement: With an application to Finnish grass-silage production. *Journal of Productivity Analysis* 22: 95–121.

Lusigi, A., and C. Thirtle. 1997. Total factor productivity and the effects of R&D in African agriculture. *Journal of International Development* 9: 529–38.

Mkandawire, T. 2005. Maladjusted African economies and globalization. *Africa Development* 30 (1/2): 1–33.

Nin, A., C. Arndt, and P. Preckel. 2003. Is agricultural productivity in developing countries really shrinking? New evidence using a modified non-parametric approach. *Journal of Development Economics* 71: 395–415.

Nin-Pratt, A. and B.Yu. 2008. An updated look at the recovery of agricultural productivity in sub-Saharan Africa. IFPRI Discussion Paper 00787, Washington, D.C.

Nin-Pratt, A & B Yu. 2010. Getting implicit shadow prices right for the estimation of the Malmquist index: The case of agricultural total factor productivity in developing countries. *Agricultural Economics* 41: 349–360

Noguer, M. and M. Siscart. 2005. Trade raises income: a precise and robust result. *Journal of International Economics* 65(2): 447-460.

Pedraja-Chaparro, F., J. Salinas-Jimenez, and P. Smith. 1997. On the role of weight restrictions in data envelopment analysis. *Journal of Productivity Analysis* 8: 215–30.

Rodrik, D. 2008. The real exchange rate and economic growth. Brookings Papers on Economic Activity 2008:2. Washington: Brookings Institution.

Rodriguez, F. and D. Rodrik. 2001. Trade policy and economic growth: A skeptic's guide to the cross-national evidence. In B. Bernanke and K. S. Rogoff (eds.) NBER *Macroeconomics Annual 2000* 15: 261-338. Cambridge, MA; MIT Press.Sala-i-Martin, X. and M. Pinkovskiy. 2010. African poverty is falling...much faster than you think! Working Paper 15775, NBER: Cambridge.

SPEED (Statistics of Public Expenditure for Economic Development). 2010. Washington, D.C.: International Food Policy Research Institute. http://www.ifpri.org/book-39/ourwork/programs/priorities-public-investment/speed-database, last accessed March 2011.

Trueblood, M. A., and J. Coggins. 2003. Intercountry agricultural efficiency and productivity: A Malmquist index approach. Mimeo. World Bank, Washington, D.C.

Van de Walle, N. 2001. *African economies and the policy of permanent crisis, 1979–99.* Cambridge: Cambridge University Press.

Varian, H. 1984. The nonparametric approach to production analysis. *Econometrica* 52 (3): 579–97.

Winters, P., A. de Janvry, E. Sadoulet, and K. Stamoulis. 1998. The role of agriculture in economic development: Visible and invisible surplus transfers. *Journal of Development Studies* 34 (5): 71–97.

World Bank. 1994. *Adjustment in Africa: Reform, results, and the road ahead. A policy research report.* New York: Oxford University Press.

World Bank. 2000. Can Africa claim the 21st century? Washington, D.C.

World Bank (2004), "Millennium Development Goals", (http://web.worldbank.org/WBSITE/EXTERNAL/EXTABOUTUS/0,,contentM K:20104132~menuPK:250991~pagePK:43912~piPK:44037~theSitePK:29708,0 0.html). Date accessed February 2010.

World Bank. 2008. World development report 2008: Agriculture for development. Washington, D.C.

World Bank. 2010. Washington, D.C.: World Bank. http://data.worldbank.org/data-catalog/world-development-indicators, last accessed March 2011.

Figure 1. Cumulative agricultural TFP growth and decomposition in efficiency and technical change for SSA, simple geometric mean (index =1 in 1961)
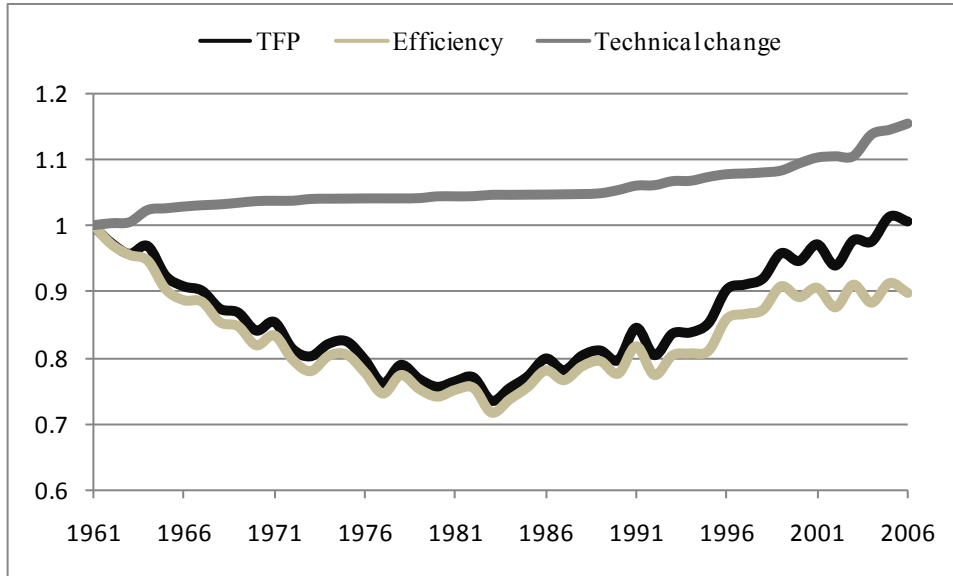
Source: Authors' estimation

Figure 2a. Contribution of different countries to TFP growth in SSA, 1984–1993
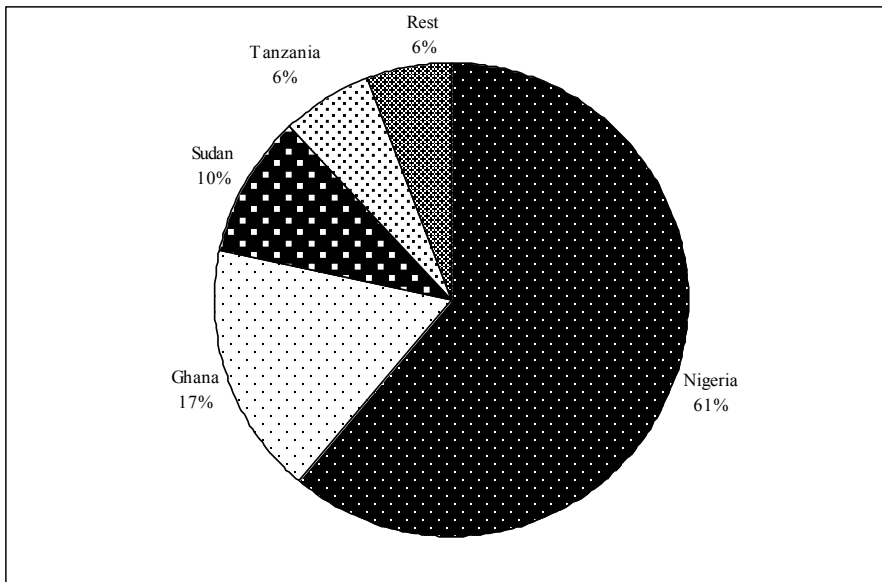
Figure 2b. Contribution of different countries to TFP growth in SSA, 1994–2003
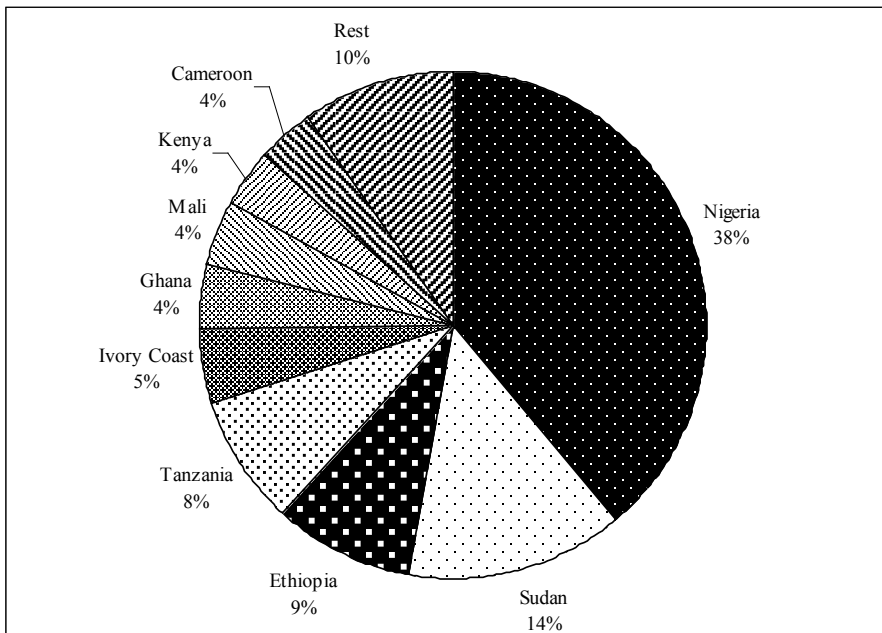
Source: Authors' estimation.

Figure 3. Estimated versus actual trade share
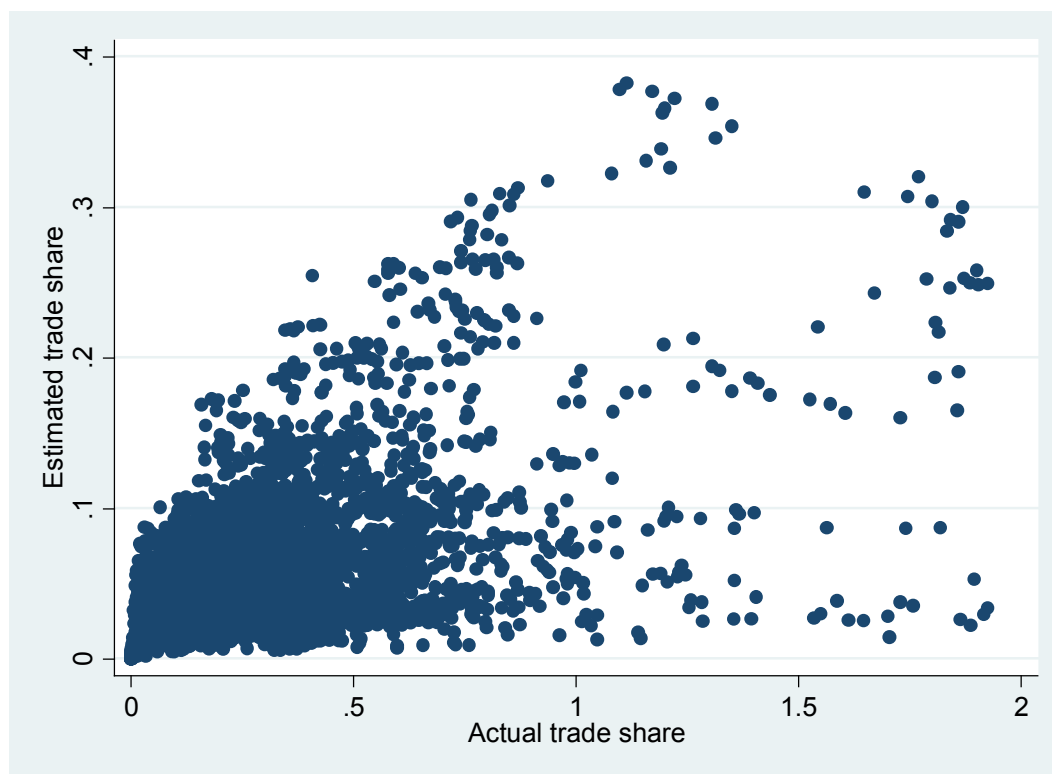
Source: Authors' estimation.

Table 1. TFP growth rate and decomposition for different periods (percentage)

	TFP	Efficiency	Technical change
1961-2006	0.02	-0.24	0.32
1961-1983	-1.33	-1.32	0.20
1984-2006	1.37	0.90	0.45
1984-1995	1.25	1.28	0.25
1996-2006	1.43	0.77	0.65

Source: Authors estimation.

Table 2. Ranking of countries by TFP growth performance, 1984-2006 and 1995-2006 (Index=1 means zero growth, and TFP=Efficiency*Technical change)

	1984-2006				1995-2006		
	TFP	Efficiency	Tech. change		TFP	Efficiency	Tech. change
Angola	1.040	1.040	1.000	Angola	1.063	1.063	1.000
Nigeria	1.034	1.034	1.000	Mozambique	1.043	1.043	1.000
Ghana	1.030	1.028	1.002	Tanzania	1.037	1.037	1.000
Tanzania	1.024	1.024	1.000	Burkina Faso	1.034	1.026	1.007
Sierra Leone	1.024	1.017	1.006	Sierra Leone	1.030	1.017	1.012
Togo	1.019	1.014	1.005	Nigeria	1.025	1.025	1.000
Kenya	1.018	1.013	1.005	Ghana	1.021	1.016	1.004
Sudan	1.017	1.017	1.000	Mali	1.021	1.019	1.002
Cameroon	1.016	1.011	1.005	Zambia	1.020	1.019	1.001
Chad	1.016	1.014	1.002	Madagascar	1.018	1.018	1.000
Mali	1.016	1.015	1.001	Ethiopia	1.016	1.015	1.001
Benin	1.016	1.000	1.016	Cameroon	1.014	1.005	1.009
Mozambique	1.014	1.014	1.000	Guinea	1.014	1.014	1.000
Burkina Faso	1.013	1.010	1.004	Zimbabwe	1.011	0.987	1.024
Zambia	1.013	1.013	1.000	Togo	1.010	1.004	1.006
Gabon	1.013	1.013	1.000	Kenya	1.010	1.001	1.009
Malawi	1.013	1.009	1.003	Ivory Coast	1.009	1.002	1.007
Ethiopia	1.010	1.010	1.001	Gabon	1.009	1.009	1.000
Ivory Coast	1.009	1.006	1.004	Malawi	1.008	1.001	1.007
Madagascar	1.004	1.004	1.000	Sudan	1.007	1.007	1.000
Guinea-Bissau	1.004	1.003	1.001	Guinea-Bissau	1.002	1.001	1.001
Zimbabwe	1.000	0.985	1.015	Benin	1.001	0.986	1.015
Senegal	1.000	0.996	1.004	Gambia	1.000	1.000	1.000
Guinea	0.999	0.999	1.000	Swaziland	0.999	0.942	1.061
Swaziland	0.993	0.957	1.037	Chad	0.998	0.994	1.004
Gambia	0.989	0.989	1.000	Senegal	0.977	0.970	1.006

Source: Authors' estimation.

Table 3. Annual changes in labor/land ratios, labor and land productivity, and TFP (percentage) in best performing countries, 1995–2006

	Labor/land	Land productivity	Labor productivity	TFP
Angola	1.82	4.50	2.63	6.35
Nigeria	-0.65	1.47	2.14	2.47
Ghana	-0.61	1.46	2.09	2.06
Mozambique	0.11	1.94	1.83	4.32
Guinea	-0.97	0.71	1.69	1.43
Cameroon	0.50	2.02	1.51	1.43
Mali	0.38	1.70	1.32	2.05
Zambia	0.58	1.76	1.17	1.98
Ethiopia	-0.73	0.42	1.16	1.64

Source: Authors estimation.

Table 4. Summary of policy variables

Variable	Source	Year	Country	Expect sign
Dependent variables				
TFP	Authors' calculation	1962-2005	39	
Set 1 - macro policies				
Money supply	WDI (2010)	1970-2005	37	+
Inflation	WDI (2010)	1970-2005	37	-
Real exchange rate	Authors' calculation	1970-2005	37	-
Undervalue of currency	Authors' calculation	1970-2005	37	+
Set 2 - support to agricultural sector				
NPC	Authors' calculation	1970-2005	37	+
NRA	Anderson and Valenzuela (2008)	1962-2005	12	-
Agri. R&D	ASTI (IFPRI, 2011)	1981-2005	26	+
Agri. expenditure share	SPEED (IFPRI, 2010)	1980-2007	12	+
Set 3 - agricultural term of trade				
RPP	Authors' calculation	1970-2005	37	+
Relative price agri./nonag.	Authors' calculation	1970-2005	28	+
Relative price agri./industry	Authors' calculation	1970-2005	28	+
Set 4 - openness of agricultural trade				
Trade openness (export+import)/GDP	Authors' calculation	1962-2005	37	+
Ag trade openness (ag export+ag import) /agGDP	Authors' calculation	1970-2005	37	+
Dependence of ag import ag import/agGDP	Authors' calculation	1970-2005	37	-
Importance of ag export ag export/agGDP	Authors' calculation	1970-2005	37	+

Source: Authors' calculation based on WDI (2010).

Table 5. Gravity model estimation

Variable	ln(openness)		ln(export share)		ln(import share)	
	coef.	std. error	coef.	std. error	coef.	std. error
lnd	-1.01	0.006***	-0.90	0.006***	-0.89	0.006***
lnn_i	-0.02	0.004***	-0.07	0.004***	-0.10	0.004***
lna_i	-0.19	0.003***	-0.15	0.003***	-0.17	0.003***
lnn_j	0.79	0.003***	0.77	0.004***	0.79	0.004***
lna_j	-0.16	0.003***	-0.16	0.003***	-0.13	0.003***
landlock_i	-0.35	0.014***	-0.23	0.015***	-0.36	0.015***
landlock_j	-1.09	0.014***	-1.08	0.015***	-0.85	0.016***
ssa_i	0.36	0.011***	0.09	0.012***	0.33	0.011***
ssa_j	-1.62	0.011***	-1.48	0.012***	-1.65	0.013***
border	-0.68	0.305**	1.06	0.313***	1.04	0.321***
borderXlnd	0.55	0.041***	0.39	0.042***	0.37	0.043***
borderXlnn_i	-0.23	0.027***	0.00	0.027	-0.28	0.028***
borderXlna_i	-0.03	0.025	-0.12	0.026***	-0.02	0.026
borderXlnn_j	-0.09	0.027***	-0.19	0.027***	0.09	0.028***
borderXlna_j	-0.10	0.025***	-0.07	0.025***	-0.17	0.026***
borderXlandlock_i	0.88	0.074***	0.58	0.071***	1.03	0.073***
borderXlandlock_j	0.80	0.073***	0.98	0.071***	0.44	0.073***
borderXssa_i	-0.19	0.129	0.05	0.119	-0.59	0.122***
borderXssa_j	0.36	0.129***	0.10	0.119	0.64	0.123***
Constant	3.22	0.061***	1.25	0.066***	1.19	0.068***
Observations	313,154		287,075		287,731	
R-squared	0.359		0.314		0.310	

Source: Authors' estimation.

Table 6. Determinants of agricultural TFP, using agricultural trade

	fixed effect	Instrument variable (IV)				
		trade share	ag trade share	ag export share	ag import share	ag export import share
money supply	0.01	-0.13	0.01	0.00	0.01	0.01
	(0.005)***	(0.707)	(0.006)	(0.013)	(0.006)**	(0.006)**
inflation	-0.01	0.15	-0.01	-0.00	-0.01	-0.01
	(0.005)***	(0.782)	(0.007)	(0.014)	(0.006)**	(0.006)**
NPC for agriculture	-0.01	0.14	-0.01	-0.00	-0.01	-0.01
	(0.004)***	(0.724)	(0.006)	(0.013)	(0.006)**	(0.006)**
relative price agri./nonag	0.01	0.40	0.02	0.03	-0.00	-0.00
	(0.024)	(1.928)	(0.026)	(0.041)	(0.026)	(0.026)
ag openness	-0.04	0.70	-0.01	0.01	-0.05	-0.05
	(0.010)***	(3.623)	(0.024)	(0.063)	(0.022)**	(0.022)**
observations	895	851	829	829	829	829
number of countries	28	28	27	27	27	27
weak identification		0.0488	184.9	22.36	220.5	110.9

Source: Authors' estimation.
Note: Standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 7. Determinants of agricultural TFP, using agricultural export and import

	ag export	IV ag export share	ag export	IV ag import share	ag export & import	IV ag export & import share
money supply	0.01	0.00	0.01	0.01	0.01	0.00
	(0.006)**	(0.008)	(0.005)*	(0.005)	(0.006)*	(0.008)
inflation	-0.01	-0.00	-0.01	-0.01	-0.01	-0.00
	(0.006)**	(0.008)	(0.004)*	(0.004)	(0.006)*	(0.008)
NPC for agriculture	-0.01	-0.00	-0.01	-0.00	-0.01	-0.00
	(0.005)*	(0.008)	(0.004)*	(0.004)	(0.005)*	(0.008)
relative price ag/nonag	0.02	0.03	0.01	0.01	0.01	0.01
	(0.024)	(0.025)	(0.024)	(0.024)	(0.024)	(0.025)
ag exports/agGDP	-0.02	0.00			-0.01	0.01
	(0.009)*	(0.020)			(0.010)	(0.019)
ag imports/agGDP			-0.02	-0.02	-0.02	-0.02
			(0.005)***	(0.007)**	(0.005)***	(0.007)**
observations	895	829	895	829	895	829
number of countries	28	27	28	27	28	27
weak identification		223.5		552.6		104.8

Source: Authors' estimation.
Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 8. Determinants of agricultural TFP, using support to subsectors

	agriculture		export crops		cereal	
	fixed effect	IV	fixed effect	IV	fixed effect	IV
money supply	0.01	-0.00	0.01	0.00	0.00	0.00
	(0.006)*	(0.008)	(0.005)	(0.005)	(0.005)	(0.005)
inflation	-0.01	0.00	-0.00	-0.00	-0.00	-0.00
	(0.006)	(0.009)	(0.005)	(0.005)	(0.005)	(0.005)
NPC for agriculture	-0.01	0.00				
	(0.005)	(0.008)				
RPP for agriculture	-0.01	-0.02				
	(0.014)	(0.014)				
NPC for export crops			-0.00	-0.00		
			(0.004)	(0.004)		
RPP for export crops			0.00	-0.00		
			(0.009)	(0.009)		
NPC for cereal					-0.00	-0.00
					(0.004)	(0.004)
RPP for cereal					-0.00	-0.00
					(0.009)	(0.009)
ag exports /agGDP	-0.00	0.01	0.01	0.01	0.01	0.01
	(0.009)	(0.019)	(0.007)	(0.012)	(0.007)	(0.012)
ag imports /agGDP	-0.03	-0.02	-0.03	-0.02	-0.03	-0.02
	(0.005)***	(0.007)***	(0.005)***	(0.007)**	(0.005)***	(0.007)**
observations	1107	995	1115	1003	1114	1002
no. of countries	37	36	37	36	37	36
weak identification		107.0		163.5		157.6

Source: Authors' estimation.
Note: Agricultural export and import shares are used as instruments. Standard errors in parentheses, *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 9. Determinants of agricultural TFP, using agricultural R&D

		IV		IV		IV	Nigeria, Ghana, Cote d'Ivoire, Sudan, Kenya		
	ag export	ag export share	ag import	ag import share	ag export & import	ag export & import share	ag export	ag import	ag export & import
money supply	0.06	0.03	0.06	0.07	0.07	0.02	0.03	0.03	0.03
	(0.038)	(0.068)	(0.037)*	(0.038)*	(0.037)*	(0.080)	(0.065)	(0.065)	(0.063)
inflation	-0.07	-0.02	-0.07	-0.08	-0.08	-0.00	-0.04	-0.03	-0.04
	(0.046)	(0.101)	(0.046)	(0.047)*	(0.046)*	(0.119)	(0.062)	(0.059)	(0.060)
NPC for agriculture	-0.09	0.22	-0.03	-0.03	-0.09	0.36	-0.04	-0.03	-0.04
	(0.026)***	(0.404)	(0.011)***	(0.012)**	(0.026)***	(0.507)	(0.086)	(0.024)	(0.084)
ag R&D stock	0.01	-0.04	0.01	-0.01	0.01	-0.05	-0.08	-0.08	-0.08
	(0.058)	(0.086)	(0.057)	(0.058)	(0.057)	(0.101)	(0.149)	(0.149)	(0.144)
relative price ag/nonag	0.03	0.01	0.02	0.01	0.03	-0.01	0.03	0.03	0.03
	(0.046)	(0.060)	(0.046)	(0.046)	(0.045)	(0.070)	(0.064)	(0.062)	(0.062)
ag exports/agGDP	-0.10	0.25			-0.07	0.43	-0.01		-0.02
	(0.027)***	(0.453)			(0.028)**	(0.575)	(0.080)		(0.081)
ag imports/agGDP			-0.05	-0.04	-0.04	-0.04		0.00	0.01
			(0.011)***	(0.016)***	(0.012)***	(0.025)*		(0.027)	(0.027)
observations	355	326	355	326	355	326	101	101	101
number of countries	18	16	18	16	18	16	5	5	5
weak identification		1.633		287.6		0.695			

Source: Authors' estimation.
Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 10. Determinants of agricultural TFP, using share of agricultural expenditure

	ag export	IV ag export share	ag import	IV ag import share	ag export & import	IV ag export & import share
money supply	0.02	0.03	0.01	0.01	0.01	0.02
	(0.023)	(0.026)	(0.022)	(0.022)	(0.022)	(0.024)
inflation	-0.06	-0.01	-0.06	-0.05	-0.05	-0.01
	(0.031)*	(0.054)	(0.030)*	(0.029)*	(0.031)	(0.050)
NPC for agriculture	-0.02	0.06	-0.03	-0.03	-0.02	0.04
	(0.019)	(0.074)	(0.011)***	(0.011)**	(0.018)	(0.068)
ag expenditure	0.00	0.00	0.00	0.00	0.00	0.00
	(0.013)	(0.014)	(0.013)	(0.013)	(0.013)	(0.013)
relative price ag/nonag	0.14	0.19	0.10	0.10	0.11	0.14
	(0.048)***	(0.076)**	(0.048)**	(0.048)**	(0.048)**	(0.070)**
ag exports/agGDP	0.00	0.12			0.02	0.10
	(0.022)	(0.111)			(0.022)	(0.102)
ag imports/agGDP			-0.02	-0.01	-0.02	-0.02
			(0.006)***	(0.007)**	(0.006)***	(0.007)**
observations	198	158	198	158	198	158
number of countries	8	8	8	8	8	8
weak identification		7.117		298.3		3.716

Source: Authors' estimation.
Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 11. Determinants of agricultural TFP, using real exchange rate

	ag openness		RPP		NPC		ag R&D		ag expenditure	
	fixed effect	IV	fixed effect	IV	fixed effect	IV	fixed effect	IV	fixed effect	IV
exchange rate	-0.01	0.01	-0.01	0.03	0.03	0.02	0.06	0.10	-0.07	-0.06
	(0.010)	(0.026)	(0.011)	(0.038)	(0.019)	(0.029)	(0.022)***	(0.092)	(0.030)**	(0.038)
NPC for agriculture	-0.01	0.01	-0.01	0.03			-0.09	-0.26	-0.08	-0.05
	(0.009)	(0.023)	(0.009)	(0.033)			(0.023)***	(0.315)	(0.031)**	(0.066)
relative price ag/nonag	-0.00	-0.00			0.04	0.03	0.05	0.10	0.11	0.10
	(0.022)	(0.023)			(0.062)	(0.070)	(0.042)	(0.139)	(0.050)**	(0.054)*
ag exports/agGDP	-0.00	0.02	-0.00	0.04	-0.05	-0.04	-0.09	-0.30	0.01	0.04
	(0.010)	(0.037)	(0.010)	(0.044)	(0.028)*	(0.059)	(0.027)***	(0.396)	(0.021)	(0.085)
ag imports/agGDP	-0.03	-0.02	-0.03	-0.02	-0.01	-0.02	-0.04	-0.02	-0.02	-0.02
	(0.005)***	(0.007)***	(0.005)***	(0.007)***	(0.009)*	(0.010)**	(0.012)***	(0.034)	(0.006)***	(0.008)***
RPP_ag			-0.01	-0.03						
			(0.013)	(0.021)						
NRA for cereal					0.00	-0.00				
					(0.003)	(0.005)				
NRA for cash crops					0.00	0.00				
					(0.008)	(0.008)				
ag R&D stock							0.01	0.02		
							(0.057)	(0.075)		
ag expenditure									0.01	0.01
									(0.013)	(0.014)
observations	944	862	1193	1051	167	146	357	328	200	160
number of countries	28	27	37	36	6	5	18	16	8	8
weak identification		30.54		21.89		18.90		0.803		4.527

Source: Authors' estimation. Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Table 12. Determinants of agricultural TFP, using currency evaluation

	ag openness		RPP		NPC		ag R&D		ag expenditure	
	fixed effect	IV	fixed effect	IV	fixed effect	IV	fixed effect	IV	fixed effect	IV
currency valuation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.00	-0.00
	(0.000)***	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)**	(0.000)	(0.000)	(0.000)
NPC for agriculture	-0.00	0.00	-0.00	-0.00			-0.09	-0.41	-0.02	0.00
	(0.000)	(0.000)	(0.001)*	(0.001)			(0.024)***	(0.500)	(0.014)	(0.025)
relative price ag/nonag	-0.01	0.00			0.06	0.04	0.05	0.18	0.05	0.05
	(0.021)	(0.023)			(0.061)	(0.065)	(0.043)	(0.233)	(0.043)	(0.046)
ag exports/agGDP	-0.00	0.01	0.00	0.01	-0.05	-0.04	-0.09	-0.48	0.02	0.07
	(0.008)	(0.014)	(0.007)	(0.013)	(0.028)*	(0.059)	(0.027)***	(0.622)	(0.023)	(0.066)
ag imports/agGDP	-0.03	-0.02	-0.03	-0.02	-0.01	-0.02	-0.04	0.00	-0.02	-0.03
	(0.005)***	(0.007)***	(0.005)***	(0.007)***	(0.009)*	(0.010)**	(0.012)***	(0.054)	(0.006)***	(0.007)***
RPP_ag			-0.02	-0.01						
			(0.010)*	(0.011)						
NRA for cereal					0.00	-0.00				
					(0.003)	(0.005)				
NRA for cash crops					0.00	0.00				
					(0.008)	(0.008)				
ag R&D stock							0.01	0.05		
							(0.057)	(0.109)		
ag expenditure									0.01	0.01
									(0.013)	(0.014)
observations	944	862	1193	1051	167	146	357	328	200	160
number of countries	28	27	37	36	6	5	18	16	8	8
weak identification		149.4		173.1		17.90		0.473		10.32

Source: Authors' estimation. Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.