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Sources of agricultural productivity growth and stagnation in sub-Saharan Africa [1]

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Abstract

This paper examines sources of agricultural growth in sub-Saharan Africa. Growth in the stock of traditional inputs (land, labor, livestock) remains the dominant source of output growth. Growth in modern input use was of secondary importance, but still accounted for a 0.2–0.4% annual growth rate in three of four sub-regions. Econometric results support earlier studies that suggest that land abundance may be a constraint on land productivity growth. Growth in agricultural exports and historic calorie availability had positive impacts on productivity. These latter results suggest that positive feedback effects exist between export performance and food security on one hand and agricultural productivity on the other.

1. Introduction

Many econometric studies have examined agricultural productivity differences among countries (e.g. Nguyen, 1979; Mundlak and Hellinghausen, 1982; Antle, 1983; Hayami and Ruttan, 1985; Lau and Yotopolous, 1989; Haley, 1991; Ghura and Just, 1992). These studies, which estimate aggregate agricultural production functions from international data, have been important in quantifying the relative importance of such factors as modern input use, research, infrastructure, and capital accumulation on agricultural growth. Of these, only the studies by Haley (1991) and by Ghura and Just (1992) pay particular attention to countries in sub-Saharan Africa (SSA).

This lack of attention is alarming for two reasons. First, agricultural productivity has been relatively stagnant in much of SSA. In the last 30 years, both land and labor productivity have declined in many SSA countries. Food production per capita overall has declined and the number of severely malnourished people in SSA has increased by over 20 million (Rao and Caballero, 1990).

There is evidence of significant productivity growth in some countries (Thirtle et al., 1993). These exceptions to the general pattern of stagnation beg the question of how such success might be replicated elsewhere in SSA.

Agricultural stagnation has obvious and disturbing short-term consequences for the poor in SSA. SSA's poor agricultural performance has a

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second, negative implication for longer term industrial and general economic growth. Empirical studies have found a significant correlation between agricultural and overall economic development (Singer, 1984). As Rao and Caballero (1990) note, "very few countries have managed to maintain high rates of overall income or employment growth without also achieving high rates of agricultural growth".

This paper examines sources of agricultural productivity differences among 28 SSA countries. These sources include land quality, modern input use, public investment in agricultural research, historic calorie availability, agricultural export growth, and agricultural export instability. Intuitively, one can see how agricultural productivity growth could enhance nutrition and agricultural trade performance. The paper's results, however, suggest that this relationship is not simply a unidirectional one from productivity to performance. Rather, in the long run, there are important positive feedback effects between calorie availability and trade performance on one hand and productivity on the other.

The paper is organized as follows. Section 2 presents the regression equation specification and discusses the explanatory variables used in our analysis. Section 3 discusses the regression results. In Section 4, the relative contribution of traditional inputs, modern inputs and 'non-conventional' inputs to agricultural output and productivity growth are assessed for four major agro-ecological regions of SSA.

2. Methods and variables

An aggregate agricultural production function was estimated from cross-section, time-series data for 28 sub-Saharan African countries for the years 1973–1985. Countries in the sample are listed in the Appendix. The production function was specified as

$$Y_{it} = \beta_0 + \sum_{j=1}^{4} \beta_j X_{jit} + \sum_{k=1}^{6} \gamma_k Z_{kit} + u_{it} \tag{1}$$

where Y_{it} is the log of aggregate agricultural output per hectare of agricultural land for the ith country in year t. The variables X_1, X_2, X_3, and X_4 are measures of labor, fertilizer, tractor, and livestock inputs respectively. The remaining Z terms are 'non-conventional' inputs hypothesized to affect a country's total factor productivity. The β_j and γ_k terms are parameters to be estimated and u_{it} is an error term.

The random errors, u_{it} have the decomposition

$$u_{it} = e_i + \eta_t + \epsilon_{it} \tag{2}$$

where error terms e_i, η_t, and ϵ_{it}, are independently distributed with zero means and positive variances. The component e_i is the random disturbance characterizing the ith country and is constant through time. The component η_t, is the random component characterizing year t and is constant across countries. Eq. (1) is thus a two-way random effects (error components) model and is estimated using the method described by Fuller and Battese (1974).

Agricultural output was defined as the total value of current output in 1979–1981 international dollars. The international dollar is a unit value developed by the Food and Agriculture Organization (FAO) to avoid the use of exchange rates in deriving production aggregates. Each commodity is assigned a single world price. Production is then weighted by the 1979–1981 average of world prices. Output was measured on a per hectare basis to avoid problems of heteroscedasticity. Agricultural land includes arable and permanent cropland and permanent pastures. Data come from the FAO Production Yearbook computer tape.

2.1. Conventional inputs

Four conventional inputs were included in the regression equation. Labor intensity, X_1, is defined as the log of the ratio of persons economically active in agriculture to agricultural land. Previous studies of agricultural productivity have included only male labor as an input. Failing to include female labor is a serious problem, particularly in SSA where women perform much of the agricultural work. Ideally, one would want a measure of the flow of labor services rather than the number of persons economically active in agriculture which is a stock measure of labor input. Unfortunately, comprehensive cross-section time series data for the flow of labor services are not available. The use of a labor stock variable of the type employed here could significantly overestimate the amount of actual labor input utilized by agriculture. Such overestimation can bias downward estimates of labor productivity as will be discussed later.

Fertilizers, X_2, is the log of the amount of fertilizers used per hectare of arable and permanent cropland. Fertilizers are nitrogen, phosphates and potash consumed (kg). Tractor use intensity, X_3, is measured as the log of tractors in service per hectare of arable and permanent cropland. The stock of livestock, X_4, was calculated from FAO data using the same aggregation scheme employed by Hayami and Ruttan (1985). Several studies have included a measure of livestock as a productive input (Nguyen, 1979; Mundlak and Hellinghausen, 1982; Antle, 1983; Hayami and Ruttan, 1985).

2.2. Non-conventional inputs

Following the tradition of Hayami and Ruttan (1985) and others, the total factor productivity level of each country is measured as a function of non-conventional inputs. These inputs are non-conventional in the sense that they capture the impact of macroeconomic factors, public investment, agroecological specificity, and other factors which affect agricultural productivity but which are not traditional choice variables in farmers' production decisions. These variables are defined as follows.

2.2.1. Land quality (Z_1)

A static land quality index for each country was obtained from Peterson (1987) which measures land quality as a function of historic precipitation and the percentage of area devoted to pastures, irrigated crops, and non-irrigated crops.

2.2.2. Irrigation (Z_2)

The level of irrigation technology and infrastructure is measured by the percentage of agricultural cropland which the FAO designates as 'purposely provided with water'. Although the static land quality index accounts for the extent of irrigation at a single point in time, the irrigation variable also accounts for changes in irrigation over time.

2.2.3. Agricultural research (Z_3)

An agricultural research intensity index was calculated as the log of the research stock per hectare of agricultural land. Data on country public research investment come from the International Service for National Agricultural Research (ISNAR) Agricultural Research Indicator Series reported in Pardoy et al. (1989). The research stock measure is an estimate of cumulative research investment over the previous 8 years. Pardey et al. report 5 year averages of research expenditures from 1960 to 1985. In constructing the research stock variable, it was assumed that expenditures where constant over each 5 year period.

2.2.4. Calorie availability (Z_4)

A number of household level studies have found that agricultural labor productivity improves with historic nutrient intake of laborers (see Behrman et al., 1988 for a recent survey). Far fewer studies have examined the impact of nutrient intake at more aggregate levels. Two exceptions are papers by Correa (1970) and Wheeler (1980) which found a strong and significant positive correlation between economic growth and nutrient intake in LDCs. Changes in calorie availability seem likely to have important productivity effects in SSA where 26% of the population is deficient in calories for maintenance and 44% are deficient in calories for work (Kates and Haarmann, 1992).

Variable Z_4 is the log of the ratio of daily calorie supply per capita to daily calorie requirement per capita. The use of calorie availability as an explanatory variable raises questions about causality. Does better nutrition lead to increased labor productivity or is more food available in areas that are more productive? Or, are both effects operative? To account for potential simultaneity bias, the calorie availability variable used in regression analysis is a lagged 5 year average of years $t-1$ to $t-5$. The lagged average was used for two reasons. First, the direction of causality from past consumption to current agricultural production is more clearly unidirectional. Second, a 5 year average better reflects historical nutrient availability.

Estimates for both calorie supply and requirements are from the FAO. Calorie supplies are calorie equivalents of a country's food supplies. Food supplies comprise domestic production, net imports, and changes in stocks. Daily calorie requirements are estimates of calories needed to sustain a person at normal levels of activity and health. Requirements for each country differ taking account of age and sex distributions, average body weights, and environmental temperatures.

The calorie availability variable may also be thought of as a measure of food security, albeit a relatively crude one. The variable says nothing about the distribution of food availability within a country. However, it seems reasonable to expect that as aggregate food availability declines chronic food insecurity increases. Chronic food insecurity represents a country's longer term difficulties in meeting basic nutritional requirements. Food insecurity may adversely effect agricultural productivity for another reason besides its more direct effect on labor productivity. In areas of chronic insecurity agricultural producers are likely to adopt risk-reducing rather than yield-increasing production strategies (Roumasset, 1976).

2.2.5. Agricultural export growth (Z_5)

The role of export growth in stimulating overall economic development (Fosu, 1990; Gyimah-Brempong, 1991; Edwards, 1993) and sectoral total factor productivity growth (Tybout, 1992; Edwards, 1993) has received much attention in the literature.

Export development has been hypothesized to stimulate productivity growth in a number of ways. First, countries benefit from basic comparative advantages and more rapid learning-by-doing from specialization. Second, expansion into international markets allows the export sector to benefit from scale economies. Third, the pressures of international competition are thought to force countries to adopt modern technologies and efficient methods of production more quickly. Fourth, exports form an important source of foreign exchange necessary for importation of modern inputs and capital formation. Finally, export levies are an important source of government revenues in many SSA countries. Changes in export earnings, therefore, affect the level of public funds available to finance irrigation projects, road construction, and other productivity-enhancing public investments.

Studies of the impact of export growth on output growth have generally examined the relationship between export growth and gross domestic product (GDP) growth, but have not specifically examined the impact of agricultural export growth on agricultural productivity. Mundlak et al. (1989) estimated agricultural productivity as a function of past agricultural export prices rather than past export earnings. Although earnings and prices are not the same, the results of Mundlak et al. do suggest a relationship between international market behavior and domestic productivity. Growth of agricultural export earnings is likely to have a 'demand-pull' effect on technological innovation in the agricultural export sector.

The following regression equation was estimated to construct and export growth and export instability variable

$$\ln(E_{it}) = \alpha_0 + \alpha_1 \ln(t) + \alpha_2[\ln(t)]^2 + \nu_{it} \tag{3}$$

where E_{it} is the value of agricultural exports in constant dollars. Separate regression equations were estimated for each country. The log quadratic specification of regression equation (3) fit the data very well with adjusted R^2 values over 0.90 for all countries in the sample. The log quadratic specification also fit the data better than simple quadratic of semi-log specifications. The predicted values of exports for country i in year t from Eq. (3) are given by $\hat{E}_{it}$. The export growth variable is

$$Z_5 = \ln \hat{E}_{it-1} - \ln \hat{E}_{it-5} \tag{4}$$

and reflects the growth trend in exports in a country over the previous 5 years.

Including export performance as an explanatory variable again raises issues of causality. Edwards (1993) provides more discussion of problems of determining causality between export growth and other measures of economic performance such as GDP and productivity growth. As with calorie intake, this was accounted for by using past values of performance as an explanatory variable. Fig. 1 shows the long-term relationship between agricultural productivity and performance. Current productivity has more immediate impacts on current food security and export performance. In the longer run, we hypothesize that food security and export performance affect future productivity. There is thus a positive feedback loop over time between productivity and performance.

2.2.6. Agricultural export instability (Z_6)

We also test the hypothesis that agricultural export instability could have a negative impact on productivity. Fluctuations in foreign exchange derived from export earnings may adversely affect the timing and availability of modern imported inputs (Love, 1989a). Also, fluctuations in foreign exchange may reduce the efficiency of public investments to raise agricultural productivity (Love, 1989b). Development projects may proceed in an erratic and halting manner. Fosu (1992), however, found little evidence to support the hypothesis that export instability had a negative impact on GDP growth in SSA.

The instability of agricultural exports was constructed as follows

$$Z_6 = \ln\left(\sum_{j=1}^{5} \hat{v}_{i(t-j)}^2\right) \quad (5)$$

where $\hat{v}_{it}$ are the residuals from Eq. (3). The instability index captures the effects of deviations from trend in export growth over the previous 5 years, placing relatively more weight on more extreme deviations from trend. This specification is similar to those employed previously in the literature (Fosu, 1990; Gyimah-Brempong, 1991).

3. Regression results

Regression results are presented in Table 1. The Fuller–Battese method (variance components model) is used. Regression equation (1) is a land productivity equation, given that the dependent variable is agricultural output per hectare. Column 1 reports results from the general specification of Eq. (1). Column 2 excludes variables found to be insignificant in the general regression. Results from Column 1 are discussed in this section while the results from Column 2 are used in the following section on growth accounting.

The model fits the data well. The R^2 between observed and predicted values of the dependent variable is over 0.94 for both models. The explanatory variables generally show a high level of statistical significance and are economically plausible. The random component (variance component) characterizing unspecified country effects is the largest portion of the error in the model.

The output elasticity of labor is about 0.59 which is very high relative to those of other conventional inputs. Haley obtained similar results in his study of agricultural production in SSA. Again, we should caution that the explanatory variable is the stock of labor (persons economically active in agriculture) rather than the

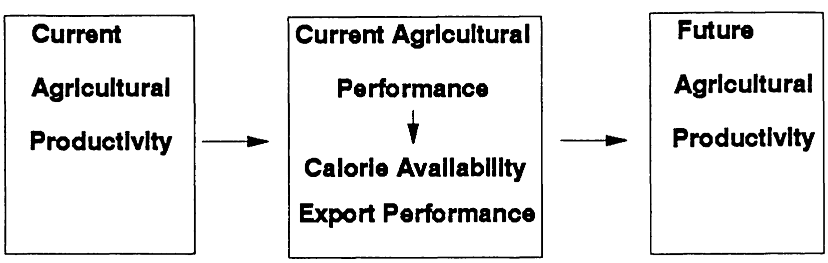

Fig. 1. Long-term relationship between agricultural productivity and performance.

Table 1
Estimation results 1973–1985 (dependent variable: log of agricultural output per hectare)

Variable	Regression coefficient (*t*-statistic) (1)	Regression coefficient (*t*-statistic) (2)
Intercept	4.500 (15.610)	4.393 (16.674)
Log(labor/agricultural land)	0.5894 (10.224)	0.6000 (10.674)
Log(livestock/agricultural land)	0.1788 (4.882)	0.1864 (5.170)
Log(fertilizers/cropland)	0.0218 (2.127)	0.0256 (2.571)
Log(tractors/cropland)	0.0418 (2.454)	0.0470 (2.817)
Land quality index	0.8866 (5.299)	0.9144 (5.646)
Percent of cropland irrigated	0.4510 (0.819)	–
Log(research stock)	0.0848 (1.440)	–
Export growth	0.0245 (3.204)	0.0244 (3.231)
Export instability index	0.0004 (0.025)	–
Log(calorie availability)	0.3479 (2.815)	0.3498 (2.867)
Variance component for cross sections	0.0817	0.0771
Variance component for time series	0.0006	0.0006
Variance component for error	0.0081	0.0081
R^2 between observed and predicted	0.95	0.95
Number of observations	364	364

flow of labor services. The labor variable used here is really a measure of rural population density, or inversely, land scarcity. Binswanger and Pingali (1988) have elaborated on the earlier work of Boserup (1965) which considered the impacts of population pressure on land productivity. They argue that land scarcity induces institutional and technological innovations which raise land productivity and that the relative land abundance in many parts of SSA are barriers to land productivity growth. Thus, the relatively large regression coefficient on the labor stock per hectare variable may be reflecting this 'Boserup effect'.

The output elasticities for traditional inputs labor and livestock are higher than those of 'modern' inputs, fertilizers and tractors. The positive and statistically significant coefficient for tractor intensity is at odds with a more detailed study by Pingali et al. (1987) which found that tractors did not increase yields in 10 out of 14 cases of tractor adoption in SSA countries. However, the results are consistent with the cross-section, time-series estimates obtained by Ghura and Just (1992) for East Africa. The land quality index was highly significant while the irrigation variable was not. This may be due to the fact that Peterson's (1987) land quality index implicitly accounts for the extent of irrigation in calculation of land quality.

The estimated elasticity of land productivity with respect to the research stock was low (less than 0.05) and statistically significant only at the 10% level for a one-tailed *t*-test. This implies that research has yet to generate broad sectoral productivity growth in SSA agriculture. We experimented with estimating different impacts of research across sub-regions and with interacting research with measures of quality of national research programs reported in Cleaver (1993). In neither case did research prove to be significant. This could be for a number of reasons. First, the time lags for research impacts may stretch back farther than the data available to construct the research stock variable. Other possible reasons discussed in the literature include lack of critical mass of researchers, lack of spending per researcher, lack research historically in tropical and desert zones, and lack of congruence between output and research mix (Lipton, 1988; Eicher, 1990).

The output elasticity of historic calorie intake is quite high, over 0.34. This is consistent with results obtained by Correa (1970) and Wheeler (1980) who found a strong responsiveness of economic growth to improvements in nutrition. Estimating a simultaneous model of basic needs provision and economic growth, Wheeler found that the elasticity of economic growth with respect to improved nutrition was nearly 2.0 in very poor less developed countries (LDCs). The very high elasticities of both labor input and calorie intake suggest that improved labor productivity through provision of basic nutrition requirements is a potentially great source of agricultural growth.

The results relating past trade performance to productivity are mixed. The coefficient on agricultural export growth was positive and significant at the 1% level (from a two-tailed t-test). We found no evidence that past export instability affected productivity. These two results for the agricultural sector in SSA match those obtained by Fosu (1990, 1992) regarding trade performance and overall GDP growth.

4. Accounting for agricultural growth

This section presents results of a simple accounting exercise which measures the relative contribution of production inputs and other variables to growth in agricultural output and land productivity. Agricultural output growth can be written as a function of agricultural intensification (an increase in output per hectare) and extensification (expansion of agricultural land). Let Q be the log of output, A the log of agricultural land area, and Y the log of land productivity (output per hectare). The continuous growth rate of output between time t and some base period, time 0, $Q_{it} - Q_{i0}$, can be written as

$$Q_{it} - Q_{i0} = (Y_{it} - Y_{i0}) + (A_{it} - A_{i0}) \tag{6}$$

In other words, output growth is the sum of land productivity growth and the rate of land expansion.

The regression results obtained from estimating Eq. (1) can be used to express land productivity growth as a function in changes in conventional and non-conventional inputs

$$Y_{it} - Y_{i0} = \sum_{j=1}^{4} \hat{\beta}_j (X_{jit} - X_{ji0}) + \sum_{k=1}^{12} \hat{\gamma}_k (Z_{kit} - Z_{ki0}) + (\hat{u}_{it} - \hat{u}_{i0}) \tag{7}$$

where $Y_{it} - Y_{i0}$ is the continuous growth rate of land productivity. The first expression on the right hand side of Eq. (7) is a weighted aggregation of input intensities. The weights are simply the regression estimates of the parameters β_j and

Table 2
Contribution of explanatory variables to output and land productivity growth, 1973–1975 to 1983–1985

	Semi-Arid Tropics	Sub-Humid Tropics	Lowland Humid Tropics	Humid Tropics
Agricultural output growth	1.64 [a]	2.07	1.15	1.86
Explained by changes in				
Agricultural land	0.16	0.27	0.53	0.26
Land productivity	1.48	1.80	0.62	1.60
Change in land productivity explained by changes in				
Conventional inputs				
Labor	0.97	1.25	0.44	0.79
Livestock	0.31	0.34	−0.23	0.37
Fertilizers	0.10	0.11	0.01	0.11
Tractors	0.14	0.07	0.03	0.30
Non-conventional inputs				
Export growth	0.01	−0.08	−0.07	−0.12
Calorie availability	0.16	0.12	0.32	0.03
Land quality	−0.06	0.00	−0.06	0.02
Residual [b]	−0.15	−0.01	0.18	0.10

[a] Figures are output-weighted geometric averages of sample countries in each agro-climatic zone.
[b] Actual change minus explained change.

γ_k. Land productivity growth is thus a decomposition of growth in conventional and non-conventional inputs. The restricted regression (Table 1, Column 2) was used in the growth accounting exercise.

Sample countries were classified into four agro-ecological zones based on Oram et al. (1990). The Semi-Arid Tropical Rainfall Zone is characterized by a 75–150 day growing season with major crops being millet, sorghum and groundnuts. The Sub-humid Tropical Summer Rainfall Zone has 150–210 day growing seasons and cropping patterns are heavily dependent on altitude. The major crop in this region is maize. Only two countries in our sample, Madagascar and Mauritius lie in the Lowland Humid Tropical Zone which has a growing season of 180–365 days. Dominant crops are rice, sugar, roots and tubers, and coffee. In the Humid Tropical Zone, the growing season increases from north to south in West Africa. Major commodities are roots and tubers. Sample countries are listed by agro-ecological zone in the Appendix.

Table 2 shows the decomposition of agricultural output and land productivity growth rates for the four agro-ecological zones between 1973–1975 and 1983–1985. Table 2 reports growth rates of output-weighted geometric averages of sample countries in each zone. Output growth over this period ranged from 1.15 to 2.07%. This rate does not keep pace with the 2.8% rate of population growth over the same period. Output growth came predominantly from land productivity growth. Land expansion, however, remains an important source of output growth, accounting for 0.16–0.53% increases in annual output growth. Growth attributable to land expansion relative to overall growth was higher in more humid regions of SSA but is relatively less important in semiarid and sub-humid zones. Land expansion was particularly important in Burundi, Cameroon, Ivory Coast, Madagascar and Sierra Leone. In the Semi-Arid Tropics and Lowland Humid Tropics, production shifted toward countries with lower land quality reducing the weighted average regional growth −0.06% per year.

Growth in land productivity came primarily from growth of conventional inputs. The major source of land productivity growth was the increase in the number of economically active persons in agriculture per hectare of agricultural land. This result is consistent with arguments put forth in Binswanger and Pingali (1988) that land abundance in tropical countries, particularly SSA,

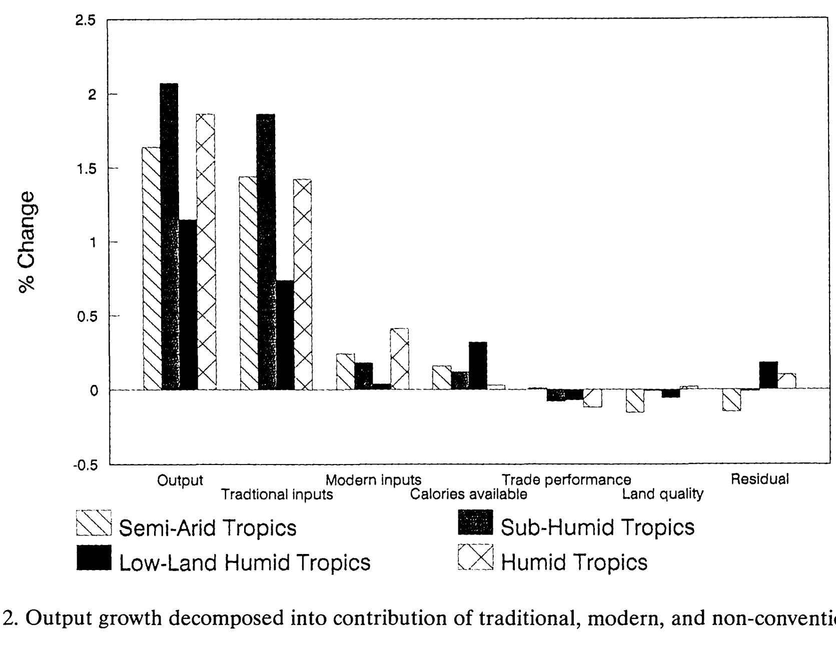

Fig. 2. Output growth decomposed into contribution of traditional, modern, and non-conventional inputs.

reduce incentives for farmers to adopt yield-increasing technologies. Substantial increases in land productivity should not be expected until land becomes relatively scarce.

We should reiterate that growth in the stock of the agricultural labor force is not the same as changes in the flow of labor services. For example, the FAO data suggest that the stock of labor per hectare in Zimbabwe has been rising. Here, the stock refers to the number of economically active persons in agriculture. However, the more detailed country level study of Thirtle et al. (1993), based on constructed Divisia indexes indicates that on-farm labor intensity has been declining. Thus, the FAO data may be underestimating growth rates of labor productivity, while capturing productivity benefits induced by growing land scarcity.

Improvements in historic calorie availability contributed more positively to output growth than increases in fertilizer use in all regions except the Humid Tropics. It should be noted that the base period is the early 1970s, when many areas were suffering from extreme drought. Recovery from the drought conditions of this period may have contributed to longer term productivity growth, particularly in the Sahel region. The results are consistent with those of Wheeler (1980) and Correa (1970) who found that improved calorie intake made significant contributions to long-term economic growth in LDCs. The results also provide some support to the 'basic needs' strategies of development (Wheeler, 1980).

Fig. 2 shows the relative contribution of different factors to agricultural output growth in a slightly different manner than Table 2. Output growth is decomposed into contributions by traditional inputs (land, labor stock, livestock) modern inputs (fertilizers, tractors), agricultural export growth, calorie availability and land quality. Fig. 2 shows that the primary source of output growth in SSA remains growth in stocks of traditional inputs. Modern inputs (tractors, fertilizers) were next in importance in terms of contribution to output growth, except in the Lowland Humid Tropics where use did not increase appreciably. Regional averages mask differences across countries, however. For example, in the Semi-Arid Tropical region, Botswana, Chad, Senegal, Somalia, and Sudan all experienced declines in fertilizer use even though the regional average of fertilizer use increased (Table 2). In Rwanda, intensity of all modern inputs declined. A deterioration of agricultural trade performance, in terms of export growth, affected all regions but the Semi-Arid Tropics. Negative export growth elsewhere accounted for an annual decrease in productivity of −0.07 to −0.12% per year (Table 2).

5. Conclusions

This paper examined sources of agricultural growth in sub-Saharan Africa. Growth in the stock of traditional inputs (land, labor, livestock) remains the dominant source of output growth. Growth in modern input use was of secondary importance, but still accounted for a 0.2–0.4% annual growth rate across three of four sub-regions. Econometric results are consistent with the argument of Binswanger and Pingali (1988) that increasing land scarcity is a prerequisite for growth in land productivity.

Results also indicated that research has yet to generate broad sectoral productivity growth in SSA agriculture. We experimented with estimating different impacts of research across sub-regions and with interacting research with measures of quality of national research programs. In neither case did we find a statistically significant relationship between research stock variables and aggregate agricultural productivity.

The estimated elasticity of agricultural output with respect to calorie intake was quite high, about 0.35. This is consistent with results obtained by Correa and by Wheeler who found a strong responsiveness of economic growth to improvements in nutrition. The very high elasticities of both labor and calorie intake suggest that improved labor productivity through provision of basic nutrition requirements is a potentially great source of agricultural growth. Improved calorie availability contributed more to output growth than did growth in fertilizer use in all regions except the Humid Tropics.

Table A1
Countries in sample grouped by agro-ecological zone

Humid Tropics	Semi-Arid Tropics	Sub-Humid Tropics
Benin	Botswana	Kenya
Burundi	Burkina Faso	Malawi
Cameroon	Chad	Tanzania
Congo	Ethiopia	Zimbabwe
Ivory Coast	Mali	
Ghana	Mauritania	*Lowland Humid Tropics*
Liberia	Niger	
Nigeria	Senegal	Madagascar
Rwanda	Somalia	Mauritius
Sierra Leone	Sudan	
Togo	Zambia	

Another important finding is that trade performance is an important determinant of longer-term productivity growth. Agricultural export growth was found to have a statistically significant positive impact on productivity. Negative export growth in many countries over the sample period accounted for productivity losses in three of four regions in the study. These latter results suggest important positive feedback effects exist between trade performance and food security on one hand and agricultural productivity on the other.

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