TECHNICAL INNOVATION AND FARM PRODUCTIVITY GROWTH IN DRYLAND AFRICA: THE EFFECTS OF STRUCTURAL ADJUSTMENT ON SMALLHOLDERS IN KENYA[1]

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This paper uses non-parametric approach to measure technical innovation and productivity growth at the smallholder farm-level in dry-land sub-Saharan Africa during the initial years of the structural adjustment programmes for agriculture. Data from Kenya for two production years, 1991/2 and 1995/6 are used to construct a Malmquist productivity index. The results show that the rise in input prices led to reduced use of modern inputs, so that efficiency increased at 12% per year. However, lower use of modern varieties and less fertiliser also gave technological regression at 2.5% per annum, so that the overall outcome was productivity growth of 3% per annum. However, productivity improvement cannot be sustainable without technological progress.

1. INTRODUCTION

The empirical evidence shows that for much of Sub-Saharan Africa (SSA) productivity per unit of land remains low (Heyden, 1986 and Frisvold & Ingram, 1995), with few isolated studies to the contrary (Thirtle *et al*, 1993 and Wiggins, 1995). This is particularly true in areas of poor infrastructure and where there is a system of mixed farming rather than specialisation, with high levels of unskilled labour and no opportunities for real wage employment.

The low productivity growth of smallholder agriculture in SSA reflects wider differences. African production rates in general compare poorly with those of the rest of the world. For example, the mean world yield of cereals is over 2,000 kg per hectare, double that of Africa (Nyariki, 1997). Other comparative statistics indicate the reasons for this. Fertiliser application in Africa is currently 3 kg per hectare of agricultural area while in Latin America it is 8 kg per hectare and in Asia 26 kg per hectare (Heyden, 1986). Recent economic decline is the

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case in most of SSA and structural adjustment programmes (SAP) designed to reverse this have not yet taken effect.

The disappointing performance in agriculture and in food production is a very serious problem since this sector is the mainstay of most African economies. It makes the single largest contribution to the gross domestic product (GDP) and provides a large share of export earnings. In Kenya, agriculture and food products account for 30% of GDP and 45% of exports. In addition, nearly 75% of employment is in agriculture or food processing (ROK, 1993). In common with other countries in the region, the extra-ordinarily high population growth and limited arable land raise serious questions as to how this sector will meet these challenges. This concern has prompted a renewed interest in agricultural production in SSA, focussing on how productivity can be improved, and particularly the use of modern cultivation techniques. While there is some debate on how this may be achieved (Tiffen, Mortimore & Gichuki, 1994), most authors consider agriculture to be crucial to the structural transformation of Third World economies. Recent studies emphasise the importance of a sustainable agricultural system to the growth of the industrial sector, as well as skilled labour, modern capital and foreign exchange (Staatz & Eicher, 1986).

Opportunities for increasing agricultural productivity in wet and fertile zones are declining and land pressure in these areas is gradually pushing farmers to more marginal dryland zones, so that ensuring adequate food for these populations is increasingly difficult (Bigsten & Ndung'u, 1992). To achieve productivity improvement in these areas management of the land such as weed control, tillage practices and moisture control are important as well as the green revolution technologies, such as improved seed and fertiliser use. There is growing evidence (see, for example, Pinstrup-Andersen, 1994) that agricultural intensification in the drylands is possible and the development of improved agricultural technology is essential to avoid famine and eradicate extreme poverty, ensure food insecurity and protect the environment.

This paper measures the level of productivity growth and technical innovation for a sample of smallholder farms in the dryland area of Kenya, in an environment of recent agricultural policy changes. The next section begins with a description of the region and the variable definitions. Section 3 outlines the methodology and compares the Malmquist productivity measures with other indices that are sometimes used in this context. Section 4 reports the results and the final section discusses the implications of the impact of the structural adjustment programmes on agricultural productivity.

2. DATA

2.1 The sample region

Makueni District is representative of Kenya's medium to low potential areas. Average annual rainfall is between 500mm in the south and south-eastern lowlands and 1300mm in the northern highlands, with the probability of rain during the growing seasons around 66%. The 'long' rains are between March and May and 'short' rains between October and December, giving two fairly brief agricultural seasons per year. Average mean temperatures are between 19^{o} and 26^{o} (Jaetzold & Schmidt, 1983). The landscape is hilly with elevations of up to 1900m above sea level to the northern parts and the eastern fringes. Soils are deeply weathered, except where eroded on the steeper slopes, or where there are unweathered rock outcrops in the escarpments. Many areas are rocky with large boulders while others are covered with humic topsoils.

Apart from some areas under large-scale livestock production and irrigation, most of the land is used for small-scale, rain-fed mixed farming. In the high altitude and hilly areas, coffee, vegetables and fruits are grown and some households also keep dairy cattle. In the lower areas, cattle, sheep, goats, rabbits and poultry are predominant, although crop production is also important. The main food crops include maize, pigeon peas, cowpeas, beans and sorghum. Both small and large-scale irrigation are also practised in some parts of the region.

2.2 Sampling techniques

A two-stage cluster and systematic sampling procedure was carried out, following Casley and Lury (1987). To ensure homogeneity, locations with fairly similar agro-ecological conditions and a common level of infrastructure development were included in clustering. The clusters were selected randomly and from these a sampling frame was developed prior to systematic sample selection. Interviews were carried out in fifty households during four visits between 1991/92 and 1995/96 (see Nyariki, 1997). The first year of the sample is significant as 1991 marked the target date for many crucial policy changes in Kenya. A 1996 government report (ROK, 1996) on price decontrols and market liberalisation lists the years of implementation. These are: meat (1987), animal feeds (1989), fertilisers (1991), minor crops (1991), dairy industry (1992), tea, rice and wheat (1991), cotton (1992), maize (1993), and seed industry (1996). These changes had a serious affect on farmers, although unfortunately, *ex-ante* and *ex-post* productivity analysis is not possible due to lack of data. Further, comparing any two years has its weaknesses since the growing seasons may not be comparable if there are different climatic conditions. Thus, any improvement or deterioration is only relative to the previous year.

2.3 Data

One issue in this study is the method and extent of output aggregation and the choice of a numeraire. Households grow a variety of crops and also keep livestock and therefore all output was converted to units of maize. This was done by applying the seasonal prices in the local markets of all goods, with respect to maize, to construct a known exchange rate as a means of conversion. Therefore, the output variable is a constructed series of maize equivalents. In the case of inputs, physical values included land area (in hectares), household and hired labour (in adult-hours) and livestock, aggregated into livestock units. The other inputs are expressed in terms of expenditures. These are, modern inputs (improved seed, fertiliser and pesticide) and capital (ox-ploughs, tractors and miscellaneous inputs).

3. MEASURING PRODUCTIVITY CHANGE

Optimal resource allocation is the major factor in explaining both the form and rate of technical change and the growth in agricultural output over time (Lingard & Rayner, 1975). Multi-factor productivity (MFP) is the ratio of aggregate output to aggregate inputs and is used to measure national levels of gross agricultural productivity. Estimation using aggregate production functions has been important in determining the impact of modern inputs, infrastructure, research and capital in agricultural productivity and hence economic growth, although the results vary considerably. Some studies on SSA indicate that there has been substantial agricultural productivity growth in recent years (see Thirtle *et al*, 1993), with a resulting increase in overall per capita food production. Others report that productivity, mainly of land and labour, has been largely stagnant in the last three decades (for example, Frisvold & Ingram, 1995). This divergence in outcomes is largely due to varying data sources and methodological approaches. But whereas aggregate national level studies result in controversial outcomes, farm level studies are even more problematic due to the difficulties of collecting a consistent sample, particularly when the objective is to assess changes over time. This study uses a robust and sufficiently large sample and provides an excellent opportunity for household level analysis.

3.1 Multi-factor productivity indices

Several approaches have been used to construct productivity and growth indices at the micro or national level. The approach is commonly based on index number techniques, for example, the Törnqvist index, which is a discrete approximation of the Divisia index. However, the disadvantage of the Törnqvist index is that it is very restrictive. For example, it requires that all inputs have prices and positive values, so that the logarithm is defined. It also assumes allocative efficiency and that the profit maximisation objectives of the farmers are met.

3.2 The Malmquist productivity growth index

More recently, the Malmquist productivity growth index has been applied in situations where profit maximisation is not necessarily the objective or where the technology is unknown. This can be decomposed into technical change (frontier shifts) and efficiency change (moving closer to the frontier). Efficiency change can be further decomposed into pure technical efficiency and scale efficiency by modelling the technology as piecewise linear and allowing for inefficiency. The Malmquist was originally proposed by Malmquist (1953) and was based on ratios of distance functions. This has been extended by Fare *et al* (1992). All the units in the sample are then measured in relation to the frontier. The Malmquist index is stated

$$M_i^{t+1}\left(y_i^{t+1}, x_i^{t+1}, y_i^t, x_i^t\right) = \frac{D^{t+1}\left(y_i^{t+1}, x_i^{t+1}\right)}{D^t\left(y_i^t, x_i^t\right)}\left[\frac{D^t\left(y_i^t, x_i^t\right)}{D^{t+1}\left(y_i^t, x_i^t\right)}\frac{D^t\left(y_i^{t+1}, x_i^{t+1}\right)}{D^{t+1}\left(y_i^{t+1}, x_i^{t+1}\right)}\right]^{1/2} \tag{1}$$

where y is output, and x is input and the superscripts are the time periods of the index. The first ratio on the right measures the change in technical inefficiency and the second ratio measures the shift in the frontier between period t and period t+1. Figure 1 shows these relationships. In the figure, technology at the base year, t, is denoted as I^t and at a later year as I^{t+1}. $I^t=\{(x^t,y^t):x^t \in L^t(y^t), y^t>=0\}$. I^{t+1} is also defined in the same way. The two observations (x^t,y^t) and (x^{t+1},y^{t+1}) are feasible in the base year, t, and the later year, t+1, respectively. The distance function measures in equation (1) are illustrated in Figure 1 and are as follows

$$M_i^{t+1}\left(y_i^{t+1}, x_i^{t+1}, y_i^t, x_i^t\right) = \frac{od/ob}{of/oc}\left[\frac{ob}{oe}\frac{oa}{oc}\right]^{1/2} \tag{2}$$

where $(od/ob)/(of/oc)$ is the ratio of the Farrell measure of technical efficiency and the rest is the geometric mean of the frontier shifts in technology measured at y^t and y^{t+1}. The shifts in technology are measured locally for the observation at t and t+1, which implies that the whole technology need not behave uniformly and that retrogression in technology is allowed.

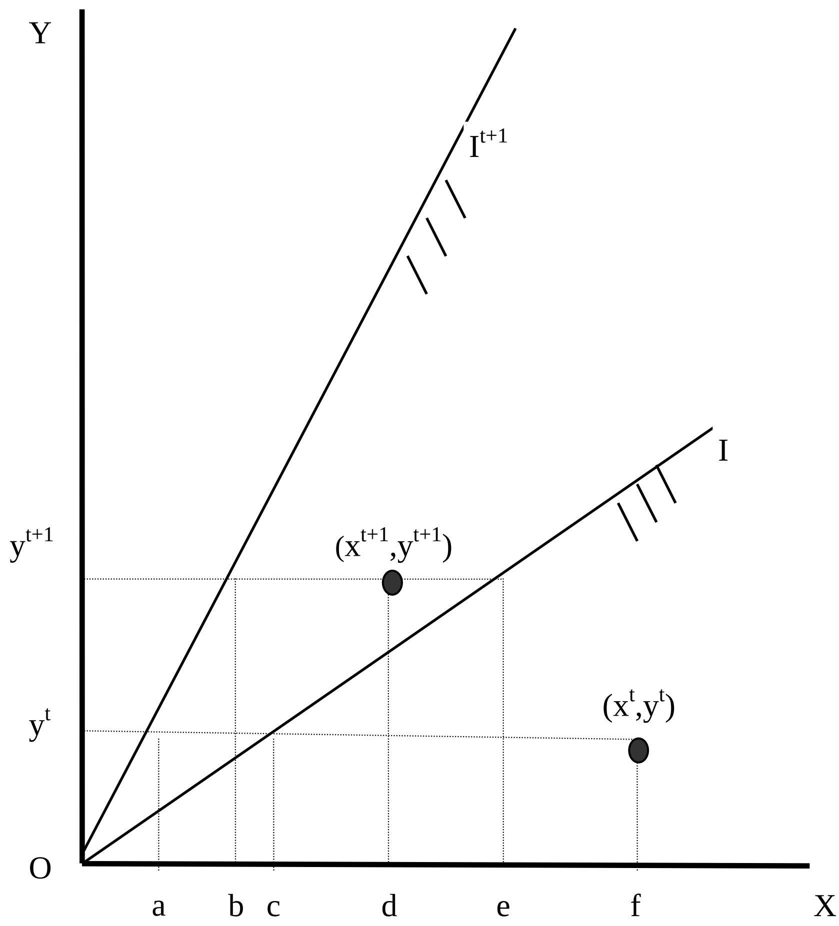

Figure 1: Malmquist input-based total factor productivity index

4. RESULTS

4.1 Productivity growth, efficiency change and technical innovation

Simple measures of yields of maize and maize-equivalents in kilograms per hectare are calculated with respect to input use and non-use (Table 1). These data can be used to compare output differences between 1991 and 1995, particularly since rainfall was at a similar level in both years. The main difference is that fewer farmers used modern inputs and other capital-intensive methods in 1995. The result of the reduction in the use of modern inputs can be seen in the lower yields levels obtained by the non-users. Thus, the structural adjustment programme has reduced yields, but the effect on TFP is ambiguous, since both output and inputs were reduced.

Productivity growth, as already noted, is the product of efficiency change and technical change. Improvements in efficiency change are associated with catching up (i.e., moving towards the frontier), while improvements in the

Table 1: Use of inputs and annual average yields (kg/ha) in Kibwezi, 1991/2 and 1995/6

Household category	Year	% households using	Maize		Maize-equivalents	
			Users	Non-users	Users	Non-users
Hybrid seed	1991/92	52	718	364	2618	2291
	1995/96	38	757	794	963	825
Fertiliser	1991/92	36	873	395	2765	2290
	1995/96	16	821	772	907	872
Pesticide	1991/92	20	1379	366	3190	2301
	1995/96	10	862	770	1399	820
Ox-plough	1991/92	54	746	315	2937	1902
	1995/96	44	932	776	869	691
Access to irrigation water	1991/92	14	1579	352	3225	2315
	1995/96	14	811	546	896	746
Ownership of cattle (richer and poorer)	1991/92	62	959	382	4019	2034
	1995/96	76	783	767	835	1012

technical change component are evidence of innovation. Table 2 shows how the two periods compare. The analysis shows that there was a productivity gain of 2.8% per annum over the period. However, the TFP gain results entirely from an efficiency gain of 5.4 per cent per year, while there was technological regress of 2.6 per cent per annum. This is not altogether surprising, since the modern inputs that embodied new technologies were used less once they were no longer artificially cheap. On the other hand, at the shadow prices calculated by the programme, there was a more than sufficient gain in efficiency to counteract this decline and give the improvement in TFP. This suggests that the policies of input subsidisation prior to structural adjustment had a negative payoff in terms of overall efficiency.

Table 2: Mean productivity, efficiency change and technical progress in Kibwezi, 1991–95

Measure	Geometric mean
TFP	0.028
Efficiency change	0.054
Technical progress	-0.026

5. CONCLUSIONS AND POLICY IMPLICATIONS

The structural adjustment programme has affected agriculture's terms of trade, since the removal of input subsidies has been the greatest price effect. The relative price changes have reduced the use of modern inputs, which gives an annual rate of technological regression of 2.6 per cent a year from 1991 to1995. However, the higher input prices do result in efficiency gains of 5.4 per cent per annum, so the overall effect is productivity growth at 2.8 per cent per annum. The snag is that this is a short-term gain which cannot continue, since efficiency was over 90% by 1995, so that little further improvement is possible. Thus, technical regression will dominate eventually and productivity must decline until this is corrected and cost effective modern technologies are introduced.

The tastes and preferences of the local community in foods consumed may have a bearing on the results of productivity growth. The preferred food in most communities in Kenya at present is maize. Even though extension workers recommend to farmers the growing of sorghum and millet, which tend to perform better in areas that receive low rainfall, farmers persistently grow maize regardless of the frequent failure of harvests. Continued cultivation of maize in such circumstances also raises the question of farmers not having faith in markets. They believe they are more assured of food when they produce their own rather than specialising because of the fear of the prospect of market failure. The question of risk and uncertainty is important too and may be having a role to play in influencing the actions of farmers and therefore the productivity of certain resources. This may suggest that assuring farmers of income by improving their livelihood opportunities, and therefore reducing perceived risk or uncertainty, could improve productivity. The issue of income brings forth poverty and productivity relationships. Poverty impairs the ability of farmers to allocate resources to achieve efficiency. Therefore they may choose less efficient methods. Farmers may choose to use less than optimum fertiliser, for example, so that they can use the 'saved' scarce resources in more immediate needs like purchasing food. They could also spend less time on owned farms so that they can work for other people for cash to acquire urgently needed goods and services.

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