1. INTRODUCTION

The Kenyan agricultural sector has undergone major structural changes since independence in 1963. Some of the changes have been in the form of institutional arrangements related to the land tenure system and marketing. Considerable changes related to the use of intermediate factors of production, such as fertilizers, seeds and machinery have also been evident. A study on Kenyan agriculture showed that while production and input use have grown, productivity has stagnated (Njue, 1993).

The importance of smallholder farms in Kenya cannot be underestimated. The percentage market share of their output has risen from slightly over 56% in 1990 to 70% in 2001 (Economic survey, 2001). The contribution in cane farming is even higher, since, according to KSB (2003), the total area under cane at the end of 2003 was 122,580 hectares and the out-grower farms (smallholder farms) represented 90% of the total cane surface area.

This sub-sector holds a key position in the Kenyan Agricultural sector. It provides direct and regular employment for about 40,000 workers. Indirectly however, the industry employs thousands of casual workers on farms as weeders and cane cutters among others. It also acts as an input supplier for other companies and as marketing and distribution agent for sugar and sugar by-products. Sugar also acts as a foreign exchange earner and if sufficiently produced it can save on import expenditure. It is also a major food item in the household budget of the average Kenyan, and refined sugar is an essential raw material in food processing, confectioneries, beverage manufacture, soft drinks and pharmaceutical industries among others. Sugarcane growing is a major source of income to over 150,000 smallholders (KSA, 1999).

However, in the past few years, sugarcane yields have been declining. It’s against this background of declining yields that we decided to estimate the total factor productivities among smallholder sugarcane farmers in Kenya. This paper therefore aims at estimating the Malmquist total factor productivity (TFP) using non-parametric methods in three different sugar schemes (regions) in Kenya. The advantage of the non-parametric Malmquist Index is that price data are not required and still it decomposes productivity into efficiency and technological change (Coelli et al., 1998).

2. THE CONCEPT OF PRODUCTIVITY

There is no universal definition of the term productivity. Economists have defined it as the ratio of output to input in a given period of time. In other words, it is the amount of output produced by each unit of input. Business Managers, on the other hand, see productivity not only as a measure of efficiency, but also connotes effectiveness and performance of individual organizations. For them, productivity would incorporate quality of output, workmanship, adherence to standards, absence of complaints, customer satisfaction, etc (Udo-Aka, 1983). The administrator is more concerned with organizational effectiveness, while the industrial engineer focuses more on those factors, which are more operational and quantifiable, work measurement and performance standards.

Productivity can be computed for a firm, industrial group, the entire industrial sector or the economy as a whole. It measures the level of efficiency at which scarce resources are being utilized. Higher or increasing productivity will, therefore, mean either getting more output with the same level of input or the same level of output with less input. Productivity can be divided into two sub-concepts, that is, Partial Factor Productivity (PFP) and Total-Factor Productivity (TFP).
PFP estimates the ratio of total output to a single input, usually labor. In most discussions, especially in economics, productivity is taken to be synonymous with labor productivity. This is because it is a simpler concept to estimate and it is a rough measure of the effectiveness with which we use the most important factor of production-labor. However, it is noteworthy that productivity is not determined by the efforts of labor alone, but in combination with land, capital, technology, management and even the environment. TFP is the ratio of output to the aggregate measure of the inputs of all the factors of production. Theoretically, this is the true measure of productivity as it incorporates the contribution of all the factor inputs. There are some problems associated with measuring total-factor productivity. For example, it is difficult to construct an index number that will serve as the input. It will mean adding hours done by labor to units of investments, the contributions of land, technology, etc. to get a single index. Even to quantify them all in monetary terms is very cumbersome.

In most studies there is an implicit assumption that the economies are producing along the production possibility frontier with full technical efficiency. These studies have adopted the conventional growth accounting approach and estimated total factor productivity (TFP) growth without distinguishing between its two components: technical progress (TP) and technical efficiency change (TEC); rather TP is synonymously considered to be the unique source of TFP growth. Defined this way, TFP growth is at best a measure of Hicks-neutral disembodied technological change. More important, failure to take account of inefficiency and TEC may produce misleading and biased TFP estimates: while high rates of TP can coexist with deteriorating technical efficiency, relatively low rates of TP can also coexist with improving technical efficiency (Nishimizu & Page, 1982; and different policy implications result from different sources of variation in TFP.

The Malmquist TFP Index

This study will utilize the Malmquist TFP index in analyzing the productivity of sugarcane production. The Malmquist TFP index measures the change between two data points by calculating the ratio of distances at each data point relative to a common technology. It has additional benefits over the Fisher and Torqvist indices, that price data are not required, and that the TFP indices obtained may be decomposed into two components, one part due to technical efficiency change (firms getting closer to the frontier) and another part due to technical change (shifts in frontier itself). The index also does not have the restrictive assumptions in the Torqvist number approach. That is, one does not need to assume that the firms are cost minimizers or profit maximizers.

The Malmquist index is defined using distance functions. Distance functions allow one to describe a multi-input, multi-output production technology without the need to specify a behavioral objective (such as cost minimization or profit maximization). One may define input distance functions and output distance functions. An input distance function characterizes the production technology by looking at a minimal proportional contraction of the input vector, given an output vector. An output distance function considers a maximal proportional expansion of the output vector, given an input vector.

The idea can be shown graphically by a simplified (one-input and one-output with constant returns to scale (CRS) technology) case. Points D and E in figure 1 below represent the input-output combinations of a production unit in periods $s$ and $t$ respectively. In both cases, it is operating below the production possibility frontier. In period $s$ (correspondingly, period $t$) with input $x^s$ ($x^t$), it should be able to produce $y^s$ ($y^t$) if it has full technical efficiency. Then the technical efficiency is measured by $y^s / y^*$ ($y^t / y^*$). Productivity change can be measured by the part of output growth that is not contributed by input growth. In Figure 1, we can calculate a productivity index by $(y^t / y^*) / (y^s / y^*)$, where $(y^t / y^*)$ is the output growth and $(y^s / y^*)$ represents a movement along the production frontier in period $s$. This can be rewritten as $(y^t / y^*) / (y^s / y^*)$, where the numerator is a distance function for output in period $t$ ($y^t$) with reference to the technology of period $s$ and the denominator is the distance function representing technical efficiency in period $s$. Figure 1 below illustrates the decomposition of the malmquist TFP index.
Efficiency change = \frac{y^t / y^c}{y^s / y^a}, \quad (1)

Technical change = \left[ \frac{y^t / y^b}{y^s / y^a} \times \frac{y^s / y^a}{y^b / y^a} \right]^{1/2}. \quad (2)

Efficiency change is the ratio between two successive output distance functions. It measures the producer’s capacity to improve technical efficiency from period s to period t. Technical change corresponds to the radial shift in the output set (measured with period t data) (Fuentes et al., 2001).

3. MODEL SPECIFICATION

Sugarcane crop is a unique crop in terms of cultivation. It is propagated vegetatively by planting sections of the stalk known as seed-cane. Once the first crop, called plant-cane, is harvested, the plant will grow back from the portion of the stalk left under the ground. The subsequent crops are known as ratoon crops. The age of ratoon has an inverse relationship with crop yield (REDDY, 2003). This study only considers the plant-crops in the two cycles—previous and current—for comparison. The main inputs and activities that enter sugarcane production
function are seedcane; fertilizer; labor (family and hired); and land preparation. During the raton crops, cane production collapses to a function of fertilizer and labor, hence we did not see the need of analyzing a TFP for the raton crops with two inputs. We therefore concentrated with the plant crops.

In using the DEA-like analysis for the \( i \)-th DMU, we have to calculate four distance functions to measure the TFP change between two periods. This requires solving of four linear programming problems for each DMU (farm). Färe et al. (1994) estimated the production frontier for a variable returns to scale (VRS) technology and separated the “scale effect” from productivity changes. However, as pointed out by Grifell-tatjé & Lovell (1995), a Malmquist index may not correctly measure total factor productivity (TFP) changes when VRS is assumed for the technology. For this reason we will assume a CRS technology which gives us:

\[
F^*_o(y_s, x_s) = \left[ d^*_o(y_s, x_s) \right]^{-1} \text{Max}_{\lambda_i} \theta^s
\]

s.t.

\[
\sum_{j} \lambda_j x^s_{oj} \leq x^s_{ij} \quad \forall i \quad (3)
\]

\[
\sum_{j} \lambda_j y^s_{oj} \geq \theta^s y^s_{ir} \quad \forall r
\]

\[
\lambda^s_j \geq 0 \quad \forall j.
\]

where, \( \theta^{\text{CRS}} \) is a TE measure of the \( j \)-th DMU under CRS and \( \lambda \) is an (\( N \times 1 \)) vector of weights attached to each of the DMUs. If \( \theta^{\text{CRS}} = 1 \) and slacks are zero (\( S^*_i = 0; \forall i \) & \( S^*_r = 0; \forall r \)), the DMU under assessment is on the estimated frontier and is technically efficient. The remaining three LP problems are simple variants of this. Note that the subscript ‘o’ has been included to remind us that these are output oriented measures. Input-oriented measures can be calculated in a similar manner. All the four distance functions have been estimated by Data Envelopment Analysis (DEA). Ali & Seiford (1993), Grosskopf (1994) explain clearly how the estimation can be done. Alongside the scheme analysis, we estimated a TFP for a frontier technology (one that encompasses all the three schemes).

4. **DEA MALMQUIST TFP RESULTS**

The output considered in this estimation is the sugarcane in tones per acre. Alongside this, five inputs have been postulated to influence cane production. These are: seed-cane (tones per acre); fertilizer (kg per acre); hired labor (man-days per acre); family labor (man-days per acre); and land preparation (machine hours per acre). The previous cycle plant-crop has been assigned as period \( s \) (base period) while the current cycle plant-crop has been assigned period \( t \). In our calculations, 41 farmers have been included for Mumias scheme. In Chemelil, 28 farmers have been included, while in West Kenya, 26 farmers have been included making a total of 95 farmers. The results have been presented first for schemes and then for the meta-frontier. Table 1 below shows the various measures of the decomposed Malmquist TFP measure for the different sugar schemes. As mentioned earlier, the Malmquist TFP can be decomposed in to one part due to efficiency change, and another part due to technical change (change in technology) as shown below.
Table 1: Total factor productivity change for plant-crops (Mumias)

<table>
<thead>
<tr>
<th>Scheme</th>
<th>Efficiency change</th>
<th>Technological change</th>
<th>TFP change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mumias</td>
<td>1.011</td>
<td>0.973</td>
<td>0.984</td>
</tr>
<tr>
<td>Chemelil</td>
<td>0.947</td>
<td>0.929</td>
<td>0.880</td>
</tr>
<tr>
<td>West Kenya</td>
<td>0.962</td>
<td>0.993</td>
<td>0.955</td>
</tr>
<tr>
<td>Overall</td>
<td>0.871</td>
<td>1.087</td>
<td>0.947</td>
</tr>
</tbody>
</table>

5. CONCLUSION

In conclusion, it can be said that the problem with Mumias is continued use of old technologies, which is causing declining technical change. There is need to fully embrace newer production methods. Efficiency wise, the scheme seems to be doing alright, but this is still more can be done. The results show that the farmers in the scheme can utilize the existing technology, and achieve better cane yields, but they would do better with newer technologies.

Chemelil has both technical change and efficiency problems. On average, the farmers are not utilizing the available technologies fully hence declining efficiency level. Additionally, adoption of newer sugarcane production technologies in the region seems to be on a downward trend. Inasmuch as this could be blamed on the farmers, extension plays a big role in informing farmers on newer cane production technologies. This is an indication that proper extension advice is missing in this area.

In West Kenya, the problem is that of efficiency change, that is, doing things better given a certain technology level. This seems to be on a downward trend. However, the farmers seem to have experienced stagnation in adoption of new technologies between the two periods as shown by there close to unity technological measure of 0.993. Efficiency means higher yields given the current technologies. For high efficiencies changes to be achieved land preparation and planting have to be done at the right time, and so is fertilizer application. Harvesting should also be synchronized and done on time in order to avoid losses due to delayed harvesting.

Technical progress involves a shift in technology, that is, adoption of new technologies. Technical progress would involve adoption of better seed varieties; better land preparation technologies; and use of the recommended fertilizers and supplementation with farm yard manure. Recommended fertilizer and manure application would ensure improved soil structure and fertility; high yielding and early maturing high sucrose content varieties would mean reduced harvesting periods, increased yields and high returns for the farms and the millers. Better land preparation methods would mean that the recommended depths are reached. This should be done especially for West Kenya.

One factor that is hindering the change in efficiencies and technical progress is the continued land subdivision which brings with it diverse management styles. This is especially so in areas where farmers have some form of autonomy in their operations like Chemelil and West Kenya. In these schemes a farmer decides what cane variety to grow, whether or not to apply fertilizer, what land preparation technique to use, the level of labor to allocate in production, and the seeding rates. This autonomy causes the diversity in the different efficiency levels. If such differences could be minimized, and some uniformity introduced, then possibly the efficiency differences could be minimized. Such uniformity would be achieved by having a universal way of doing things in the schemes.
6. REFERENCES


Kenya Sugar Authority (1999), *Kenya Sugarcane Authority Yearbook of statistics*.

Kenya Sugar Board (2003), *Kenya Sugarcane Board Yearbook of statistics*.


