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Factor substitution and wage employment in agriculture. The case of Kilombero Sugar Estate, Tanzania

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Despite the fact that monetary agriculture has made an increased contribution to the gross domestic product, wage employment in agriculture has been declining. Therefore possibilities were studied of substituting labour for machinery in Tanzanian agriculture, using the Kilombero Sugar Company as a case study. In order to calculate the exchangeability labour vs. machinery from the production functions, that of the constant elasticity of the substitution - which was also successful in other investigations - was used instead of the Cobb-Douglas function. It was found that there were little chances of labour substituting for machinery in Kilombero. The declining rate of wage employment in Tanzanian agriculture must be seen as a consequence of subsidized machinery imports. Cutting this subsidisation and increasing wages might lead to increased wage employment in agriculture.

1. Introduction

The majority of developing nations depend largely on agriculture as the main source of income. In Tanzania for example, about 50 % of the gross domestic product (GDP) and more than 75 % of the foreign exchange earnings accrue from the agricultural sector (Tanzania 1983). About 90 % of the population live in rural areas engaged in subsistence agriculture. Thus, locating industries with strong backward linkages to the resource base within Tanzania's rural areas will promote the country's development.
Initially, it was thought that the development of industries would assist in reducing the total labour force which depend on agriculture. Table 1 shows that wage employment in agriculture is about 20 % of the total wage employment compared to about 18 % of manufacturing in the period between 1979 to 1986. However, the share of agriculture in wage employment has been declining, from 21.4 % in 1979 to 16.8 % in 1986, whereas the share of agriculture in the GDP has been increased from 41.8 % in 1976 to 58.9 % in 1986 (table 1). This shows that the growth in wage employment of the agricultural sector, has not kept pace with the growth of the sector in terms of its monetary contribution to the GDP. It is also evident that without expanding the wage employment in the agricultural sector, there might be unemployment problems in Tanzania because the growth of urban labour force is exceeding the growth in urban employment opportunities. With a high rural-urban migration, this problem becomes even worse. It was reported that wage employment in the urban areas was growing at 5.9 % per annum while the urban population and labour force has been growing at 7.6 % per annum (OGWEL and MLAMBITI 1976).

Various reasons have been given why the relative share of wage employment has been declining in the agricultural sector (ODADA 1985). This paper tries to find out whether factor substitution can be used to rescue the declining rate of wage employment in the agricultural sector. Further the study aimed to find out if the existing technology in sugarcane production allows capital to be substituted by labour. This involved the estimation

Table 1: Tanzania gross domestic product (GDP) at constant (1976) prices and wage employment 1976-1986

	1976	1977	1978	1979	1980	1981
Total GDP factor cost 1976 prices (Tshs mil.)	21,652	25,698	28,582	32,317	37,454	43,906
Monetary agriculture factor cost GDP (Tshs. mil.)	9,046	11,131	12,506	14,728	16,636	20,338
Share of agriculture in GDP (%)	41.8	43.3	43.8	45.6	44.4	46.3
Manufactoring factor cost GDP (Tshs. mil.)	2,811	3,287	3,859	3,868	4,097	4,501
Share of manufactoring in GDP (%)	13	12.8	13.5	12	10.9	10.2
Total wage employment (number '000')	-	-	-	596.8	603.2	638.2
Wage employment in agriculture (number '000')	-	-	-	128	131	129.6
Share of agriculture in wage employment (%)	-	-	-	21.4	21.7	20.3
Wage employment in manufacturing (number '000')	-	-	-	107.1	105.8	114.2
Share of manufacturing in wage employment (%)	-	-	-	17.9	17.5	17.9

	1982	1983	1984	1985	1986
Total GDP factor cost 1976 prices (Tshs mil.)	52,546	62,608	78,143	108,083	143,034
Monetary agriculture factor cost GDP (Tshs. mil.)	26,449	32,737	41,295	61,231	84,153
Share of agriculture in GDP (%)	50.3	53.7	54.1	56.6	58.9
Manufactoring factor cost GDP (Tshs. mil.)	4,361	4,869	5,932	6,665	7,417
Share of manufactoring in GDP (%)	8.3	8.0	7.7	6.9	6.2
Total wage employment (number '000')	676.0	686.9	633.4	662.1	692.7

Wage employment in agriculture (number '000')	134.4	131.9	108.1	109.2	116.5
Share of agriculture in wage employment (%)	19.9	19.2	17.1	16.5	16.8
Wage employment in manufacturing (number '000')	118.2	115.4	115.9	121.1	123.3
Share of manufacturing in wage employment (%)	17.5	16.8	18.3	18.3	17.8

Source: Tanzania Economic Survey 1986 and 1987. Ministry of Finance and Economic planning

of the elasticity of factor substitution between capital and labour. Since there was no way of choosing the production function of Kilombero Sugar Estate through prior reasoning, the investigation used both the Cobb-Douglas (C-D) and the constant elasticity of substitution (CES) production functions[1]. The aim was twofold: firstly through the goodness of fit to determine which of the two production functions is appropriate, and secondly to determine whether the elasticity of factor substitution is constant but taking values other than one.

2. Elasticity of factor substitution

One of the common measures of factor substitution is the elasticity of factor substitution (δ). This is the proportionate change in the ratio of the inputs, i.e. capital and labour divided by the proportionate change in the marginal rate of technical substitution of labour for capital ($MRTS_{K,L}$).
That is:

$$\delta = \frac{\Delta \left(\frac{K}{L}\right) / \frac{K}{L}}{\Delta \left(MRTS_{K,L}\right) / MRTS_{K,L}} \qquad (1.1)$$

where K is capital input and L is labour input. The numerator expresses the proportionate change in the ratio of capital and labour and the denominator represents the proportionate change in $MRTS_{K,L}$. $MRTS_{K,L}$ is the change in the amout of labour divided by the change in the amount of capital i.e.

$$\frac{\Delta L}{\Delta K}$$

Assuming perfect competition and profit maximization, the $MRTS_{K,L}$ is equal to the ratio of factor prices $\frac{P_K}{P_L}$, where P_L = the wage rate and P_K = value of capital.
Under these assumptions equation (1.1) can be defined as:

$$\delta = \frac{\Delta \left(\frac{K}{L}\right) / \frac{K}{L}}{\Delta \left(\frac{P_K}{P_L}\right) / \frac{P_K}{P_L}} \qquad (1.2)$$

[1]Another production function which could have been considered, is the variable elasticity of factor substitution (VES), but due to data limitation the function was not estimated.

i.e. proportionate change in the ratio of inputs divided by proportionate change in the ratio of factor prices.
From equation (1.2) δ measures how rapidly factor proportions change for a change in relative prices. Since the combination of certain levels of factors represents the available production technology, δ specifically measures the extent to which the available technology is flexible enough with respect to easiness of allowing substitution between capital and labour.
The levels of mechanization and labour utilization in a given economy greatly depend on the policies of that country. Thus, as far as capital and labour substitution is concerned, appropriate wage and transfer of technology policies are crucial.
If there are possibilities of substituting factors, that is if δ is large, then a policy which makes capital cheaper for example subsidization of machinery imports, relative to labour services would decrease wage employment and the relative share of labour in total output. This means that output can be increased by increasing only one factor (capital). If elasticity of factor substitution is small, that is, substitution possibilities are low, it becomes difficult to get increased output by increasing only one factor of production because diminishing returns to the other factor increase (ODADA 1985).
Kilombero Sugar estate was selected for this study mainly because of data availability. It is one of the largest agricultural estates in Tanzania, employing over 8000 people. In addition the estate has been experiencing problems which make the capacity of the factories underutilized (SENKONDO 1988).

3. Models

The first task of the study was to find out whether the elasticity of factor substitution is unity or can take a value other than unit that is, whether the underlying production function is CES or C-D. This involved the estimation of C-D and CES production functions.
C-D production function of the form

$$Q_i = AK^{\alpha}L^{\beta}E^{u} \qquad (1.3)$$

was estimated for this study, where Q is the level of output i.e. the quantity of sugarcane harvested, K is the capital input, L is the labour input, u is the stochastic disturbance term, and A, α, and ß, are the parameters of the function.

The CES production function, as developed by ARROW et al. (1961) is

$$Q_t = \gamma[\delta K^{-P} + (1-\delta) L^{-P}]^{-v/P} e^{u} \qquad (1.4)$$

where Qt = output
K = capital input
L = labour input
e = 2.7 1828.....
γ is the efficiency parameter, δ the distribution parameter, v returns to scale parameter and P the substitution parameter. U is the stochastic disturbance term.
By taking logarithms of (1.4), the model can be estimated by setting the likelihood function and obtain maximum likelihood estimators of Γ, δ, v and P (KMENTA 1971):

$$\ln Q_i = \ln \gamma - \frac{v}{P} \ln [\delta K^{-P} + (1-\delta) L^{-P}] + u \qquad (1.5)$$

Alternatively, by applying Kmenta's recommendation of using Taylor's series formular, and expanding Q_i around P = 0 and dropping the terms involving powers of P higher than 1, (1.6) can be estimated using ordinary least squares:

$$\ln Q_i = \ln\gamma + v\delta \ln K + v(1-\delta) \ln L - \tfrac{1}{2}Pv\delta(1-\delta)[\ln K - \ln L]^2 + e \qquad (1.6)$$

The CES production function reduces to the C-D production function if P = 0. When P = 0, the term [Pv $\delta(1-\delta)$] $[\ln K - \ln L]^2$ will disappear. If the estimation of the parameter attached to $(\ln K - \ln L)^2$ is not significantly different from zero, we reject the CES model in favour of C-D. In this study the unitary elasticity of the C-D production function hypothesis was tested by examining the statistical significance of the coefficient attached to $(\ln K - \ln L)^2$.
Models 1.3 (in logarithmic form) and 1.6 were estimated using ordinary least squares, on Kilombero data.

4. Data sources

Data were based on Kilombero I and II nucleus estates. The estates are organized into 10 sections of about 400 ha. To get more variations, the data for the 10 sections were observed for 5 years that is, from the 1981/82 to 1985/86 cropping seasons. It was believed that there had been changes in the use of inputs and technology within the sections in the period under observation.

Labour data were collected in man-days. These covered manual planting, seedcane preparation and transport, weeding, fertilizer application, harvesting, loading and transportation labour. Data on the quantity of sugarcane harvested were obtained from the records kept by the plantation department. It was noted that sugarcane yields declined with each subsequent ratoon in Kilombero estates, but they do not differ significantly in sucrose content (SENKONDO 1988). In this paper therefore, no attempt was made to distinguish between plantcane and ratoons.The output variable was taken simply as the quantity of sugarcane harvested in t.

Data on capital were the most difficult to measure in this study. There are different sizes of machinery and implements undertaking various farm operations, and the rate of their utilization (that is wear and tear) is not documented. Thus the value of machinery services seemed a more appropriate way of measuring the capital services. These data were easily obtained from cost accounts sections. To this figure, an allowance was added for certain repairs and maintenance, and loan repayment (including interest rate). This was done by the cost accountants.

5. Regression results

Equations 1.3 and 1.6 were fitted using the ordinary least squares technique to combined crossection and time series data for the estate in the stated period. The basic assumptions underlying the least squares estimate were made:

$$E(U_i) = 0,\ E(U_i^2) = \delta^2 \text{ and } E(U_i U_s) = 0 \quad \forall i \neq s$$

The results of the estimated production functions were

C-D production function:

$$\ln Q = 3.72 + 0.07 \ln L + 0.355 \ln K \qquad (1.7)$$

t-values (16.2)* (0.8)(8.4)*
$R^2 = 0.72$ $\bar{R}^2 = 0.71$
$F = 59.1$
$n = 50$

CES production function:

$$\ln Q = 2.0 + 0.14 \ln L + 0.204 \ln K - 0.077 (\ln K - \ln L)^2$$

t-values (14.3)* (1.9)* (3.5)* (3.9)* (1.8)
R^2 = 0.78 $\bar{R}^2$ = 0.77
F = 53.7 n = 50

* Significant at P < 0.05

With the exception of the coefficient for labour in C-D production function, all other coefficients were statistically significant at the 5 % level. The insignificance of the coefficient for labour in the C-D production function might have been due to the fact that most farm operations are mechanized. The explanatory variables explained about 70 % of the variations in the dependent variable. The estimates of the C-D production function produced degrees of returns to scale of 0.425.

The CES production function produced significant results. About 77 % of the variations in the dependent variable were explained by the included explanatory variables. The degree of returns to scale was 0.344. This is significantly different from 1, indicating that Kilombero Sugar estate is experiencing decreasing returns to scale.

The coefficient attached to $(\ln K - \ln L)^2$ of the CES production function was significant at the 5 % level, which suggests that the unitary elasticity of the factor substitution assumption of the C-D production function does not hold true in sugarcane production at Kilombero Sugar estate. The results indicate that the value of δ is not unity. Despite the fact that the variable elasticity of substitution production function was not estimated, the results showed statistical significance of the CES, which made us assume that δ is constant only at values other than unity, irrespective of the level of factor use. In view of the fact that C-D production functions have been traditionally used in agriculture, the above findings suggest that the assumption of unitary elasticity may not be appropriate, and one may have to sacrifice the simplicity of the C-D production function and adopt the CES production function. The CES production function produced elasticity of factor substitution of 0.4, which is significantly greater than zero. These results compare favourably with those of ODADA (1985) in Kenya's Sugar Industry. In that study, unitary elasticity of factor substitution assumption was rejected and the elasticities obtained were less than unit and significantly greater than zero.

6. Summary and conclusion

The aim of this paper was to find out whether there are substitution possibilities in Kilombero Sugar estate, so that recommendations can be made to rescue the declining share of wage employment in agricultural sector. C-D and CES production functions were estimated in order to select the best fitting production function which was assumed to be the underlying production function in sugarcane production. The CES production function qualified on the underlying criterion.

The results indicated that there were little chances of substituting labour for machinery in the estate. This implies that the factor shares problem is not as important as initially assumed. When δ is less than 1 the share of the factor whose price has risen (and whose quantity has fallen) will increase (YOTOPOULOS and NUGENT 1976). This implies that as the wage rate of sugarcane labourers is increased, the relative share of labour in the total output increases. Kilombero improves the incentives and wage rates, the wage employment increases considerably.

Various reasons have been given as to why the relative share of wage labour in agriculture is declining. Probably the most important one is the subsidization of farm machinery and implements import. This has been blamed for the decline in the relative share of wage employment in agriculture. In Tanzania for example, there are exemptions for those who import farm machinery. If output is increased and a rural-urban labour migration exists, there may be an increase in agricultural wage rate due to high revenues to farmers and

scarce labour force. However, the increase in output may not be strong enough to outweigh the effects of labour-saving technological progress (which is subsidized). As a result, the relative share of wage employment in agriculture declines. MAITHA (1973) argues that the subsidization of farm machinery has been one of the reasons for a decline in wage employment in agriculture in Kenya.

Sugarcane production requires heavy machinery, especially in land clearing and stubble ploughing. However, machinery ownership has to be based on the total cultivable land and the nature of the activities to be carried out. There is a certain limit to the number of machinery to be owned. In Kilombero Sugar Company net returns on sugarcane are humpered by the heavy overhead costs which are not producing corresponding increases in yields (SENKONDO 1988). As machinery indiscriminately used, wage employment in agriculture declines. There is a need for reversing this trend, and apply relatively more labour-intensive techniques of production. Activities which can be well performed by hand digging or oxen ploughing need not be tractorized. Rising costs of fuel and scarcity of foreign exchange call for reducing unnecessary tractorization.

Despite the fact that sugarcane manual operations are tedious, and therefore tend to be avoided by labourers, incentives and competitive wages can make them more attractive. Furthermore, with a slow rate of growth of employment, wage employment in the agricultural sector can considerably reduce wage unemployment problems in Tanzania.

This paper suggests that the declining rate of wage employment in agriculture might have been due to subsidization of farm machinery imports which leads to indiscriminate tractorization. Increases in wage incentives can considerably increase the relative share of wage employment in agriculture.

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E.M.M. SENKONDO und G.C. ASHIMOGO: Faktorsubstitution und Lohnarbeit in der Landwirtschaft. Das Fallbeispiel 'Kilombero Sugar Estate' in Tansania

Trotz der Tatsache, daß die marktorientierte Landwirtschaft einen größeren Beitrag zum Bruttosozialprodukt erbrachte, verringerte sich der Umfang der Lohnarbeit in der Landwirtschaft. Die Publikation untersucht die Möglichkeiten, im tansanischen

Landwirtschaftssektor Handarbeit durch Maschinenarbeit zu ersetzen und nutzt dabei die Kilombero Sugar Company als Fallstudie. Zur Berechnung der Austauschmöglichkeiten Handarbeit zu Maschinenarbeit von den Produktionsfunktionen wurde statt der Cobb-Douglas-Funktion die der konstanten Elastizität der Substitution genutzt, die auch in anderen Publikationen eine bessere Analyse der Praxisprobleme ermöglichte. Die Studie zeigt, daß im Fallbeispiel wenig Chancen für den Ersatz von lebendiger Arbeit durch Maschinen gegeben sind. Die in Tansania festzustellende Abnahme der Lohnarbeit in der Landwirtschaft muß als Folge subventionierter Maschinenimporte angesehen werden. Ein Wegfall dieser Subventionen und eine Anhebung der Löhne könnte zu einer Ausweitung der Lohnarbeit in der Landwirtschaft führen.

E.M.M. SENKONDO et G.C. ASHIMOGO: Substitution des facteurs et travail salarié dans l'agriculture. Le cas exemple de Kilombero Sugar Estate en Tanzanie

Malgré le fait que l'agriculture orientée vers le marché ait rapporté une plus grande contribution au produit national brut, le volume du travail salarié a diminué dans l'agriculture. La publication examine les possibilités de remplacer dans le secteur agricole tanzanien le travail manuel par le travail mécanique, en utilisant comme cas exemple le Kilombero Sugar Company. Pour calculer les possibilités d'échange travail manuel/travail méchanique des fonctions de production, on a utilisé au lieu de la fonction Cobb-Douglas celle de l'élasticité constante de la substitution, qui a permis déjà dans d'autres publications une meilleure analyse des problèmes de la pratique. L'étude montre qu'il y a, dans l'exemple, peu de chances pour le remplacement du travail humain par les machines. La baisse du travail salarié que l'on constate dans l'agriculture tanzanienne s'explique évidemment par les importations de machines subventionnées. La suppression de ces subventions et une augmentation des salaires pourraient, par contre, favoriser l'extension du travail salarié dans l'agriculture.

E.M.M. SENKONDO y G.C. ASHIMOGO: Substitución de factores y trabajo asalariado en la agricultura. El ejemplo de un caso en Kilombero Sugar Estate en Tanzania

A pesar del hecho que la agricultura orientada al mercado contribuyó más al producto social bruto, la importancia del trabajo asalariado iba disminuyendo. La presente ponencia analiza las posibilidades para substituir el trabajo manual por trabajo mecanizado en el sector agrario de Tanzania el ejemplo de la Kilombera Sugar Company. Para evaluar la posible substitución del trabajo manual por el trabajo mecanizado, se aprovechó, de las functiones de producción, en vez de la función Cobb-Douglas, de la constante elasticidad de la substitución que también en otras publicaciones posibilitó un mejor análisis de los problemas practicos. El estudio muestra que en el ejemplo del caso hay pocas posibilidades para substituir el trabajo humano por máquinas. La constatada disminuión del trabajo asalariado en la agricultura de Tanzania se debe a importaciones subvencionadas de máquinas. La supresión de estas subvenciones y un aumento del salario podería llevar al incremento del trabajo asalariado en la agricultura.