TIME - SERIES PRODUCTION FUNCTIONS AND TECHNOLOGICAL PROGRESS IN KENYAN INDUSTRY

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The slow rate of growth of employment in the modern sector of the economies of the LDCs has stimulated great interest in the elasticities of substitution between capital and labour in these countries.[1] The main reason for this interest in the elasticities of substitution is the determination of the degree of substitutability between capital and labour. From this knowledge we can deduce some useful results concerning growth, employment and distribution of income. Technological progress could also be another explanation of this slow growth of employment in LDCs but very few studies has attempted to estimate the nature of technological progress in LDCs. In this paper we attempt to estimate both elasticities of substitution and technological progress in the main sectors of the Kenyan economy.

In the case of Kenya a number of studies have appeared on employment and productivity mainly in the manufacturing sector.[2] However, very few of these studies have directly estimated the elasticity of substitution although some reject the capital-labour hypothesis even without direct evidence.[3] Most of these studies assume constant returns to scale and to our knowledge, very few attempts have been made to estimate returns to scale. Our knowledge about technological progress in Kenya is meagre and there are no estimates available due to paucity of data.

THE MODEL.

Our estimates of the elasticity of substitution are based on the constant elasticity of substitution (CES) production function. In this study we are also interested in estimating the extent of technical progress in Kenya's economy. If we assume the Hicks-Neutral technological progress, the CES production function can be written:

$$Q = A\, e^{\lambda t} \left| \delta\, k^{-\ell} + (1-\delta) L^{-\ell} \right|^{-\frac{v}{\ell}} \qquad (1)$$

where O, K and L are value added, capital and labour. λ, δ, ℓ and v are technology, distribution, substitution and homogeneity parameters.

Due to lack of data on capital, we cannot estimate (1) directly. However, if we assume constant returns to scale and further that factor and product markets are competitive, then we can estimate the elasticity of substitution and technical progress from data on value added, wages and labour. Thus for $v = 1$, the following regression equation can be derived from (1)[4].

$$\log q = a_o + a_1 \log w_t + a_2 t \qquad (2)$$

Where q = value added per man (Q/L)

w = the wage rate (W/L)

t = trend term

The economic parameters are estimated or calculated from the regression coefficients as follows:

$$\sigma = a_1$$

$$\lambda = a_2/(1-a_1)$$

where Λ is the elasticity of substitution and λ is the technological progress parameter.

Equation (2) is the celebrated ACMS formulation for estimating the elasticity of substitution and has been widely used. However, estimates of σ from it are characterized by some problems of identification and specification.[5] If the constant returns to scale assumption is dropped, then another equation can be derived to estimate the elasticity of substitution, technical progress and the returns to scale parameter.[6] From (1), the marginal product for labour is given by:

$$\frac{\partial O}{\partial L} = k\, O^{1+(\alpha/v)}L^{-1-\alpha}$$

where $k = A\, e^{rt(1-\delta)}\, A\, e^{rt}$

By equating the marginal product with the wage rate and after some rearrangement, we have the following estimating equation.

$$\log Q_t = b_0 + b_1 \log w_t + b_2 \log L_t + b_3 t. \qquad (3)$$

where $\Lambda = b_1/b_2$

$$\lambda = b_3/(1-b_2)$$

$$v = \frac{b_2 - b_1}{1 - b_1}.$$

Equations (2) and (3) are our basic estimating equations.

Empirical Results:

Equations (2) and (3) were fitted to time-series data covering eight sectors over the period 1956 - 72.[7] The eight sectors are large scale Agriculture, Mining and Quarrying, Manufacturing, Transport and Communications, Building and construction, Commerce, services and the public sector. Equation (2) fitted the data better than equation (3). In equation (3) employment (L) is included to pick up dramatic and sudden changes in value added (Q). Thus the L variable should explain qualitative changes in Q that do not follow a smooth growth pattern over time. Equation (3) did not fit the data. The coefficient of L was insignificant most of the time and L was highly correlated with the wage rate. Hence equation (3) was dropped in favour of equation (2).

There are three possible explanations as to why equation (3) fails to fit our data. First, the sectors considered in this paper may not be characterized by increasing returns to scale. Second, the period covered by the data could be relatively short and hence equation (3) inappropriate. Third, there were no significant dramatic and sudden changes in value added during the period 1956 - 72.

The results of equation (2) are shown in table 1 below.

TABLE 1

ESTIMATES OF EQUATION 2 (1956 - 1972)

	Sector	Constant	log w_t	Time	$\bar{R}^2$
1.	Agriculture	.780	1.045 (.500)	.044 (.027)	.980
2.	Mining & Quarrying	9.966	1.001 (.638)	.177 (.025)	.971
3.	Manufacturing	6.072	.755 (.171)	.086 (.013)	.987
4.	Transport & Communications	7.093	.028 (.038)	.062 (.007)	.979
5.	Building & Construction	5.349	.815 (.246)	.065 (.019)	.949
6.	Commerce	2.697	.784 (.192)	.093 (.012)	.954
7.	Services	5.065	.118 (.149)	.018 (020)	.248
8.	Government	2.676	.218 (.333)	.087 (.016)	.993

The numbers in brackets are standard errors of the coefficients.

Equation (2) produced insignificant results in three sectors, namely transport and communications, services and government. Services had the poorest results and only the trend term coefficient was significant in transport and communications and the public sector. The wage rate coefficient in mining and quarrying is significant at the ten per cent level. All the other coefficients are significant at least at the five per cent level. The estimated economic parameters from the sectors with significant results are shown below.

TABLE 2

ESTIMATED ECONOMIC PARAMETERS

Sector	$\hat{\sigma}$	$\hat{\lambda}$
Agriculture	1.05	-0.98
Mining & Quarrying	1.01	-0.18
Manufacturing	0.76	0.35
Building & Construction	0.82	0.35
Commerce	0.78	0.01

In the four sectors the estimated elasticity of substitution is not significantly different from unity.[8] This implies that capital-labour substitution is not as limited as calimed in some quarters. Thus increasing the level of wages can be expected to impede employment creation through capital substitution for the expensive labour.

The estimated coefficient for technological progress suggests that there was technological retregression in Agriculture and, Mining and Quarrying during the period 1956 - 72. This agrees with other economic indicators in these two industries. In agriculture employment has declined considerably during this period and the rate of capital formation has been very low. In Mining and Quarrying, both employment and capital formation have been declining during this period. Manufacturing and building and Construction show reasonable rates of technological progress and Commerce shows the least technological progress.

All the coefficients of the technological progress parameters are consistent with Hicks-neutral or labour augmenting technological change. Hicks-neutral technological progress in a CES production function is determined according to table 3 below.

TABLE 3

HICKS-NEUTRAL TECHNOLOGICAL PROGRESS IN A CES PRODUCTION FUNCTION

$\sigma < 1$	$\sigma > 1$
If $b_2 > 0$	If $b_2 > 0$
$\lambda > 0$	$\lambda < 0$
$-\rho\lambda < 0$	$-\rho\lambda < 0$

FOOTNOTES

* I would like to thank ILO for financial support but any errors are my responsibility.

1. See for example, C.K., "Capital Substitution in Manufacturing in Underdeveloped Countries, "Econometrica" Vol.37, (July 1969), in A.D. Witto, Alternative Estimates of Capital-Labour Substitution in Manufacturing in Developing Economies: Comments On Professor Clague," Econometrica, Vol.39 No.6 (November, 1971) J.P. Behram, "Sectoral Elasticities of Substitution between capital and Labour in a Developing Economy. Time series Analysis in the Case of Post-war Chile," Econometrica, Vol.40, No.2 (March, 1972), M.A. Oyelabi, "Tests of Factor Substitution in Nigeria's Manufacturing Sector", Eastern Africa Economic Review, Vol.3 No.1 (June, 1971) and J.K. Maitha, "Capital-Labour Substitution in Manufacturing in a Developing Economy: The Case of Kenya, " Eastern Africa Economic Review, Vol.5. No.2 (December, 1973).

2. See J.R. Harris and M.P. Todaro, "Wages, Industrial Employment and Labour Productivity", Eastern Africa Economic Review, Vol.1 No.1 (June, 1969), J.R. King, "Wages, Employment and Productivity in Kenya: A Comment", Eastern Africa Economic Review, Vol.4 No.2 (December, 1972) and W.J. House, "Wages, Employment and Productivity in Kenya: Some further Evidence", Eastern Africa Economic Review, Vol.5 No.1 (June, 1973) J.K. Maitha, op.cit.

3. W.J. House, op.cit. tried to estimate the elasticity of substitution using the Arrow, et.al, model and obtained elasticities slightly larger than unity. However, using the same model, the author, op.cit. finds that for most of Kenyan manufacturing industries, the elasticity of substitution tends to be unity.

4. For the original derivation, see, Arron, K.J., H.B. Chenery, B.S. Minhas and R.M. Solow,"Capital-Labour Substituition and Economic Efficiency," Review of Economics and Statistics, August (1961).

5. For example, see, J.P. Moroney, "Identification and Specification Analysis of Alternative Equations for Estimating the Elasticity of Substitution," Southern Economic Journal, Vol.XXXVI (january, 1970)

6. See for example, C.E. Ferguson, "Substitution, Technical Progress and Returns to Scale," American Economic Review, Vol.LV, (May,1965)

7. The data for value added, wages and employment were obtained from the Statistical Abstracts 1962 - 1973.

8. This result agrees with other estimates of the elasticity of substitution by the author.