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TRANSLOG COST FUNCTION ANALYSIS FOR MANUFACTURING SECTOR IN KENYA

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ABSTRACT

Developing countries need to have in place a vibrant manufacturing sector since it is a key driver of economic growth and development. This is because the sector enables a country to be competitive, boosts productivity and creates employment in the economy. The study sought to estimate the Translog cost function for Kenya's manufacturing sector for 2019 as well as to estimate the cost factor share equations by expressing cost as a function of four inputs namely, labour, electricity, water, and petroleum products. The production function was assumed to be the Cobb-Douglas type. Using the Taylor series expansion, the Translog cost function was estimated. The parameters for the various restricted forms of the cost functions were estimated with generalized nonlinear least square estimation procedures using STATA.

Keywords: Cost Function, Energy, Manufacturing sector, Translog,

1. Introduction

The manufacturing sector is a key driver to economic growth and development in any country as it provides employment opportunities, boosts a country's competitiveness and promotes productivity. Many developing countries aim to highly industrialize but due to the structure of their economies which are primarily agricultural, their industrial sectors are not robust (Gudka, 2020). In Kenya, for instance, the target is to achieve at least a sustained industrial growth of at least 15% per annum, but this growth has been declining in the recent years. The manufacturing sector in Kenya has experienced fluctuating growth expanding to a high of 3.6% in 2015 to a low of 0.5% in 2017 but recovered in 2018. The latter growth was contributed by the increase in manufacturing activities and revamping of the agro-processing industry.

The contribution of manufacturing sector to GDP in Kenya is estimated at approximately 10% and this is expected to continue according to the government's planning document, Kenya Vision

2030 (Onuonga, Etyang' & Mwabu, 2011). The manufacturing sector is the third largest end user of energy in Kenya, the second largest user of petroleum products and the largest consumer of electricity (Republic of Kenya, 2019). The slow growth rate of the sector has led to slowed productivity and lack of competitiveness. The reason for this is attributed to high production cost due to increased cost of materials, high cost of energy both electricity and fuel, cost of credit, poor transport facilities, high cost of labor as well as increased competition from imports.

A cost function relates the total cost of production for a level of output to input factor prices and technical change. Generally, a translog cost function is paired with its factor share equations to obtain accurate estimates of parameters. Thus, the factor shares are functions of the same variables and parameters as those of the cost function. The principle of duality in the theory of production can be used to specify cost functions from which the demand for factor inputs can be derived under certain assumptions of cost minimization and perfect competition (McFadden, 1978). The cost function approach has several advantages. First, the cost function can be specified from factor input prices for a given level of output. This leads to computational simplicity in computing factor demands. Second, the conditional factor demand equations can be obtained simply by partial differentiation of the corresponding indirect cost function. Third, the cost function provides a convenient way for specifying empirical functional forms for application to price data where the quantity of factor demands is not known (Marcin (1991).This paper considers the translog cost function as developed by Christensen, Jorgensen, and Lau, (1973) for representing manufacturing costs and the derived conditional factor demand equations.

1.1 Statement of the Problem

The manufacturing sector is an important engine for sustained economic growth and development, poverty alleviation and job creation. Despite its importance, the contribution of the sector to Kenya's GDP has stagnated at around 10% over the years. The government has introduced renewed interest in the sector and has put forth efforts to revamp it targeted at 15% annual growth by 2022 according to the Big 4 Agenda (Gudka, 2020). The annual growth has averaged at 4% which is below the recommended 15% per annum. This has led to reduced competitiveness and productivity of the sector. The major contribution of the declining performance is the high cost of production. The high cost of energy and the low quality and reliability of power have contributed to the dismal overall performance of the sector. The country's rate of inflation is rising and this has greatly increased the cost of living for the general population. Thus, local consumption of domestic goods has reduced due to the reduction in the purchasing power. This situation is further exacerbated by the rising energy and fuel costs that raise the cost of production and this cost is passed ultimately to the final consumer. Further the cost of labor, credit and materials has been rising, this paper aims at estimating a Cobb-Douglas cost function of Kenya's manufacturing sector for inputs labor, electricity, water, and petroleum products for 2019.

1.2 Objectives of the Study

I. To estimate the translog cost function for Kenya's manufacturing sector for 2019
II. To estimate the cost factor share equations for Kenya's manufacturing sector for 2019

2.0 Empirical Literature Review

Marcin (1991) used cost function approach to estimate derived demand for composite wood products where he used translog cost function to represent residential construction costs and derived conditional factor demand equations. Results of the regression estimates of the parameters of the translog cost function indicated significant autocorrelation and collinearity of input variables leading to problems in obtaining expected signs and consistent parameter estimates, however, the parameters were positive and significant in the generalized Cobb-Douglas cost function and in all unitary elasticity models.

Kavoi, Hoag, and Pritchett (2009) estimated the production structure of smallholder dairy farms in Kenya's marginal zones, where restricted translog cost function was used to derive a system of input share equations, which were estimated simultaneously with the cost equation by the iterative Zellner procedure. The elasticities of inputs and the price elasticities of factor demands were computed, and economies of scale were determined. The results indicated that the production structure is a fairly well integrated system of activities, despite scale diseconomies. The Morishima elasticities indicated that factor inputs are substitutable.

Onuonga, Etyang, and Mwabu (2011) used translog total cost function to examine energy demand elasticities and the substitution possibilities between energy and non-energy inputs in the Kenyan manufacturing sector over the period 1970 to 2005. They found that oil and electricity were significant substitutes in the Kenyan manufacturing sector although, the substitution possibilities were low. The study found electricity and oil to be price inelastic and were not substitute to each other.

Khalil (2005) estimated the translog production and cost functions using 30 selected manufacturing industries in the Jordanian economy in 2002. The symmetric translog production and cost functions were estimated using the Iterative Zellner-Efficient Estimate (IZEF). The objective was to test for hypotheses for constant returns to scale, weak separability restrictions and Cobb-Douglas hypothesis. The null hypotheses were rejected, implying that constant returns to scale, value added specification and Cobb-Douglas hypothesis were not satisfied with the Jordanian manufacturing data. The results of the study indicated that the cost share of capital, labor and materials were positive at each data point and the production function was well-behaved since positivity and concavity of the function were satisfied. In checking for substitutability of factors using the fitted cost shares of inputs and estimates of the symmetric cost function, the results indicated that capital-labor substitutability was larger than capital-materials and labor-materials. The price elasticities for the factor inputs showed that capital and labor demand were more elastic that the demand for materials.

Berndt and Wood (1975) attempted to characterize the structure of technology in United States manufacturing industry between 1947 and 1971. They employed the translog cost function with four inputs namely: capital, labor, energy and all other intermediate materials. The authors derived the Allen partial elasticities of substitution (AES) between the inputs. They used the Iterative 3-stage least square (I3SLS) estimator to estimate the translog cost function. The cost function was seen to be well behaved; satisfying the positivity and concavity conditions. It was also established that energy demand was price responsive, energy and labor were slightly substitutable while energy and capital were complimentary. The study came to the conclusion that the lifting or price ceilings on energy types would tend to reduce the energy and capital intensiveness of producing a given level of output and increase the labor intensiveness.

3.0 Methodology

There are a number of methods used by economists and econometricians to examine the production process. Theoretical models of a firm's production function, such as the Cobb-Douglas or translog functional forms, allow estimation of the various factors of production (Berndt and Wood, 1975). From a production function, we can derive the cost function, which describes the quantities of inputs needed, along with the cost, to produce a set level of output. The cost function to be estimated is a function of output (Y), and prices of inputs namely labor (X_1), electricity (X_2), water (X_3) and petroleum products (X_4).

$C = f(y, P_i)$ where P_i , i= 1,2, 3, and 4 are the prices of factors

The objective of the producers is to minimize cost subject to output. Here we assume a Cobb-Douglas type of production function specified as

$$Y = \propto_0 \prod_{i=1}^{4} X_i^{\propto_i}$$

Min $C = P_1X_1 + P_2X_2 + P_3X_3 + P_4X_4$
s.t $Y = \propto_0 X_1^{\propto_1} X_2^{\propto_2} X_3^{\propto_3} X_4^{\propto_4}$

The translog cost function is written as a logarithmic Taylor series expansion to the second term of a twice differentiable cost function around variable levels of 1 whereby $\ln Y = 0, \ln p_i = 0$ where $i = 1,2\ 3,4$

The cost function is rewritten in log form to become $\ln C^* = (\ln Y\,, \ln p_1\,, \ln p_2\,, \ln p_3\,, \ln p_4)$

The first and second order derivatives evaluated at $\ln(.) = 0$ becomes;

$$\ln C^* = \propto_0 ;\ \frac{\partial lnC^*}{\partial \ln y} = \propto_\gamma : \frac{\partial lnC^*}{\partial \ln p_i} = \propto_i : \frac{\partial^2 lnC^*}{\partial \ln p_i \ln p_j} = \beta_{ij} : \frac{\partial^2 lnC^*}{\partial \ln p_i \ln y} = \beta_{\gamma i}$$

The Taylor series expansion thus becomes

$$\ln C^* = \propto_0 + \propto_\gamma \ln Y + \frac{1}{2}\beta_{\gamma\gamma}(\ln Y)^2 + \sum_{I=1}^{4} \propto_I \ln p_i + \frac{1}{2}\sum_i \sum_j \beta_{ij} \ln p_i \ln p_j + \sum_{i=1}^{4} \beta_{\gamma i} \ln Y \ln p_i + \varepsilon$$

Where $\beta_{ij} = \beta_{ji}$ which implies the symmetry constraint.

In order to correspond to a well behaved production function, a cost function must be homogenous of degree 1 in prices which implies that;

$\sum_{I=1}^{4} \propto_I = 1$

$$\sum_{i=1}^{4} \beta_{\gamma i} = 0$$

$\sum_j \beta_{ij} = \sum_i \beta_{ij} = \sum_i \sum_j \beta_{ij} = 0$

Using Shephard's lemma, we partially differentiate the cost function with respect to factor prices $\frac{\partial C}{\partial P_I} = X_i$, to obtain the input demand functions.

In logarithmic form, this is expressed as

$\frac{\partial \ln C^*}{\partial \ln p_i} = \frac{\partial C}{\partial p_i} \cdot \frac{p_i}{C} = \frac{p_i X_i}{C} = S_i$

Where S_i is the cost share of the ith factor input.

The translog cost function yields the cost share equations

$$S_i = \frac{\partial \ln C^*}{\partial \ln p_i} = \propto_i + \beta_{\gamma i} \ln Y + \sum_j \beta_{ij} \ln p_j + \varepsilon$$

Where $i = 1, 2, \dots, K$.

Since the cost shares must sum into 1, the following restrictions are imposed

$$\sum \alpha_i = 1$$

$$\sum_i \beta_{ij} = 0$$

$$\sum_j \beta_{ij} = 0$$

To make the model more operational and to solve the problem of singularity, we divide the first $K - 1$ prices by the Kth price. The factor share equations to be estimated will thus be as follows;

$$S_1 = \alpha_1 + \beta_{11} \ln(\frac{p_1}{p_4}) + \beta_{12} \ln(\frac{p_2}{p_4}) + \beta_{13} \ln(\frac{p_3}{p_4})$$

$$S_2 = \alpha_2 + \beta_{21} \ln(\frac{p_1}{p_4}) + \beta_{22} \ln(\frac{p_2}{p_4}) + \beta_{23} \ln(\frac{p_3}{p_4})$$

$$S_3 = \alpha_3 + \beta_{13} \ln(\frac{Y}{p_4}) + \beta_{23} \ln(\frac{p_1}{p_4}) + \beta_{33} \ln(\frac{p_2}{p_4}) + \beta_{34} \ln(\frac{p_3}{p_4})$$

4.0 Estimation of Cost

Parameters for the various restricted forms of the Translog cost functions were estimated with generalized nonlinear least square estimation procedures using STATA. Following Zellner (1962), it is also assumed that the error in each equation is homoscedastic but that there is a non-zero correlation between contemporaneous disturbance terms across equations. Based on the adding-up requirement of the input shares, one equation, petroleum products input demand share, is excluded from the system. By thus deleting one of the share equations from the system and using the iterative Zellner estimation procedure until convergence, we realize maximum-likelihood estimates. The iterative Zellner procedure is a computationally efficient method for obtaining maximum likelihood estimates and is used by researchers for estimating translog cost function (Christensen & Greene, 1976; Kavoi *et. al*, 2009).Results of the regression estimates of the parameters of the Translog cost function and its various restricted forms are presented in Table 1.

Table 1: Parameter estimate of the Translog Cost Function

lnC1	Coef.	Std. Err.	T	P>t	[95% Conf.	Interval]
lnY	1.009196	6.253995	0.16	0.88	-16.3547	18.37307
lnP1	-64.3004	126.6635	-0.51	0.638	-415.975	287.3738
lnP2	6.93677	6.078722	1.14	0.317	-9.94047	23.81401
lnP3	-30.4745	18.83421	-1.62	0.181	-82.7666	21.81767
lnP4	-29.2956	55.23991	-0.53	0.624	-182.666	124.075
lnYlnY	0.229039	0.165414	1.38	0.238	-0.23022	0.6883
lnYlnP1	1.343989	3.222918	0.42	0.698	-7.60427	10.29225
lnYlnP2	0.639559	0.648348	0.99	0.38	-1.16054	2.439661
lnYlnP3	-0.77674	1.35888	-0.57	0.598	-4.54959	2.996118
lnYlnP4	-1.12694	0.92276	-1.22	0.289	-3.68893	1.435056
lnP1lnP2	2.933464	4.653643	0.63	0.563	-9.98712	15.85405
lnP1lnP3	4.254866	11.32839	0.38	0.726	-27.1978	35.70751
lnP1lnP4	6.086082	18.55972	0.33	0.759	-45.444	57.61612
lnP2lnP3	-3.33328	1.478878	-2.25	0.087	-7.4393	0.772749
lnP2lnP4	-1.36741	1.32586	-1.03	0.361	-5.04859	2.313766
lnP3lnP4	6.222958	7.422892	0.84	0.449	-14.3863	26.83221
_cons	214.5635	264.2966	0.81	0.462	-519.242	948.3686

There was serious multicollinearity which made standard error big and t-statistics were not significant as shown in Table 2.

Table 2: Test results for multicollinearity

```
             |  lnYlnP2  lnYlnP3  lnYlnP4 lnP1lnP2 lnP1lnP3 lnP1lnP4 lnP2lnP3 lnP2lnP4 lnP3lnP4
-------------+-----------------------------------------------------------------------------------
     lnYlnP2 |   1.0000
     lnYlnP3 |  -0.0268   1.0000
     lnYlnP4 |  -0.0847   0.8028   1.0000
    lnP1lnP2 |   0.9942   0.0643  -0.0193   1.0000
    lnP1lnP3 |  -0.1296   0.5821   0.2521  -0.0870   1.0000
    lnP1lnP4 |  -0.2579   0.4012   0.6703  -0.2441   0.5335   1.0000
    lnP2lnP3 |   0.9957   0.0312  -0.0364   0.9984  -0.1074  -0.2421   1.0000
    lnP2lnP4 |   0.9934   0.0663  -0.0221   0.9995  -0.0883  -0.2531   0.9974 1.0000
    lnP3lnP4 |  -0.0504   0.5487   0.4821  -0.0188   0.8497   0.7924  -0.0324 -0.0229   1.0000
```

The Breusch-Pagan / Cook-Weisberg test for heteroskedasticity test confirms the absent of heteroskedasticity since the F-probabilities (0.6347) which is more than 0.05; hence the null hypothesis of constant variance in the residuals is not rejected. Therefore, it became a problem to use the translog cost function to estimate the manufacturing cost unless we add more data. We therefore, estimated the cost using the general cobb-Douglas cost function presented in Table 3.

Table 3: Parameter estimate of the Cobb-Douglas Cost Function

lnC1	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
lnY	0.808875	0.093113	8.69	0	0.61041	1.00734
lnP1	-2.65141	1.818473	-1.46	0.165	-6.52739	1.224574
lnP2	0.195116	0.139292	1.4	0.182	-0.10178	0.49201
lnP3	0.658702	0.429124	1.53	0.146	-0.25595	1.573357
lnP4	0.681577	0.452694	1.51	0.153	-0.28332	1.646471
_cons	0.735398	2.95571	0.25	0.807	-5.56455	7.035344

The cost Cobb-Douglas function can be written as:

$$Ln\ C = 0.735398 + 0.808875 \ln Y - 2.65141 \ln P_1 + 0.195116 \ln P_2 + 0.658702 \ln P_3 + 0.681577 \ln P_4$$

All the coefficients, except for Ln Y, are not statistically significant. However, the model was statistically significant with probability 0 <0.05, and Adjusted R-squared of 0.8253. The Breusch-Pagan / Cook-Weisberg test for heteroskedasticity test confirms the absence of heteroskedasticity since the F-probabilities (0.3772) which is more than 0.05; hence the null hypothesis of constant variance in the residuals is not rejected. There was no multicollinearity in the Cobb-Douglas model as shown Table 4

Table 4: Test results for multicollinearity

	lnY	lnP1	lnP2	lnP3	lnP4
lnY	1				
lnP1	0.3068	1			
lnP2	0.0506	-0.3775	1		
lnP3	0.0439	0.4186	0.1039	1	
lnP4	0.2883	0.5855	-0.1171	0.1022	1

The estimated share equations are presented in Table 5.

Table 5: Parameter estimates of the share model

	Coef.	Std. Err.	Z	P>z	[95% Conf.	Interval]
b1	-0.13851	0.074514	-1.86	0.063	-0.28455	0.007537
d11	0.01804	0.023706	0.76	0.447	-0.02842	0.064503
d12	-0.0613	0.017424	-3.52	0	-0.09545	-0.02715
d13	0.025935	0.020502	1.26	0.206	-0.01425	0.066117
b2	1.048009	0.092976	11.27	0	0.865781	1.230238
d22	0.071813	0.024896	2.88	0.004	0.023017	0.120609
d23	-0.00294	0.009724	-0.3	0.763	-0.022	0.016124
b3	0.075932	0.0561	1.35	0.176	-0.03402	0.185887
d33	-0.00368	0.02431	-0.15	0.88	-0.05133	0.043963

Most of the parameters in the share model are insignificant with only the cross cost share between labor and electricity; own cost share of electricity and the constant coefficient for electricity share equation.

5.0 Conclusions

The Translog cost function has the advantage of flexibility of specification and can be applied to multiproduct, multifactor cost functions. Unfortunately, both the Translog cost function parameters and the general cobb- Douglas parameters for Kenya's 2019 manufacturing data were insignificant. The trans-log cost function and its associated factor input share equations have been used extensively to obtain empirical evidence on substitution, factor demand and scale elasticities in production. The study recommends further research on Translog cost estimation of Kenya 's manufacturing sector using more observations and more inputs.

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