MODELING OF SUPPLY AND DEMAND FOR MAIZE IN KILIFI DISTRICT, KENYA: A COBWEB MODEL APPROACH

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ABSTRACT

The study aimed at assessing the determinants of demand and supply of maize in Kilifi, Kenya using the cobweb model for analysis. Results showedthat variations in production of maize were explained by the prices of cassava, income per capita of consumers and time trend. Price of cassava (maize substitute) werestrongly significant ($p<0.01$) and had expected negative sign. This implied that if the price of cassava increased, farmers would shift from maize production to cassava production. In the model, an increase of price of a bag of cassava by 1 US$ would decrease the production of maize by 0.95 per cent in the long-run. Income per capita of consumers was significant ($p<0.1$) though with unexpected sign. The study established that there is need for intensification of maize production due to its importance through provision of the prerequisite incentives such as extension and inputs.

Key words:*Cobweb model, farmgate price,lagged supply*

INTRODUCTION

Kilifi district lies between latitudes $3^{o}16'$south and about 4^{o} south, and longitudes 39^{o}east and 40^{o} east. It borders Kaloleni district to the south west, Kinango and Taita districts to the west, Malindi district to the north, Mombasa district to the south and Indian Ocean to the east. The district covers an area of 3,870.2 km^2[1]. The vastness of the district makes it to experience different agroclimatic zones. The district has three main agroecological zones namely agro ecological zones I, II, and III [2,1]. The definition of a zone is based on the distance from the Indian Ocean coast line. Zone I lies 0 to 15 km from the coast line, zone II extends from 15 to 35 km from the coast line, and zone III extends from 35 km and beyond.

The average annual rainfall ranges from 400mm in the hinterland to 1200 mm at the coastal belt. The coastal belt receives an average annual rainfall of about 900mm to 1100mm with marked decrease in the intensity to the hinterland. Evaporation ranges from 1800mm along coastal strip to 2200mm in the Nyika plateau in the interior. Highest evaporation rate is experienced during the months of January to March in all parts of the district [1].

Agriculture is the mainstay of the majority of the people in the district. The main food crop produced is maize while cash crops grown include coconuts, cashew nuts, citrus fruits and mangoes [1,3]. These crops are grown in smallholder farms which average 5.4ha. The growth of agriculture sector is faced with many challenges which include unfavourable land tenure, crop diseases, unavailability of modern agricultural inputs, inadequate soil management techniques, post harvest losses and low acreage due to low use of modern farming methods and unfavourable climatic conditions which causes drought and perennial food shortages in the semi-arid areas [1].

MATERIALS AND METHODS

Theoretical framework

A basic assumption of most economic analysis of firm behavior is that a firm acts so as to maximize its profits, that is, it chooses actions ($a_1, \ldots, a_n$) so as to maximize R($a_1, \ldots, a_n$) – C($a_1, \ldots, a_n$)[4]. The profit maximization problem facing the firm can thus be written as;

$$\underset{a_1,\ldots,a_n}{Max} \quad R(a_1,\ldots,a_n) - C(a_1,\ldots,a_n) \qquad (i)$$

Where a_i is a particular action chosen by the firm, R is revenue to the firm, and C is the cost the firm incurs. From application of calculus an optimal set of actions, $a^* = (a_1^*, \ldots, a_n^*)$, is characterized by the conditions;

$$\frac{\delta R(a^*)}{\delta a_i} = \frac{\delta C(a^*)}{\delta a_i} \quad i = 1, \ldots, n \qquad (ii)$$

For a firm that takes prices as given in both its output and its factor markets, let **p**be a vector of prices for inputs and outputs of the firm and y be the output. The profit maximization problem of the firm can be stated as

$$\pi(p) = \max\ p\mathbf{y} \qquad (iii)$$
$$such\ that\ y\ is\ in\ Y$$

where Y is the output set.

For a firm producing only one output, the profit function can be written

$$\pi(p, w) = \max\ pf(x) - wx \qquad (iv)$$

The cobweb model

The cobweb model is an attempt to describe temporary equilibrium market prices in a market with a lag in supply [5]. The pioneering work in this model is traced to 1930s[6,7]. Kaldor wrote a paper, “A Classificatory Note on the Determinateness of Equilibrium”, in 1934, whose subject was the analysis of these models. The economist, Mordecai Ezekiel followed with another paper “The Cobweb Theorem”, in 1938 which gave the phenomenon and its particular diagrams popularity. According to [5], when suppliers have naive price expectations and both the supply and demand curves are monotonic, only three types of dynamics are possible; convergence to an equlibrium price, convergence to a period 2 price cycle or exploding unbounded price osccilations.

The key issue in cobweb models is time because the way in which expectations of prices adapt determines the fluctuations in prices and quantities. In Burundi, [8] applied a version of this model to study the determinants of beef meat supply where they found that there is a relatonship between beef production, expected beef producer price, expected goat meat price (price of substitute), and expected GDP per capita.Later [9] introduced adaptive expectations into these models. Other writers such as [10,11,12,13]have penned various articles in this field. According to [14], there are two hypotheses of cobweb model:

(1) the current production of certain product depends on its earlier price , i.e. the supply function

(2) the current demand quantity of certain product depends on its current price, i.e. the demand function . According to the hypotheses mentioned above, a cobweb model can be presented with the three following simultaneous equations:

$$Q_t^d = \alpha - \beta p_t$$
$$Q_t^s = -\delta + \gamma p_{t-1} \qquad \text{(v)}$$
$$Q_t^d = S_t^d$$

However, [15] criticizes the cobweb model as not entirely satisfactory on the grounds that:

(i) it assumes some formof equilibrium behavior at each time, when the model aims at justifying the attainmentof the market equilibrium; and

ii) it does not offer the possibility of monotone convergence to market equilibrium but only oscillating convergence.

Modeling demand and supply of maize

In agricultural markets the amount to be produced is chosen before prices are observed. Producers' expectations about prices are based on observations of previous prices. This is because the supply model for agricultural produce is dynamic. The cobweb model is based on a time lag between supply and demand decisions. Agricultural markets are a context where the cobweb model might apply, since there is a lag between planting and harvesting[16]. This being a market model, the usual three market components will apply, namely the demand function, the supply function and the equilibrium condition. The demand condition is always a function of current price and is thus a straightforward case of

$$Q_{dt} = D(P_t) \qquad \text{(vi)}$$

For supply situation let the output in period *t* be based on the then-prevailing price P_t. Since this output will not be available for sale until period (*t+1*), P_t then determines not Q_{st} but it determines $Q_{s,t+1}$.According to[17] this results in a lagged supply function of the form

$Q_{s,t+1} = S(P_t)$ (vii)

The complete market model with the functions expressed in the general form is given by;

$\overline{Q}_{dt} = \overline{Q}_{st} = \overline{Q}$ (viii)

$Q_{dt} = D(P_t)$ (vi)

$Q_{st} = S(P_{t-1})$ (ix)

$Q_{dt} = Q_{st}$ (x)

$Q_{dt} = \alpha - \beta P_t$ $(\alpha, \beta > 0)$(xi)

$Q_{st} = -\gamma + \delta P_{t-1}$ $(\gamma, \delta > 0)$(xii)

If we equate equations *x* and *xvi* together so as to reflect the equilibrium market conditions, we will have:

$\beta P_t + \delta P_{t-1} = \alpha + \gamma$ (xiii)

Normalizing the equation and shifting the time subscripts ahead by one period (*t+1*) yields:

$P_{t+1} + \frac{\delta}{\beta} P_t = \frac{\alpha + \gamma}{\beta}$ (xiv)

Several authors have provided a time path solution to this problem [18, 17,19]provide a time path solution to this problem as:

$$P_t = \left(P_0 - \frac{\alpha+\gamma}{\beta+\delta}\right)\left(-\frac{\delta}{\beta}\right)^t + \frac{\alpha+\gamma}{\beta+\delta} \qquad \text{(xv)}$$

P_0 is the initial price

$(\alpha+\gamma)\big/(\beta+\delta)$ is the intertemporal equilibrium price of the model and can be expressed as $\overline{P}$.

Equation 14 can thus be written as;

$$P_t = \left(P_0 - \overline{P}\right)\left(-\frac{\delta}{\beta}\right)^t + \overline{P} \qquad \text{(xvi)}$$

The term $\left(-\delta/\beta\right)$ is responsible for the nature of oscillation of the model.

Data source and analysis

The data source for this paper was the district annual agricultural production reports and FAO for the period 1991-2011 [20]. Figures for annual maize production and farm gate prices for the period under review were used. Prices of cassava which is a substitute for maize were also used. National per capita income was another variable which was used as an approximation of disposable income of the population in Kilifi district. The per capita income figures were obtained from World Bank data inventory [21].

Descriptive statistics in form of line chart was used to show productivity trends over time. A two-stage Engel-Granger cointegration model based on the hypothesized relationship $Y_t=f$ (price of maize, price of cassava, per capita income) was used to test the relationship between annual production (Y_t) and the identified variables.

Two implicit modelswere estimated, as shown below;

$$Demand = f(current\ price)$$

$$Supply = f(last\ season\ price).$$

Production theory predicts that current demand is a function of current price while current supply is a function of last season's price. This relationship with annual maize production as the dependent variable was used to generate parameters of the relationship using Eviews 6.

RESULTS AND DISCUSSION

The results of the study showed that over time there has been a decline in maize production in Kilifi district (Figure 1). The decline in productivity may be as a result of land fragmentation due to increasing population, expensive and unavailable inputs and insufficient precipitation among others causes.

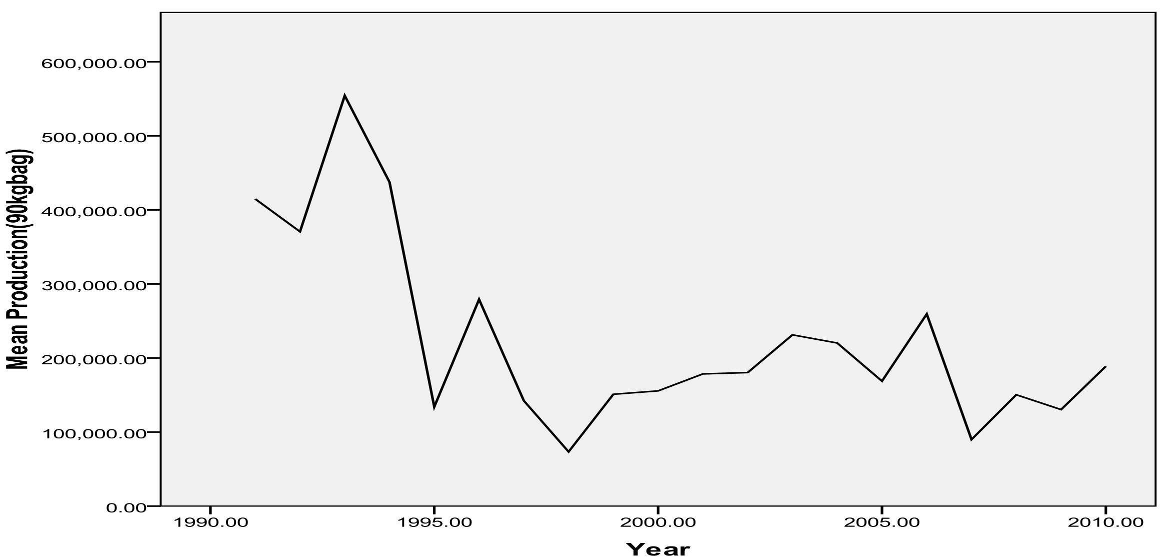

Figure 1: Maize productivity trends
Source: Authors' results

Prices have maintained a sustained upward trend over the study period though at a moderate pace (Figure 2) below. In the last few years the prices have however risen sharply partly as a result of shortage of maize supply globally since grains in major producing countries have been turned into a source of bio-fuels rather than food.

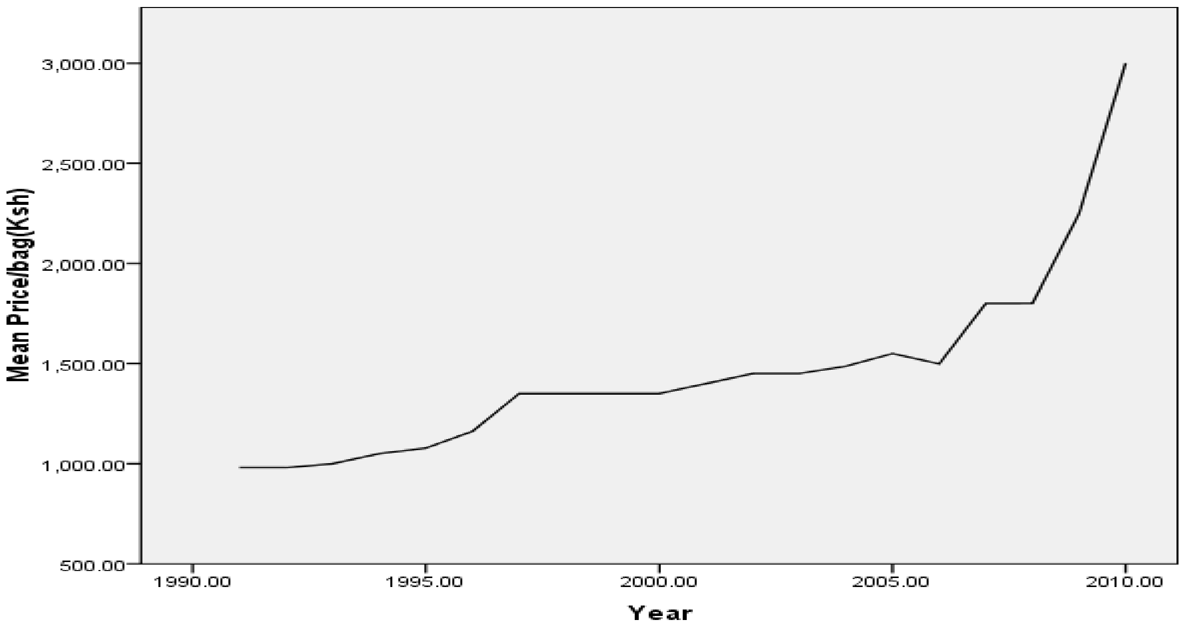

Figure 2:Price trends over time
Source: Authors' results

A test of unit root was carried out to define the variable stationarity in following table.

Table1: Unit Test

Variables	Augmented Dickey-Fuller Unit Test			Phillips-Perron Unit Test		
	T-test Calculated Value	**5% Critical Value (Tabulated Value)**	**Decision**	**Test Statistics (Calculated Value)**	**5% Critical Value (Tabulated Value)**	**Decision**
Prodmaize (log form)	-3.01	-3.76	Non-stationary	-3.07	-3.67	Non-stationary
Pmaize1 (log form)	-2.26	-3.73	Non-stationary	-1.83	-3.69	Non-stationary
Pcassava1 (log form)	-1.57	-3.69	Non-stationary	-1.33	-3.69	Non-stationary
Percapincome1 (log form)	-1.76	-3.71	Non-stationary	-1.40	-3.69	Non-stationary

The unit test was used to explore the statistical parameters of time series data. When time series data are non-stationary, the OLS regression will be spurious and the estimates will be inefficient. Two types of unit tests (Augmented Dickey-Fuller and Phillips-Perron) were run in level with trend and intercept.

A two-step process was followed. First, a cointegration test was done to check if there is a long-run relationship among variables and if need be a vector correction model could be run. It was found that all the four variables are integrated of order 1, that is, I(1) (these non-stationary variable time series turn to be stationary after first difference), except income per capita which is stationary after second difference, that is, it is I(2). Therefore, Johansen cointegration likelihood test relations could not be run because in its restriction, all variables have to be of the same integrated order. InsteadEngel-Granger two-step co-integration procedure which is very flexible was used.

After carrying out an OLS of production of maize (logprodmaize) on prices of maize and cassava (logpmaize and logpcassava one period lagged) and income per capita (logpercapincome one period lagged) it was found that the residuals are stationary or I(0). The implication is that the OLS results are no longer spurious. Therefore, it was concluded that there is a long-run co-integration (movement) or long-run equilibrium among the four variables. The model is a long-run model.

Long-run Model

In our long-model, we include the time trend for the sake of getting a parsimonious model.

Table 2: Long-run Model

Variable	Coefficient	Std. Error	t-statistic	Prob.
C	53.03025	15.42514	3.43791	0.004
LOGPMAIZE1	-1.380466	1.31202	-1.052168	0.3105
LOGPCASSAVA1	-0.945574	0.266471	-3.548508	0.0032
LOGPERCAPINCOME1	-3.798717	2.074501	-1.831147	0.0884
T	0.170929	0.072822	2.347214	0.0341
R-squared	0.649171	Mean dependent var		12.15934
Adjusted R-squared	0.548934	S.D. dependent var		0.520842
S.E. of regression	0.349805	Akaike info criterion		0.958051
Sum squared resid	1.713087	Schwarz criterion		1.206588
Log likelihood	-4.101485	Hannan-Quinn criter.		1.000113
F-statistic	6.47637	Durbin-Watson stat		2.8423
Prob(F-statistic)	0.003627			

Table 3: Post-Estimation Tests

Tests	**Calculated Value**	**Prob**	**Decision**
Normality Jarque-Bera Test	3.33	0.19	Residuals are normally distributed
Serial Autocorrelation Breusch-Godfrey Serial Test LM test (F-test value)	3.43	0.07	No serial autocorrelation
Heteroscedasticity Breusch-Pagan-Godfrey (F-test value)	1.43	0.28	No Heteroscedasticity
Ramsey Reset Test (F-test value)	2.68	0.13	No specification error by choosing a linear model

From the results in Table 3 we conclude by saying the coefficients of the long-run model are Best-Linear-Unbiased-Estimate (BLUE). 55 per cent in the variations in production of maize are explained by the four predetermined variables (prices of maize and cassava, income per capita of consumers and timetrend). The model is the correct best-fit Model (F-test=6.3 and very significant $p<0.01$).

Price of maize is not statistically significant and does not have expected sign (this is a supply response model) in the long-rung. Price of substitute cassava is very significant ($p<0.01$) and has expected negative sign. If the price of cassava increases, farmers will shift from maize production to cassava production. Production of maize will go down in the long-run. In the model, an increase of price of a bag of cassava by 1 US$ will decrease the production of maize by 0.95 per cent in the long-run since this value can be well understood in elasticity terms.

Income per capita of consumers is significant ($p<0.1$) and has a negative sign. The implication is that an increase in income per capita in Kilifi will decrease the production of maize by 3.70 % in the long-run. This is in line with Engel law which states that an increase in income of consumer leads to a decrease in budget allocated to food consumption. It may also be in line with local preferences where *pilau*[1] and *biriani*[1] are local delicacies but more expensive than maize. So with increase in income people move away from maize to these local delicacies.

Short-run Model: ECM

To derive the short-run relationship, the residuals of the above long-run model were lagged twice in order to preserve the degree of freedom. The results are as follows:

Table 4: ECM

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.246999	0.12515	1.973616	0.0701
DLOGPMAIZE1	-1.851211	1.152373	-1.606434	0.1322
DLOGPCASSAVA1	-1.09746	0.305734	-3.589585	0.0033
DLOGPERCAPINCOME1	-5.228433	3.244032	-1.611708	0.131
U1	-1.516908	0.271482	-5.587516	0.0001
R-squared	0.751893	Mean dependent var		-0.063233
Adjusted R-squared	0.675553	S.D. dependent var		0.561265
S.E. of regression	0.319698	Akaike info criterion		0.787254
Sum squared resid	1.32869	Schwarz criterion		1.03458
Log likelihood	-2.08529	Hannan-Quinn criter.		0.821357
F-statistic	9.849207	Durbin-Watson stat		2.29205
Prob(F-statistic)	0.000684			

Table 5: Post-estimation tests

Tests	Calculated Value	Prob	Decision
Normality Jarque-Bera Test	3.41	0.18	Residuals are normally distributed
Serial Autocorrelation Breusch-Godfrey Serial Test LM test (F-test value)	0.89	0.44	No serial autocorrelation
Heteroscedasticity Breusch-Pagan-Godfrey (F-test value)	0.44	0.78	Homoscedasticity
Ramsey Reset Test (F-test value)	0.35	0.56	No specification error by choosing a linear model

In the results succeed all the tests (normality, serial autocorrelation, heteroscedasticitya and Ramsey Reset specification error tests). We conclude by saying the coefficients of the short-run model are Best-Linear-Unbiased-Estimate (BLUE). The variations in production of maize are explained by our 4 predetermined variables (prices of maize and cassava, income per capita of consumers and time trend) by 68%. The model is the correct best-fit Model (F-test=9.85 and very significant $p<0.01$).

In the short-run, both coefficient of price of maize and income per capita of consumers are not statistically significant. Besides, price of maize bears an unexpected negative sign. The coefficient of price cassava is very statistically significant ($p<0.01$) and has expected negative sign since it is a substitute crop. In the short-run, an increase of 1US$ in price of cassava will lead to a decrease of production of maize by 1.10 percent point in Kilifi.

The coefficient of the variable U1 or Error Correction coefficient has an econometric and economic meaning. First, it is very significant and has an expected negative sign, which means that the model under consideration has a long-run relationship or long-run equilibrium. Second, this error correction coefficient measures the speed of adjustment (-1.5269) towards the long-run equilibrium and is very high. It indicates a feedback of about 152.69% of the previous year's disequilibrium from long-run elasticity of maize price. It implies that the speed in which maize price adjust from short-run disequilibrium to changes in maize supply in order to attain long-run equilibrium is 152.69% within one year. This reflects a high level attention attached to maize production by authorities.

CONCLUSION

In the long-run, the production of maize is influenced by the price of cassava, its substitute. An increase of consumer's income also has negative impact on maize sector but remains inelastic like the cassava price.Price of cassava comes out to be the sole factor of maize production in short-run. The lagged error correction term coefficient was negative and significant and validates the ECM specification. This suggests that the errors are fully corrected within the year they occur. The error correction term may also reflect the speed at which the authorities intervene to correct any shock (drought, price of inputs or maize volatility, etc.) that emerges in the same year. A special attention need to be devoted to the production of maize so that it remains more competitive than the production of cassava since the former is the staple food for the country. This may be done through intensive extension service and appropriate incentive in the areas of inputs (credit access, fertilizer, etc.).

In depth analytical studies need to be conducted to find out the actual cause(s) of decline in maize productivity in Kilifi district over the years.

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