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Economic Analysis of Factors Affecting Maize Production in Tanzania: Time Series Analysis

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Abstract

Maize is an important food and income earner for rural and urban dwellers in Tanzania. Despite efforts done by the government and private sector, the yield of maize has remained significantly below the average of less than 2 metric tonnes per hectare. This threatens food insecurity and poverty for rural people. This study analyses the economic factors affecting maize production in Tanzania for a period of 61 years. Time series data on aggregate maize production, fertilizer price, total area under maize cultivation, the total seed used, expected price of maize and average annual rainfall for the period 1961-2020 were analyzed using a vector error correction model. Empirical findings revealed that the total area under maize cultivation, the total seed used and average annual rainfall have a positive relationship with aggregate maize production; but fertilizer price and expected price of maize have a negative relationship with aggregate maize production. In terms of statistical significance, the study found that the area cultivated was statistically significant; but seed used, price of fertilizer, expected price of maize and average annual rainfall were statistically insignificant. The study recommends formulation of policies about intensive agriculture, fertilizer and seed subsidization and irrigation schemes to increase productivity.

Keywords: Agriculture, Food, Maize, Food security, Productivity

1.0. Introduction

1.1. Background Information

Reports by FAO (2021) and Jha et al. (2020) indicate that, maize production is important for food security in rural and urban dwellers in Tanzania. However, several restraints have been identified as hampering maize productivity. These comprise climatic change, technology and three policies related to; land, the trade and exchange rate and agricultural pricing (Benfika *et al.*, 2022; Jha et al., 2020). During the period that these restraints have been observed, maize production has never been able to uphold its position as the key supplier to the agricultural sector. However, since independence, particularly starting around the early 1960s to date maize yield has remained significantly less than 2 metric tonnes per hectare (Jha et al., 2020). For example, since 2011 to date, the average maize production has been approximately 1.3mt/ha, despite suitable climatic conditions for growing maize in Tanzania. This is an average that is relatively low about our neighboring country of Kenya which attained an average of 1.6 metric tonnes per hectare (Jha et al., 2020). Other performance indicators in agriculture show further confirmation of the relative decline of the agricultural sector from there. For example, the total maize yield per acre has been deteriorating with low levels ranging from an average of 0.7 to 1.6 tonnes per acre against a possible range of 4.0 to 8.0 tonnes per acre on production and productivity respectively (Mkonda and He, 2018; Jayne et al., 2020; URT, 2019). Also, Solomon (2020) observed a decline in the 2020 production gap trend.

The factors that dictate the level of maize production as studied by various researchers include mineral fertilizer, for example, various studies done by Bayu (2020) and Abate et al. (2015) noted that, mineral fertilizer plays the greatest role in increasing agricultural production eg.,1KgN +P205+k20 can average increase grain yield by 10kg, also a study carried out by Manjunatha et al.(2019) shows that, of all the yield increasing farm inputs, mineral fertilizer plays the highest role 35-40 percent increasing productivity. Therefore, the price of fertilizer will be one of the tools for assessing the maize yield. Also, it is followed by the factor of improved seeds and the study done by Msuya et al. (2008) stresses that, the area cultivated for maize comes as an utmost element of maize production in Tanzania with a coefficient of 0.6988 with a positive sign. This entails that a rise in the area of land use under cultivation for maize production would significantly increase maize output. Also the empirical studies done by (Jayne et al., and Djurfeldt et al., 2020) revealed that, the area under maize cultivation is an important determinant of maize production in Tanzania.

As maize plays a major role in the food supply at the household level, the decrease in maize production may result in food insecurity (Jha et al., 2020). Thus, the government has been making efforts in different eras but productivity has remained low(Xiong and Tarnavsky, 2020; Jha et al., 2020). Although, various studies have highlighted different variables as a determinant of low maize production but productivity is still low in Tanzania (Jha et al., 2020; FAO, 2021; Solomon, 2020) . Due to the importance of maize in terms of household income, food security and rural development for rural and urban dwellers; further studies are needed to go beyond the known factors that have been studied in many of the previous studies and explore new ones. Therefore, this paper goes beyond focusing on a limited factor of price expectation. Remember that, the variable price itself is not new but the expected future price and its effect on maize producers' production behavior are limited. To fill in this empirical gap, the study examined the economic impact of the expected price of maize on the production of maize in Tanzania for a sample period of 1961 to 2020. Also, the findings of this paper could help policymakers to come up with a policy or strategy to address the production from the period of independence to 2020 as it has been observed that, despite the efforts made by the government and private sector, since the early 1960s the yield of maize has remained significantly below which are less than 2 metric tonnes per hectare which threatens food insecurity and poverty for rural people.

2.0. Methodology

2.1. Data Type and Sources

The study used secondary data on aggregate maize production, seed availability, the area cultivated, the price of maize, the price of fertilizer, and average annual rainfall from the year of independence in 1961 to 2021 were selected. These variables are the major ones that affect maize farmers in Tanzania as other factors such as agronomic practices are never used by farmers. Since the study focused on secondary data, the statistical document relating to aggregate maize production in Tanzania was reviewed. Data on aggregate maize production in tonnes, the area cultivated in hectares, and seed used in tonnes were collected from the FAO STAT database an organisational website responsible for gathering agricultural data. Other data such as actual prices of maize in tonnes/Tsh were collected from the Ministry of Industries, Trade and Marketing (MITM). The data were used to compute the expected future price of maize. Also, data on fertilizer prices in 50kg/Tsh were collected from Tanzania Fertilizer Regulatory Authority (TFRA) and finally data on annual rainfall in milliliters were collected from the Tanzania Metrological Agency (TMA), an institution responsible for metrology.

2.2. Estimation Model

Before estimation, data were transformed into natural logarithms and then differenced by using the Augmented Dickey Fuller test to make them stationary for a unit root test with test statistics greater than the critical value even at a 1% level of significance. In this paper the data were differenced once and all variables became stationary. Since the variable became stationary after the first difference in the meaningful mean time series a vector error correction model was employed because the variables were differenced once and cointegrated. Consider the time series variables yt below for time series which are not stationary in their level: -

$$Yt= \beta0 + \beta1ArHt\text{-}1 + \beta2SAvt\text{-}1 + \beta3Pt\text{-}1 + \beta4Pft\text{-}1 + \beta5Rnt\text{-}1 + \mu t \qquad (1)$$

Where: Yt = Aggregate Maize Production (tonnes), ArHt1 = Area under maize cultivated (Ha), SAvt1= Total Seed Available for use (tonnes) and Pt1 =Expected Price of Maize (Ton/Tshs), Pft1 =Price of Fertilizer Input (50Kg/Tshs), Rnt1=Average Annual Rainfall (mm), βs = (β0, β1, β2, β3, β4 β5), = Estimated Parameters, μt = Stochastic Error Term and t= Time dimension 1961 – 2020.

To solve the heteroscedasticity and non-stationarity problems on time series data the above time series were transformed by introducing natural logarithms and then the data were differenced (Gujarati, 2004). In this paper data differenced once and all variables become stationary. Therefore, the estimate equation is:

$\Delta Yt = \beta 0 + \beta 1 \Delta ArHt\text{-}1 + \beta 2 \Delta SAvt\text{-}1 + \beta 3 \Delta Pt\text{-}1 + \beta 4 \Delta Pft\text{-}1 + \beta 5 \Delta\ Rn\ t\text{-}1 + \mu t$………………(2)

Where: ΔYt represents first the difference in aggregate maize production
$\Delta ArHt\text{-}1$ = first difference of total area under maize cultivated
Δ SAvt-1 = first difference total seed available for use
Δ Pt-1 = first difference of expected price of maize
Δ Pft-1 = first difference of price of fertilizer input
ΔRn t-1 = first difference of average annual rainfall
μt = Stochastic Error Term
Δ= the difference operator
t=1961-2020
β=parameter to be estimated

Since time series yt is in their difference of one the variables are cointegrated and the VECM model was employed.

2.3. Test of Regression Assumptions/Conditions

To avoid spurious regression which entails misleading results the raw data were transformed by using the first difference to remedy the non-stationarity problem. Therefore, the Augmented Dickey Fuller (ADF) test was employed to check whether time series data were stationary or not stationary. Variance Inflation Factor (VIF) was applied to test if independent variables suffer multicollinearity problems. For the existence of serial autocorrelation on the model, Durbin-Watson (D-W) was used as an appropriate tool for the test. Breusch-Pagan/Cook-Weisberg test was an appropriate tool used to check and detect the problem. Ramsey RESET test was used to ensure that no variable was excluded from the analysis. The test also signified whether the variables had any power in explaining the change in the dependent variable. This is confirmed by the model if the value of the F-statistics is less than 0.05 at a 5 percent level of significance.

2.3.1. Unit Root test for stationarity and Cointegration

The Augmented Dickey-Fuller test was used to test the stationarity of data. For the stationarity test results, the raw data were not stationary when were tested for both variables. Thus, both variables, were differenced until the t* value/ test statistic was less than critical values even at a 1% significant level on which stationary was observed and declared that the series data were stationary (does not have a unit root). In this paper both data were stationary at the first difference.

Table 1: The Augmented Dickey Fuller Results for stationary (n = 57)

Differenced Variable	t* Value	Critical value	Critical value	Critical value
Differenced data for aggregate maize production (Y)	Test statistics	1%	5%	10%
Z(t)	-14.675	-3.594	-2.936	-2.602
Differenced Variable	t* Value	Critical value	Critical value	Critical value
Differenced data for Area Cultivated (ArH)	Test statistics	1%	5%	10%
Z(t)	-7.909	-3.594	-2.936	-2.602
Differenced Variable	t* Value	Critical value	Critical value	Critical value
Differenced data for Seed Availability (SAv)	Test statistics	1%	5%	10%
Z(t)	-7.889	-3.594	-2.936	-2.602
Differenced Variable	t* Value	Critical value	Critical value	Critical value
Differenced data for Expected Price (P)	Test statistics	1%	5%	10%
Z(t)	-6.909	-3.594	-2.936	-2.602
Differenced Variable	t* Value	Critical value	Critical value	Critical value
Differenced data for Price the of Fertilizer (Pf)	Test statistics	1%	5%	10%
Z(t)	-11.626	-3.594	-2.936	-2.602
Differenced Variable	t* Value	Critical value	Critical value	Critical value
Differenced data for Average Annual Rainfall (Rn)	Test statistics	1%	5%	10%
Z(t)	-14.224	-3.594	-3.594	-2.602

Mackinnon's approximate p-value for Z (t) = 0.0000.

The result from Table 1 shows the Augmented Dickey Fuller Results for the stationary test of differenced data for Aggregate maize production (Y), Area under Maize Cultivated (ArH), Seed Availability (SAv), Expected price of maize (P), Price of Fertilizer (PF) and Annual Rainfall (Rn) at trend lags (1).

2.3.2. Test for Cointegration

The results from Johansen tests for cointegration in Table 2 show that there is a maximum of five cointegration since the trace value is greater than the 5% critical value. Therefore, there is a long-run relationship between the variables and VECM Model was an appropriate model.

Table 2. Johansen Tests for Cointegration

Trend: Constant				Number of observations = 57	
Sample:1964-2020					lags =1
Max. rank	Parms	ALL	Eigen value	Trace Statistics	5% critical value
0	6	-770.22986	.	1263.9565	39.37
1	17	-138.25161	1	110.7211	33.46
2	26	-82.891066	0.90518	86.6109	27.07
3	33	-39.58564	0.84162	72.0816	20.97
4	38	-3.5448269	0.78425	56.69955	14.07
5	41	24.802931	0.70069	56.69955	3.76
6	42	35.451509	0.70069		

2.3.3. Test for Multicollinearity

Table 3 shows Variance Inflator Factor (VIF) results among the independent variables.

Table 3. Test for Multicollinearity by using VIF

Variable	VIF	1/VIF
Differenced Area Cultivated	1.81	0.551602
Differenced Price of Fertilizer	1.85	0.540699
Differenced Seed Availability	1.22	0.816419
Differenced Expected Price	1.50	0.666930
Differenced annual rainfall	1.01	0.992321
Mean VIF	1.48	

The result from Table 3 shows that there is no multicollinearity among the independent variables since Mean VIF is less than 10.

2.3.4. Test for Serial Autocorrelation

In this test Durbin-Watson d-test (D-W d test) was applied to cross-check the existence of serial autocorrelation on data. The results show that Durbin-Watson d-statistic result (6, 49) = 2.767646 while R^2=(0.64). Therefore, since R^2<D-W d statistics then serial autocorrelation does not exist.

2.3.5. Test for Heteroskedasticity

Breusch-Pagan/Cook-Weisberg test was an appropriate tool for Heteroskedasticity detection to see if the variable has a constant variance, whereby H0: Constant variance and H1: No constant variance. The result computed in the Stata was as follows:-

H_0: Constant variance; variables: The fitted value of p
Chi square (1) =0.47
Prob> Chi square = 0.4940

Therefore, from the results above, the acceptance of the null hypothesis was fulfilled implying that there is no heteroskedasticity since Prob>Chi Square= 0.4940 is greater than Chi Square= 0.47.

2.3.6. Stability test

Ramsey RESET test was used to ensure that no variable was excluded from the analysis. The test also signifies whether the variables have any power in explaining the change in the dependent variable. This is confirmed by the model if the value of the F-statistics is less than 0.05 at a 5 percent level of significance. The results computed in the Stata were as follows: -

H_0: the model has no omitted variables
F (3,23) =5.63
Prob>F=0.0048

From the findings the value of the F-statistics was 0.0048 which is less than 0.05. Hence, the study concluded that the model was well-specified.

3.0. Results

These results are organized into descriptive and inferential statistics where descriptive statistics involved presenting the trends of each variable used graphically. However, inferential statistics rely on an econometric model to forecast production. To make the result meaningful, all necessary assumptions and interpretations were observed.

3.1. Descriptive Statistics

This part presents a descriptive analysis of the data set. The study used country data from Tanzania from 1964 to 2020. The major reason for choosing this data was the ability of the data set to answer the main objectives of the study.

Table 4. Descriptive Statistics (1964-2020)

Variable	Obs	Mean	Std. Dev.	Min.	Max.
Maize Production	57	2,065,099.00	1,089,857.00	488,000.00	5,440,710.00
Area under Cultivation	57	1,608,487.00	695,794.40	790,000.00	3,982,280.00
Seedtons	57	33,128.41	14,376.54	16,000.00	79,645.70
Actual Price	57	76,680.97	106,680.70	10,500.00	487,910.00
Expected Price	57	8,753.77	25,025.77	(41,210.00)	98,460.00
Fertilizers	57	8,960.71	13,056.76	2,020.00	80,000.00
Rainfall	57	1,090.21	1,443.72	409.00	7,034.95

Table 4 shows that, on average maize production was 2,065,099 tons per year and it fluctuated between 488,000 tons per year and 5,440,710 tons per year within a period of 1964 and 2020. During the same period the average area under cultivation was 1,608,487 hectares and the area under cultivation fluctuates between 790,000 hectares per year and 3,982,280 hectares per year. Similarly, the average quantity of seed used by farmers was 33,128.41 tons per year used by farmers which increased from 16,000 tons to 79,645.70 tons per year depending on the demand for seeds by farmers. The study also suggests that, the average actual price was TZS 76,680.97 per 90kg with a minimum actual price of TZS 10,500 per 90kg and a maximum actual price of TZS 487,910 per 90kg. Likewise, the average expected price was TZS 8,753.77 per 90kg with the minimum expected price reduced to TZS 41,210 per 90kg from TZS 98,460 per 90kg. However, the average fertilizer was 8,960.71 tons per year used by farmers and it fluctuates between 2,020 tons per year and 80,000 tons per year. The study found from 1964 to 2020, on average the country received 1,090.21 mm of rainfall which fluctuated between 409.00 mm per year and 7,034.95 mm per year. The fluctuations in rainfall may be associated with climate change.

3.2. Inferential Statistics

3.2.1. Hypothesis testing

This study was guided by five hypotheses as shown below, and the F-statistics was used to test the joint hypotheses of formulated model. If F-statistic is greater than its probability we accept alternative the hypothesis and reject the null hypothesis, and vice versa is true.

H_1: There is a significant positive relationship between aggregate maize production and total area under maize cultivation
H_1: There is a significant positive relationship between aggregate maize production and total seed available
H_1: There is a significant positive relationship between aggregate maize production and the expected price of maize
H_1: There is a significant negative relationship between aggregate maize production and price the of the fertilizer
H_1: There is a significant positive relationship between aggregate maize production and average annual rainfall.

Table 5. Hypotheses test results using F-statistics

Variables	F (Parms, d.f)	p>F	Decision Rule
ΔAHv	F(1, 41) = 17.91	Prob > F = 0.001	Accept H1
ΔSav	F(1, 41) = 2.72	Prob > F = 0.1066	Accept H1
ΔP	F(1, 41) = 0.62	Prob > F = 0.4364	Accept H1
ΔPf	F(1, 41) = 9.04	Prob > F = 0.0045	Accept H1
ΔRn	F(1, 41) = 0.09	Prob > F = 0.7716	Accept Ho

From Table 5 above, we accept an alternative hypothesis for the area under maize cultivation, total seed available for use, the expected price of maize and price of fertilizer which implied that, there is a significant and positive relationship between aggregate maize production and maize cultivated total area, seed available for use, the expected price of maize and price of fertilizer there is a significant negative relationship. Since F-statistics are greater than its probabilities that is, 17.91 > 0.001, 2.72 >0.1066, 0.62 >0.4364 and 9.04>0.0045. While for the average annual rainfall we accept the null hypothesis and reject the alternative hypothesis. This implied that, there is no significant relationship between aggregate maize production and the average level of average annual rainfall since the F-statistics is less than its probability i.e., 0.09 < 0.7716.

3.2.2. Estimated Vector Error Regression Result

To determine the impacts of area harvested, seed used, expected price of maize output, price of fertilizer and average annual rainfall on the aggregate maize production in Tanzania, an estimated vector error correction model was employed and the results are presented in Table 6.

Table 6. Vector Error- Correction Model Output

Sample	: 1964-2020				No. of obs.		= 57
					AIC		= 7.417784
Log-likelihood	= -157.3179				QIC		= 7.669609
Det (sigma mil)	=. 0000325				SBIC		= 8.086986
Δ Y	Coeff.	Std. Err.	z	p>|z|	[95% conf		Interval]
ΔY t-1	0.0007226	0.0731254	0.01	0.992	-0.1426005		0.1440457
ΔAHv	0.0013032	3.829886	0.17	0.000	-0.0013036		-0.0013029
ΔSAv	0.0012844	0.0429895	0.03	0.976	-0.0829735		0.0855423
ΔP	-0.0000781	0.0000218	-0.00	1.000	-0.0829735		17862.61
ΔPf	-0.0014092	0.1068282	-0.01	0.989	0.2107886		0.2107886
ΔRn	0.0052296	0.2333902	0.02	0.982	0.4626661		0.4522068
constant	-8792.19	83936.23	1.27	0.21	62900.94		276124.40

3.2.2.1. Aggregate maize production and Area under maize cultivated

The findings show a positive relationship between aggregate maize production and cultivated area. The area under maize cultivated with an elasticity of 0.0013032 is statistically significantly different from zero and it influenced aggregate maize production (p =0.000). This suggests that, a unit increase in area cultivated led to an increase in aggregate maize production of 0.0013032 tonnes during the sample period of the study. The probable reason is that, in Tanzania, agriculture practices are extensive agriculture rather than intensive agriculture and the only way to increase production is by increasing the area under cultivation. Therefore, the government must allocate arable land for agriculture to boost production by increasing farm size. These findings are similar to those of Djurfeldt et al. (2020) carried out in Tanzania who reported that the coefficient of area of land for maize cultivation is a positive sign.

3.2.2.2. Aggregate maize production and Seed availability for use

As expected, it was found a positive relationship between aggregate maize production and seed availability. Given the importance of maize seed, the total seed available for use had a coefficient of 0.0012844 which was statistically insignificant and equal to zero and it did not influence aggregate maize production due to a p-value of 0.976 which is greater than 0.05 level of significance. This finding confirms that a unit increase in seed availability for use could not lead to an increase in aggregate maize production of 0.0012844 tonnes. This described the practice of extensive agriculture through expanding areas under maize production which goes hand in hand with increasing the use of seeds. Given the situation, the availability of seeds for farmers enables them to plant seeds that are viable and increase production. These results are supported by Meja et al. (2021), who documented that the coefficient of seed availability on maize production is positive. A similar finding was reported by Paull and Malacarne's (2022).

3.2.2.3. Aggregate maize production and Expected Price of Maize Output

Results showed a negative relationship between aggregate maize production and the expected price of maize, which is inconsistent with the cobweb theory. The expected price of maize output had a coefficient of -0.0000781 which is statistically insignificant and equal to zero. This implies expected price did not influence aggregate maize production as a p-value of 1.000 is greater than the 0.05 level of significance. The finding confirms that, a unit increase in the expected price of maize output could not increase the aggregate maize production by 0.0000781 tonnes. Most farmers practice subsistence agriculture with consideration of the influence of expected price in the market. Also, the heart of growth in agricultural output production is a technical change mechanism, not the price of output effect; therefore, policymakers should bear this in mind by concentrating on the technical change mechanism.

3.2.2.4. Aggregate maize production and price of fertilizer input

The study confirmed that, there was a negative relationship between aggregate maize production and the price of fertilizer. Since, the price of fertilizer had a coefficient of -0.0014092 which is statistically insignificantly different from zero. This suggests that the price of fertilizer input did not influence the aggregate maize production due to a p-value of 0.989 which is greater than the 0.05 level of significance. The finding justifies, a unit increase in the price of fertilizer led to a decrease in aggregate maize production of 0.014092 tonnes during the sample period. A probable reason is that fertilizer prices are very expensive for most smallholder farmers to meet, thus farmers fail to use fertilizer due to the high transaction cost. Also, farmers, who cannot afford the high price, resort not to using fertilizer, using manure or buying small portions of fertilizer. Therefore, for fertilizer prices to have a positive impact on maize production, the government must subsidize the fertilizer. The finding of fertilizer price concurred with Rogers et al. (2022) who reported the decline in production associated with the unit increase in the price of fertilizer input.

3.2.2.5. Aggregate maize production and average annual rainfall

The result shows that, there was a positive relationship between aggregate maize production and annual average rainfall. As average annual rainfall was statistically insignificant equal to zero (p-value of 0.982 is greater than 0.05 level of significance). The average annual rainfall had a coefficient of 0.0052296 indicating that, a unit increase in average annual rainfall led to an increase in aggregate maize production of 0.0052296 tonnes. A probable reason is that, in the study area agriculture depends much on rainfall. Therefore, due to agricultural rainfall dependency in Tanzania, the government through the National Environmental Management

Council (NEMC) must act through its policies by conserving the environment to ensure sustainable rainfall. The finding of a positive relationship is supported by the ideas of Batho and Mwakaje (2019) who documented that average annual rainfall on aggregate maize production has a positive sign regardless of climate variation.

3.3. Conclusion and Recommendations

The study found that the quantity of maize production increased more as land under cultivation with maize grain increased too. The policy recommendation that can be derived from this finding is that policymakers need to improve the institutional environment in the maize subsector by allocating more arable land to expand farming activity and overall aggregate production in the study area. The empirical results have shown that the effect of the expected price is negative although insignificant. A policy recommendation that can be derived from this finding is that policymakers need to set price policies that build a strong communication and transportation infrastructure between producers, retailers, and wholesalers and also develop strong institutions to support the market which will facilitate the flow of price signals between these actors to influence aggregate maize production positively. However, the heart of growth in agricultural output production is a technical change mechanism, not the price of output effect; therefore, the policymaker should bear this in mind.

The price of fertilizer is found to be a negative and insignificant factor influencing aggregate maize output in the study area. Therefore, for a country to improve maize production through fertilizer: The policymakers needed to come up with policies that eliminate tariffs on processed fertilizer and fertilizer components which will help to lower the transaction cost of fertilizer from its distribution chains to end users. Plan for proper and effective subsidy programs that will help to lower fertilizer prices. To understand the global fertilizer industries and the way they affect the Tanzania market. The empirical results show that, the effect of average annual rainfall was positive although insignificant in influencing maize production. For a country to improve production policy should be put in place to encourage agricultural reforms by adopting mechanized agriculture like irrigation schemes as one of intensification in agriculture to be away from the climatic change effect which will result in changes in rainfall patterns.

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