Cogent Food & Agriculture

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/oafa20

Supply and demand responsiveness to maize price changes in Kenya: An application of error correction autoregressive distributed lag approach

Maurine Adhiambo Abodi, Gideon Aiko Obare & Isaac Maina Kariuki |

To cite this article: Maurine Adhiambo Abodi, Gideon Aiko Obare & Isaac Maina Kariuki | (2021) Supply and demand responsiveness to maize price changes in Kenya: An application of error correction autoregressive distributed lag approach, Cogent Food & Agriculture, 7:1, 1957318, DOI: 10.1080/23311932.2021.1957318

To link to this article: https://doi.org/10.1080/23311932.2021.1957318

© 2021 The Author(s). This open access article is distributed under a Creative Commons Attribution (CC-BY) 4.0 license.

Published online: 03 Aug 2021.

Submit your article to this journal

Article views: 407

View related articles

View Crossmark data

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=oafa20

Abodi et al., *Cogent Food & Agriculture* (2021), 7: 1957318
https://doi.org/10.1080/23311932.2021.1957318

cogent food & agriculture

FOOD SCIENCE & TECHNOLOGY | RESEARCH ARTICLE

Supply and demand responsiveness to maize price changes in Kenya: An application of error correction autoregressive distributed lag approach

Maurine Adhiambo Abodi[1]*, Gideon Aiko Obare[1] and Isaac Maina Kariuki[1]

Received: 29 December 2020
Accepted: 15 July 2021

*Corresponding author: Maurine Adhiambo Abodi, Department of Agricultural Economics and Agribusiness Management, Egerton University, 536-20115, Egerton, Kenya
E-mail: maurineabodi@gmail.com

Reviewing editor:
Manuel Tejada Moral, University of Seville, SPAIN

Additional information is available at the end of the article

Abstract: Whereas maize is a primary staple food in Kenya, production volumes have not kept pace with local demand and consumption over time. This has constrained the achievement of the Kenyan government's stated objective of food access, diversity, and nutritional status. Using secondary data from FAOSTAT from 1963 to 2016 and applying the error correction version of the autoregressive distributed lag model, we estimate Kenya's maize subsector's price supply and demand responsiveness. We find that maize supply responds significantly to producer price, the area under maize cultivation, and fertilizer use both in the short and long run. However, the supply elasticity of maize with respect to producer price is inelastic, suggesting that maize supply does not respond well to price incentives. On the demand side, we find that maize demand significantly responds to the production and price of substitutes both in the short and long run. The findings suggest that support price is a necessary but not sufficient condition for improving maize productivity, food security, and income for maize consumers and producers. Therefore, there is a need for enhanced efficient and effective use of the land resource through productivity-enhancing inputs, considering that land expansion is a limited option.

Subjects: Agriculture & Environmental Sciences; Agriculture; Agriculture and Food

Maurine Adhiambo Abodi

ABOUT THE AUTHOR

Maurine Adhiambo Abodi is an agricultural economist with research interests in agricultural and rural development, institutional economics, agricultural production economics, and international trade. She holds a master of science degree in Agricultural and Applied Economics from Egerton University and a bachelor of science degree in Agribusiness Management from Laikipia University.

PUBLIC INTEREST STATEMENT

The significance of maize as a food security crop in Kenya is increasingly becoming indispensable. However, with the widening gap between maize supply and demand, the government is tasked to ensure it meets both maize producers' and consumers' needs. Therefore, maize supply and demand response is the first step towards improving food security, economic growth, and poverty reduction. An understanding of the maize supply and demand responsiveness to price changes is therefore very essential for the formulation of policies that can revitalize both maize production and marketing in Kenya. The empirical results of this study reveal that the existing government policies should focus more on the removal of bottlenecks in maize pricing by promoting effective maize market reforms that can allow free maize marketing and pricing.

cogent oa

© 2021 The Author(s). This open access article is distributed under a Creative Commons Attribution (CC-BY) 4.0 license.

Keywords: Supply response; demand response; cointegration; autoregressive distributed lag approach; price; maize productivity

1. Introduction

Maize is a staple food in Kenya and its availability is synonymous with food security (Kariuki et al., 2020; Nyameino et al., 2003). It contributes 3% and 12% to Kenya's gross domestic product (GDP) and agricultural GDP, respectively (KNBS, 2019). In addition, it accounts for 36% of caloric food intake and provides at least 72% starch, 10% protein, and 4% fat. It also supplies an energy density of 365kcal/100 g (Ranum et al., 2014). The main maize growing areas in Kenya include, Trans Nzoia, Nakuru, Uasin Gishu, and other parts of the Western and Nyanza regions.

The significance of maize as a food security crop in Kenya has necessitated the government's intervention in the maize subsector through policies that can improve maize production and marketing (Olwande et al., 2009). These policies have often aimed at maintaining stabilized and reasonably high maize prices as an incentive for producers to increase maize production (Mugwe et al., 2020). For this reason, the production and marketing of maize in Kenya have over the years received budgetary support through marketing boards (Nyangito & Kimenye, 1995; Nyoro et al., 2007). However, maize production has not kept pace with consumption (Karanja et al., 2019; Nyoro et al., 2004). The problem of information asymmetry further compounds this supply-demand variation since information on current market prices is scarce, and therefore projecting future prices of maize is a daunting task (Gitau & Meyer, 2018). Additionally, economic information on agricultural supply response is limited.

Agricultural supply response is closely related to a change in agricultural output due to a price change (Omodho, 2009). In Kenya, maize producers gain from maize production when maize prices are high and incur losses when maize prices are low. Additionally, price variability has been a major challenge in the recent past (Onono, 2018). Therefore the supply response of maize to price is one of the major policy concerns in Kenya and other developing countries since it is a vital component in agricultural growth and poverty alleviation for a vast majority of developing economies (Mose et al., 2007).

Moreover, Kenya's most important food policy objective is to improve maize supply as a mechanism for increasing Kenya's food security and income to a vast majority of maize producers (Mose et al., 2007; Nyoro, 2002). Over the years, price incentives in the agricultural sector have been viewed as significant instruments that would stimulate maize production (Gabre-Madhin & Haggblade, 2004; Ombuki, 2018). Some researchers argue that higher prices are more likely to benefit producers and impose costs on the net buying consumers who cannot respond to price incentives (Alene et al., 2008; Omodho, 2009). Additionally, price incentives are vital in promoting agricultural growth through market liberalization, which significantly depends on how farmers respond to various price incentives (Jayne et al., 2001; Mose et al., 2007).

Notwithstanding the significant role that price incentives play in maize production and consumption, Kenya's maize subsector still faces the challenge of ensuring maize prices are affordable for consumers and at the same time profitable for producers (Onono, 2018). The strategy of stabilizing maize producer prices through the provision of price incentives to motivate maize producers to increase maize production has also not been sustainable (Mugwe et al., 2020; Onono, 2018). In light of this dilemma, maize producer supply response cannot be studied independent of consumer's response since the effect of a price increase on the quantity of maize supply and demand are reliant on producers' and consumers' price incentives (Foster & Mwanaumo, 1995; Jayne & Argwings-Kodhek, 1997). By understanding how maize consumers respond to maize price changes in Kenya, policy-makers can gain insights into the effects of a policy change on consumer welfare and food security (Jayne & Argwings-Kodhek, 1997).

Despite several studies on the supply responsiveness of maize to its price, much is unknown about the actual responses of maize consumers to price changes. Besides, most of the past empirical studies considered the supply side ignoring the demand side (Adefemi, 2011; Foster & Mwanaumo, 1995; Heltberg & Tarp, 2002; Kuwornu et al., 2011; Mose et al., 2007; Omodho, 2009). Additionally, most of the empirical studies on supply response of maize have shown varying results in terms of the magnitude of the elasticities hence difficult to rely on (Mose et al., 2007; Ogazi, 2009; Sedghy et al., 2016; Shoko et al., 2016). Other studies like that by Jayne and Argwings-Kodhek (1997) only focused on estimating consumer response to maize without considering producer responses.

This paper complements the above literature by providing empirical evidence on aggregate maize price supply and demand responsiveness to own-price changes by estimating the supply and demand elasticities. These estimates of supply elasticities would provide valuable guidelines in policy formulation, especially in light of the fluctuations in maize yield per hectare. The focus is on the aggregate maize sector, and therefore the prices used are aggregated across all producer and consumer types. The study only reports prices from the Kenya National Bureau of Statistics (KNBS) for both consumers and producers.

2. Literature review

The measurement of supply response has proved to be important for policy-makers in Kenya and other developing countries. It has also proved to be important in facilitating appropriate and informed decision-making by all players in the production and consumption marketing chain. For this reason, the debate on supply responsiveness in Kenya concentrates on the role of price and non-price factors in influencing supply response (Olwande et al., 2009; Onono et al., 2013). Some researchers argue that price incentives are significant in promoting maize supply response (Marienga et al., 1996; Omodho, 2009), while others maintain that both price and non-price factors are important determinants of supply in Kenya (Kere and Mwangi., 1986; Mose et al., 2007).

Recent maize supply response studies in Kenya show that appropriate fertilizer application is the most critical factor in maize supply response in Kenya (Kinyanjui, 2019; Otieno, 2019). Additionally, other studies argue that women's empowerment is the most important factor that contributes to an increase in maize supply (Diiro et al., 2018). Another study by Mugwe et al. (2020) that applied an autoregressive distributed lag model in an analysis of maize supply response in Kenya found that climate change is the most important factor that contributes to a decline in maize supply. Therefore, according to the above studies done in Kenya, there is no agreement on the most important factor that determines maize supply response in Kenya.

Maize supply response studies in other countries attach a pivotal role to both price and non-price factors in maize supply response. For instance, a study by Shoko et al. (2016) focused on analysing maize supply response in South Africa and found that maize farmers are more responsive to non-price factors than price factors. Similarly, Huong and Yorobe (2017) estimated maize supply response in Vietnam in a rational expectation hypothesis model. They found that maize supply responds positively to expected price, the quantity of fertilizer used, and the area under irrigation. The findings of Huong and Yorobe (2017) are further corroborated by the findings of a study by Ratri et al. (2019) in Central Java that revealed a positive and inelastic maize supply response to price and fertilizer and elastic response to the harvested area.

Haggblade et al. (2017) analysed demand for cereals in Addis Ababa, Ethiopia using Quadratic Almost Ideal Demand System model (QUAIDS). Their result showed that all cereals' demand becomes elastic when only substitution effects are considered, as expected for normal goods. However, demand for millet was the least responsive to changes in its price in the urban area. Rice demand was less responsive to its own price when compared to maize and sorghum. Further, the authors discovered that own-price elasticities for maize and sorghum demand were highly elastic

for lower-income households than higher-income households. Additionally, they found higher elasticities for sorghum and millet suggesting strong future growth potential in demand.

Using a heterogeneous agent modelling approach to simulate the production and consumption responsiveness of households producing maize, beans, and bananas in Uganda, Musumba and Zhang (2016) established the existence of a degree of substitution between maize and other cereals. The authors also observed that higher prices lower the household maize consumption and increase household income implying that the higher the prices, the higher the household income. Additionally, their findings indicated that maize price increase lowers the poverty rate for households who are net sellers.

With an exception of the study by Musumba and Zhang (2016), which analysed both supply and demand responses, most empirical studies conducted partial analyses of either supply or demand. Furthermore, literature on maize demand response in Kenya is scarce. Secondly, most of the reviewed studies have not tested the time-series properties of the data used in the analysis. Thirdly, the supply response studies in Kenya reveal a lack of consensus on the most important factor in maize supply response. Finally, some of the reviewed studies like the study by Shoko et al. (2016) are not devoid of methodological weaknesses since they used the Nerlovian Partial Adjustment model, which may have led to spurious regressions. This paper uses an error correction version of the Autoregressive Distributed Lag Approach in the analysis of both supply and demand responses to address these weaknesses.

3. Materials and methods

3.1. Data

We used secondary data sources to generate 54-year annual time series data on Kenyan maize producer and consumer prices, the area under maize cultivation, fertilizer cost, rainfall amount, maize production quantity, national income, and prices of maize substitutes for the period between 1963 and 2016. The sources of the time series data included both international and domestic sources. International sources included FAOSTAT and World Bank online database where we compiled data on the area under maize cultivation, fertilizer quantity, maize production, and national income. On the other hand, domestic sources consisted of publications from the Kenya National Bureau of Statistics (statistical abstracts and economic survey documents) from which data on producer prices and domestic prices were obtained. Producer prices were compiled as annual averages from all the 8 major maize producing regions in Kenya to generate aggregate producer prices. Consumer prices were also compiled from retail maize prices as annual averages from all the 8 major maize producing regions of Kenya to arrive at the aggregate consumer prices. Maize producers were assumed to use previous period prices to predict prices for the subsequent periods. Finally, data on the amount of rainfall were obtained from the meteorological department of the Kenyan Ministry of Agriculture.

3.2. Outcome variables

Produced quantities or output has been a dominant measure of supply in many of the supply response studies (Huong & Yorobe, 2017; Kuwornu et al., 2011; Ratri et al., 2019). We used produced quantities as a proxy for maize supply. Following the works of Haggblade et al. (2017) and Musumba and Zhang (2016), maize quantity consumed (Qconsumed) was used as a proxy for maize demand and was regarded as a dependent variable on the demand response equation.

3.3. Choice of explanatory variables

Following producer behaviour theory and consumer behaviour theories of Sadoulet and De Janvry (1995), in addition to price, several factors can influence both supply and demand for maize. Thus, the *ceteris paribus* assumption is seldom, if ever satisfied. Therefore, the quantity supplied and demanded of maize was specified as a function of more than one predetermined variable. For this reason, the independent variables which were chosen to influence supply and demand for maize

were adapted and updated from the works of Haggblade et al. (2017), Huong and Yorobe (2017), Kuwornu et al. (2011), Musumba and Zhang (2016), Ratri et al. (2019), and Shoko et al. (2016) to fit the context of the study. Based on the above studies, variables that we identified as covariates in the supply function included the land area under maize cultivation, producer price of maize, the quantity of fertilizer used in maize production, and the amount of rainfall. On the other hand, the demand response variables of interest included production, per capita gross domestic product (gdppercapita) which we used as a proxy for national income (taking into consideration the entire Kenyan economy as the unit of measurement), domestic wheat price (whtdomprice), as we considered wheat as a maize substitute, and the dollar-shilling exchange rate.

3.4. Modelling

The error correction version of the ARDL model was preferred for the analysis over other approaches such as the Nerlovian partial adjustment model and Engle-Granger two-step procedure since it gives a direct interpretation of the distribution of the implied lags in terms of producer and consumer behaviour and also in terms of short and long-run elasticities of supply and demand (Kripfganz & Schneider, 2018; Pesaran & Shin, 1999). Secondly, it gives more efficient and reliable results in small and finite sample sizes. Given a sample size of 54 that we used in this study, the model would produce consistent and reliable results both on theoretical and empirical grounds. Finally, the error correction version of the ARDL model can produce feasible results when the data set in question contains both exogenous and endogenous variables which are integrals of different orders (McKay et al., 1999)

We followed three steps in the application of the error correction version of the ARDL modelling approach. Firstly, we determined the order of integration of the series using unit root tests to confirm whether the variables are stationary. A stationary series has a constant mean and variance (MacKinnon, 1996). We used the Augmented Dickey-Fuller (ADF) test for stationarity since it takes care of possible autocorrelation in the error terms (Nkoro & Uko, 2016). We further confirmed the results of the test by performing the Dickey-Fuller Generalized Least Squares (DFGLS) test which is a more powerful test for unit roots and accounts for structural breaks in the series (Gujarati & Porter, 2009). These tests were done under the null hypothesis that the series is non-stationary. This hypothesis is rejected if the test statistic is greater than the critical value in absolute terms. Additionally, we transformed all the variables into logarithms to allow both supply and demand to respond proportionately to a rise or fall in each of their explanatory variables. This prevents changes in the elasticities as supply and demand quantities change. We tested this hypothesis at a 5% significance level. We performed these tests using the following functional form:

$$\Delta Z_t = \beta_1 + \beta_{2t} + \delta Z_{t-1} + \sum_{i=1}^{n} \alpha_i \Delta Z_{t-1} + \varepsilon_t \quad (1)$$

where Δ is the change operator, Z_t is variable in the series to be checked for stationarity, Z_{t-1} represents one period lagged values, ΔZ_{t-1} shows the first difference. The number of lagged difference terms was determined empirically to ensure that the error term is serially uncorrelated so that unbiased estimates of the coefficients can be obtained (Gujarati & Porter, 2009). n is the lagged value of Z to control for a higher order of correlation and ε_t indicates white noise error term.

Secondly, we tested the existence of a unique or long-run cointegrating relationship using the bounds test approach represented by equation 2, thus:

$$\Delta Y_t = \gamma + \sum_{i=1}^{p} \delta_i Y_{t-i} + \sum_{i=0}^{q} \beta_i' X_{t-i} + \varepsilon_t \quad (2)$$

where Y_t is a vector representing maize quantity supplied or maize quantity demand in time t, which was allowed to be integrated of order zero or order one and is a function of its own lagged values, the current and lagged values of other exogenous variables in the model. t is time in years, δ and β are coefficients to be estimated and they represent elasticities of supply or demand to various explanatory variables. γ is a constant; i=1, … k; p, q are optimal lag orders which we chose based on Schwartz Bayesian information criterion (SBIC); we used p lags for the dependent variable

and *q* lags for the exogenous variable. *i* is the optimal lag structure for all the variables; *t-i* is the optimal number of lags and e_t is a vector of the error terms.

We determined the direction of the relationship between domestic maize supply and demand and other explanatory variables through a joint significance test of the coefficient of the lagged dependent variables under the null hypothesis of no long-run relationship or no cointegration which is represented by $H_0 : \delta_{1i} = \delta_{2i} = \delta_{3i} = 0$ (where i = 1, 2, 3) and the alternative hypothesis of the existence of cointegration represented by $H_1 : \delta_{1i} \neq \delta_{2i} \neq \delta_{3i} \neq 0$ which we tested during estimation. Due to the evidence of the existence of long-run relationship, we specified the ARDL model equation as:

$$\Delta Y_t = \gamma + \sum_{i=1}^{p} \delta_1 \Delta Y_{t-i} + \sum_{i=0}^{q} \beta_i' \Delta X_{t-i} + \varepsilon_t \quad (3)$$

Finally, following Pesaran et al. (2001) we added an error correction term to the model to incorporate both long-run and short-run dynamics. We specified it as presented in equation 4 to obtain short-run elasticities of supply and demand. The re-parameterization of ARDL into error correction model by adding error correction term was possible since the ARDL model is a single equation model which is of the same form as the error correction model (Nkoro & Uko, 2016)

$$\Delta Y_t = \gamma + \sum_{i=1}^{p} \delta_1 \Delta Y_{t-i} + \sum_{i=0}^{q} \beta_i' \Delta X_{t-i} + \lambda ECT_{t-1} + \varepsilon_t \quad (4)$$

where,

$$\lambda = (1 - \sum_{t=1}^{p} \delta_1) \quad (5)$$

is the speed of adjustment with a negative sign

We defined the error correction term as presented in equation 6. ECT is the residual from the regression of the long-run equation and it captures short and long-run dynamics and the forward-looking behavior of both maize producers and consumers. Additionally, it shows how much of the disequilibrium in the previous period's supply or demand is corrected in the current period *t*.

$$ECT_t = \ln Y_{t-1} - \theta X_t \quad (6)$$

where

$\theta = \frac{\sum_{t=0}^{q} \gamma_i}{y_{0i}}$ is the long-run parameter which incorporates long-run dynamics to give both short-run and long-run coefficients.

4. Results and discussion

4.1. Supply responsiveness

We used both the ADF and DFGLS tests to check the unit root problem for all the supply response variables in their level form. Table 1 presents the unit root test results for all the level variables.

From Table 1, it is evident that production, producer price, land area (which was used as a proxy for the area of land under maize cultivation) and fertilizer quantity have unit roots in their level form. Therefore, the variables are non-stationary. However, the results indicate that rainfall has no unit root hence it is stationary. The DFGLS statistics validate the results of the ADF test statistics. Therefore, we accept the null hypothesis that production, producer price, land area, and fertilizer quantity are non-stationary in their level form. However, we reject the null hypothesis for rainfall and conclude that rainfall is stationary. These test results are similar to the findings of Mose et al. (2007), Huq and Arshad (2010), and Muchapondwa (2009) who also found that rainfall was stationary in level form.

Since all the variables were non-stationary in level form except rainfall, there was a need to establish their order of integration to guide the selection of an appropriate estimation model.

Table 1. Unit root test results for level variables

	ADF		DFGLS		
Variable	**Test statistics**	**Critical value**	**Test statistics**	**Critical value**	**Inference**
lnproduction	−2.255	−2.929	−2.625	−3.108	Non stationary
lnproducer price	−0.924	−2.928	−3.323	−3.304	Non stationary
lnland area	−0.656	−2.928	−1.988	−3.159	Non stationary
lnrainfall	−4.78	−2.928	−5.437	−3.202	Stationary
lnfertilizer quantity	−2.688	−2.928	−2.007	−3.202	Non stationary

Table 2. Unit root test for the first differenced variables

	ADF		DFGLS		
Variable	**Test statistic**	**Critical value**	**Test statistic**	**Critical value**	**Inference**
lnproduction	−5.486	−2.93	−4.905	−3.112	Stationary
lnproducer price	−6.076	−2.928	−5.368	−3.209	Stationary
lnland area	−5.18	−2.929	−3.747	−3.164	Stationary
lnfertilizer quantity	−5.274	−2.928	−5.623	−3.209	Stationary

Table 3. Bounds test for cointegration or long-run relationship

Test statistic	**Lower bound I(0)**	**Upper bound I(1)**
F-statistic 13.981	2.86	4.01
t-statistic −7.677	−2.86	−3.99

Hence, we tested the first difference of each series to establish the order of integration. Table 2 presents the results of ADF and DFGLS tests for first difference of each level variable.

Both the ADF and DFGLS tests of the first differenced variables revealed that production, producer price, land area under maize cultivation, and fertilizer quantity are stationary in their first differenced form since their test statistics are greater than their respective critical values in absolute terms. Hence, they are integrated of order one (I (1)). In testing the stationarity of the first differenced variables, we ignored rainfall because it is integrated of order zero (I (0)). These findings are in line with Mose et al. (2007), Omodho (2009); Muchapondwa (2009), who analysed supply responsiveness of maize and found stationarity in data after the first differencing.

Finally, we performed a bounds test of cointegration on the series under the null hypothesis that the time series are not cointegrated. This hypothesis is rejected when the calculated F statistic is greater than the upper bound critical value (I (1)) or if the t statistic is less than the upper bound critical value (I (1)). The results of this test are given in Table 3.

From Table 3, the calculated F value of 13.981, which is greater than the critical value (4.01) for the upper bound at a 5% significance level was obtained. Similarly, the t value of −7.677, which, is less than the upper bound critical value (−3.99) was obtained at a 5% significance level. Based on these tests, we reject the null hypothesis that the variables have no long-run relationship. Consequently, we accept the alternative hypothesis that the variables have a long-run relationship at a 5% significance level. These results are consistent with past empirical studies (Akanini and Okeowo, 2011). The cointegration results suggest that the ARDL model alone is not appropriate for

Table 4. Long-run supply response results

Variable	Coefficient	Std. Error	Probability
lnproduction (−1)	0.427***	0.134	0.003
lnproducer price	−0.009*	0.052	0.08
lnproducer price (−1)	0.102*	0.053	0.061
lnland area	0.892***	0.164	0.000
lnland area (−1)	−0.486**	0.197	0.018
lnrainfall	0.017	0.051	0.741
lnfertilizer quantity	0.016***	0.006	0.007

Note: (−1) represents first period lag while ***, **, and * represent significance at 1%, 5% and 10% respectively

analysing the supply response of maize. To this end, we incorporated an error correction term to the ARDL model to estimate supply responsiveness to price changes.

4.1.1. Long-run supply response results

The findings in Table 4 reveal that the coefficient of the first lag of production (lnproduction (−1)) was positive and significant at a 1% significance level with an elasticity of 0.427 implying that a 1% increase in maize production in the previous period is associated with 0.427% increase in maize supply in the current period, other factors held constant. This could be attributed to the asset fixity problem once capital is devoted to maize production since maize constitutes a larger percentage of agricultural production in Kenya. Thus, the moment a production increase occurs, it is likely to continue into the near future. Therefore, maize producers optimizing under such constraints will increase their optimal production and the resultant adjustment will be necessary. Secondly, this may imply the presence of adjustment difficulties on the part of the maize producers. This means that there are physical and technological constraints on the part of the farmer that have to be eradicated before the full adjustment of maize supply to the equilibrium level. This result corroborates the argument of Kiiru (1995).

The long-run elasticity of the current producer price was −0.009 which was both inelastic and significant at a 10% significance level. This result suggests that a 1% increase in producer price of maize is associated with a 0.009% decrease in maize supply, other factors held constant. This result is consistent with the findings by McKay et al. (1999), and Muchapondwa (2009). However, the result is contrary to the findings of a similar study done by Onono et al. (2013) in Kenya. The difference could be attributed to dissimilar data periods that the two studies covered. The negative price elasticity of supply implies that price incentives may not always play a positive role in increasing maize production. However, this does not necessarily mean that maize producers are not rational in making their production decisions. It could be possible that the prevailing market price for maize is too low such that the maize producers do not consider any slight increase in the price as an incentive to increase their maize production. This is a case of perverse maize supply response as indicated by Ghatak and Inersent (1986) which would make a pricing policy fruitless.

The coefficient of the first lag of producer price of maize (lnproducer price (−1)) was positive and significant at a 10% significance level in the long run with an elasticity of 0.102 indicating that a 1% increase in maize price in the previous period, leads to 0.102% increase in maize supply in the current period, other factors held constant. This implies that maize producers base their expected price formation on the previous period's available set of information. The significance of the lagged price of maize further lends support to the fact that farmers use adaptive expectations in making their production decisions. Thus their production decisions are based on prices they expect to prevail several months after harvest. Although the magnitude of elasticity of lagged price was higher than that of the current price in the long run, it was still inelastic, a fact that could be attributed to several factors: Firstly, maize producers form their expected prices based on

calculations from previous price records which may be inaccurate. Secondly, other factors like natural calamities such as floods, drought, and famine are unpredictable but can result in detrimental effects which can spontaneously negatively affect maize supply. This result agrees with the findings of Ogazi (2009), Onono et al. (2013), and Muchapondwa (2009).

Similarly, the coefficient of the land area was positive and significant at a 1% significance level. A percentage increase in the area of land allocated to maize cultivation is associated with a 0.892% increase in maize supply, all other factors held constant. This means that bringing more land under maize production is a way of increasing maize supply. This result is consistent with the past empirical findings (Blandford, 2019; Huong & Yorobe, 2017). Furthermore, the first lag of land area (lnland area (−1)) was negative and significant at a 5% significance level. This result implies that a percentage increase in land allocated to maize production in the previous period leads to a 0.486% decrease in maize supply in the current period; other factors held constant.

The fertilizer quantity coefficient was positive and significant at a 1% significance level in the long run, suggesting that the higher the fertilizers use per hectare, the higher the maize supply, other factors held constant. This result implies that the quantity of fertilizer used in maize production is an important consideration in aggregate maize supply response because fertilizer use has immensely increased maize supply in Kenya. This increase is attributable to heavy government subsidies on fertilizer cost which encourages greater adoption. These findings are consistent with those by Mose et al. (2007); Onono et al. (2013) who established that fertilizer is the most significant input in maize production.

4.1.2. Short-run supply response results

Table 5 presents short-run supply elasticities with respect to various explanatory variables. The coefficient of the error correction term which represents the speed of adjustment had an expected sign and was statistically significant at a 1% significance level. Its value was −1.104, which implies that about 110% of the deviations in maize supply from long-run equilibrium are corrected in the current period. This shows that the feedback mechanism is effective in converging maize supply towards long-run equilibrium. However, the value of the coefficient of the error correction term is more than 1 indicating that adjustment towards long-run equilibrium would be in a dampening manner.

Table 5. Short-run supply response results

Variable	Coefficient	Std. error	Probability
Speed of adjustment	−1.104***	0.144	0.000
Dlnproducer price	0.096***	0.026	0.001
Dlnland area	0.590***	0.133	0.000
Dlnrainfall	0.035	0.047	0.46
Dlnfertilizer quantity	0.019***	0.004	0.000
constant	5.500	2.332	0.023
R^2			0.6303
Adjusted R^2			0.5728
Jarque-Berra statistic probability value			0.8876
Durbin Watson statistics			1.7016
Breusch-Godfrey LM test probability value			0.1019
Breusch-Pagan probability chi-square value			0.271
Mean VIF value			3.12

Note ***, **, * represents significance at 1%, 5%, and 10% respectively

We also found an inelastic short-run supply response to the producer price of maize (Dlnproducer price). A percentage increase in maize price is associated with a 0.096% increase in maize supply; all other factors held constant. This result is similar to Olwande et al. (2009); Onono et al. (2013), who also found that maize supply elasticities with respect to producer price were inelastic in the short run. Furthermore, the results are contrary to the findings of a survey done by Rao (1989) which revealed that food supply response with respect to price in Africa ranges from 0.3 to 1.2. This difference could be attributed to the varying time series periods that these two studies covered.

The coefficient of land area (Dlnland area) was 0.590 which was positive and significant at a 1% significance level. A percentage increase in land area under maize cultivation is associated with a 0.590% increase in maize supply, *ceteris paribus*. This result indicates that land is the most important fixed factor contributing to maize supply. Increasing land allocation to maize production through land consolidation would be desirable and imply economies of scale. However, in Kenya population increase has led to the subdivision of land into uneconomical parcels. Therefore, increasing land size may not be realistic. This necessitates more efficient and effective use of available units of land. Similar results were found by Olwande et al. (2009).

Fertilizer quantity (Dlnfertilizer quantity) also had a positive and significant effect on maize supply in the short run as was expected with an elasticity of 0.019. This implies that a percentage increase in fertilizer use leads to a 0.019% increase in maize supply. However, the coefficient of fertilizer quantity was inelastic implying that fertilizer subsidy alone may not instantly encourage greater adoption. Hence more emphasis should be given to the dissemination of information on fertilizer use through research and extension services. This result is consistent with Onono et al. (2013) who also found that fertilizer use had a positive and significant effect on maize supply.

The regression analysis revealed an adjusted R^2 of 0.5728. This indicates that 57.28% of the variations in maize supply were explained by the estimated explanatory variables. Therefore, the model best fits the data. We used the cumulative sum of squares test to test the stability of the estimated parameters. Figure 1 shows that all the parameters used in the supply response analysis lie within the 5% statistical significance level so the model is stable. We also performed post-estimation diagnostic tests to establish the conformity of the time series variables to assumptions of homoscedasticity, normality, and serial correlation. The results of these tests are presented in Table 5. Jarque-Bera normality test (p = 0.8876) was statistically insignificant. Therefore, we accepted the null hypothesis of normality. We also did a multicollinearity test on the series to verify the existence of collinearity among the variables and obtained a mean VIF of 3.12 which is less than 10. This suggests that there was no multicollinearity in the series. Further, we used Durbin Watson (DW) test to test for serial correlation. The DW statistic of p = 1.7016 shows that we accept the null hypothesis of no serial correlation. We also validated the DW test result by the Breusch-Godfrey LM test for serial correlation which showed a probability value of 0.1019. We also performed heteroscedasticity test using the Breusch-Pagan test and obtained a probability chi-square value of 0.2710 which confirmed that the data used in the analysis is homoscedastic.

4.2. Demand responsiveness

We again used both the ADF and DFGLS tests to check the unit root problem in all the variables in their level form. Using SBIC in choosing optimal lag length, the null hypothesis that the series is non-stationary is not rejected for both ADF and DFGLS test statistics. Therefore, maize quantity consumed (lnQconsumed), production, consumer maize price, domestic wheat price, and GDP per capita are non-stationary in their level form since their test statistics are less than their critical values at a 5% significance level. Table 6 presents the ADF and DFGLS test results for unit root for level variables.

Since all the variables were non-stationary in their level form, we performed the ADF and DFGLS tests for the first differences of all the variables under the null hypothesis that the series is non-

stationary. At a 5% significance level, this hypothesis is rejected. Therefore, all the variables are integrated of order one (I (1)). Hence, an error correction version of the ARDL model was still appropriate for the estimation of demand responsiveness to price. Table 7 reports the ADF and DFGLS unit root tests for the first differenced variables.

Following Pesaran et al. (2001) and Narayan (2005), we did a bounds test for cointegration to investigate the existence of a long-run relationship in the data series. Table 8 shows the calculated F value of 6.451 which is greater than the critical value (4.376) for the upper bound at a 5% significance level. Similarly, the calculated t value of −5.521 which is less than the upper bound critical value (−4.044) at a 5% significance level was also obtained. Based on these tests, the null hypothesis of no long-run relationship is rejected.

4.2.1. Long run demand response results

Table 9 presents long-run elasticities of demand with respect to maize consumer price (lnmaize-consprice), production, substitute price (lnwhtdomprice), and national income (lngdppercapita). The estimated elasticity of the first lag of quantity of maize consumed (lnQconsumed (−1)) which we used as a proxy for maize demand was 0.541 which was significant at 1% significance level in the long run. This suggests that the current year's maize demand is positively and significantly influenced by the previous year's maize demand. Therefore, a 1% increase in the previous year's maize demand would increase the current year's maize demand by 0.541%. This can be explained by the fact that maize consumers have static expectations which lends support to the proposition of Nerlove (1958) who opined that both maize producers and consumers have a belief that current prices and consumption patterns tend to persist in the near future due to uncertainty.

The coefficient of production (lnproduction) was positive and significant at a 5% significance level, implying that a 1% increase in maize supply leads to a 0.791% increase in maize demand, other factors held constant. Even though the coefficient shows that the elasticity of maize demand with respect to maize output is inelastic, its magnitude is high, a clear indication that maize supply plays a very crucial role in determining maize demand.

Similarly, the elasticity of wheat domestic price was 1.045 which was both elastic and significant implying that a 1% increase in wheat domestic price is associated with a 1.045 point increase in demand for maize. The positive sign signifies that a degree of substitution exists. The relatively high cross elasticity shows that the degree of substitution is high. This could be ascribed to the fact that people consume more maize when wheat prices increase. This result is similar to the findings of a study done by Musumba and Zhang (2016) who found significant cross-price elasticity of demand. This result contrasts the findings of Van Zyl (1986) who established that the cross elasticity of demand for maize was low and portrayed that the degree of substitution between maize and other commodities was small. However, this result also agrees that a degree of substitution does exist. This can be attributed to the fact that maize is a food security crop and therefore consumers tend to shift to its consumption whenever the prices of other substitutes increase.

4.2.2. Short-run demand response results

Table 10 reports short-run elasticities of demand. The coefficient of the error correction term which represents the speed of adjustment had an expected sign and was significantly different from zero. Its value was −0.789, which implies that about 78.9% of the deviations in the quantity of maize demanded from long-run equilibrium are corrected in the current period. This also indicates that any shock on maize quantity demanded is restored by 78.9% in the current period.

The coefficient of production (Dlnproduction) had a positive and significant effect on maize demand with an elasticity of 0.638 which was significant at a 5% significance level. This result suggests that a 1% increase in maize production is associated with a 0.638% increase in maize demand in the short run, other factors remaining constant. This finding could be attributed to the

fact that high production represents a high availability of maize for consumption in the market at relatively low prices. Therefore, if there is a high supply of maize, consumers can access it at relatively low prices hence increasing demand. This result is consistent with the findings of Chapoto et al. (2010) and De Groote and Kimenju (2012) regarding food staple prices.

Similarly, the coefficient of wheat domestic price was also positive and significant at a 5% significance level with a coefficient of 0.829. The result implies that a 1% increase in wheat domestic price leads to a 0.829% increase in demand for maize in the short run, holding other factors constant. The positive coefficient emphasizes the importance of maize as a staple and a food security crop compared to other possible substitutes. This finding is consistent with the results by Musumba and Zhang (2016) who established the existence of substitution between maize and other cereals when market prices increase for other cereals.

We performed post-estimation diagnostic tests to indicate the appropriateness of the error correction version of the ARDL model to the assumptions of homoscedasticity, multicollinearity, normality, and serial correlation. The Adjusted R^2 value was 0.9693 which suggests that 96.93% of the variations in the dependent variable are explained by the explanatory variables. We used the cumulative sum of squares test (CUSUM) to test the stability of the estimated parameters. Figure 2 shows that all the parameters used in the demand response analysis lie within the 5% statistical significance level so the model is stable. Jarque-Bera normality test value (p = 0.2863) was statistically insignificant. Therefore, we accepted the null hypothesis that the residuals are normally distributed. We also obtained a mean VIF of 3.12 which was less than 10. Therefore, the series does not suffer from multicollinearity problems. Further, we used Durbin Watson (DW) test to test for serial correlation. The DW statistic of (p = 1.829) shows that we accept the null hypothesis of no serial correlation. We further validated the DW test result by the Breusch-Godfrey LM test for serial correlation which showed a p value of 0.5182. Finally, we used White's test to test heteroscedasticity and we obtained a probability value of 0.3615. Therefore, we accepted the null hypothesis of homoscedasticity.

5. Conclusion and recommendations

Using time-series data from 1963–2016, we analysed the supply and demand responsiveness of maize producers and consumers to maize prices using the error correction version of the ARDL model. The findings show a significant response of maize supply to its first period lagged value, producer price, the area under maize cultivation, and fertilizer use in the long run. Similarly, in the short run, the findings show that maize supply responds positively to producer price, the area under maize cultivation, and fertilizer use. However, maize demand responds positively to production and wheat domestic price in the short run while in the long run maize demand responds significantly to its lagged value, wheat domestic price, and production.

The estimated supply price elasticities, though not high, indicate that price policy can still partly be used to increase maize supply in Kenya in the short run. However, in the long run, supply price elasticity is negative and significant. This situation implies that if the government has to achieve its goal of a sustainable increase in maize supply, a substantial increase in maize prices is necessary. Nevertheless, this may not be possible due to the existing structural adjustment programs and market liberalization policy. Therefore, instead of pursuing price incentive policies, the government should free maize marketing, pricing, and movement to allow forces of supply and demand to come into play to control maize pricing. This would help in mitigating the effects arising from the challenges that maize farmers face in adjusting to the full equilibrium level of supply.

The inelastic maize supply response to fertilizer use suggests that the current fertilizer subsidy policy alone is not sufficient in promoting the greater adoption of fertilizer use in maize production in Kenya. Therefore government policies should focus mostly on support services that can allow the dissemination of information on effective fertilizer use to maize producers.

The fact that the domestic wheat price was significant and highly elastic in the long run suggests that maize has possible substitutes. Therefore, increasing wheat production to increase the local supply of wheat can enhance food security in the country because much of the wheat consumed in the country is imported and prices are inclusive of import duties. Additionally, there is a need to increase local production of wheat and other possible substitutes of maize to curb over-reliance on maize imports whenever there is a deficit in local maize production. The government of Kenya should also introduce policy measures that would make reduce the domestic wheat price by improving wheat value chain efficiency or enhancing market development.

Therefore, the government and policymakers in the maize subsector should initiate a package of changes to elicit a better response from both maize producers and consumers. These include but are not limited to the removal of bottlenecks in maize pricing by promoting effective maize market reforms. Once the Kenyan market channels and prices are freed, private traders can then bid up formally depressed maize prices. Under positive price elasticity of supply, higher prices would then induce higher production. This will, in turn, have a positive effect of enabling maize producers to get higher incomes. The higher incomes will consequently have a significant multiplier effect on the maize consumers due to the relatively high marginal propensity to consume for poor farmers and consumers. The results suggest that the newly adopted policy of the Kenyan government to free maize prices will have relatively positive supply and demand impacts, thereby contributing to an improvement in the country's food security status and poverty reduction.

Acknowledgement
We Acknowledge the support of African Economic Research Consortium in this research. Additionally, we acknowledge the sources of the data that were used in this study, especially the Food and Agriculture Organisation (FAO) which is available for public use at the FAOSTAT website; the World Bank and World Trade Organisation for their online published data; and the Kenya National Bureau of Statistics (KNBS) whose data from statistical abstracts and economic survey documents were also very instrumental in this study. We are responsible for any error of omission and commission.

Author details
Maurine Adhiambo Abodi[1]
E-mail: maurineabodi@gmail.com
ORCID ID: http://orcid.org/0000-0002-7078-7473
Gideon Aiko Obare[1]
Isaac Maina Kariuki[1]
[1] Egerton University, Nakuru Kenya.

Disclosure
This research work was supported by the African Economic Research Consortium in collaboration with the Government of Kenya. All authors have approved this article and declare no conflict of interest in its publication.

Funding
The study was funded by the African Economic Research Consortium in collaboration with the Government of Kenya.

Data availability statement
Data used in this research is available upon request. We understand the share upon reasonable request data policy.

Citation information
Cite this article as: Supply and demand responsiveness to maize price changes in Kenya: An application of error correction autoregressive distributed lag approach, Maurine Adhiambo Abodi, Gideon Aiko Obare & Isaac Maina Kariuki, *Cogent Food & Agriculture* (2021), 7: 1957318.

References

Adefemi, O. J. (2011). Transactions costs and agricultural household supply response of maize farmers in Osun State of Nigeria. *Journal of Economic Theory*, *5*(1), 28–31. https://doi.org/10.3923/jeth.2011.28.31

Alene, A. D., Manyong, V. M., Omanya, G., Mignouna, H. D., Bokanga, M., & Odhiambo, G. (2008). Smallholder market participation under transactions costs: Maize supply and fertilizer demand in Kenya. *Food Policy*, *33* (4), 318–328. https://doi.org/10.1016/j.foodpol.2007.12.001

Blandford, D. (2019). Supply response to increased demand for food. *Global Challenges For Future Food And Agricultural Policies*, *1*, 61.

Chapoto, A., Govereh, J., Haggblade, S., & Jayne, T. S. (2010). *Staple food prices in Zambia*. Comesa-MSU-IFPRI African Agricultural Marketing Project (AAMP) 2010 seminar, Maputo, Mozambique. https://agecon search.umn.edu/record/58556

De Groote, H., & Kimenju, S. C. (2012). Consumer preferences for maize products in urban Kenya. Food and Nutrition Bulletin, 331, 99–110. https://doi.org/10.1177/156482651203300203

Diiro, G. M., Seymour, G., Kassie, M., Muricho, G., & Muriithi, B. W. (2018). Women's empowerment in agriculture and agricultural productivity: Evidence from rural maize farmer households in western Kenya. *PloS One*, *13*(5), e0197995. https://doi.org/10.1371/journal.pone.0197995

Foster, K. A., & Mwanaumo, A. (1995). Estimation of dynamic maize supply response in Zambia. *Agricultural Economics*, *12*(1), 99–107. https://doi.org/10.1111/j.1574-0862.1995.tb00354.x

Gabre-Madhin, E. Z., & Haggblade, S. (2004). Successes in African agriculture: Results of an expert survey. *World Development*, *32*(5), 745–766. https://doi.org/10.1016/j.worlddev.2003.11.004

Ghatak, S., & Inersent, K. (1986). *Agriculture and economic development* (pp. 177–214). The John Hopkins University Press, Baltimore.

Gitau, R., & Meyer, F. (2018). Spatial market integration in the era of high food prices. A case of surplus and deficit maize markets in Kenya. *Agrekon*, *57*(3–4),

251–265. https://doi.org/10.1080/03031853.2018.1526693

Gujarati, D. N., & Porter, D. (2009). Basic Econometrics Mc Graw-Hill International Edition. New York: McGraw-Hills Inc.

Haggblade, S., Me-Nsope, N. M., & Staatz, J. M. (2017). Food security implications of staple food substitution in Sahelian West Africa. *Food Policy*, *71*, 27–38. https://doi.org/10.1016/j.foodpol.2017.06.003

Heltberg, R., & Tarp, F. (2002). Agricultural supply response and poverty in Mozambique. *Food Policy*, *27* (2), 103–124. https://doi.org/10.1016/S0306-9192(02)00006-4

Huong, N. V., & Yorobe, J. M. (2017). Maize supply response in Vietnam. *Asian Journal of Agriculture and Development*, *14*(1362–2017–855), 89–105. http://doi.org/10.22004/ag.econ.259249

Huq, A. S. M. A., & Arshad, F. M. (2010). Supply response of potato in Bangladesh: A vector error correction approach. *Journal of Applied Sciences*, *10*(11), 895–902. https://doi.org/10.3923/jas.2010.895.902

Jayne, T. S., & Argwings-Kodhek, G. (1997). Consumer response to maize market liberalization in urban Kenya. *Food Policy*, *22*(5), 447–458. https://doi.org/10.1016/S0306-9192(97)00034-1

Jayne, T. S., Yamano, T., Nyoro, J. K., & Awuor, T. (2001). *Do farmers really benefit from high food prices? Balancing rural interest in kenya's maize pricing and marketing policy*. No. 1093-2016-88037. Michigan State University. https://doi.org/10.22004/ag.econ.55149

Karanja, D. D., Jayne, T. S., & Strasberg, P. (2019). *Maize productivity and impact of market liberalization in Kenya*. Tegemeo Institute.

Kariuki, G. M., Njaramba, J., & Ombuki, C. (2020). Maize output supply response to climate change in Kenya. An econometric analysis. *European Scientific Journal*, *16*(3), 1857–7851. Doi:10.19044/esj.2020.v16n3p63

Kere, P. H., & Mwangi, W. M. (1986). The supply responsiveness of wheat farmers in Kenya. Eastern Africa Economic Review, 2(2), 151–155

Kiiru, M. W. (1995). Determination of the price elasticity of sunflower supply in Kenya (Doctoral dissertation). University of Nairobi, Kenya.

Kinyanjui, S. N. (2019). *Feed the crop, not the soil!: Explaining variability in maize yield responses to nutrient applications in smallholder farms of western Kenya*. Wageningen University, Netherlands.

KNBS. (2019). *Economic Survey: Annual report*. Retrieved June 12, 2020, from https://africacheck.org/wp-content/uploads/2018/05/Economic-Survey-2018.pdf

Kripfganz, S., & Schneider, D. (2018). Response surface regressions for critical value bounds and approximate p-values in equilibrium correction models. Manuscript, University of Exeter and Max Planck Institute for Demographic Research. University of Exeter Business School, United Kingdom. Available at www.kripfganz.de/research/Kripfganz_Schneider_ec.html.

Kuwornu, J. K., Izideen, M. P., & Osei-Asare, Y. B. (2011). Supply response of rice in Ghana: A co-integration analysis. *Interventions*, *2*(2222-1700), 6. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.453.6853&rep=rep1&type=pdf

MacKinnon, J. G. (1996). Numerical distribution functions for unit root and cointegration tests. *Journal of Applied Econometrics*, *11*(6), 601618. https://doi.org/10.1002/(SICI)1099-1255?(199611)11:6<601::AID-JAE417>3.0.CO;2-T

Marienga, A. J., Cacho, O., & Rambaldi, A. (1996). The supply response analysis of maize production in Kenya. (Masters thesis, University of England)

McKay, A., Morrissey, O., & Vaillant, C. (1999). Aggregate supply response in Tanzanian agriculture. *Journal of International Trade & Economic Development*, *8*(1), 107–123. https://doi.org/10.1080/09638199900000008

Mose, L. O., Burger, K. E. E. S., & Kuvyenhoven, A. R. I. E. (2007) (October). Aggregate supply response to price incentives: The case of smallholder maize production in Kenya. In *Africa crop science conference proceedings in Egypt: Africa Crop Science Society* (Vol. 8, pp.1271–1275). Wageningen University, Nertherlands. https://www.researchgate.net/profile/Kees_Burger/publication/228433230

Muchapondwa, E. (2009). Supply response of Zimbabwean agriculture: 1970–1999. African Journal of Agricultural and Resource Economics, 3(311-2016-5512), 28–42. doi:10.22004/ag.econ.56954

Mugwe, J. N., Ayieko, D., Bett, K., & Mogaka, H. (2020). Determinants of smallholders farmers' participation in collective marketing of maize in the central highlands of Kenya. *African Journal of Rural Development*, *4*(2), 225–241. http://www.afjrd.org/jos/index.php/afjrd/article/view/2000

Musumba, M., & Zhang, Y. W. (2016). *Implications of seasonal price and productivity changes at the household level in Uganda-A Heterogeneous Agent Approach*. No. 333-2016-14253. https://doi.org/10.22004/ag.econ.236282.

Narayan, P. K. (2005). The saving and investment Nexus for China: Evidence from cointegration tests. *Applied Economics*, *37*(17), 1979–1990. https://doi.org/10.1080/00036840500278103

Nerlove, M. (1958). Distributed lags and estimation of long-run supply and demand Elasticities: Theoretical Considerations. *American Journal of Agricultural Economics, Agricultural and Applied Economics Association*, *40*(2), 301–310. https://doi.org/10.2307/1234920.

Nkoro, E., & Uko, A. K. (2016). Autoregressive Distributed Lag (ARDL) cointegration technique: Application and interpretation. *Journal of Statistical and Econometric Methods*, *5*(4), 63–91. http://www.scienpress.com/Upload/JSEM/Vol%205_4_3.pdf

Nyameino, D., Kagira, B., & Njukia, S. (2003). Maize market assessment and baseline study for kenya, regional agricultural trade expansion support program (RATES), Nairobi. *Kenya. MS. c Thesis*. University of Nairobi, Kenya.

Nyangito, H. O., & Kimenye, L. N. (1995). Agricultural development policies in Kenya: 1963–1995. In Njunguna, N and Owino, L. (eds.), Towards Indigenising the policy debate: From sessional paper no. 10 to structural adjustments.Institute of Policy Analysis and Research, Nairobi.

Nyoro, J. K. (2002). Kenya's competitiveness in domestic maize production: Implications for food security. *Tegemeo Institute, Egerton University, Kenya*, 1. https://www.ascleiden.nl/Pdf/paper07112002.pdf

Nyoro, J. K., Ayieko, M., & Muyanga, M. (2007). The compatibility of trade policy with domestic policy interventions affecting the grains sector in Kenya. *Tegemeo Institute, Egerton University*. https://www.researchgate.net/profile/Milu_Muyanga/publication/237789199

Nyoro, J. K., Kirimi, L., & Jayne, T. S. (2004). Competitiveness of Kenyan and Ugandan maize production: Challenges for the future (No. 1093-2016-88049). Michigan State University. https://ageconsearch.umn.edu/record/55158

Ogazi, C. G. (2009). Rice output supply response to the changes in real prices in Nigeria: An autoregressive distributed lag model approach. *Journal of Sustainable Development in Africa*, *11*(4), 83–100.

Olwande, J., Ngigi, M., & Nguyo, W. (2009). Supply responsiveness of maize farmers in Kenya: A farm-level analysis. Working Paper (No. 1005-2016-78929).

Ombuki, C. (2018). Factors influencing maize production in rural Kenya: Case of Kisii county. Master's thesis. Machakos University.

Omodho, G. A. (2009). Agricultural supply response: A look at the determinants of maize production in Kenya (1963-2006) (Doctoral dissertation, University of Nairobi, Kenya).

Onono, P. A. (2018). Response of sorghum production in Kenya to prices and public investments. *Sustainable Agriculture Research*, *7*(2), 19–29. https://doi.org/10.5539/sar.v7n2p19

Onono, P. A., Wawire, N. W., & Ombuki, C. (2013). The response of maize production in Kenya to economic incentives. *International Journal of Development and Sustainability*, *2*(2), 530–543.

Otieno, H. M. (2019). Growth and yield response of maize (Zea mays L.) to a wide range of nutrients on ferralsols of western Kenya. *World Scientific News*, *129*, 96–106.

Pesaran, M. H., & Shin, Y. (1999). An autoregressive distributed lag modelling approach to cointegration analysis. In: S. Strom (Ed.): *Econometrics and economic theory in the 20th century: the ragnar frisch centennial symposium*. Cambridge, UK: Cambridge University Press.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, *16*(3), 289–326. https://doi.org/10.1002/jae.616

Ranum, P., Peña-Rosas, J. P., & Garcia-Casal, M. N. (2014). Global maize production, utilization, and consumption. *Annals of the New York Academy of Sciences*, *1312*(1), 105–112. https://doi.org/10.1111/nyas.12396

Rao, J. M. (1989). Agricultural supply response: A survey. *Agricultural Economics*, *3*(1), 1–22. https://doi.org/10.1111/j.1574-0862.1989.tb00068.x

Ratri, D. R., Rahayu, W., & Antriyandarti, E. (2019). Determinants of maize supply from dryland farming: Evidence from Central Java. *Asian Journal of Scientific Research*, *12*(79–83), 100-115. https://doi.org/10.3923/ajsr.2019.79.83

Sadoulet, E., & De Janvry, A. (1995). *Quantitative development policy analysis* (Vol. 1). Johns Hopkins University Press.

Sedghy, B. M., Tamini, L. D., & Lambert, R. (2016). Supply response of corn farmers in Quebec: Analysing the impact of prices volatility. Cahier de recherche/Working Paper, 1. http://dx.doi.org/10.2139/ssrn.3265470

Shoko, R. R., Chaminuka, P., & Belete, A. (2016). Estimating the supply response of maize in South Africa: A Nerlovian Partial Adjustment Model Approach. *Agrekon*, *55*(3), 237–253. https://doi.org/10.1080/03031853.2016.1203802

Van Zyl, J. (1986). A statistical analysis of the demand for maize in South Africa. *Agrekon*, *25*(3), 45–51. https://doi.org/10.1080/03031853.1986.9524080

cogent • food & agriculture

Appendices

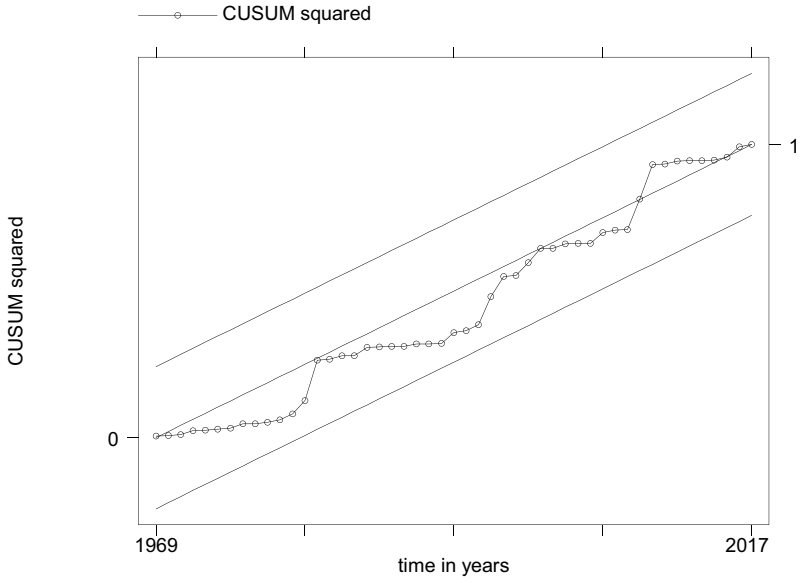

Figure 1. Cumulative sum of squares test for supply response parameters.

Table 6. Unit root tests for level variables

	ADF		DFGLS		
Variable	**Test statistic**	**Critical value**	**Test statistic**	**Critical value**	**Inference**
lnQconsumed (−1)	−1.655	−2.928	−2.919	−3.209	Non stationary
lnproduction	−2.16	−2.93	−2.572	−3.112	Non stationary
lnmaizeconsprice		−0.461	−2.928	−2.533	−3.209
Non stationary					
lnwhtdomprice	−0.706	−2.928	−1.839	−3.209	Non stationary
lngdppercapita	−1.882	−2.928	−5.623	−3.209	Non stationary

Table 7. Unit root test results for differenced variables

	ADF		DFGLS		
Variable	**Test statistic**	**Critical value**	**Test statistic**	**Critical value**	**Inference**
lnQconsumed (−1)	−6.661	−2.929	−4.815	−3.216	Stationary
lnproduction	−5.475	−2.933	−4.69	−3.116	Stationary
lnmaizeconsprice		−6.705	−2.929	−6.429	−3.216
Stationary					
lnwhtdomprice	−4.697	−2.929	−4.348	−3.216	Stationary
lngdppercapita	−4.803	−2.929	−3.525	−3.216	Stationary

cogent • food & agriculture

Table 8. Bounds test for cointegration or long run relationship

Test statistic	Lower bound I(0)	Upper bound I(1)
F-statistic 6.451	3.104	4.376
t-statistic −5.521	−2.890	−4.044

Table 9. Long-run demand response results

Variable	Coefficient	Std. Err.	Probability
lnQconsumed (−1)	0.541***	0.146	0.001
lnproduction	0.791**	0.280	0.027
lnmaizeconsprice	−0.114	0.254	0.684
lnwhtdomprice	1.045**	0.319	0.013
lngdppercapita	0.621	0.493	0.214

Note: (−1) represents first period lag while ***, **, and * represent significance at 1%, 5% and 10% respectively

Table 10. Short-run demand response results

Variable	Coefficient	Std. Err	Probability
Speed of adjustment	−0.789***	0.143	0.000
Dlnproduction	0.638**	0.343	0.026
Dlnmaizeconsprice	−0.104	0.328	0.73
Dlnwhtdomprice	0.829***	0.339	0.004
Dlngdppercapita	0.761	0.617	0.224
constant	−4.315	0.224	0.001
R^2			0.973
Adjusted R^2			0.9693
Durbin Watson statistics			1.8292
Breusch Godfrey probability chi-square value			0.5182
Jarque-Berra statistic probability value			0.2863
White's test statistic probability value			0.3615

Note ***, **, * represents significance at 1%, 5%, and 10% respectively

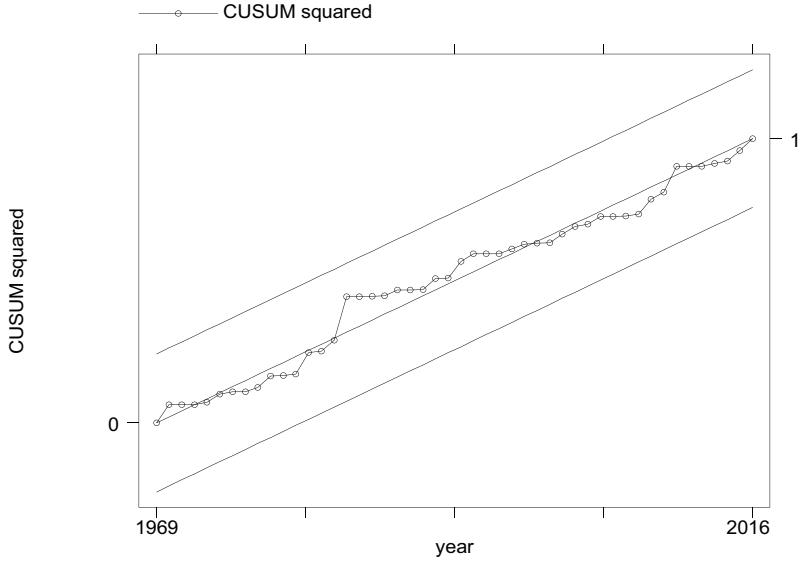

Figure 2. Cumulative sum of squares test for demand response parameters.

© 2021 The Author(s). This open access article is distributed under a Creative Commons Attribution (CC-BY) 4.0 license.

You are free to:
Share — copy and redistribute the material in any medium or format.
Adapt — remix, transform, and build upon the material for any purpose, even commercially.
The licensor cannot revoke these freedoms as long as you follow the license terms.

Under the following terms:
Attribution — You must give appropriate credit, provide a link to the license, and indicate if changes were made.
You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.
No additional restrictions

You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits.

***Cogent Food & Agriculture* (ISSN: 2331-1932) is published by Cogent OA, part of Taylor & Francis Group.**

Publishing with Cogent OA ensures:

- Immediate, universal access to your article on publication
- High visibility and discoverability via the Cogent OA website as well as Taylor & Francis Online
- Download and citation statistics for your article
- Rapid online publication
- Input from, and dialog with, expert editors and editorial boards
- Retention of full copyright of your article
- Guaranteed legacy preservation of your article
- Discounts and waivers for authors in developing regions

Submit your manuscript to a Cogent OA journal at www.CogentOA.com