Is Maize Demand Irreversible in South Africa? Estimating the price elasticity using the Wolfram - Houck Procedure

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Abstract: This research paper seeks to empirically estimate and test reversibility or non-reversibility of the maize demand using the Tweeten – Quance and Wolffram – Houck methodology in South Africa with the use of annualized seasonal data for the periods 1970/71 to 2012/13. The test procedure seems to hold in South Africa in the case of demand for maize and the function is found to be irreversible. This is shown by the coefficients of both the increases and decreases in the price of maize, which are found to be non-identical. The results indicate that when maize prices increase by 1%, demand for maize falls by almost 12%, while decreases in maize price drive demand up by nearly 20%. The structural VAR on the other hand, which assumes that innovations are proliferated in the maize demand, maize prices, wheat prices and income, indicates that the SVAR is just –identified. These results reveal that ignoring such structural changes when conducting policy changes might be detrimental to the agricultural sector.

Keywords: Maize prices; Non-reversible; Structural VAR; Innovation accounting, South Africa

JEL Classification: C13; C50; E3; Q11

1. Introduction

The economy of South Africa has experienced a number of political changes, political and economic instability in the past three decades. There has seen some agricultural reforms and changes hence some changes in total production. The agricultural sector, especially commercial farming is considered very important to the economy due to its contribution to the South Africa's gross domestic product (GDP). Maize is one of the top ten agricultural products in South Africa by value followed by wheat. The sector manages to produce quantities that could be said to be sufficient despite some major challenges such as the climate change that has seen several agricultural areas experience severe drought, which hampers maize production.

The year 1996 saw the abolishment of the maize marketing board and this allowed prices and production decisions to respond to market forces of demand and supply.

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The deregulation allowed producers to sell to whomever they wished, including the international markets. The maize production between the periods 1997 to 2012 is given on figure 1 below.

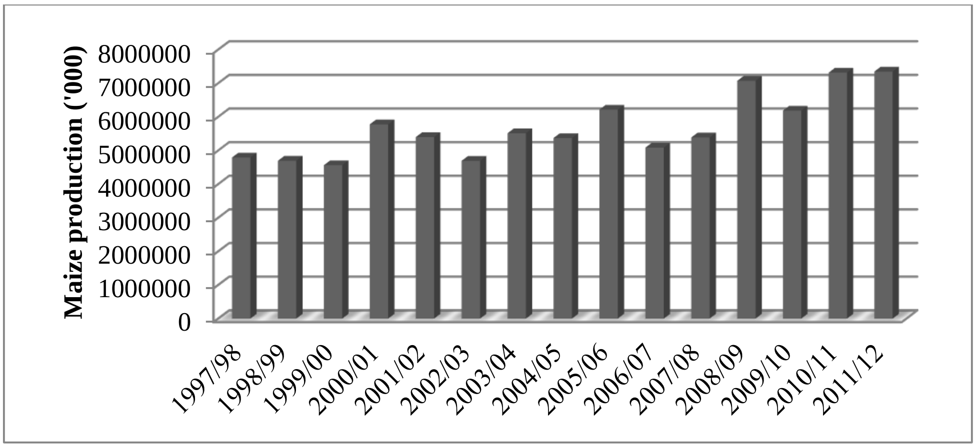

Figure 1. Maize production (1997–2012)

Source: Abstract of Agricultural Statistics 2013

The figure above highlights the production trends of maize and as depicted, production has been on the rise or simply fluctuating. The years 1997 – 1999 saw maize production averaging 4,681,667 tons with some increase of about 24 percent experienced in year 2000 and followed by decreases in 2001 and 2002. This shows that maize production has been highly volatile since its production depends largely on weather conditions. Favourable weather conditions (rainy) will see more output being produced.

Since the majority of maize output is aimed at commercial trading, the maize prices have been soaring to alarming heights. Chabane (2004) in her paper asserts that according to Naledi[1] (2002) apart from the weather conditions, producer prices have been on the upward trend and increased from R1200 per ton in September 2001 to R2500 in 2002, which is a whopping 108 percent. Increases like this translate into high maize prices to the consumers and this, in the long run might not be good the economy since the majority of the population depends largely on maize as their staple meal. The wholesale price trends for both the white and yellow maize are depicted in figure 2 below.

[1] National Labour & Economic Development Institute.

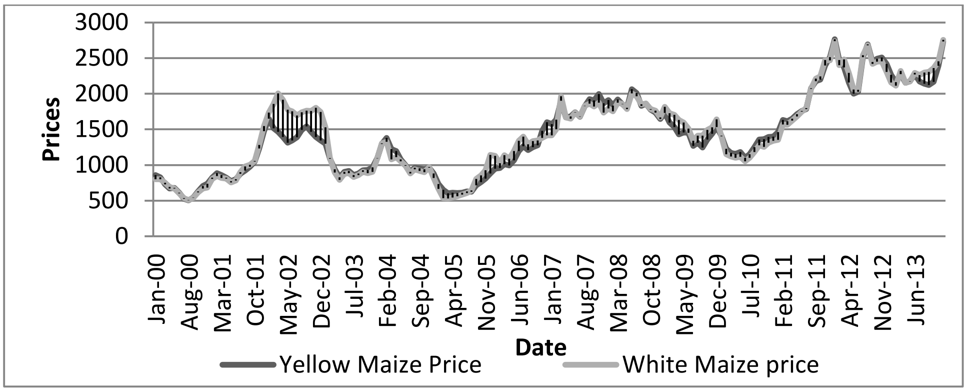

Figure 2. Maize prices

Source: FAOSTAT

In view of the significance of prices and other economic factors on the agricultural products in South Africa, several studies have touched on elasticities of agricultural products. One of such studies is by Roberts and Schlenker (2010), in which they tried to identify both the supply and demand elasticities of agricultural products in the USA. The estimated elasticities were used to evaluate the effect of subsidies on food prices and quantities. The results found that food prices would increase by about 30% as a result of subsidies. Another paper that attempted the effect of purchasing and price subsidy policies for agricultural products is by Chen *et al* (2014). In that study, Chen *et al* (2014) asserts that a good harvest would lead to fall in agricultural prices due to very low price elasticity and this gives rise to a reasonably high degree of disparity in prices.

The most recent study on South Africa is by Abidoye and Mabaya (2014), though not directly investigated the price transmission mechanism on maize consumption, it did highlight that the adoption of genetically modified crops did influence maize prices. The literature on the non-reversibility of maize or agricultural products was limited to the US economy and due to the demographic differences between the US economy and the developing economies, such studies cannot be generalised. This therefore compelled this study to test the validity of the Houck model.

2. Methodology

The main aim of this paper is to estimate the price elasticity of maize demand in South Africa using a non-reversible function. In an attempt to unpack the non-reversibility of maize demand in South Africa, we employ the Wolffram - Houck[1] procedure coupled with the structural vector autoregressive analysis in this study.

[1] See (Wolffram, 1971; Houck, 1977).

The study utilizes the annual data spanning from 1970/1971 to 2012/2013 for South Africa. This study therefore, adopts the non-reversibility method advocated by Tweeten and Quance (1969), which was backed by Wolffram (1971). The non-reversibility theorem asserts that the functions are expressed in terms of asymmetrical changes from past points of time. Houck (1977), however, indicated that segmenting the variables often hinges variations from the previous position and as a result the first observation had no descriptive power. He then improved on those two studies and came up with the Houck theorem, which this study utilized. The Houck procedure is explained below and it assumes that we have the dependent variable Y, which depends upon the values taken by X and that both these variable are time series variables. The hypothesis is that a one unit increase in X from one period to the next has a different contribution on Y than a one unit decrease in X does. This written algebraically as:

$$\partial Y_i = \varphi_0 + \varphi_1 \partial X_i^{'} + \varphi_2 \partial X_i^{''} \qquad (1)$$

For i = 1 , 2, 3, ………., t; where $\partial Y_i = Y_i - Y_{i-1}$, $\partial X_i^{'} = X_i - X_{i-1}$ iff $X_i \succ X_{i-1}$ and zero otherwise; $\partial X_i^{''} = X_i - X_{i-1}$ iff $X_i \prec X_{i-1}$ and zero otherwise; X_0 is the initial value of X and Y_0 is the initial value of Y. The value of Y at any time‘t’ is given by:

$$Y_t = Y_0 + \sum_{t=1}^{t} \partial Y_i \qquad (2)$$

For i = 1, 2, 3, …………, t, t+1, …..T; where T is the total number of observations beyond the initial value. The difference between the current and the initial value of Y is the sum of period to period changes that have happened, such that:

$$Y_t - Y_0 = \sum_{i=1}^{t} \partial Y_i \qquad (3)$$

Inserting the first equation into the third equation and simplifying will yield:

$$\left.\begin{aligned} Y_t - Y_0 &= \sum_{i=1}^{t} [\varphi_0 + \varphi_1 \partial X_i^{'} + \varphi_2 \partial X_i^{''}] \\ &= \varphi_0 t + \varphi_1 (\sum \partial X_i^{'}) + \varphi_2 (\sum \partial X_i^{''}) \end{aligned}\right\} \qquad (4)$$

Let Y_i^*, R_t^* and D_t^* be $Y_t - Y_0$, $\sum \partial X_i^{'}$ and $\sum \partial X_i^{''}$ respectively such that:

$$Y_i^* = \varphi_0 t + \varphi_1 R_t^* + \varphi_2 D_t^* \qquad (5)$$

Where R_t^* is the sum of all period to period increases in X and D_t^* is the sum of all period to period decreases in X and φ_0 a trend coefficient. Variables R_t^* and D_t^* are always positive and negative respectively. The non-reversible condition will hold only if $\varphi_1 \neq \varphi_2$**.** This model will thus be termed non-reversible model.

This model however seeks to find the contributory impact of the increases and decreases in the independent variables, which in our case are the maize prices, gdp (proxy for income), prices of close substitutes (wheat). Our modified model is presented as follows:

$$\partial Y_i = \varphi_0 + \varphi_1 \partial X_{1i}^{'} + \varphi_2 \partial X_{1i}^{''} + \varphi_3 \partial X_{2i}^{'} + \varphi_4 \partial X_{2i}^{''} + ... + \varphi_n \partial X_{(n-1)i}^{'} + \varphi_{n+1} \partial X_{(n-1)i}^{''} \quad (6)$$

This can also be re-written as equation (5) in the following:

$$Y_i^* = \varphi_0 t + \varphi_1 R_{x_1,t}^* + \varphi_2 D_{x_1,t}^* + \varphi_3 R_{x_2,t}^* + \varphi_4 D_{x_2,t}^* + ... + \varphi_n R_{x_{n-1},t}^* + \varphi_{n+1} D_{x_{n-1},t}^* \quad (7)$$

For i = 1, 2, 3, ………., t; where $R_{x_1,t}^*$ represents the incremental changes in the first explanatory variable at period t**,** up to variable $X_{n-1,t}$, $D_{x_1,t}^*$ up to $D_{x_{n-1},t}^*$ are all decrement changes in explanatory variables. The reversibility conditions will now be $\varphi_1 \neq \varphi_2$, $\varphi_3 \neq \varphi_4$, **…….,** $\varphi_n \neq \varphi_{n+1}$ depending on the number of explanatory variables.

Following the non-reversibility model above, using Sim's (1980) VAR presentation, with four variables, we write the VAR model as:

$$BX_t = \Gamma_0 + \Gamma_1 X_{t-1} + \varepsilon_t \quad (8)$$

Solving for X_t yields

$$\left.\begin{aligned} B^{-1}BX_t &= B^{-1}\Gamma_0 + B^{-1}\Gamma_1 X_{t-1} + B^{-1}\varepsilon_t \\ X_t &= B^{-1}\Gamma_0 + B^{-1}\Gamma_1 X_{t-1} + B^{-1}\varepsilon_t \end{aligned}\right\} \quad (9)$$

For simplicity, assume the following model,

$$y_t = c + A_1 y_{t-1} + A_2 y_{t-2} + ... + A_p y_{t-p} + \varepsilon_t \quad (10)$$

Where y_t is an (nx1) vector containing the variables included in the VAR model of this study, c is an (nx1) vector of constant terms (intercepts), A_i is a (nxn) vector of matrices coefficients and ε_t is an (nx1) vector of stochastic error terms.

3. Empirical Results

The nature of the data used in the study is given in table 1 below. The residuals from GDP, wheat prices and maize prices are found to be not normality distributed since the null hypotheses of normality are rejected at 5 percent level of significance. This is shown by their low probability values of 0.0014, 0.015 and 0.0034 for the respective variables. These non-normality of residuals from these variables could be attributed some outliers and even possibly the presence of structural breaks.

Table 1. Descriptive statistics

Variable →	***M_CONS***	***GDP***	***M_PRICE***	***W_PRICE***
Mean	6606.791	732034.9	630.7960	1154.937
Median	6425.000	331980.0	464.0000	648.4200
Maximum	8933.000	3138980.	2266.780	4522.340
Minimum	4824.000	12791.00	37.68000	6.790000
Std. Dev.	1093.316	890786.8	615.0467	1293.485
Skewness	0.598483	1.316220	1.075703	1.252121
Kurtosis	2.691991	3.606987	3.094275	3.252158
Jarque-Bera	2.736944	13.07588	8.308733	11.34988
Probability	0.254496	0.001447	0.015696	0.003431
Sum Sq. Dev.	50204277	3.33E+13	15887862	70270394
Observations	43	43	43	43

Source: Author's calculations

The detection of normality/non-normality in the residuals from the variables used in this study compels us to establish the stationarity tests, although the non-reversibility procedure does not require that. This is performed to determine such prior to estimation of the SVAR model and to avoid the likelihood of false conclusions resulting from spurious regression. It is therefore imperative to establish the order of integration of the variables applied in this study. As mentioned above about the structural nature of the variables: maize demand (Cons), maize prices (Mpr), gross domestic prices (GDP) and wheat prices (Wpr), the study employs the Zivot-Andrews (Zivot & Andrews, 1992) unit root test of which the results are presented in table 2 below.

Table 2. Z-A and ADF unit root test results

	Z-A Test			ADF Test			
Variables	***Z-A Stat C only***	***Z-A Stat T***	***Z-A Stat C & T***	***ADF Stat (none)***	***ADF Stat C only***	***C & T***	***Overall decision***
$CONS_t$	-4.132[1] ***A***	-4.132[1] ***A***	-4.52[1] ***A***	1.6908[0] ***A***	-0.3022[0] ***A***	-2.686[1] ***A***	NS
MPR_t	-0.860[4] ***R***	-2.008[4] ***A***	-2.02[4] ***A***	5.2531[4] ***R***	3.4445[4] ***R***	0.9029[9] ***A***	$NS^{Z\text{-}A}$
WPR_t	-2.24[4] ***A***	-3.80[4] ***A***	-3.75[4] ***A***	4.2944[4] ***R***	3.2770[4] ***R***	-0.157[2] ***A***	$NS^{Z\text{-}A}$
GDP_t	2.4513[0] ***A***	-0.94[0] ***A***	-0.92[0] ***A***	25.9644[0] ***R***	19.4293[0] ***R***	7.4279[0] ***R***	$NS^{Z\text{-}A}$

Notes:

1) A = Accept null, R = reject null, NS = Non-Stationary in both tests, $NS^{Z\text{-}A}$ = Non-stationary using Z-A test;
2) The [ ] contains the lag length selected using the SIC;
3) The significance level chosen is 5%.

The lag length is selected using the SIC imbedded with the e-views software package. For statistical analysis of this paper, the ADF (Dickey & Fuller, 1979) test of unit root cannot be relied upon due to the span of the series used. This is attributable to some major economic happenings that could have occurred during the period under consideration that could have generated potential non-stationaries. Such non-stationaries can have some implication for over or under estimation of the results, hence the Z-A test. The overall results indicate that the variables are integrated of order one.

3.1. Estimation of the Non-Reversible Equation

Given the non-reversibility condition(s) as stated in 3 above, equation (7) was estimated and the results are presented in table 3 below. The explanatory variable is $C_t - C_0$, where C_t is the value of maize consumption at period t and C_0 is maize consumption at initial period, that is the starting period. This dependent variable ($C_t - C_0$) represents Y_t^* in (7).

Table 3. Irreversible function estimation results

Variable	*Coefficient*	*Std. Error*	*t-Statistic*
R_{MPRICE}	-0.127231	0.048946	-2.599415
D_{MPRICE}	0.192622	0.787199	0.244693
R_{WPRICE}	0.033619	0.449600	0.074776
D_{WPRICE}	0.138705	0.466008	0.297645
R_{GDP}	0.001091	0.000617	1.768233
C	685.1639	127.9463	5.355091
R-sqrd = 0.83807		***Adj. R-sqrd = 0.81557***	

The results above indicate that about 84% of Y_t^* is explained by both increases and decreases in the maize price, wheat prices and only increases in GDP. Decreases in GDP were not observed hence the exclusion of D_GDP. The maize price bears a negative sign, indicating that when prices increase, consumption of maize falls by about 12 percent, while decreases in maize price will increases maize consumption by about 20 percent. The first non-reversibility condition is that $\varphi_1 \neq \varphi_2$ ($-0.127231 \neq 0.192622$) and the second condition being $\varphi_3 \neq \varphi_4$ ($0.033619 \neq 0.138705$) and these two conditions hold and suggest that maize demand is indeed irreversible in South Africa. It is however, noted that since decreases in GDP were not observed, this variable was excluded in the non-reversibility equation since we could not attain $\varphi_5 \neq \varphi_6$.

3.2. Impulse Responses from Svar Model

In an attempt to establish the structural nature of the maize product in South Africa, it is imperative to revisit the VAR model that incorporates the structural changes. This however requires that the SVAR models be identified. Identification of such models assists in avoiding the problems in dynamic simultaneous equation models and this requirement is attributable to Sims (1980) and Gottschalk (2001). One distinctive feature of the SVAR modes is that it treats all variables as endogenous. This type of method helps us to obtain the structural innovations, that is, coefficients that have the economic interpretation from the reduced innovations (Ravnik & Zilic, 2011). The SVAR model takes the form of the AB model as postulated by Lutkepohl (2005) with the following appearance: $Au_i = Be_i$, so that it becomes possible to construct matrices A and B. The A matrix obtained after imposing the restrictions on the VAR model was given as:

$$A=\begin{bmatrix} . & . & . & . \\ a_{21} & . & . & . \\ a_{31} & a_{32} & . & . \\ a_{41} & a_{42} & a_{43} & . \end{bmatrix}=\begin{bmatrix} . & . & . & . \\ 0.8418 & . & . & . \\ -0.0637 & 0.2343 & . & . \\ -0.1092 & -0.0714 & -0.0043 & . \end{bmatrix}$$

and the B matrix as:

$$B=\begin{bmatrix} b_{11} & . & . & . \\ . & b_{22} & . & . \\ . & . & b_{33} & . \\ . & . & . & b_{44} \end{bmatrix}=\begin{bmatrix} 0.052290 & . & . & . \\ . & 0.178684 & . & . \\ . & . & 0.165787 & . \\ . & . & . & 0.032264 \end{bmatrix}$$

This results coupled with the identification of the VAR model suggest that the model was just-identified and hence the innovations in the Choleski decomposition have a direct economic interpretation (Enders, 2010). The Choleski decomposition requires that $a_{12}=a_{13}=a_{14}=a_{23}=a_{24}=a_{34}=0$, that is all the elements above the principal diagonal to be zero. At this stage, it is imperative to present the structural innovations in order to find the effect of structural shocks on maize consumption in South Africa. The results of structural innovations are presented in figure 3 below:

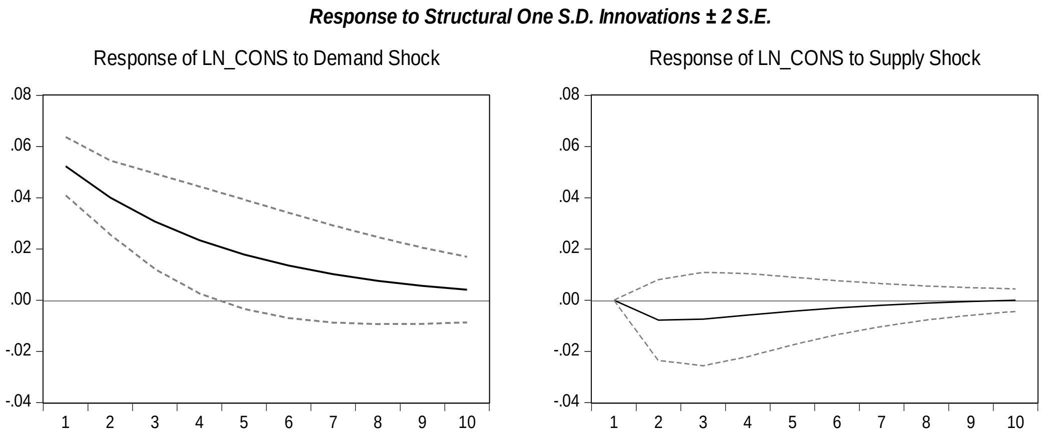

Figure 3. Structural Impulse response functions

The results indicate that maize consumption responds negatively to demand shocks, while it responds negatively to supply shocks in periods 2 and 3, otherwise positive for periods 4 through 10. In the case of demand shocks, demand tends to responds negatively throughout the periods. Prices changes as well cannot ignored when addressing the demand and consumption of maize in the economy. Any of the changes in the variables will bring some responses in maize consumptions.

4. Conclusion

The study employed a time series annual seasonal data for South Africa spanning the periods 1970/71 to 2012/13. In order to test the non-reversibility of the maize function, the data was transformed into changes from the previous points as per the T-Q and the W theorems. The data descriptive statistics revealed that the residuals from GDP, wheat prices and maize prices are not normality distributed since the null hypotheses of normality are rejected at 5 percent level of significance. These non-normality could be as a result of some major outliers in the series and the possibly of the presence of structural breaks. The unit root test was performed as a precautionary measure to establish the order of integration, using both the Z-A unit root test as well as the ADF unit root test. The results from these tests suggested that maize consumption, maize prices, wheat prices and GDP were all integrated of order one.

The results indicate that when maize prices increase by 1 percent, consumption of maize falls by approximately 12 percent, while on other hand decreases in maize price drive consumption up by nearly 20 percent in the short-run. It is also noted that, despite almost all non-reversibility conditions being met, decreases in income are not observed due to the violation of the conditions and hence the variable being dropped from the system. The structural VAR on the other hand, which assumes that innovations are proliferated in the maize demand, maize prices, wheat prices and income indicate the VAR is just –identified. This enabled us to estimate the SVAR and test for structural shocks using innovation accounting practices (IRF[1]), which produced two significant demand and supply shocks. These results complement those obtained from the Houck procedure and suggest that maize consumption in South Africa is significantly affected by structural shocks from maize prices and wheat prices.

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