Impact of Meat Consumption on Green House Gas Emissions in South Africa

Hiywot Menker, Uwilingiye Josine, Johane Dikgang

PEERC, UJ

Abstract

Significant amounts of global emissions come from the livestock sector, and around 70% of which is emitted by developing countries. Reducing the consumption of meat is one of the mitigation actions that can be employed to lessen the impact of Green House Gas (GHG) emissions on climate. A shift in consumption of livestock could mitigate up to 5-6 billion tonnes of GHG emissions. Despite the above, the global consumption of meat has been increasing in the last decade: chicken consumption increased by 2%, and beef consumption increased by 1.6% per annum. In South Africa, a shift in diet towards protein-filled diets-in the last two decades has been observed. Empirical evidence on the impact of meat consumption of South African households on emissions is important to sustainably develop the livestock sector as well as mitigate climate change. A number of studies conducted on meat consumption focus on identifying factors that affect consumption of different meat types, and the corresponding price and income elasticities of meat consumption. This study looked at the impact of the demand for meat on GHG emissions in South Africa. The Linear Almost Ideal Demand System (LA/AIDS) model was employed to analyze the demand for beef, chicken, mouton and pork. The study first analysed the LA/AIDS demand system of meat after testing for the time series properties of the system. Unit root tests show that beef shares, chicken shares, mouton shares, pork shares, prices of beef, chicken, mouton and pork, and real expenditures are found to be integrated of order 1. Long run relationship is found for all the meat shares, and a cointegrated vector error correction model was estimated. Elasticity calculated show mouton and beef ; mouton and chicken; and pork and chicken; beef and pork to be substitutes with one another, where as to beef and pork, and chicken and beef are complements (though the values are small). Meat consumption was then forecasted until 2023 based on the model parameter estimates. Mouton is found to be the largest emitter of Methane gas followed by beef. Emission from chicken consumption is the lowest.

1. Introduction

Livestock farming is the major contributor towards food security in South Africa. Despite its importance, significant proportions of green house gases are also emitted from this sector. 18% of global emissions come from livestock digestion, production of feed for livestock and land use changes. Farming livestock – cattle, sheep, goats, pigs and chickens – contributes around 6 billion tonnes of greenhouse gases (carbon dioxide, methane and nitrous oxide) to the atmosphere each year. While estimates vary, this could represent up to 18% of global emissions. Around 1.6-2.7 billion tonnes of greenhouse gases each year, mostly methane, are produced from livestock digestion. Another 1.3-2.0 billion tonnes of Nitrous Oxide come from producing feed for livestock. And the final 1.6 billion tonnes comes from land use changes, such as clearing for animal pastures.

The emission level and intensity varies across the globe where around 70% is emitted by developing countries. Impact of emissions on climate can be lessened by employing mitigation actions. Only through technology and management the livestock sector can reduce emissions of around 2.4 million tonnes per year. Shift in consumption of livestock could also mitigate up to 5 to 6 billion tonnes of GHG emissions.

Consumption of meat has been increasing in the last decade with varying consumption levels among meat categories. Chicken consumption has increased by 2% per annum while beef increased by 1.6% per annum (DAF, 2014). In South Africa, consumption behavior influenced by increase in average income in the last two decades has led to shift in diet towards protein-filled diets (Goldblatt, 2004). Future demand for livestock is anticipated to come from increased demand for livestock products. A number of studies have shown the increase in demand to come from increase in population, income levels and urbanization. Meeting this increasing demand requires increasing areas of grazing systems and feedlots. But grazing areas are becoming scarce in South Africa (Scollan et al., 2010), as rangelands are shown to be decreasing in size (GTI, 2015), and the feedlots are expected to level off after 2030 (DEA, 2013). In setting up the baseline livestock production a number of future macroeconomic and international factors were considered. These include population, price of crude oil, foreign exchange rates, GDP per capita, and interest rates. Agriculture is also expected to expand to keep up with the demand of the growing population. A s a result food demand over the next decade is not expected to increase at the same rate (BFAP, 2015).

1.a Livestock sector

Animal production sector is mainly natural resources dependent, with the veld (rangeland) resources as its main source of fodder. Of the 80% of the land available for agriculture, 13% of this land is used for crop production (arable land), while 87% of the land is used for animal production (livestock and wildlife) (DAFF, 2014).

Despite its huge significance towards achieving food security, the sector faces challenges to satisfy the increasing demand for livestock products sustainably. While trying to satisfy the increasing demand for livestock products, scarce resources like water and land have been shifted from more productive uses in the economy and high health risks are facing consumers. The sector's impact on climate change cannot be ignored as well.

Grazing land has declined over time due to expanding human settlements and activities like crop farming, forestry and mining. In addition, the productivity of all the rangelands of South Africa has been deteriorating as a result of desertification, bush encroachment and the loss of edible plant species (Goldblatt, 2014). Other studies also identify factors that contribute to the deterioration of the veld condition in South Africa. They include: wood cutting, fire, rainfall, especially drought, and overgrazing or selective grazing (Pretorius, 1998). The veld condition influences the carrying capacity of the land (Rethman & Kotze, 1986; Snyman1998; Turner & Tainton 1989; Danckwerts & Teague, 1989), and heavy grazing in turn impacts on species diversity and composition, and on ecosystem processes. Increasing production requires increasing the limited resource base required to make the process profitable and/or follow intensive production systems. Recent data shows that close to 75% of South Africa's cattle spend a third of their lives in feedlots, fed by grains grown on the country's scarce arable land (Goldblatt, 2014). The land and water resource requirement of feedlot raised animal is much higher than that fed on grasses. For instance, "compared to naturally fed beef, it takes about 65 times the quantity of surface water to produce feedlot finished beef in South Africa if the feed crops are irrigated – 860 litres for every 500 g grain-fed steak" (Goldblatt, 2014).

1.b Literature

The literature on demand for meat focuses on the impact of prices and income/expenditure on meat consumption. In some of the studies the relationship between quantity demanded of meat and the exogenous variables is assumed to be linear and the relationship is estimated using single equation methods using OLS. Others estimated the demand system using systems of equations and a dynamic or static approach has been used to estimate demand when time series data is used. Taljaard , Jooste & Asfaha (2006) studied the factors affecting the demand for beef, mouton, pork and white meat in south Africa using single equation approach . Taljaard et al. (2004)& (Marion et.al, 2017) estimated the LD/AIDS demand model for meat (beef, chicken, pork, and mouton) in South Africa using time series data. Taljaard et al. (2010) studied the contribution of economic and non economic factors in determining the demand for meat in South Africa using time series data from 1970 to 2003.Bowmaker & Nieuwoudt (1990) used the 2 Stage Least Squares (2SLS) procedure and estimated the short run demand equations for beef, mutton and pork using monthly data. The results from the studies significantly differ in elasticity estimates for meat demand and some found unique co-integrating relationships among variables of interest while others have not. The differences in results can come from differences in types of data used (retail and whole sale prices), the period the study covered (long or short term), differences in real price movements between the time periods covered in the studies, and adoption of different estimation methods (linear models and system of equations).

There are few studies that looked into emission from the livestock sector. According to a report compiled by DEA (2014) 93% of the total GHG emission from the livestock sector between 2000 and 2010 was found to be associated with enteric fermentation and the remaining to be generated from manure management. Enteric fermentation were closely linked to the cattle numbers in the study. Enteric fermentation emissions declined between 2000 and 2010 mainly because of decline in population numbers. And cattle (including dairy) were the main emitters followed by sheep. They did not include enteric fermentation emissions from poultry considering the value to be negligible, but stressed the need to include it as the numbers of poultry is big.

This study extended the use of theory based meat demand models to estimate and forecast GHG emissions after estimating meat demand model for South Africa. All the major meat categories (beef, mouton, chicken and pork) are included in the study. Elasticities derived from the model give policy direction in mitigating emissions from livestock sector. Direct and indirect emissions from manure management are not included in the analysis. This study looked at only emissions from consumption of meat in the local market (slaughtered locally), and does not include animals produced for export markets

2. Data and Model specification

2.1 Data

In this study quarterly data spanning form 2008q1 to 2018q3 for beef, pork, and mouton are used. The variables used to estimate both linear and dynamic LAIDS are the average monthly price of each type of meat obtained from BFAP (University of Pretoria). Note that the data were available at monthly frequency and we converted them to quarterly series. The quantities for all meat type were obtained from the Organization for Economic Co-operation and Development (**OECD**) database and the total expenditure was calculated by summing up expenditure on each type of meat products and it was deflated by the price index to obtain the real expenditure. Moreover, the share of each type of meat also obtained by dividing of the expenditure on each meat type to total expenditure. As it is crucial to test the univariate characteristics of the series when dealing with time series data, we performed the unit roots test using augmented Dickey Fuller (1976) and we found all the variables to be nonstationary and integrated of order one.

2.2 Model specification

This study has employed the Linear Almost Ideal Demand System (LA/AIDS) method to analyze the demand for beef, white meat, mouton and pork demand in South Africa. The model used was initially developed by Deaton and Muellbauer (1980) and a number of empirical studies have used these models since.Deaton and Muellbauer (1980) derived and estimated the Almost Ideal Demand System (AIDS) from a particular cost or expenditure function that belongs to the Price Independent Generalized

Logarithm class of preference. The model related the value shares to the logarithms of total expenditure. The study first analysed the static LA/AIDS demand system of meat followed by the dynamic version of the linear AIDS after testing for the time series properties of the system.

The general specification of the LA/AIDS model is given by the following equation:

$$w_i = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \log p_j + \beta_i \log(M / P) \qquad (1)$$

where w_i is the share associated with the i^{th} meat category, α_i is the constant in the i^{th} share equation, γ_{ij} is the slope coefficient associated with the j^{th} good in the i^{th} share equation, p_j is the price of the j^{th} good, M is the total expenditure on the system of goods given by the following equation: $M = \sum_{i=1}^{n} p_i q_i$ where : q_i is the quantity demanded for the i^{th} good. P is the general price index defined by:

$$\log P = \alpha_0 + \sum_{i=1}^{n} \alpha_i \log p_i + 1/2 \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} \log p_i \log p_j \qquad (2)$$

Mostly prices are relatively collinear and P is approximately proportional to some price index. Hence to avoid non-linearity and reduce multi-colinearity effects in the model a linear approximation equation is suggested by Deaton and Muellbauer (1980). They suggest the use of Stone's (1953) price index.

$$\ln p_i = \sum_{i=1}^{N} w_i \ln p_i \qquad (3)$$

When the data is observed over some period of time the LAIDS model is given as follows:

$$w_{it} = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln p_{jt} + \beta_i \ln(x_t / P_t) + u_t, \ for\ all\ i = 1\ to\ N, t = 1\ to\ T, \qquad (4)$$

where N is the number of meat categories in the demand system, T is the number of years, w_{it} is the expenditure share of the i^{th} meat category at year t, x_t is the total meat consumption expenditure at time t, p_t is the aggregate price index, and $\alpha, \gamma, and \beta$ are parameters to be estimated. And the stone price index is given by

$$\ln p_t = \sum_{i=1}^{N} w_{it} \ln p_{it} \qquad (5)$$

To comply with the theoretical properties of consumer theory the adding up, homogeneity, and Slutsky symmetry restrictions are imposed on the parameters in the AIDS model. The Adding up restriction allows the budget share to sum to unity, the homogeneity condition assumes a proportional change in all prices and expenditure does not affect the quantities purchased or the consumer does not exhibit money illusion. And symmetry represents consistency of buyers' choices. The theoretical demand properties of adding up, homogeneity, and Slutsky symmetry are satisfied by the AIDS model, given approximate parametric restrictions. First, for adding up, the budget shares sum to 1 if $\sum_{i=1}^{n} \alpha_i = 1$, $\sum_{i=1}^{n} \beta_i = 0$, $\sum_{i=1}^{n} \gamma_{ij} = 0$. Second, the homogeneity condition requires that $\sum_{j=1}^{n} \gamma_{ij} = 0$. Finally, the symmetry restriction holds if $\gamma_{ij} = \gamma_{ji}$.

Elasticity estimation is an important part of the modeling procedure. The demand elasticities are calculated as functions of the estimated parameters. Following Green and Alston (1990), the different elasticities are calculated as follows:

$$\eta_i = 1 + \beta_i / w_i \ (Income / \exp enditure\ elasticity\ )$$
$$\phi_{ij} = -\delta_{ij} + w_j + \gamma_{ij} / w_i \ (compensated\ elasticities)\ and\ the\ uncompensated\ elasticities\ are\ calculated\ from$$

$$\eta_{ii} = -\delta_{ij} - \beta_i + \gamma_{ij} / w_i \text{ and } \eta_{ij} = \gamma_{ij} / w_i - \beta w_j / w_i$$

3. Econometric approach

One of the important aspects when dealing with aggregate time series data is to analyze univariate characteristics of each individual time series data in order to avoid spurious regression.In case the series contains unit roots, the estimation of static LAIDS model which ignore statistical property of individual time series data may give unreliable results since the asymptotic distribution of the estimators would be biased and conventional distributional tests of significance of individual coefficients, overall significance and goodness fit of the model will be unreliable (Granger and Newbold, 1994). Moreover, the static LAIDS model assumes that the consumer behaviors are always in equilibrium, hence it fails to distinguish consumer behavior in short run and long run.The short run consumer behavior plays a crucial role in demand analysis asit can capture habit persistence, adjustment cost, imperfect information, incorrect expectations, and misinterpreted real price changes which prevent consumers to instantly adjust their expenditure to price and income changes (Anderson and Blundell 1983).

The model that omitsshort run aspect of consumer behavior will tend to suffer for dynamic specification. To overcome the shortcoming of static LAIDS, dynamic modelling of LAIDS model, mainlyEngle-Granger (1987) two stages approach has been extensively used in studies of demand for food and meat products (Balcombe & Davis, 1996; Attfield, 1997; Karagiannis et al., 2000; Karagiannis&Mergos, 2002). This methodology approach first tests the existence of stable long run relationship among the variables; and in case the long run equilibrium relationship holds, an error correction model which incorporates both short run and long run estimates can be formulated. However, using Engle and Granger (1987) two steps approach imposes prior restrictions on LAIDS model by treating prices and real expenditure as exogenous.This invalidates the results in case one of the meat prices or real expenditure is endogenous. Moreover, since we have more than two variables in LAIDS model, it is possible to have more than one cointegration relationship which requires an econometric method that is suitable to more than two cointegrating relations. For that reason, since all the variables in our model are non-stationary and integrated of order one, this study usesmulti-cointegration approach proposed by Johansen's (1991,1995) which treats all the variables as endogenous, and it can also be used to detect more than one cointegrating relationship among variables.

In order to test cointegration using Johansen methodology approach, we need first to estimatea Vector autoregressive model(VAR) with p lags, which is represented as follows:

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + ... + A_K y_{t-p} + Bx_t + \varepsilon_t \qquad (6)$$

Where y_t is a vector of non-stationary I(1) variables, $A_1, A_2, ...A_p$ and B are different matrices of coefficients to be estimated, x_t is a vector of deterministic variables and ε_t is a vector of innovations. Using Granger representation theorem, the VAR model can be reformulated as Vector Error correction(VECM) model and rewritten in its first difference form as:

$$\Delta y_t = \prod y_{t-1} + \sum_{i=1}^{k-1} \Gamma_i \Delta y_{t-1} + Bx_t + \varepsilon_t \,(7)$$

Where $\Pi = \sum_{i=1}^{K} A_i - I$ and $\Gamma_i = -\sum_{j=i+1}^{K} A_j$

The parameters in Equation 6 are estimated using Maximum likelihood estimation; and theoretical restrictions adding-up, homogeneity, and symmetryare tested on the parameters of VECM-LAIDS model.The errors are assumed to have zero mean, constant variance, and to be uncorrelated.

After obtaining the results of VECM, the model can then be used to forecast meat shares, andin this studywe used dynamic forecasting. Unlike static forecasting, the dynamic forecasting uses previous forecasted value of endogenous variable to forecast future values while static foresting makes use of actual values for each subsequent forecast using prior information on the exogenous variable.

4. Estimation procedure and Results

4.1 Econometric results

First separability tests were conducted among the four meat categories of beef, chicken meat, mouton and pork. This follows from consumer theory where utility maximizing consumers allocate their income or total expenditure in two stages (Eales and Wessels, 1999; Goldman and Uzawa, 1964). First, total expenditure is allocated over the broad categories of goods by a consumer. Then in the second stage the broad expenditures are allocated to individual goods within a group. To arrive at the second stage budgeting, weak separability of the utility function over the broad categories of goods is required. The null hypothesis of weak separability among beef, white meat, mouton and pork was rejected using both the F-test and the Likelihood Ratio (LR) test. This implies that the demand for each of the meat categories should include the prices of the other meats. In this case each meat category could be a substitute or complement of the other.Hence we can estimate the meat demand using the proposed methodology outlined in section 3.

Prior to estimation of VECM, we specify VAR with 2 lags to account the loss of degree of freedom given limited sample size. The test for stability indicate that the VAR is stable since no roots lies outside unit circle. The results for stability test are depicted in Table 1. Note that we omitted pork share in VAR estimation to avoid collinearity.

Table 1. Stability tests

Endogenous variables: BEEF_SHARE
CHICKEN_SHARE MOUTON_SHARE
LPR_BEEF LPR_CHICKEN
LPR_MOUTON LPR_PORK
LRTOT_EXP
Exogenous variables: C
Lag specification: 2 2

Root	Modulus
-0.933885	0.933885
0.933885	0.933885
-0.921608 - 0.111090i	0.928280
-0.921608 + 0.111090i	0.928280
0.921608 - 0.111090i	0.928280
0.921608 + 0.111090i	0.928280
-0.776076 - 0.405726i	0.875733
-0.776076 + 0.405726i	0.875733
0.776076 - 0.405726i	0.875733
0.776076 + 0.405726i	0.875733
-3.54e-16 - 0.695302i	0.695302
-3.54e-16 + 0.695302i	0.695302
0.478436 - 0.290187i	0.559562
0.478436 + 0.290187i	0.559562

-0.478436 - 0.290187i	0.559562
-0.478436 + 0.290187i	0.559562

No root lies outside the unit circle.

VAR satisfies the stability condition.

By performing diagnostic tests on the estimated VAR and we found that the residuals are autocorrelated up to two lags using Lagrange-multiplier (LM) test. However, we fail to reject the null hypothesis of normality and homoscedastic residuals according to Jarque Bera test and white heteroscedasticity test with no cross terms.

We then proceed and test for cointegration. Based on pantula principle, both Trace and Maximum Eigen Value tests indicate existence of three long run relationship (cointegration). The results are displayed in the table 2. Note that all the four models beside the model that omit intercept and trend in cointegration equation suggested three cointegration relations.

Table 2: Deterministic Trend Specification of the VAR

Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend	Intercept Trend
Trace	2	3	3	3	3
Max-Eig	2	3	3	3	3

Next, cointegrating rank (rank of matrix Π) is estimated using Johansen methodologyby including intercept and quadratic trends in the three cointegrating equations. According to the results of trace statistics and Max Eigenvalue we fail to reject the null hypothesis that the number of cointegrating vector is equal to three against the alternative of four at 5% level of significance. The results are shown in table 3.

Table 3: Johansen cointegrating tests

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.938618	334.7410	175.1715	0.0000
At most 1 *	0.870070	223.1156	139.2753	0.0000
At most 2 *	0.831256	141.4851	107.3466	0.0001
At most 3	0.499631	70.31026	79.34145	0.1971
At most 4	0.382926	42.61387	55.24578	0.3917
At most 5	0.235808	23.30321	35.01090	0.4890
At most 6	0.205682	12.54575	18.39771	0.2704
At most 7	0.079992	3.334900	3.841465	0.0678

Trace test indicates 3 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.938618	111.6254	55.72819	0.0000
At most 1 *	0.870070	81.63051	49.58633	0.0000
At most 2 *	0.831256	71.17483	43.41977	0.0000
At most 3	0.499631	27.69639	37.16359	0.3987
At most 4	0.382926	19.31067	30.81507	0.6060
At most 5	0.235808	10.75746	24.25202	0.8581
At most 6	0.205682	9.210848	17.14769	0.4739
At most 7	0.079992	3.334900	3.841465	0.0678

Max-eigenvalue test indicates 3 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

Since we obtained 3 cointegrating relations using Johansen cointegrating approach, we then proceed and formulate the VECM with optimal lag equal to 1. Note that since trace and Maximum Eigen values tests suggested 3 cointegrating relations, we need to normalize the variable regarded as the dependent variable by imposing the restriction of 1 to each meat share category coefficient. We also impose over identification restriction on estimated the loading matrix by imposing zero restriction to weakly exogenous variables in the system. Furthermore, we also impose the theoretical demand properties of homogeneity and symmetry. The results are reported in the table 4.

Table 4: VECM estimation results

Cointegrating Eq:	CointEq1	CointEq2	CointEq3
BEEF_SHARE(-1)	1.000000	0.000000	0.000000
CHICKEN_SHARE(-1)	0.000000	1.000000	0.000000
MOUTON_SHARE(-1)	0.000000	0.000000	1.000000
LPR_BEEF(-1)	-0.094318	0.167602	-0.031617
	[-6.11464]***	[16.4707]***	[-5.21689]***
LPR_CHICKEN(-1)	0.167602	-0.104221	0.016583
	[16.4707]***	[-8.88281]***	[1.81032]*
LPR_MOUTON(-1)	-0.031617	-0.027692	-0.027692
	[-5.21689]***	[-12.5214]***	[-12.5214]***
LPR_PORK(-1)	-0.041667	-0.035688	0.042726
	[-2.10535]***	[-1.76992]***	[2.86202]***
LRTOT_EXP(-1)	-0.052393	-0.387395	0.197455
	[-0.65801]	[-4.87281]***	[3.31304]***
@TREND(08Q1)	0.000421	-0.000504	-0.000426
C	0.600812	5.191554	-3.014216

Error Correction:	D(BEEF_SHARE)	D(CHICKEN_SHARE)	D(MOUTON_SHARE)	D(LPR_BEEF)	D(LPR_CHICKEN)	D(LPR_MOUTON)	D(LPR_PORK)	D(LRTOT_EXP)
CointEq1	-0.401191***	0.000000	0.000000	0.000000	0.000000	0.000000	0.968624	-0.294462

	[-11.9106]	[NA]	[NA]	[NA]	[NA]	[NA]	[2.19394]	[-2.60244]
CointEq2	0.000000	-0.628353***	0.000000	-0.320915	-0.257971	1.257391	3.723455	0.000000
	[NA]	[-4.19085]	[NA]	[-0.37825]	[-0.26940]	[1.30262]	[1.93664]	[NA]
CointEq3	-0.623385	0.000000	-0.636650***	0.000000	1.819013	-1.924115	4.753703	0.356910
	[-3.68551]	[NA]	[-4.47114]	[NA]	[3.05017]	[-1.20698]	[1.83449]	[1.66663]

T-statistic in blanket (significant at 1%; * significant at 5%; *** significant at 10%)**

Looking at VECM results, all the coefficients are statistically significant at 1 percent level of significance except the coefficient of log of real total expenditure in beef share equation. The adjustment coefficients which indicate the speed at at which endogenous variable returns to equilibrium after a change in other variables. For the three meat share speed of adjustment lies between 0 and -1 and statistically significant at 1% level, this show that there is convergence to the equilibrium.

We furthermore investigate the adequacy of estimated VECM model by performing diagnostic tests. We first test for autocorrelation, the Lagrange-multiplier (LM) test show that the residuals are serial dependent up to two lags since the P-value is less than 5% level of significance.Nevertheless, given limited number of observations,we are not able to increase the lags to resolve autocorrelation. For Jarque Bera for normality, we reject the null hypothesis of normality of the residuals. However,Paruolo (1997), argue that if normality of the residuals is rejected for other reasons (kurtosis), Johansen results are not affected. Hence, the skewness joint probability of 0.1795 indicate that the residuals are multivariate normal. Moreover using White heteroscedasticity test with no cross terms, we fail to reject the null hypothesis of homoscedasticity at 5 % level of significance since the P value of 0.3673 is greater than 0.05 level of significance.

We also formally test whether the residuals of the three cointegration equations representing beef share, chicken share and mouton share are stationary using ADF tests. The results are shown in the table below:

Table 5: Stationarity test results

Variable	**MacKinnon p-values**
	ADF statistic
CE_BEEF SHARE	-6.705924***[0.0000]
CE_CHICKEN SHARE	-7.502121*** [0.0000]
CE_MOUTON SHARE	-6.914361*** [0.0000]

P-values in the blankets(** significant at 1%; * significant at 5%; *** significant at 10%)

The ADF test show that the residuals coming from the three meat share equation are stationary. We the conclude that the estimated VECM model is adequate andthe parameter estimates of the VECM model, beef shares, chicken shares, pork shares, prices of -beef, chicken, pork and mouton, and total expenditure were forecasted both in sample and out of the sample period. The results were used to estimate GG emissions from consumptions of the different categories of meat.

4.2 Elasticities

Table 1. Own and Cross price elasticities

	Beef	Mouton	Chicken	pork
Beef	-0,38097	0,24238	-0,11283	0,251436
Mouton		-0,65404	0,373592	-0,24208
Chicken			-0,28834	0,168323

Table 1 shows own and cross price elasticities for and among beef, mouton, and chicken and pork.

Own price elasticity is the change in the amount of meat consumptions as a result of a percentage change in own price, where as cross price elasticity is change consumption of a certain meat category in response to a percentage change of other meat types.

All of the own-price elasticities are negative and range between zero and one, showing that they are normal goods. The compensated own-price elasticity is the largest for mutton (-0.65), which is followed by beef (-0, 38097), and chicken is the last one with elasticity value of -0, 28834.

When we look at the cross price elasticities, pork seems to be a substitute to all except mouton, where as chicken is substitute for mouton and pork but complement with beef. The largest value of cross price elasticity is between mouton and chicken.

The long run own price elasticities estimated in this study are smaller (except that of beef) than the short run elastisities estimated by Marion et.al (2017), but all the own price elasticity values are bigger than the long run elasticities found by Taljaard (2003). Our results are not comparable with the above studies as in the first case long run relationship was not found, and the time frame is different in the second study.

4.3 Methane Emissions

Greenhouse gas (GHG) emissions from enteric fermentation consist of methane gas produced in the digestive systems of ruminants and, to a lesser extent, of non ruminants. Greenhouse gas (GHG) emissions from manure management consist of methane and nitrous oxide gases from aerobic and anaerobic manure decomposition processes. Methane (CH4) gas is produced through anaerobic decomposition of stored or treated manure, while Nitrous Oxide (N2O) is produced directly by nitrification and de-nitrification processes in the manure. N2O is also produced indirectly by nitrogen (N) volatilization and re-deposition processes, and leaching of manure N. In calculating green house gas emissions from meat consumption, number of animal heads and GHG emission factors are crucial. The IPCC default Tier 1 Emission factors (EF) for the different livestock types are used in the analysis (Francesco et.al, 2014).

The emissions are calculated as follows:

$$Emissions\,(CH_4)_T = EF_{(T)} \times \frac{N_{(T)}}{10^6}$$

Where, Emissions (CH4)(T) = Methane emissions for animal category T ,Gg CH4 yr-1;

EF(T) = emission factor for animal type T , kg CH4 head-1;

N(T) = number of heads for animal category T ; and

T = animal category

The past and future GHG emissions from consumption of beef, chicken and mouton are shown in the figures below.

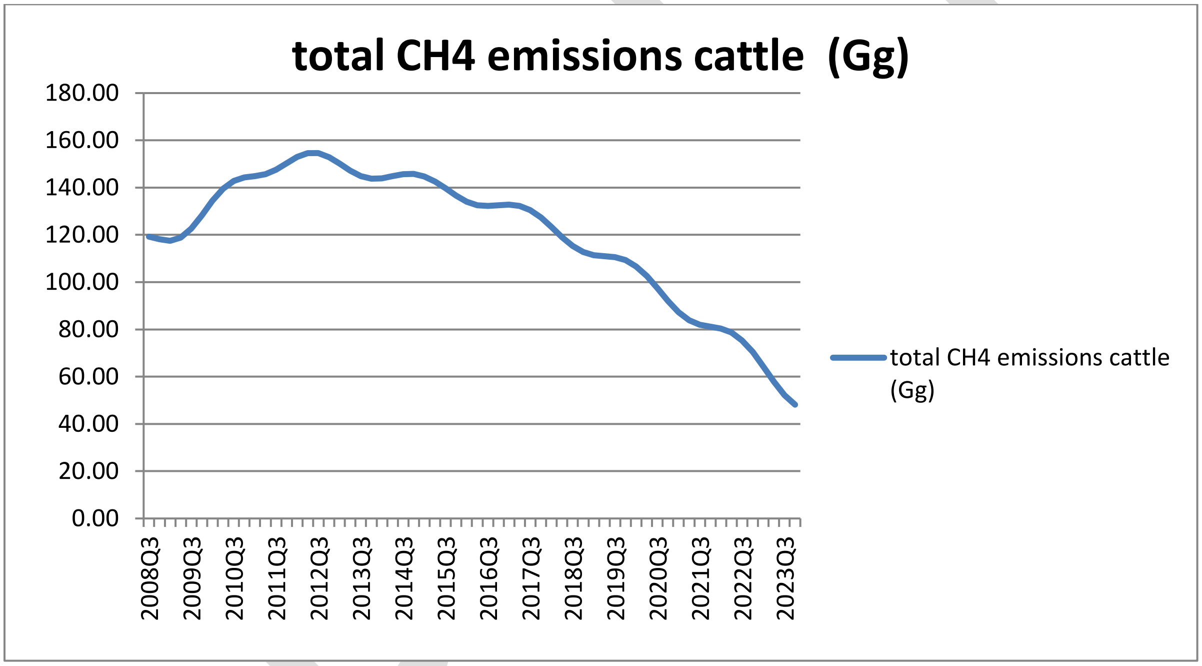

Figure 1: Methane gas emissions cattle (Gg)

Emission from beef consumption has been dropping continuously through the time periods, following decrease in demand for beef. The highest emission level was reached around 2012.

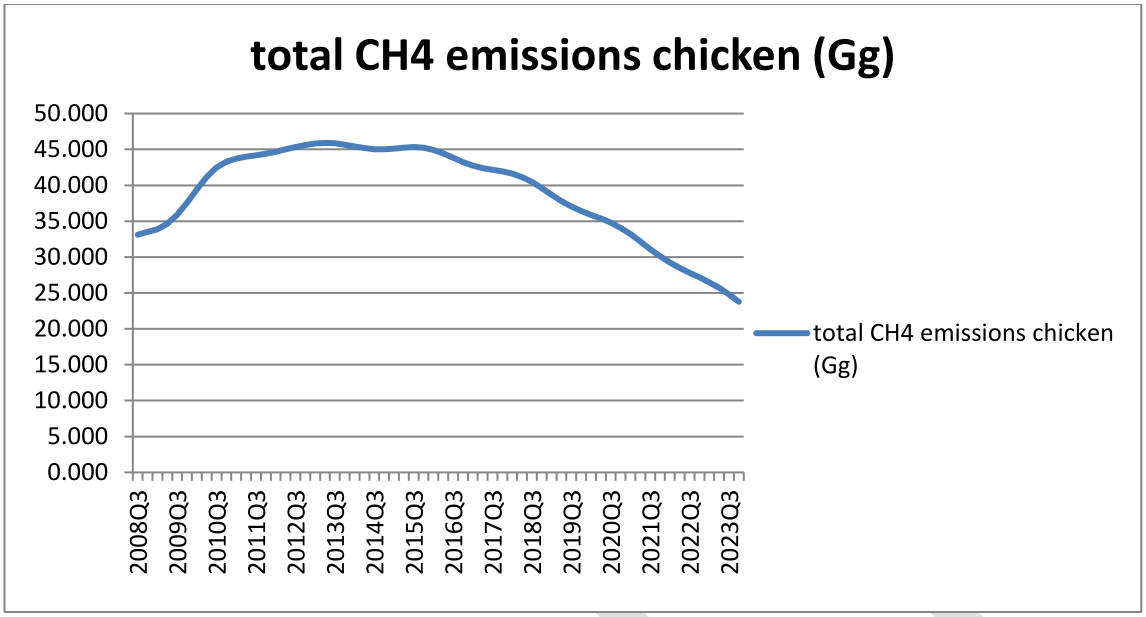

Figure 2: Methane gas emissions chicken (Gg)

Emission from chicken consumption reached maximum between 2012 and 2014 and then declines slowly then after.

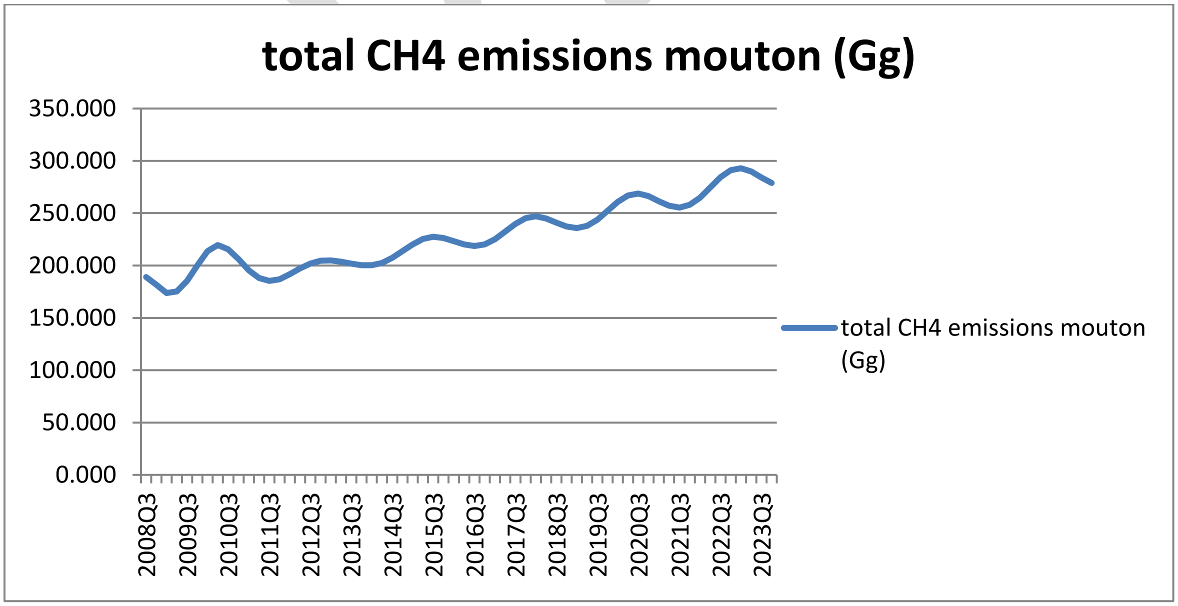

Figure 3: Methane gas emissions Mouton (Gg)

Emissions from mouton consumption seem to increase continuously despite it is the expensive meat category in the country.

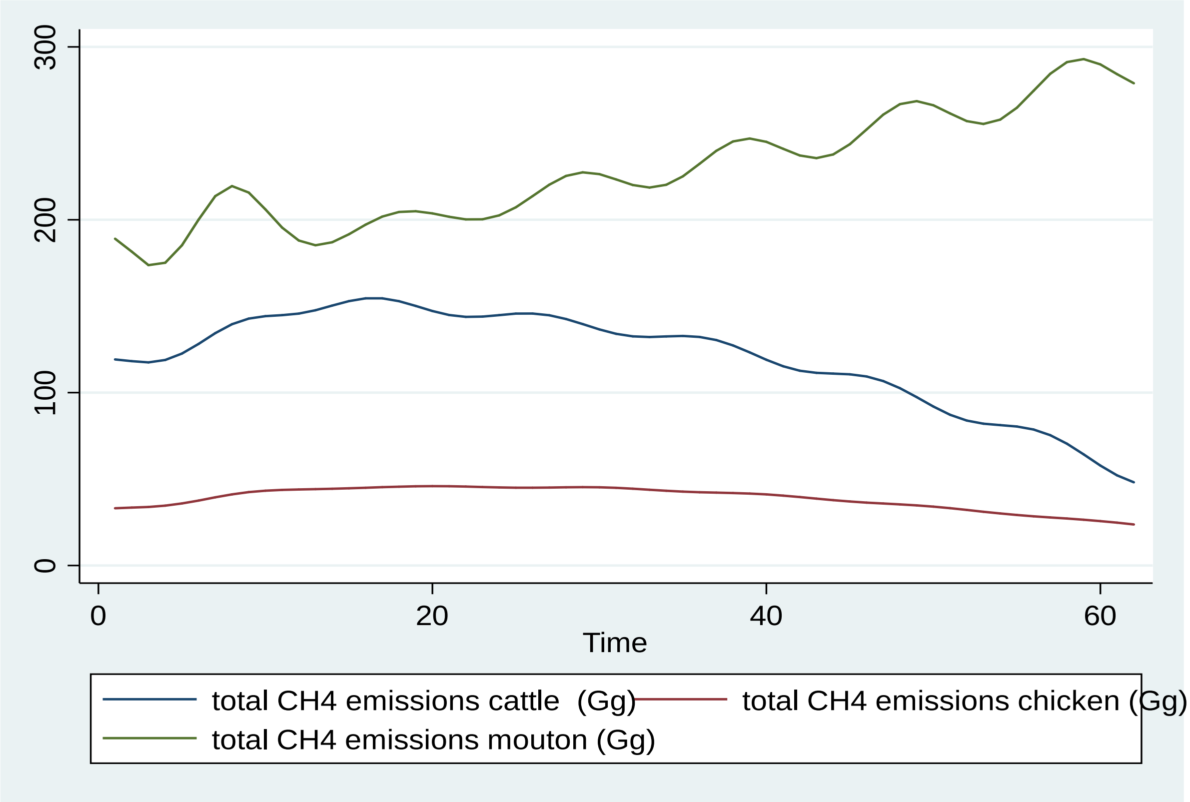

Figure 4: Methane gas emissions beef, chicken, Mouton (Gg)

Mouton is the largest emitter of Methane gas followed by beef. Chicken is the least emitter. Interventions to reduce emissions from livestock sector need to focus on reducing demand for high emitting meat consumption and substituting them with low emission meat categories. In this case the demand for mouton and beef can be reduced if their substitutes become cheaper in the faces of increasing beef and mouton prices. Emissions from chicken should also be reduced through adopting improved management practices. From the elasticity estimates, mouton consumption responds more to own price changes followed by beef. Pork does not seem to be considered as a substitute for mouton, but chicken is a substitute to mouton consumption. And though chicken seems to complement beef, the cross price elasticity between them is small.

Hence increasing chicken consumption seems a more plausible option in reducing GHG emissions while addressing the need for meat consumption.

5. Conclusion

Understanding past and likely future trends in greenhouse-gas emissions can be used in planning the most efficient/ cost effective means to achieve sustainable development. Shift in consumption towards chicken is beneficial both to consumers and the whole economy. Economic, environmental and health benefits can be achieved simultaneously if there a shift in consumption towards chicken. It can also be beneficial to the economy in the face of scarce grazing land and feed lots as beef production requires more grazing land, feedlots and water which are scarce resources in the country.

The baseline emissions are analysed assuming no mitigation actions are conducted in livestock production and management. These include improvements in feed types and their efficient utilization, manure management, etc. Changing these conditions is expected to bring significant change in emission levels. In the absence of such interventions, reduction in methane emissions can be achieved by bringing changes in meat consumption choices.

Prices can also be used as incentive mechanisms to strike the balance among the health, food security and environmental benefits from livestock consumption. Since chicken consumption responds less to its price change and it is substitute to the other meat catagories, efforts should focus on how to incentivize chicken consumption with the expectation of reducing other meat types which are high emitters of GHG.

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