# Modeling South Africa's Meat Import Demand System

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**Abstract**

A modified Central Bureau of Statistics (CBS) differential model was used to provide the first estimate of South Africa's meat import demand system. In addition to price and scale the model also included a trend and trend-squared term to measure changes in technology and/or consumer demands for meat outputs.

Cross-prices elasticity (cij) indicates that poultry is a statistically significant substitute for pork, sheep/goat, and offal. Scale coefficients were highly significant, positive for beef and negative for other meat. The trend and squared trend terms were also highly significant, implying changes in import demand not driven by price or scale changes. During 1997-2010 periods, changes in import demand caused poultry and pork to rise and import demand for beef, sheep/goat, and offal meats to decline.

A simulation model was developed that converted an expected CBS endogenous into "predicted" quantities. The in-sample quantity predictions are remarkably accurate, indicating the model performs very well in forecasting South Africa's meat imports given prices and scale. Results of model simulations conclusively demonstrate meat changes similar to the CBS model.

**Key words**: import demand system, South Africa, poultry, beef, pork, sheep/goat, offal.

## Introduction

In 2010, South Africa became a member of the International political organization of leading emerging economics, known as BRICS, including Brazil, Russia, India, China, and South Africa. This places South Africa a possible forefront in leading trade to other countries. Particularly, South Africa enjoys a strategic advantage over other Sub-Saharan African countries due to existing infrastructure, roads, railways, harbors, marketing skills, and cultural ties borne of historical relations. Will South Africa, with large untapped agricultural resources supply meat products to Sub-Saharan countries? South Africa's livestock is the largest agricultural sector, contributing 49.4 percent to the total gross value of agricultural production in 2011/12, and was followed by horticultural products (25.5 percent) and field crops (25.1 percent) (Trends in the Agricultural Sector 2011). However, the initial assessment of the livestock sector indicated that total livestock number including cattle, pigs, sheep, and goats declined from 43 million in 1975/76 to 39.3 million heads in 2009/2010, while poultry meat production is rising.

South Africa's per capita meat consumption indicated a major trend; a decrease in red-meat (cattle, pork, and sheep/goat) per capita consumption showed a decline from 33.1 kg to 25.1 kg, and a substantial increase in poultry meat from 13.5 to 32.6 kg, during 1975/76 to 2009/10. This means that over the last 35 years, the share of poultry consumption rose from 29 percent to 57 percent of total meat consumption, while red-meat consumption declined from 71 to 43 percent.

On the production side, South Africa meat growth rate increased at an average rate of 2.76 percent annually during the 1975/76 to 2009/10 periods. Poultry grew the fastest at 4.5 percent rate, while total red-meat production (beef, pig, sheep/goats) was slowly at 1.45 percent annually

(Abstract of Agricultural Statistics, 2011). Recent data showed an annual decline of 2.3-percent in commercial slaughtering of red-meat-producing livestock types during 2006/7 - 2010/2011, and a positive but lower rate in broiler slaughtering (Trends in the Agricultural Sector 2011). The assessment of South Africa's meat production and consumption, not only reveals shortfall of domestic production to meet rising consumer's demand, but also meat imports make up 16 percent of consumption and rising . The goal of this paper is therefore to model the pattern of meat imports and evaluate consumers demand shift from red meat to poultry during 1997-2010.

**Literature Review**

Changing meat demand in general from red-meat to poultry was studied by several authors worldwide. For example, in the United States, health issues (linking fat content and high cholesterol levels and strokes) initiated a change in meat demand from beef to poultry/chicken, lean pork, and fish products (Piggott and Marsh, 2004; Moschini and Meilke, 1989; and McGruirk et al., 1995). In the UK the decline in beef and veal consumption during 1990-1998 was attributed to safety concerns about beef as a food, animal welfare, and environmental issues, outbreaks of animal diseases, changes in demographics, changes in relative prices, health concerns (fat-content), and the demand for convenience (Resurreccion, 2003). Similarly, Huston (2000) explained demand shift from red-meat to poultry to factors such as safety, health issues, convenience (time to cook and prepare), and high prices relative to others. Some of these factors, if not all, contributed to decrease in U.S. per capita consumption of beef from 84 to 62.5 pounds per year, and a remarkable increase in chicken from 40 to over 80 pounds during 1970-1999 (Davis and Stewart, 2002). Increasingly, the amounts of fat-content in meat are generally seen as negative. This was confirmed in four European countries; France, Germany, Spain, and the UK (Grunert, 1997), and in South Africa (Shongwe et al., 2007).

Few authors reported changing lifestyles has led to the shift toward more convenience in meat and food preparation worldwide. Anderson and Shugan (1991) and Grunert (2006) found that consumer demand for convenience boosted demand for poultry relative to beef, the market leader. Grunert (2006) called convenience the most significant trend that contributed to rising chicken sales. Chicken cuts appeal to satisfy consumers demand for convenience due to its higher degree of processing compared with other meats. Demand for convenience gained importance shortly after the US National Chicken Council reported that tendency for convenience increased share of cut up chicken demand for processed cut up pieces from 34.7 percent of total US processed broilers in 1974 to 65.4 percent in 1999 (Davis and Stewart, 2002).

In South Africa, Nieuwoudt (1998) and Louw et al. (2010) explained changing demand for meat in general to growth in population and per capita income, urbanization, and foodstuff preference among population groups; whites, blacks and coloreds. More specifically, (Louw et al, 2010) explained the rise in demand for poultry to "global derived factors," including health concerns, expansion of fast food outlets, and demand for convenience. Also in South Africa, Taljaard et al. (2006) used econometric models to analyze factors that led to the changes in consumer demand for beef, pork, sheep, and poultry. The model analyzed economic factors (own price, income and relative price) and non-economic factors combined (health and safety, convenience, quality, animal welfare and the environment) for three periods: whole 1970-2003, 1970-1988, and 1985-2003. Stronger relation was found between demand and economic factors for the whole and first period, compared with the second period, when non-economic factors had a larger impact determining changes in meat consumption. These non-economic variables were analyzed together as a group, and were not individually specified in the model.

During the past few decades, several authors investigated demand for meat imports such as Hayes, Wahl, and Williams (1990) in the United States, Kawashima and Sari (2010); Yang, and Koo (1994) in Japan, Lopez (2009) in Mexico, Ablayeva, et al. (2004) in Russia**,** and Pantzios and Fousekis (1999) in Greece**.** To the authors' knowledge, no study was found dealing with the import demand for meats in South Africa.

**Major Objective**

Our objective is to estimate South Africa's meat import demand system. To achieve this objective, we modeled South Africa's meat import demand system during the period 1997 to 2010. Demand shift among various meats, their own prices, and cross-price elasticities were estimated to determine the patterns of consumer demand for the different meats and substitution effects. The analysis used CBS model and added a trend variable that might capture possible change, triggered by consumers' rising preference for certain meat.

The remainder of the paper is organized as follows. The first section presents an examination of South Africa's meat import volume, prices, and expenditure shares. The description of data sources used in the study is followed by the methodology, the empirical results, tests from the linear CBS model, and the conclusion.

## South Africa's Commercial Imports of Meat

SA's imports of poultry meats increased the most among all meats imports, followed by pork (though from a small base), while imports of beef and other meats declined (Table 1). In 2011, poultry meat imports increased to 349.5 million from 103.2 million kg in 1997, or a compound rate of 8.47 percent per year. Over 57 percent of the poultry imports originated from Brazil, 25 percent from the EU-27, 8.25 percent from Argentina, 5.5 percent from Canada, and 2.7 percent from the United States.

Table 1 : South Africa's meat imports, 1997-2011

| | Poultry | Beef & veal | Pork | Other | Total |
|---|---|---|---|---|---|
| | | | 1,000 tons | | |
| 1997 | 103.2 | 48.4 | 6.4 | 57.8 | 215.9 |
| 1998 | 86.7 | 15.8 | 6.8 | 53.4 | 162.8 |
| 1999 | 98.2 | 16.4 | 11.5 | 58.2 | 184.3 |
| 2000 | 93.4 | 12.9 | 10.9 | 72.4 | 189.7 |
| 2001 | 78.3 | 4.7 | 8.6 | 51.0 | 142.6 |
| 2002 | 93.9 | 4.2 | 8.2 | 34.6 | 140.9 |
| 2003 | 153.0 | 9.9 | 17.6 | 33.1 | 213.6 |
| 2004 | 182.0 | 15.9 | 21.6 | 36.9 | 256.5 |
| 2005 | 214.0 | 19.7 | 26.9 | 45.5 | 306.1 |
| 2006 | 293.6 | 19.0 | 20.6 | 55.8 | 389.0 |
| 2007 | 276.0 | 16.9 | 22.6 | 58.0 | 373.5 |
| 2008 | 220.3 | 7.0 | 17.8 | 51.0 | 296.1 |
| 2009 | 230.9 | 9.6 | 27.3 | 43.5 | 311.3 |
| 2010 | 265.2 | 5.8 | 26.1 | 41.8 | 338.9 |
| 2011 | 349.5 | 10.4 | 32.1 | 40.7 | 432.7 |

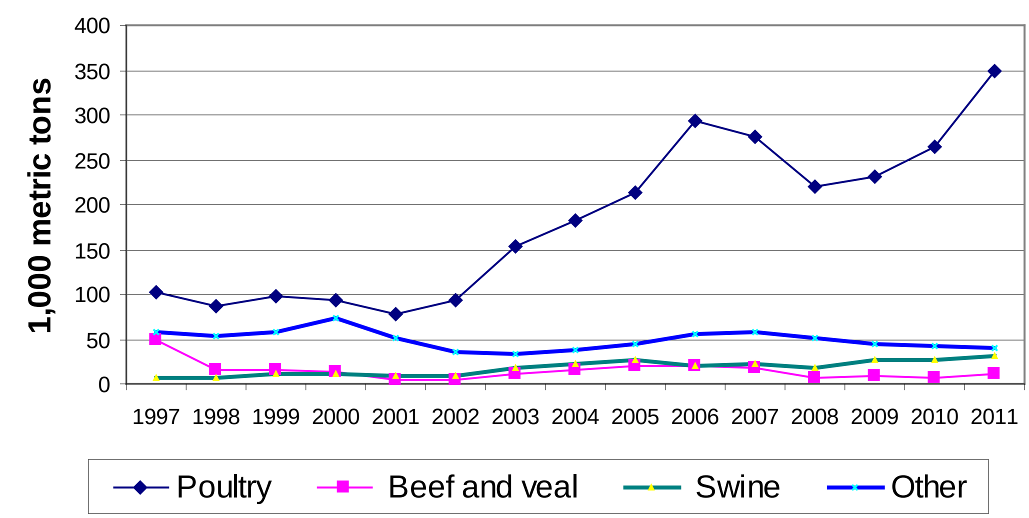
Source : World Trade Atlas, April 2012

South African imports of poultry from the United States were small, due to the Anti-dumping duties case against U.S. poultry products, and the imposition in 2000 of anti-dumping tariffs, amounting from Rand 2.24/ kg to 6.96/kg (US$0.32 to 1.00) in addition to an import duty of Rand

2.20/kg (about US$0.31/kg). This case is not yet resolved **(**GAIN Report, Republic of South Africa, 2011)**.**

South Africa's pork imports also increased from 6.4 to 32.1 million kg, but beef declined substantially from 48.4 million kg in 1997 to 5.82 million kg in 2010. Imports of the category of other meats (mainly sheep/goat and offal meats), decreased from 57.8 to 40.7 million kg, but its two major components were growing adversely; sheep/goat meat imports were down from 35.8 million kg to only 7.3 million kg, while imports of edible animal offal were up from 22 million kg to 33.4 million kg (WTA). These changes in import demand for meat during 1997-2011 are attributed to consumer's preferences, meat relative prices, population growth, rising per capita income, and the appreciation in the value of the rand vis-à-vis the dollar since 2002, among other factors (Figure 1).

**Figure 1: South Africa's meat imports, 1997-2011**

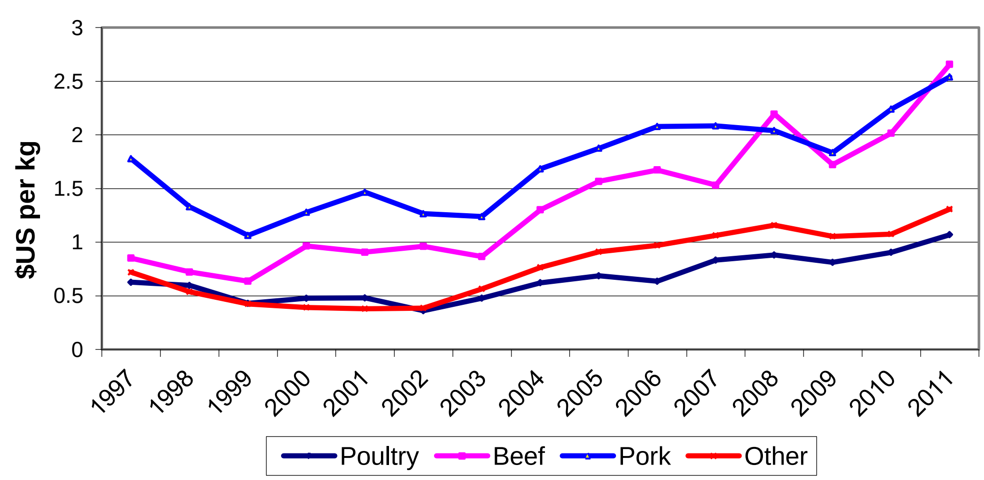



Source: World Trade Atlas, May, 2012.

## Commercial Meat Import Prices and Expenditures

Non-poultry meats carry the highest import prices in South African markets as indicated by average-weighted import value per unit, including transportation, insurance and other charges. The unit value of pig meat imports remained consistently higher than bovine, poultry, and other meats throughout 1997-2010. In 1997, pig meat unit value at $1.78 per kilogram (kg) more than double that of beef ($0.85/kg) or other meat ($0.72/Kg), and poultry was the least expensive at $0.63/kg in nominal prices. These relative unit values of the four categories stayed unchanged moving in tandem with one another, declining marginally from 1997 to 2001 before turning upward during the international commodity boom of 2007-2008, reaching their peaks in 2010 (Figure 2). In 2009, unit values were slightly off due to the economic recession that resulted in higher unemployment rate, lower household income, and reduced demand of all meats (Louw et al, 2010).

**Figure 2 : Unit Value of imported meats, 1997-2011**




Source: World Trade Atlas, April, 2012.

Total expenditures on all meat imports increased from a total of $155 million in 1997 to $363 million in 2010, and $548 million in 2011, a rise of 51 percent over 2010. Import value of poultry climbed the most, from $62 million to $ 240 million in 2010, and $374 million, which is a rise of 55 percent in one year. Poultry was followed by expenditures on other meat imports (from $41 to $64 million in 2011), and pork from $11.3 to $81 million. Total expenditures on other meat imports rose despite declining in volume from 58,000 tons in 1997 to 41,000 tons in 2011. This was mainly due to rising import unit values of mutton from $0.65/Kg in 1997 to $2.46 in 2011. On the other hand, expenditures on beef imports substantially declined from $40 million in 1997 to only $28 million in 2011.

**Data Sources**

Monthly statistical data were compiled from the World Trade Atlas covering the period January 1997 to October 2010 to model South Africa's meat import demand system. The data included volumes, prices, and unit value of each meat category. Meat trade was divided into four categories: poultry, beef, pork, and all other meats, including sheep, goat, edible animal offal, horses, asses, and mules, salted, dried or cured meat, and animal fat.

Data for each meat category were aggregated and a unit value ($US per kilogram) was calculated as a weighted average for each of the four categories. The poultry category consisted of fresh, chilled, and frozen poultry meat, whole and in parts (HS 0207). The beef category consisted of fresh or chilled (HS 0201) and frozen (HS 0202). The pork category included fresh, chilled, and frozen (HS 0203). The category of "other" meat consisted of sheep or goats (HS 0204), horses, asses, and mules (HS 0205), edible animal offal and other game (HS 0206 and HS 0208), and a variety of small miscellaneous items (HS 0209 and HS 0210).

## The applied model

One of the most well known models in the analysis of the demand system is the Almost Ideal Demand System (AIDS), developed by Angus Deaton and John Muellbauer in the late 1970's. The AIDS model is frequently used with different specifications, including a linear and/or quadratic expenditure system, the working model, the Rotterdam model, and the Translog models. This paper used the Central Bureau of Statistics (CBS) model developed by Keller and Van Driel in 1985, due to several advantages entailed in the CBS model. The basic system is linear in its parameters and restrictions. Because it is a differential system, it can be applied to derived demand as Theil demonstrated. If the $c_{ij}$ are negative semi-definite, then system is globally negative semi-definite, which is an important condition for the estimation of the demand system.

A demand system for the four categories of imported meats was estimated using monthly data from January 1997 to October 2010, comprising a total of 166 observations. The system is estimated under the assumption that import demand for these meats can be separated from the demand for all other products. The demand system is conditioned on expenditures for these four categories of meat imports as indicated above. The demand model used here is based on consumer demand theory; meat imports are treated as inputs into consumer products. As inputs, they should be modeled using derived demand. Theil (1977) demonstrated that differential consumer demand systems could be used to model cost-minimizing input demands. One merely needs to re-interpret some of the terms. All differential demand systems use the total differential of the budget constraint:

(1) $$\partial\left(\sum_i q_i p_i = x\right) \rightarrow \sum_i w_i \partial \ln p_i + \sum_i w_i \partial \ln q_i = \partial \ln x$$

where $q_i$ and $p_i$ are the quantity and price of good i, x the total expenditure, or in the case of derived demand, the total cost of inputs, and $\partial \ln \cdot$ stands for the change in the natural logarithm of the term "·". The term $w_i$ is the budget share for product "i" defined as:

$$(2)\quad w_i = \frac{p_i q_i}{x}$$

The summation terms in equation (1) are often replaced with divisia price and quantity indices, defined as:

$$(3)\qquad \partial P = \sum_i w_i \partial \ln p_i$$

$$(4)\qquad \partial Q = \sum_i w_i \partial \ln q_i$$

Equations (3) and (4) can be inserted in (1) and rearranged to produce:

$$(5)\qquad \partial \ln x - \partial P = \partial Q$$

In their development of the Central Bureau of Statistics (CBS) model, Keller and Van Driel (1985) used equation (6) below, which is a more appealing version from the standpoint of consumer theory. In a derived demand context of the current analysis, equation (6a) is more convenient. Actually the forms in (6) and (6a) are equivalent; one simply uses different sides of equation (5) in the specification.

$$(6)\qquad w_i \cdot \left[\partial \ln q_i - \partial Q\right] = \sum c_{i,j} \partial \ln p_j + b_i \left[\partial \ln x - \partial P\right], \text{ or}$$

$$(6a)\qquad w_i \cdot \left[\partial \ln q_i - \partial Q\right] = \sum c_{i,j} \partial \ln p_j + b_i \partial Q$$

Theil (1977) showed that changes in the divisia quantity index corresponded to changes in total output. The coefficient $b_i$, that multiplies the quantity index in (6a), shows how demand for an input responds to changes in the total output. As is common in applied demand analysis, we will refer to the $b_i$ as "scale" terms. If all the $b_i$'s are 0, the technology has constant returns to scale. Negative $b_i$ imply that the cost share (the w) for input "i" decreases as the total scale of output increases, and *vice versa*. The $c_{ij}$ coefficients show how quantity "i" react to changes in the price of "j." The $c_{ij}$ also include $c_{ii}$. These coefficients can be used with the budget share to derive price and scale elasticities of demand using the following formulas:

(7) $$\varepsilon_{ij} = \frac{c_{ij}}{w_i}$$

(8) $$\eta_i = 1 + \frac{b_i}{w_i}$$

In (7) and (8) $\varepsilon_{ij}$ is the elasticity of demand for input i and price j and $\eta_i$ is input i's scale elasticity of demand.

Keller and Van Driel demonstrated that the CBS model is a locally-flexible functional form. One can take any set of demand elasticities and find a set of CBS coefficients consistent with these elasticities. In order to be consistent with optimization, the coefficients have to be homogenous of degree 0, consistent with the budget or total- cost constraint defined in equation (1) and symmetric. This will be true if the following two equations hold:

(9) $$\sum_i c_{ij} = 0 \forall j$$

(10) $$\sum_i b_i = 0$$

Equations (9) and (10) imply that the $c_{ij}$ and the $b_i$ coefficients sum to 0 when added over all the inputs. Other constraints require demand has to be homogeneous of degree 0 in prices-expenditures and symmetric as shown in equation (11) and (12), respectively:

(11) $$\sum_j c_{ij} = 0 \forall i$$

(12) $$c_{ij} = c_{ji} \forall i, j$$

All constraints in (9-12) are linear equality restrictions. Optimal cost-minimizing demand derivatives also have to be negative semi-definite (NSD) in prices. The CBS system is globally NSD when the matrix of $c_{ij}$, is itself NSD, which could be achieved by imposing economic restrictions of equations (9-12) on all CBS estimations. One implication of demands being NSD is that their own-price elasticities of demand are negative.

**Estimation forms for the CBS Model**

The CBS and other differential models of demand start with demand derivatives. Demand derivatives are not observed; prices and quantities are. The CBS models are estimated under the assumption one can approximate the differential equations with finite differences. A general way to write the difference equation would be:

$$
(13)\quad \begin{aligned} & w_{it}\left[Ln\left[\frac{q_{i,t}}{q_{i,b}}\right]-\sum_j w_j Ln\left[\frac{q_{j,t}}{q_{j,b}}\right]\right]=y_{it}=\sum_k H_{k,t}*d_{i,k} \\ & \sum_j c_{ij} Ln\left[\frac{p_{j,t}}{p_{j,b}}\right]+b_j\left(Ln\left[\frac{X_t}{X_b}\right]-\sum_j w_{jt} Ln\left[\frac{p_{j,t}}{p_{j,b}}\right]\right)+e_{it} \end{aligned}
$$

The terms $q_{i,t}$ $p_{i,t}$ and $X_t$ are actual quantities, prices and expenditures for a specific month. The $q_{i,b}$ $p_{i,b}$ and $X_b$ are the baseline values; the baseline expenditure is consistent with the baseline prices and quantities. The term $e_{i,t}$ is a random error term. By virtue of the model's construction, the error terms in each time period sum to 0. As a result, one must drop an equation to estimate the model. If the model is estimated using maximum-likelihood methods, the estimates are independent of the equation dropped.

The $H_{k,t}$ are a set of other exogenous variables that act as taste-technology shifters; the $d_{i,k}$ are estimated coefficients, which have to sum to 0 over "i" for each "k" if the budget constraint is to hold. The H variables include an intercept, a trend, a squared trend, and 12 monthly dummies. The intercept and monthly dummies are perfectly collinear, so the dummies' coefficients are identified by making each meat's set of monthly dummies sum to 0 when summed over the year.

Unlike the other terms in (13), the $H_{k,t}$ are not explicitly differenced from a baseline. The interpretation of the intercept and error depends on what one uses as a baseline. The most common baseline used in this type of demand analysis is last period's value; for example $q^b_{i,t}$ would be $q_{i,t-1}$. In this type of non-linear first difference approach, the intercept would represent the difference of a trend, and the intercept's coefficient is generally interpreted as a taste-change variable.

This analysis follows Hahn and Mathews (2007) who used a non-lagged baseline, to calculate average prices and quantities to create baseline prices, quantities, shares, and expenditures. This type of formulation is based on the assumption that average quantities are optimal given average prices, which might not be the case. The intercept terms in this case can be interpreted as correcting the baseline quantities or measuring the shift necessary to make them optimal. The monthly dummies allow for some monthly variation in this "correction." The intercept can be interpreted as the average correction for the year; the dummies are the seasonal variance from that average. If the monthly dummy coefficient for a product is 0, that product's demand is at its yearly average level in that month. The trend and trend-squared terms allow shifts in demand[1]. Because these are derived demands the demand shifts can be due to both changes in consumer tastes and meat-processing technology. If the trend and squared trend coefficients are all 0, there are no taste-technology shifts.

Also, like Hahn and Mathews, we specified our error term as a vector autoregressive (VAR) process:

(15)

[1] Using both a trend and its square gives us more flexibility in modeling the pattern of shifts.

In (15) the term $v_{i,j,k}$ is the estimated effect of the k-lag of demand “j” on the current error for demand “i”, while $u_{i,t}$ stands for an identically, independently distributed random component[2]. The initial runs used a 3rd-order VAR. Because of the construction of the endogenous variables, the errors, e, and u, also sum to 0 over equations in each time period. The sum of the $v_{i,j,k}$ over “i” is also 0 for each j,k pair. The current and lagged errors are perfectly collinear. To identity the $v_{i,j,k}$ the “j” subscript is defined for only 3 of the 4 quantities.

It has long been known (Barten,1969) that the solution to estimating systems with singular errors is to estimate the model using all but one of the equations, then using the economic restrictions to estimate the parameters associated with the dropped equation. If one uses Full Information Maximum Likelihood estimation (FIML), the estimates are independent of the excluded equation.

## Empirical Results

The major objective of estimating this model is to determine whether South Africa’s import demands were stable or experienced a shift during 1997-2010. The elasticities implied by the estimates and the model’s ability to explain meat imports are also of interest.

The model’s estimation took two phases. The first phase tested seasonality and stochastic structure, two issues of minor interest. There are 33 independent monthly dummy effects, and 27 independent terms in the VAR. Restricting these terms could save considerable degrees of freedom and might possibly improve the estimates of the elasticities and shifts. The second phase focused on testing hypotheses about demand shifts and elasticities, using trend and trend-squared coefficients to determine any demand shifts.

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[2] The “$u_{i,,t}$’s” are independently distributed over time; they will have covariance over equations.

*First Phase: VAR-related tests*

When estimating the models, the beef equation was dropped. Also to identify the VAR, one of the lagged errors needs to be dropped, and that was mostly the beef lagged errors. However, in the early parts of testing the VAR other errors were sometimes dropped. The model likelihood should be invariant to the dropped lagged error. By dropping different lagged errors for the VAR, the likelihood stayed invariant that provided strong evidence that the VAR specifications were set up correctly. Dropping pairs of errors from one or all of the lags of the VAR will be restrictive. Results from testing the exclusion of meat pairs as well as all four meats from each of the three lags of the VAR are shown in Table 2.

VAR results indicate that all first-order pairs are significant, but none of the second and third-order pairs are. Also, dropping all second and third-order error terms is an insignificant restriction (see the bottom of Table 2. Given that the last two of the three lags are insignificant, a switch was made to a first-order VAR for the testing subsequent models. This way, another 2, usable observations were gained.

As noted above, the use of a VAR in demand systems is not unprecedented; however, the most commonly used autoregressive structure for demand systems was developed in 1975 by Berndt and Savin, who used a "scalar" rather than vector autoregression:

(16)

where, $\rho$ is the first-order autoregressive parameter. Berndt and Savin demonstrated that if the

Table 2: Exclusion of meat pairs and all four meats from VAR lags

| | | Test against free model | | |
|---|---|---|---|---|
| Excluded lag | Excluded meat | Test | Degrees of freedom | Chi-square alpha |
| First lag | beef, pork | 67.24 | 6 | 0.00% |
| | beef, chicken | 62.97 | 6 | 0.00% |
| | beef, other | 72.43 | 6 | 0.00% |
| | pork, chicken | 41.77 | 6 | 0.00% |
| | pork, other | 32.99 | 6 | 0.00% |
| | chicken, other | 59.53 | 6 | 0.00% |
| | all 4 | 158.36 | 9 | 0.00% |
| Second lag | beef, pork | 0.64 | 6 | 99.57% |
| | beef, chicken | 4.07 | 6 | 66.69% |
| | beef, other | 0.58 | 6 | 99.67% |
| | pork, chicken | 1.37 | 6 | 96.75% |
| | pork, other | 1.30 | 6 | 97.17% |
| | chicken, other | 4.06 | 6 | 66.88% |
| | all 4 | 8.35 | 9 | 49.96% |
| Third lag | beef, pork | 0.56 | 6 | 99.71% |
| | beef, chicken | 2.27 | 6 | 89.29% |
| | beef, other | 3.26 | 6 | 77.52% |
| | pork, chicken | 1.89 | 6 | 92.99% |
| | pork, other | 4.15 | 6 | 65.63% |
| | chicken, other | 3.10 | 6 | 79.59% |
| | all 4 | 7.78 | 9 | 55.61% |
| Lags 2 & 3 | all 4 | 20.63 | 18 | 29.83% |

error terms were set to depend only on its own lags, then the autoregressive coefficients had to be the same across equations. The VAR approach used here was able to nest this typical scalar approach and simultaneously provide valuable estimation advantage, because going “scalar” replaces a 9-degree-of-freedom VAR with a single coefficient. That being the case, obtained result of the test showed that the 8-degree-of-freedom test of this restriction is 18.62, which has a chi-square alpha level of 1.71 percent and is rejected at the 5 percent level.

The next individual elements of the first-order VAR were tested, using a double-looping procedure. Whereby a procedure was set up, where the computer tested each of the individual elements of the VAR, selected the one with the least-significant estimate, imposed it on the following loops and retested the remaining terms until all the terms were excluded. Each of these tests uses 1 degree of freedom and results are shown in Table 3.

Table 3: More tests on VAR error terms

| Excluded term | | | Step tests, take away a lag | | | Cumulative tests | | |
|---|---|---|---|---|---|---|---|---|
| Equation | Lagged error | Step | Test | Chi-square alpha | HB[1] criteria | Test | Chi-square alpha | Result |
| Other | poultry | 1 | 0.01 | 93.13% | 5.00% | | | |
| poultry | Pork | 2 | 0.50 | 48.14% | 2.50% | 0.50 | 77.76% | Insignificant at 5% level for both (adjusted) step and cumulative |
| poultry | Other | 3 | 0.19 | 66.06% | 1.67% | 0.70 | 87.41% | |
| Pork | Other | 4 | 0.62 | 42.95% | 1.25% | 1.32 | 85.79% | |
| Other | Pork | 5 | 2.79 | 9.50% | 1.00% | 4.11 | 53.41% | |
| Pork | poultry | 6 | 5.01 | 2.52% | 0.83% | 9.12 | 16.72% | |
| Beef | Pork | 7 | 107.54 | 0.00% | 0.71% | 116.65 | 0.00% | Significant at 5% level both criteria These last three tests result in the exclusion of the lagged error from all equations. |
| Pork | | | | | | | | |
| Beef | poultry | 8 | 60.53 | 0.00% | 0.63% | 60.53 | 0.00% | |
| poultry | | | | | | | | |
| Beef | Other | 9 | 85.78 | 0.00% | 0.56% | 85.78 | 0.00% | |
| Other | | | | | | | | |

[1] Holm–Bonferroni criteria level. Basically 5% divided by step. As one adds tests to a model, one increases the chances of making a type-1 error. The HB correction is designed to correct this problem.

There are 3 lagged errors and 4 equations; since each lagged error's coefficients have to sum to 0 across the equations, there are a total of 9 degrees of freedom in these tests. After excluding all the insignificant terms from the model we end up with poultry, pork, and other meat demands affected only by their own lagged errors. Because the VAR coefficients have to cancel across all the equations, beef demand is affected by all three of the other lagged errors.

***Second Phase: Dummy-variable and demand shift tests***

The second phase of the model's testing dealt with the monthly dummies, intercepts, trends, and squared trend terms, examining any possible shifts. To speed up the estimation, two sets of double loops were run, a coarse screening followed by a finer one. In the first set, the intercepts, dummies, trends, and/or squared trends were eliminated from all 4 equations. In the second, only individual coefficients were tested that were significant in the first screening. The trend shift in meat imports was mostly affected by poultry meat. Estimated coefficient of 0.2918 was the largest, followed by pork that was positive. Beef and other meat coefficients were negative, indicating declining trend during 1997-2010 (Tables 5 and 6).

In the coarse screening, 7 insignificant monthly dummies are eliminated: February, March, April, May, June, July, and October. Therefore, we conclude that imports in these months would be at the yearly-average demand. In comparison, demands in the other 5 months differ from the yearly average because they were statistically significant. Results of the intercepts and trends are significant for all 4 meats (Table 4). The rest of the demand shifters are significant in only two equations. Beef and pork as a pair have the significant trend-squared terms and November dummies. The January dummy is significant for pork and other meat. Poultry and other meat have significant August and September dummies, while beef and poultry have demand shifts in December. Table 4 exposed tests of only those statistically significant individual coefficients.

Table 4: Statistically significant results of tested demand shifters

| | | Tests 1 degree of freedom | | | Cumulative tests, from previous groups | | | |
|---|---|---|---|---|---|---|---|---|
| Equation | variable | Test | Chi-square alpha | HB[1] criteria | Test | Degree of freedom | Chi-square alpha | Result |
| Other | intercept | 14.12 | 0.02% | 0.36% | 52.46 | 35 | 2.92% | Rejected by both HB and cumulative tests |
| Other | trend | 0.59 | 44.15% | 0.33% | 53.05 | 36 | 3.33% | |
| poultry | intercept | 9.01 | 0.27% | 0.31% | 62.06 | 37 | 0.61% | |
| poultry | trend | 1.74 | 18.71% | 0.29% | 63.80 | 38 | 0.55% | |
| W/O trend-sq. in beef & pork | | 11.55 | 0.07% | 0.28% | 75.35 | 39 | 0.04% | |
| W/O intercept in beef & pork | | 6.96 | 0.83% | 0.26% | 82.31 | 40 | 0.01% | |
| W/O trend in beef & pork | | 2.47 | 11.58% | 0.25% | 84.78 | 41 | 0.01% | |
| W/O the rest of the dummy coefficients | | 36.99 | 0.00% | 0.24% | 121.77 | 42 | 0.00% | |

[1] Holm–Bonferroni criteria level as in previous tables.

[2] The dummies' coefficients are required to sum to 0 for each type of meat. Once one is down to the final 2, eliminating 1 eliminates the other.

[3] HB stands for Holm–Bonferroni, a correction procedure for multiple hypothesis tests. In this case the HB target is 5% divided by the step.

**Final model estimates**

In order to evaluate the statistical properties of the model's estimates, we ran 5,000 Monte-Carlo iterations of the model using the final, estimated coefficients and normally-distributed errors. The results for the VAR, the dummies and shifters, and the CBS price and scale coefficients are in Tables 5 and 6. Table 5 shows that all of the autoregression coefficients are positive and highly significant;

all the Z statistics are larger than 11. There is significant positive autocorrelation in the pork, poultry, and other meat equations. Beef demand shifts in the opposite direction to offset the auto regression in the other three products.

Table 5 : Intercepts, demand shifters and monthly dummies

| | | intercept | trend | trend squared | Jan | Aug | Sep | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|
| Beef | Estimate | 0.1622 | -0.5470 | 0.3340 | | | | -0.0212 | 0.0212 |
| | std. error | 0.0226 | 0.0772 | 0.0681 | | | | 0.0034 | 0.0034 |
| | *Z-stat* | *7.19* | *-7.09* | *4.90* | | | | *-6.31* | *6.31* |
| Pork | Estimate | -0.1164 | 0.4443 | -0.3340 | -0.0212 | | | 0.0212 | |
| | std. error | 0.0205 | 0.0743 | 0.0681 | 0.0034 | | | 0.0034 | |
| | *Z-stat* | *-5.68* | *5.98* | *-4.90* | *-6.31* | | | *6.31* | |
| Poultry | Estimate | -0.1601 | 0.2918 | | | 0.0145 | 0.0067 | | -0.0212 |
| | std. error | 0.0275 | 0.0470 | | | 0.0046 | 0.0046 | | 0.0034 |
| | *Z-stat* | *-5.82* | *6.20* | | | *3.17* | *1.46* | | *-6.31* |
| Other | Estimate | 0.1143 | -0.1892 | | 0.0212 | -0.0145 | -0.0067 | | |
| | std. error | 0.0246 | 0.0417 | | 0.0034 | 0.0046 | 0.0046 | | |
| | *Z-stat* | *4.65* | *-4.54* | | *6.31* | *-3.17* | *-1.46* | | |

Table 6: Own, cross-price, and scale b coefficients.

| | | Beef | Pork | Poultry | Other | Scale or $b_i$ |
|---|---|---|---|---|---|---|
| Beef | estimate | -0.0032 | -0.0107 | 0.0022 | 0.0116 | 0.0449 |
| | std. error | 0.0069 | 0.0088 | 0.0120 | 0.0094 | 0.0134 |
| | *Z-stat* | *-0.45* | *-1.21* | *0.18* | *1.24* | *3.34* |
| Pork | estimate | | -0.0818 | 0.0805 | 0.0120 | -0.0194 |
| | std. error | | 0.0172 | 0.0187 | 0.0139 | 0.0146 |
| | *Z-stat* | | *-4.77* | *4.31* | *0.86* | *-1.33* |
| Poultry | estimate | | | -0.1182 | 0.0355 | 0.0031 |
| | std. error | | | 0.0314 | 0.0206 | 0.0214 |
| | *Z-stat* | | | *-3.77* | *1.72* | *0.14* |
| Other | estimate | | | | -0.0591 | -0.0285 |
| | std. error | | | | 0.0240 | 0.0140 |
| | *Z-stat* | | | | *-2.46* | *-2.03* |

Seasonality, intercept, trend, and trend-square effects are presented in table 5. Rising imports are statistically significant around the Christmas/New year celebrations: poultry and beef in December, pork in November, and other meat in January. Poultry imports are highest in August and the lowest in December. Statistically significant and negative imports for beef were in November, pork in January, and poultry in December.

Trend coefficients are negative for beef and other meat imports, positive for poultry and pork, all of which are highly significant. However, trend-squared coefficients for beef and pork have the opposite signs of the trend estimated, and are also highly significant.

**Table 7: Cost-minimizing price elasticities**

| | Beef | Pork | poultry | other | Scale |
|---|---|---|---|---|---|
| Beef | -0.033 | -0.112 | 0.023 | 0.122 | 1.470 |
| Pork | -0.070 | -0.540 | 0.531 | 0.079 | 0.872 |
| poultry | 0.004 | 0.147 | -0.216 | 0.065 | 1.006 |
| Other | 0.056 | 0.058 | 0.172 | -0.287 | 0.862 |

Note: Table 7 is calculated from table 6, by multiplying the estimated coefficients by the share of each meat kind.

Testing the demand elasticities (own-, cross-price, and scale (bi) coefficients) indicated a statistically significant changes (Table 7). All own-price coefficients are inelastic, negative as expected, and statistically significant, except for beef. The reason might be due to declining beef imports to only 1.7 percent of all meat imports and rising domestic production over the 1997-2010. The most elastic own-price elasticities was for pork (-0.540), followed by other meat (-0.287), poultry (-0.216), and beef was the least elastic (-0.033). All own-price elasticities were highly significant at the 1 percent level, except for beef. Previous study on South Africa's total meat demand system during 1970-2000, found all compensated own-price elasticity were inelastic (Taljaard et al., 2003). Pork was the most elastic (-0.31) followed by chicken (-0.19) and beef (-0.16). Differences in the magnitude of own -price elasticities could be attributed to different methodology and time periods. Moreover, Taljaard et al.'s model estimated total meat demand system, while this study estimated meat import demand system.

The Model's estimated cross-prices elasticity (cij) indicates that poultry is a substitute for pork and other meats, and a reasonable substitute for beef that was not statistically significant. Similarly, pork appears to be complementary to beef, but was statistically insignificant. As mentioned above, the insignificant relationship of beef with poultry and/or pork may be due to its small imported amounts.

Beef's scale coefficient is significant and positive, implying that a 1% increase in total meat imports increases beef demand by more than 1%, as seen in table 7. The scale coefficient in the other meats was significant, but negative, indicating that a 1 % decrease in total meat imports decrease other meats demand by more than 1 %. Scale coefficients of poultry and pork are positive and negative signs, respectively, both of which were not significant.

**Simulation of empirical meat imports**

One of the problems with the CBS model is that its endogenous variable is a non-linear function of the quantities imported. Analysts are generally more interested in measuring and forecasting actual imports rather than CBS endogenous variables. A simulation model was developed that converted an expected CBS endogenous into "predicted" quantities. These two versions of r-squares for the model are shown in table 8. In most cases, the CBS endogenous variable prediction is more accurate than the quantity prediction. Poultry is the one exception.

Table 8: R-squares in percent relative to the Naïve Model

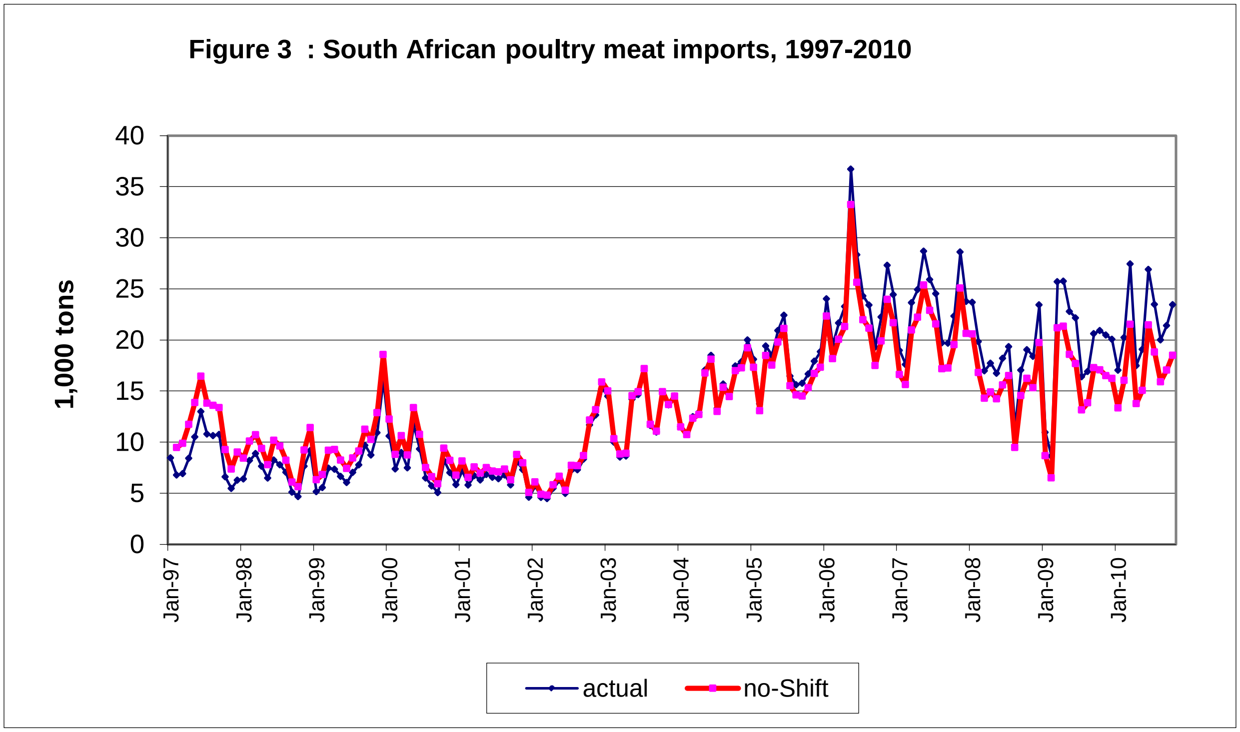
| | CBS endogenous variable | Quantity via simulation |
|---|---|---|
| Beef | 83.14 | 42.83 |
| Pork | 60.40 | 57.64 |
| Poultry | 78.87 | 86.97 |
| Other | 86.52 | 57.20 |

It is not uncommon for these types of non-linear models to produce negative r-squares when solved for the "true" endogenous variable. The CBS quantity predictions are remarkably accurate. Note also that the sum of squares total is based on the naïve model, and much lower than the sum of squares from the mean imports. The CBS model performs remarkably well in forecasting SA meat imports given prices and scale.

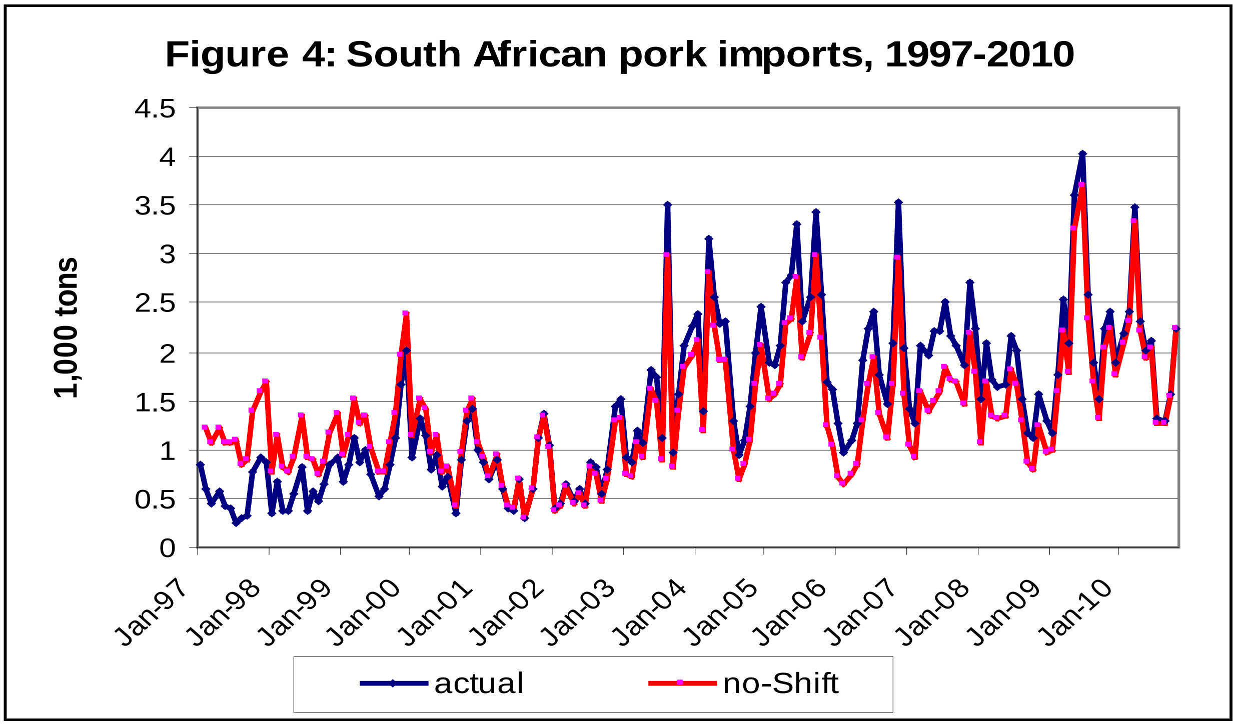
The statistically significant trend and squared trend coefficients show that there have been some taste-and/or technology changes to demand. To explore the implications of these shifts on meat imports, the simulation model was used to translate these shifts in the CBS variables to changes in imported quantities.

The demand shifts implied by the trend and trend squared were taken and "centered" on their mean values. This centering means the average demand for the entire sample will work as the baseline demand. The centering also means that middle parts of the sample period will tend to show the smallest (or no) shift effects. We then simulated how the demand shifts; initiated by the trend and squared trend terms that would change actual import- demand (figures 3-6). Since poultry and pork have positive trend coefficients, this implies that demands would tend to increase over time. Beef and other meats show the opposite pattern.

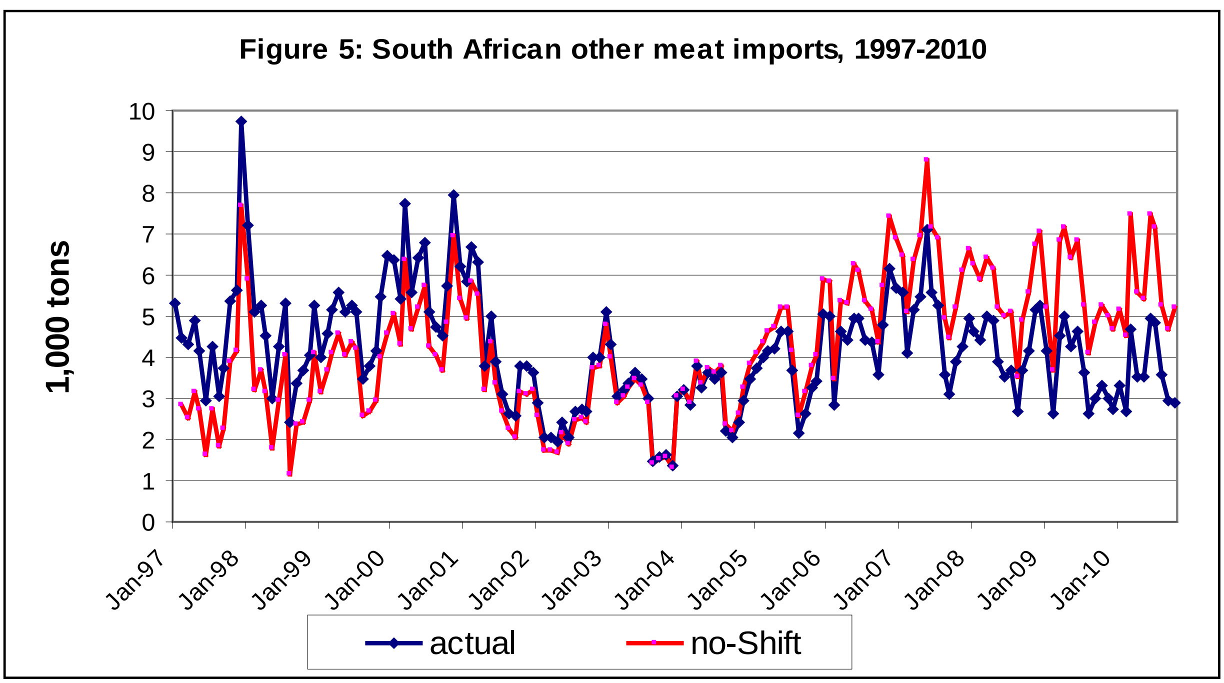
**Poultry** chart shows that the actual demand is lower than the no-shift demand in the early part of the sample and higher at the end. The interpretation implies that the demand shift caused rising poultry imports at the end, and would have decreased demand in the early part of the sample (Figure 3).



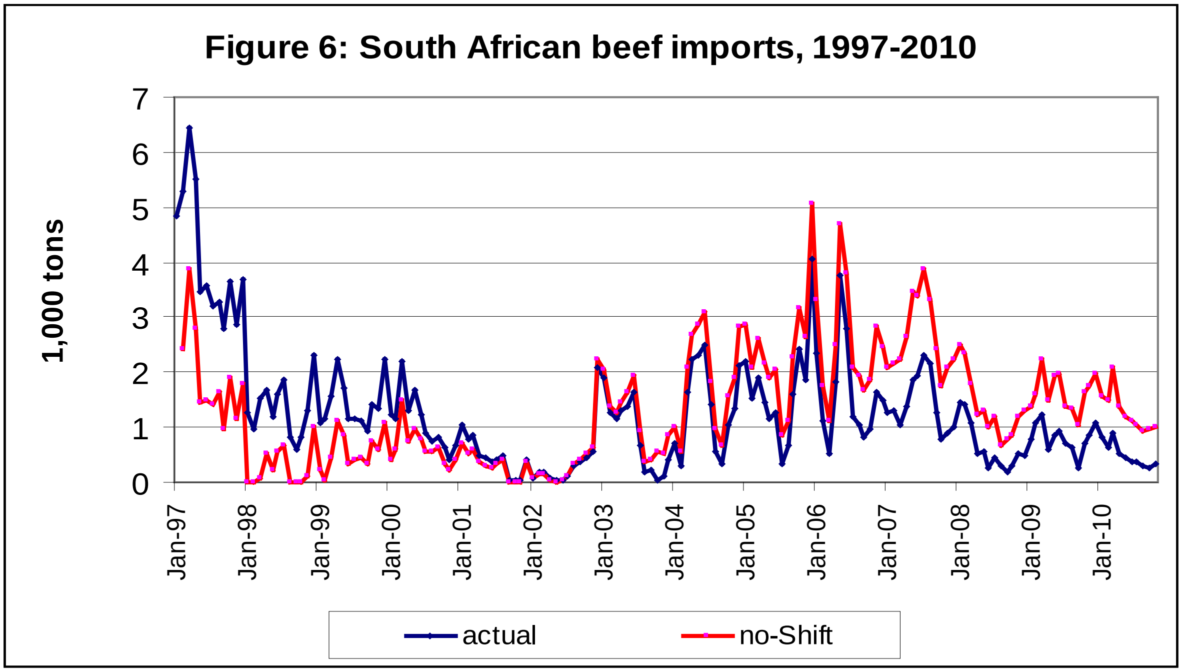

Pork has statistically significant positive trend coefficient and statistically significant negative trend-squared coefficient (Table 5). The squared trend (smaller in obsolete value) offsets the final trend term to some extent, turning actual pork demand lower than no-shift demand in the early part of the sample and there is little difference between the two at the end (Figure 4).




**Other meats** show that the actual demand is higher than the no-shift demand in the early years of the sample and lower at the end. The model's results showed a statistically significant negative trend-coefficient, indicating lower actual import demand at the end (figure 5).



**Beef** has negative trend and positive trend-squared coefficients. Because the first coefficient is larger than the second, in obsolete value, the demand shifts decreased beef in the early part of the sample and increased it at the end (Figure 6).




## Conclusion

Results of the CBS model provide the first estimate of South Africa's meat import demand system. This is a derived demand system conditional on total "scale" of the market; in theory "scale" measures the total outputs produced from the imported meat inputs. In addition to price and scale the demand system also included a trend and trend-squared term to measure changes in technology and/or consumer demands for meat outputs.

Poultry was found to be a statistically significant substitute for pork, sheep/goat, and offal meats, but not significant with respect to beef. Also, pork tends to be complementary to beef, but was statistically insignificant. Most likely, the insignificant relationships are due to beef small imports, averaging less than 3 percent of all meat imports over the last 5-years.

The trend and squared trend terms were also highly significant. These terms imply changes in demand not driven by price or scale changes. During 1997-2010 periods, changes in import demand caused poultry and pork to rise and import demand for beef, sheep/goat, and offal meats to decline. A simulation model was developed that converted an expected CBS endogenous into "predicted" quantities. The in-sample quantity predictions are remarkably accurate, indicating that the model performs very well in forecasting South Africa's meat imports given prices and scale. The simulation model was also used to translate the trend and trend-squared effects into changes in the tonnage of meat imported.

One problem with the analysis is that while the trend and trend squared terms show that there have been shifts in import demand, they do not allow us to identify the source of these shifts. Because these are derived demand changes in consumer tastes, or meat processing technology, or both , it is not possible to identify which of the two factors are most important. The exploration of these factors is beyond the scope of the present research.

As noted in the literature review, there is some support for the hypothesis that consumer demand has shifted in South Africa. It is common to find consumer demand shifts in other countries, and other research has identified factors that have shifted demands outside South Africa. Future research may expand the model to address South Africa's total demand for meat, including production and imports. Future research can also attempt to identify the sources of meat-demand shifts in South Africa. Factors that appear important elsewhere may also matter in South Africa. For example: do consumers shift from fatty red-meat cuts to lean cuts or poultry meats? Is the shift toward chicken due to health concerns or to convenience and time saving as women participation in the workforce rise? Do animal welfare and the environment factors play significant role among consumers?

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