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A MULTI-STAGE ALMOST IDEAL DEMAND SYSTEM: THE CASE OF BEEF DEMAND IN COLOMBIA.

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Abstract

The main objective in this paper is to obtain reliable long-term and short-term elasticities estimates of the beef demand in Colombia using quarterly data since 1998 until 2007. However, complexity on the decision process of consumption should be taken into account, since expenditure on a particular good is sequential. In the case of beef demand in Colombia, a Multi-Stage process is proposed based on an Almost Ideal Demand System (AIDS). The econometric novelty in this paper is to estimate simultaneously all the stages by the Generalized Method of Moments to obtain a joint covariance matrix of parameters estimates in order to use the Delta Method for calculating the standard deviation of the long-term elasticities estimates. Additionally, this approach allows us to get elasticities estimates in each stage, but also, total elasticities which incorporates interaction between stages. On the other hand, the short-term dynamic is handled by a simultaneous estimation of the Error Correction version of the model; therefore, Monte Carlo simulation exercises are performed to analyse the impact on beef demand because of shocks at different levels of the decision making process of consumers. The results indicate that, although the total expenditure elasticity estimate of demand for beef is 1.78 in the long-term and the expenditure elasticity estimate within the meat group is 1.07, the total short-term expenditure elasticity is merely 0.03. The smaller short-term reaction of consumers is also evidenced on price shocks; while the total own price elasticity of beef is -0.24 in the short-term, the total and within meat group long-term elasticities are -1.95 and -1.17, respectively.

Keywords:Multi-Stage Almost Ideal Demand System, Beef Demand, Elasticities, Monte Carlo Simulation, Generalized Method of Moments, Delta Method.

1 Introduction

Colombian beef demand is important for a number of reasons. Historically consumers have generally preferred beef to other types of meat. Approximately beef accounted for 60% of the total meat budget, as compared to only 30% for poultry and 10% for pork. In addition, the beef sector is an important component of the Colombian economy, accounting for 3.4% of GDP in 2007 and providing 1.4 million jobs [DANE, 2007]. Moreover, the beef sector is a significant component of the Colombian exports to Venezuela, one of Colombia's most important trade partners. Approximately, 15% of Colombian beef production is exported to Venezuela. Recently, the Venezuelan government decided to stop imports from Colombia, a policy generating preoccupation among specialist due to its consequences for the beef sector. On the other hand, Colombia is currently negotiating international trade agreements with the United States and the European Union. The implication is that the Colombian beef sector would have international competition from countries with high subsidies, as a consequence, the internal beef price would decrease. These changes would, in turn, affect internal beef demand. So on the whole, understanding beef demand is necessary for the Colombian agricultural policy.

Although the beef sector is important for the Colombian economy, little effort has been made to estimate demand elasticities and simulate different scenarios that impact on the sector. Therefore from an economic point of view, the objective of this study is to obtain reliable estimates of Colombian meat demand, and make some simulation exercises in order to evaluate the impact of different shocks on beef demand. Given that policy evaluations and simulations require reliable estimates of demand responsiveness to price and expenditure [Wahl et al., 1991], the methodology used to estimate elasticities is the Almost Ideal Demand System (AIDS), because

> "...gives an arbitrary first-order approximation to any demand system; it satisfies the axioms of choice exactly; it aggregates perfectly over consumers without invoking parallel linear Engel curves; it has a functional form which is consistent with known household-budget data; it is simple to estimate, largely avoiding the need for non-linear estimation; and it can be used to test the restriction of homogeneity and symmetry through linear restrictions on fixed parameters."
>
> *[Deaton and Muellbauer, 1980, pp 312]*

Specifically, we use a Multi-Stage AIDS model due to consumers follow multiple steps when acquiring goods in the market. This approach allows us to estimate long-term elasticities in each stage, and also, total elasticities which incorporate interaction between levels. Additionally from an econometric perspective, it is well known that the level of uncertainty associated with elasticities estimates is very important; therefore, a simultaneous estimation procedure permits to estimate a joint covariance matrix which can be used to calculate standard deviation of the elasticities through the Delta Method. This is the methodological novelty of our paper. In particular, we use the Generalized Method of Moments to estimate the complete system.

Referring to short-term dynamics, we estimate an Error Correction version of the Multi-Stage Almost Ideal Demand System, and then, we simulate shocks at different levels of the decision making process of the consumers and measure their impacts. This strategy allows us calculating, the short-term impact on beef demand associated with changes in the consumer's total expenditure and prices of beef, poultry and pork.

There is extensive empirical literature on the demand for meat. In most of this literature the demand is estimated using the AIDS methodology [Galvis, 2000, Clark, 2006, Asatryan, 2003, Holt and Goodwin, 2009, Sulgham and Zapata, 2006, Fuller, 1997]. Even though there have been efforts in Colombia to determine beef demand elasticities [Caraballo, 2003, Galvis, 2000] most of the literature is focused on North America and Asia. Due undoubtedly to widely varying economic conditions across countries, the estimates of the elasticities of demand vary greatly. For example, the expenditure elasticity of beef consumption varies between 0.23 and 1.68. In the wealthier countries in the West, it is often below 1.0 [Clark, 2006, Sulgham and Zapata, 2006, MAFF, 2000, Barreira and Duarte, 1997], while in the poorer countries in the East it is generally above 1.0 [Liu et al., 2008, Ma et al., 2003, Chern et al., 2003, Rastegari and Hwang, 2007]. The own-Marshallian price demand elasticity is between -1.19 and -0.10, usually less than -1 [Galvis, 2000, Golan et al., 2000, Fousekis and Revell, 2000]. The compensated price elasticities show that changes in price does not affect the demand for beef as much.

In the specific case of Colombia, [Galvis, 2000] estimated the elasticities of demand for beef, poultry, and pork using the Seemingly Unrelated Regression (SUR) technique. He estimated an expenditure elasticity of demand for beef between 0.67 and 0.79, while the Marshallian (own price) elasticity is between -1.19 and -1.41. The cross-price elasticity of poultry prices on beef demand is between 0.27 and 0.96, and the cross-price elasticity of pork on beef demand is between 1.08 and 1.37. However, [Galvis, 2000] did not perform unit root tests, so the regressions might be spurious in the event that the variables are not cointegrated.

The empirical results in this article indicate that the long-term total and within meat group uncompensated price elasticities are -1.95 and -1.17, respectively. The total and within group compensated price elasticities are -1.78 and -0.51, and the total consumer expenditure elasticity of demand is 1.78. The results also indicate that consumers substitute beef for poultry, but not beef for pork. The short-term elasticities, calculated through Monte Carlo simulations, are smaller. They indicate that an increase of 1% in the price of beef decreases its demand by 0.24%, while increasing total expenditure by 1% has no significant impact on the demand for beef in Colombia.

The paper is organized as follows. Section II provides the methodology, section III presents the long-term results, section IV presents some Monte Carlo simulation exercises, and section V concludes.

2 Methodology

The methodology used in this paper is based on a Multi-Stage model which replicates the decision making process of the consumers when they buy beef [Michalek and Keyzer, 1992, Gao et al., 1996, Shenggen et al., 1995]. Necessary and sufficient conditions for estimating a Multi-Stage budgeting process are that the direct utility function must be additively separable and the specific satisfaction functions in each stage should be homogeneous. [Gorman, 1957] provided conditions for this procedure to be optimal subject to the condition that must have more than two groups in each stage. [Blackorby and Russell, 1997] extends Gorman's classic result to encompass the two-group cases that he did not take into account. These conditions are very restrictive, and must be in general considered implausible. However, [Edgerton, 1997] showed that a Multi-Stage budgeting process will lead to an approximately correct allocation if preferences are weakly separable and the group price indices being used do not vary too greatly with utility level. This means that a change in price of a commodity in one group affects the demand for all commodities in another group in the same manner and that the group price indices do not vary too greatly with expenditure level.

In particular, we estimate a Multi-stage Ideal Demand System of three levels to obtaining the long-term elasticities in each level, and also, the total elasticities. The complete system is estimated using the Generalized Method of Moments. Following this strategy, the resulting three problems will be smaller and more tractable from an empirical point of view than the original problem, because including all goods prices in each of the equations is often faced with the problem of having too many variables [Segerson and Mount, 1985]. The long-term estimation is based on equation (1).

In order to simulate shocks in the short-term at different levels of the decision making process of consumers, we estimate the Error Correction version of the Multi-Stage AIDS model. This strategy allows calculating by Monte Carlo simulations, the short-term impact on beef demand associated with changes in the consumer's total expenditure and the prices of beef, poultry and pork. This estimation is based on equation (11).

This strategy considers the complex decision process through which an individual makes consumption decisions. Specifically, there are three levels: the upper one determines the aggregate level of food consumption; the middle one, conditioned by the upper one, determines the consumption of meat, and the lower level, conditioned by the other two, determines the beef, poultry, and pork demand.

In order to handle each stage budgeting process, an Almost Ideal Demand System is introduced [Deaton and Muellbauer, 1980]. The mathematical specification of the AIDS model is the following,

$$w_{it} = \alpha_i + \sum_{j=1}^{N} \gamma_{ij} ln(p_{jt}) + \beta_i ln(X_t/P_t) + e_{it}, \tag{1}$$

for $i = 1, 2, ..., N$, $j = 1, 2, ..., N$ y $t = 1, 2, ..., T$, where the share in the total expenditure of the good i (w_{it}) is a function of the prices (p_{jt}), real expenditure(X_t/P_t) and an error (e_{it}). The general price index is usually represented by a nonlinear equation which is, in most cases, replaced by the Stone price index

$$ln(P_t^S) = \sum_{i=1}^{N} w_{it} ln(p_{it}) \tag{2}$$

However, the Stone index typically used in estimating Linear AIDS is not invariant to changes in units of measurement, which may seriously affect the approximation properties of the model and can result in biased parameter estimates [Pashardes, 1993, Moschini, 1995]. To overcome this problem other specifications for the price index can be used, such as the Paasche or Laspeyres index:

$$ln(P_t^P) = \sum_{i=1}^{N} w_{it} ln(p_{it}/p_i^0), \tag{3}$$

$$ln(P_t^L) = \sum_{i=1}^{N} w_i^0 ln(p_{it}), \tag{4}$$

where the superscript represents a base period.

It is worth noting the constraints (additivity, homogeneity and symmetry) that are imposed by the microeconomic theory.

$$\sum_{i=1}^{N} \alpha_i = 0, \sum_{i=1}^{N} \gamma_{ij} = 0, \sum_{i=1}^{N} \beta_i = 0 \tag{5}$$

$$\sum_{j=1}^{N} \gamma_{ij} = 0 \tag{6}$$

$$\gamma_{ij} = \gamma_{ji} \tag{7}$$

From the above specification the following long-term elasticities in each level can be calculated:

$$\eta_{it} = 1 + \beta_i / w_{it} \tag{8}$$

$$\epsilon_{ijt}^M = -I_A + \gamma_{ij}/w_{it} - \beta_i (w_{jt}/w_{it}) \tag{9}$$

$$\epsilon_{ijt}^H = -I_A + \gamma_{ij}/w_{it} + w_{jt} \tag{10}$$

where $I_A = 1$ if $i = j$.

Where $\eta_{it}, \epsilon_{ijt}^M$ and ϵ_{ijt}^H are expenditure elasticity, marshallian (uncompensated) elasticities and hicksian (compensated) elasticities.

It is required to investigate the time series properties of the data used in order to specify the most appropriate dynamic form of the model and to find out if the long-term demand relationships provided by equation (1) are economically meaningful or they are merely spurious. If all variables in equation (1) are cointegrated, the Error Correction Linear AIDS is given by the following form:

$$\Delta w_{it} = \sum_{j=1}^{N} \delta_{ij} \Delta w_{jt-1} + \sum_{j=1}^{N} \gamma_{ij} \Delta ln(p_{jt}) + \beta_i \Delta ln(X_t/P_t) + \lambda \hat{e}_{i,t-1} + \mu_{it}, \quad (11)$$

for $i = 1, 2, ..., N$, $j = 1, 2, ..., N$ y $t = 1, 2, ..., T$,

where Δ refers to the difference operator, $\hat{e}_{i,t-1}$ represents the estimated residuals from the cointegrated equation (1), $-1 < \lambda < 0$ is the velocity of convergence, and μ_{it} is the error term. Intertemporal consistency requires that $\sum_{i=1}^{N} \delta_{ij} = 0$ [Anderson and Blundell, 1983] and identification of the lagged budget shares requires $\sum_{j=1}^{N} \delta_{ij} = 0$ [Edgerton, 1997].

Once the cointegrated equations are estimated, we can calculate the long-term total demand elasticities. [Edgerton, 1997] provided expressions to get elasticities associated with the lower level and we adapt these equations as follows:

$$\eta_{it}^{(T)} = \eta_{it} \times \eta_{Meat,t} \times \eta_{Food,t} \quad (12)$$

$$\epsilon_{ijt}^{M(T)} = \epsilon_{ijt}^{H} + w_{jt} \times \eta_{it} \times \epsilon_{Meat,t}^{H} + w_{jt} \times w_{Meat,t} \times \eta_{it} \times \eta_{Meat,t} \times \epsilon_{Food,t}^{M} \quad (13)$$

$$\epsilon_{ijt}^{H(T)} = \epsilon_{ijt}^{H} + w_{jt} \times \eta_{it} \times \epsilon_{Meat,t}^{H} + w_{jt} \times w_{Meat,t} \times \eta_{it} \times \eta_{Meat,t} \times \epsilon_{Food,t}^{H} \quad (14)$$

where superscript, $i, j = beef, pork, poultry$.

The total expenditure elasticity of beef demand, $\eta_{it}^{(T)}$, is a product of the expenditure elasticity of food, the food expenditure elasticity of meat, and the meat expenditure elasticity of beef. The total price elasticities, $\epsilon_{ijt}^{M(T)}$ and $\epsilon_{ijt}^{H(T)}$, are the result of a direct effect within the meat group, but also of the reallocation effects of meat within food, and food within total consumption. Finally, we obtain standard deviations for the total elasticities with the Delta Method where this method establishes that given $Z = (Z_1, Z_2, \ldots, Z_k)$, a random vector with mean $\theta = (\theta_1, \theta_2, \ldots, \theta_k)$, then if $g(Z)$ is a differentiable function, we can approximate its variance by

$$Var_\theta g(Z) \approx \sum_{i=1}^{k} (g_i'(\theta))^2 Var_\theta(Z_i) + 2 \sum_{i>j} g_i'(\theta) g_j'(\theta) Cov_\theta(Z_i, Z_j)$$

where $g_i'(\theta) = \frac{\partial}{\partial z_i} g(z)|_{z_1=\theta_1, z_2=\theta_2, \ldots, z_k=\theta_k}$.

Let $g(Z) = \eta_i^{(T)} = \eta_i \times \eta_{Meat} \times \eta_{Food}$, the total expenditure elasticity in the lower stage. We approximate its variance by

$$Var_\theta \eta_i^{(T)} \approx \left(\frac{1}{w_i} (\eta_{Meat} \eta_{Food}) \right)^2 Var(\beta_i)$$

$$
\begin{aligned}
&+ \left(\frac{1}{w_{Meat}}(\eta_i \eta_{Food})\right)^2 Var(\beta_{Meat}) \\
&+ \left(\frac{1}{w_{Food}}(\eta_i \eta_{Meat})\right)^2 Var(\beta_{Food}) \\
&+ 2\left(\frac{1}{w_i w_{Meat}}(\eta_i \eta_{Meat})(\eta_{Food})^2\right) Cov(\beta_i, \beta_{Meat}) \\
&+ 2\left(\frac{1}{w_i w_{Food}}(\eta_i \eta_{Food})(\eta_{Meat})^2\right) Cov(\beta_i, \beta_{Food}) \\
&+ 2\left(\frac{1}{w_{Meat} w_{Food}}(\eta_{Meat} \eta_{Food})(\eta_i)^2\right) Cov(\beta_{Meat}, \beta_{Food})
\end{aligned}
$$

where $\theta = (\beta_i, \beta_{Meat}, \beta_{Food})$, and $i, j = beef, pork, poultry$.

Observe that we need the covariance between the expenditure parameters at different stages. Therefore, we have to estimate the three levels simultaneously.

Now let $g(Z) = \epsilon_{ijt}^{M(T)} = \epsilon_{ijt}^{H} + w_{jt} \times \eta_{it} \times \epsilon_{Meat,t}^{H} + w_{jt} \times w_{Meat,t} \times \eta_{it} \times \eta_{Meat,t} \times \epsilon_{Food,t}^{M}$ i.e.,

$$
\begin{aligned}
\epsilon_{ij}^{M(T)} &= (-I_A + \gamma_{ij}/w_i + w_j) \\
&+ w_j(1 + \beta_i/w_i)(-1 + \gamma_{Meat}/w_{Meat} + w_{Meat}) \\
&+ w_j w_{Meat}(1 + \beta_i/w_i)(1 + \beta_{Meat}/w_{Meat})(-1 + \gamma_{Food}/w_{Food} - \beta_{Food})
\end{aligned}
$$

We can approximate the variance of the Marshallian total price demand elasticity by

$$
\begin{aligned}
Var_{\theta}\epsilon_{ij}^{M(T)} &\approx \left(\frac{1}{w_i}\right)^2 Var(\gamma_{ij}) \\
&+ \left(\frac{w_j}{w_i}\epsilon_{Meat}^{H} + \frac{w_j w_{Meat}}{w_i}\eta_{Meat}\epsilon_{Food}^{M}\right)^2 Var(\beta_i) \\
&+ \left(\frac{w_j}{w_{Meat}}\eta_i\right)^2 Var(\gamma_{Meat}) \\
&+ \left(w_j \eta_i \epsilon_{Food}^{M}\right)^2 Var(\beta_{Meat}) \\
&+ \left(\frac{w_j w_{Meat}}{w_{Food}}\eta_i \eta_{Food}\right)^2 Var(\gamma_{Food}) \\
&+ \left(-w_j w_{Meat} \eta_i \eta_{Food}\right)^2 Var(\beta_{Food}) \\
&+ 2\left(\frac{w_j}{(w_i)^2}\epsilon_{Meat}^{H} + \frac{w_j w_{Meat}}{(w_i)^2}\eta_{Meat}\epsilon_{Food}^{M}\right) Cov(\gamma_{ij}, \beta_i) \\
&+ 2\left(\frac{w_j}{w_i w_{Meat}}\eta_i\right) Cov(\gamma_{ij}, \gamma_{Meat})
\end{aligned}
$$

$$
\begin{aligned}
&+ \quad 2\left(\frac{w_j}{w_i}\eta_i\epsilon^M_{Food}\right)Cov(\gamma_{ij},\beta_{Meat})\\
&+ \quad 2\left(\frac{w_j w_{Meat}}{w_i w_{Food}}\eta_i\eta_{Food}\right)Cov(\gamma_{ij},\gamma_{Food})\\
&+ \quad 2\left(\frac{-w_j w_{Meat}}{w_i}\eta_i\eta_{Food}\right)Cov(\gamma_{ij},\beta_{Food})\\
&+ \quad 2\left(\frac{w_j}{w_i}\epsilon^H_{Meat}+\frac{w_j w_{Meat}}{w_i}\eta_{Meat}\epsilon^M_{Food}\right)\left(\frac{w_j}{w_{Meat}}\eta_i\right)Cov(\beta_i,\gamma_{Meat})\\
&+ \quad 2\left(\frac{w_j}{w_i}\epsilon^H_{Meat}+\frac{w_j w_{Meat}}{w_i}\eta_{Meat}\epsilon^M_{Food}\right)\left(w_j\eta_i\epsilon^M_{Food}\right)Cov(\beta_i,\beta_{Meat})\\
&+ \quad 2\left(\frac{w_j}{w_i}\epsilon^H_{Meat}+\frac{w_j w_{Meat}}{w_i}\eta_{Meat}\epsilon^M_{Food}\right)\left(\frac{w_j w_{Meat}}{w_{Food}}\eta_i\eta_{Food}\right)Cov(\beta_i,\gamma_{Food})\\
&+ \quad 2\left(\frac{w_j}{w_i}\epsilon^H_{Meat}+\frac{w_j w_{Meat}}{w_i}\eta_{Meat}\epsilon^M_{Food}\right)\left(-w_j w_{Meat}\eta_i\eta_{Food}\right)Cov(\beta_i,\beta_{Food})\\
&+ \quad 2\left(\frac{w_j}{w_{Meat}}\eta_i\right)\left(w_j\eta_i\epsilon^M_{Food}\right)Cov(\gamma_{Meat},\beta_{Meat})\\
&+ \quad 2\left(\frac{w_j}{w_{Meat}}\eta_i\right)\left(\frac{w_j w_{Meat}}{w_{Food}}\eta_i\eta_{Food}\right)Cov(\gamma_{Meat},\gamma Food)\\
&+ \quad 2\left(\frac{w_j}{w_{Meat}}\eta_i\right)\left(-w_j w_{Meat}\eta_i\eta_{Food}\right)Cov(\gamma_{Meat},\beta Food)\\
&+ \quad 2\left(w_j\eta_i\epsilon^M_{Food}\right)\left(\frac{w_j w_{Meat}}{w_{Food}}\eta_i\eta_{Food}\right)Cov(\beta_{Meat},\gamma_{Food})\\
&+ \quad 2\left(w_j\eta_i\epsilon^M_{Food}\right)\left(-w_j w_{Meat}\eta_i\eta_{Food}\right)Cov(\beta_{Meat},\beta_{Food})\\
&+ \quad 2\left(\frac{w_j w_{Meat}}{w_{Food}}\eta_i\eta_{Food}\right)\left(-w_j w_{Meat}\eta_i\eta_{Food}\right)Cov(\gamma_{Food},\beta_{Food})
\end{aligned}
$$

where $\theta = (\gamma_{ij}, \beta_i, \gamma_{Meat}, \beta_{Meat}, \gamma_{Food}, \beta_{Food})$. Again, we ought to estimate the three levels simultaneously because we need covariances between parameters in different stages.

Finally, let $g(Z) = \epsilon^{H(T)}_{ijt} = \epsilon^H_{ijt} + w_{jt} \times \eta_{it} \times \epsilon^H_{Meat,t} + w_{jt} \times w_{Meat,t} \times \eta_{it} \times \eta_{Meat,t} \times \epsilon^H_{Food,t}$, i.e.,

$$
\begin{aligned}
\epsilon^{H(T)}_{ij} \quad &= \quad (-I_A + \gamma_{ij}/w_i + w_j)\\
&+ \quad w_j(1+\beta_i/w_i)(-1+\gamma_{Meat}/w_{Meati} + w_{Meat})\\
&+ \quad w_j w_{Meat}(1+\beta_i/w_i)(1+\beta_{Meat}/w_{Meat})(-1+\gamma_{Food}/w_{Food} + w_{Food})
\end{aligned}
$$

We can approximate the variance of the Hicksian total price elasticity by

$$
Var_\theta \epsilon^{H(T)}_{ij} \quad \approx \quad \left(\frac{1}{w_i}\right)^2 Var(\gamma_{ij})
$$

$$
\begin{aligned}
&+ \left(\frac{w_j}{w_i}\epsilon^H_{Meat} + \frac{w_j w_{Meat}}{w_i}\eta_{Meat}\epsilon^H_{Food}\right)^2 Var(\beta_i) \\
&+ \left(\frac{w_j}{w_{Meat}}\eta_i\right)^2 Var(\gamma_{Meat}) \\
&+ \left(w_j\eta_i\epsilon^H_{Food}\right)^2 Var(\beta_{Meat}) \\
&+ \left(\frac{w_j w_{Meat}}{w_{Food}}\eta_i\eta_{Food}\right)^2 Var(\gamma_{Food}) \\
&+ 2\left(\frac{w_j}{(w_i)^2}\epsilon^H_{Meat} + \frac{w_j w_{Meat}}{(w_i)^2}\eta_{Meat}\epsilon^H_{Food}\right) Cov(\gamma_{ij}, \beta_i) \\
&+ 2\left(\frac{w_j}{w_i w_{Meat}}\eta_i\right) Cov(\gamma_{ij}, \gamma_{Meat}) \\
&+ 2\left(\frac{w_j}{w_i}\eta_i\epsilon^H_{Food}\right) Cov(\gamma_{ij}, \beta_{Meat}) \\
&+ 2\left(\frac{w_j w_{Meat}}{w_i w_{Food}}\eta_i\eta_{Food}\right) Cov(\gamma_{ij}, \gamma_{Food}) \\
&+ 2\left(\frac{w_j}{w_i}\epsilon^H_{Meat} + \frac{w_j w_{Meat}}{w_i}\eta_{Meat}\epsilon^H_{Food}\right)\left(\frac{w_j}{w_{Meat}}\eta_i\right) Cov(\beta_i, \gamma_{Meat}) \\
&+ 2\left(\frac{w_j}{w_i}\epsilon^H_{Meat} + \frac{w_j w_{Meat}}{w_i}\eta_{Meat}\epsilon^H_{Food}\right)\left(w_j\eta_i\epsilon^H_{Food}\right) Cov(\beta_i, \beta_{Meat}) \\
&+ 2\left(\frac{w_j}{w_i}\epsilon^H_{Meat} + \frac{w_j w_{Meat}}{w_i}\eta_{Meat}\epsilon^H_{Food}\right)\left(\frac{w_j w_{Meat}}{w_{Food}}\eta_i\eta_{Food}\right) Cov(\beta_i, \gamma_{Food}) \\
&+ 2\left(\frac{w_j}{w_{Meat}}\eta_i\right)\left(w_j\eta_i\epsilon^H_{Food}\right) Cov(\gamma_{Meat}, \beta_{Meat})
\end{aligned}
$$

$$
\begin{aligned}
&+ 2\left(\frac{w_j}{w_{Meat}}\eta_i\right)\left(\frac{w_j w_{Meat}}{w_{Food}}\eta_i\eta_{Food}\right) Cov(\gamma_{Meat}, \gamma Food) \\
&+ 2\left(w_j\eta_i\epsilon^H_{Food}\right)\left(\frac{w_j w_{Meat}}{w_{Food}}\eta_i\eta_{Food}\right) Cov(\beta_{Meat}, \gamma_{Food})
\end{aligned}
$$

3 Results

The model is estimated using quarterly data for the period 1998-2007. The time series data for prices and per-capita consumption of beef, poultry and pork are taken from Federacin Colombiana de Ganaderos (Fedegan). Data for per-capita expenditures are obtained from the Colombian National Accounts [DANE, 2007]. Prices are built from the implicit price indices formed as the ratio between nominal and real expenditures, i.e., Paasche indices.

We should use the True Cost of Living index, but [Deaton and Muellbauer, 980a] used Taylor's expansion of the cost function to show that a first order approximation to the TCOL will be the Paasche like index. An empirical evidence that supports this argument is that most price indices are highly correlated [Edgerton, 1997].

Table (1) indicates that food expenditure is 25% of per-capita expenditure, of which expenditure on meat is 30%, and finally beef expenditure is 60% of the latter. Thus, beef consumption accounts for 4.5% of per-capita expenditure.

Historical data indicate that meat budget shares of the various types of meat have not changed. Between 1998 and 2007 average quarterly consumption of beef declined from 5.75 to 4.44 kg/capita, while poultry consumption rose from 2.92 to 5.49 kg/capita and pork consumption increased from 0.63 to 0.92 kg/capita. It seems likely that this shift in consumption has been caused by changes in the relative prices of the different kinds of meat, as the data indicate that over the period, the price index of beef rose by 200%, while the price index of poultry increased by only 47% and the index of pork 110%.

Unit Root tests were carried out [Kwiatkowski et al., 1992], which indicated that all of the data series are I(1) (See Table (2)). In order to account for endogeneity, the [Johansen, 1988] cointegration test was carried out at each budgeting allocation level based on equations (1).[1] As can be seen in Table (3), we can not reject the null hypothesis of one cointegration vector in each equation. On the other hand, we use [Hayes et al., 1990] statistical tests for testing weak separability on the second stage, i.e. meat decision. We use a Wald test under the null hypothesis of weak separability, and we can not reject it, the p-value is 0.17.

We estimate simultaneously long-term system equations (1) for the three stages through Generalized Method of Moments. In all stages, the Laspeyres index is used to build moment conditions, because of endogeneity caused due to the Stone index uses shares in its construction and it is not invariant to changes in units of measurement. We imposed homogeneity and symmetry conditions due to these conditions being important for demand theory, and not always being treated as verifiable conditions [Parikh, 1988].[2]

Long-term elasticities associated with each level are calculated using equations (8), (9) and (10). Equations (12), (13) and (14) are used to calculate total long-term elasticities. As can be seen in Table (4), beef, pork and poultry are luxuries, although this is not the result obtained for poultry if one only looked at within meat group elasticity. On the other hand, meat expenditure elasticity is 2.16, but its total expenditure elasticity is 1.65.[3] Although it is less than one, the food expenditure elasticity is still high at 0.76.

Table (4)

[1]Information criteria was used to select VEC order and deterministic components of the cointegration test. Residuals from estimated models are normal, homoskedasty and not autocorrelated. Outcomes upon author's request.

[2]Residuals are normal and homocedastick, but because of autocorrelation, we estimate the covariance matrix through consistent process [Newey and West, 1987]. Outcomes upon author's request.

[3]This is calculated as 2.16 (within expenditure elasticity) $\times$ 0.76 (food expenditure elasticity).

As can be seen in Table (5), there is substitution of poultry for beef within the meat group, but this effect is not present if one takes into account that a change of poultry price implies reallocation effects of meat within food and food within total consumption. As regards total uncompensated and compensated own-price elasticities, we can see that beef is quite elastic, and the differences between within meat group and total elasticities are large. This fact can be misleading if the within elasticities are used for making policy judgements.

Table (5)

4 Simulations

In order to calculate short-term elasticities, Seemingly Unrelated Regression Equations are used for estimating an Error Correction Linear AIDS with the three stages simultaneously.[4] Monte Carlo simulation exercises are done based on the estimated model in order to analyse the short-term dynamics of beef demand. The algorithm used solves the model for each observation in the solution sample, using a recursive procedure to compute values for the endogenous variables. The model is solved repeatedly for different draws of the stochastic components (coefficients and errors). During each repetition, errors are generated for each observation in accordance with the residual uncertainty in the model. The three stages are linked by prices and expenditures; for example, a shock on consumption expenditure causes a direct effect on food demand, which implies an expenditure effect on meat demand, and as consequence a reallocation within the group. On the other hand, a change of beef price implies a direct effect within the meat group, but also affects meat within food and food within consumption.

The simulation results suggest a good fit for each equation in the model; during the period analysed observed data fell inside the 95% prediction interval (outcomes upon author's request).

We analyse transitory effects associated with a positive shock on total expenditure, and increases in beef, poultry and pork prices. We use our simulated model to measure the impact on beef demand by comparing in-sample forecasted beef demand with and without the shocks for the first quarter of 2007. Given that a comparison is being performed, the same set of random residuals is applied to both scenarios during each repetition. This is done so that the deviation between the scenarios is based only on differences in the exogenous variables, not on differences in random errors.

The first exercise is evaluating the short-term effect on beef demand associated with a positive shock on total expenditure. Specifically, we increase the consumer expenditure by 1%, and compare this scenario with the baseline scenario (without shock). We find that there is an increase in beef demand by only 0.034%. On the other hand, we evaluate the short-term effects in beef demand associated with transitory increases in beef, pork and poultry prices. As can

[4]Residuals are not autocorrelated and homocedastick. Outcomes upon author's request

be seen on Table (6), an increase of 1% in beef price reduces its own demand by 0.24%. Finally, there is a substitution effect of poultry for beef, because an increases of 1% on poultry price causes an increase in beef demand by 0.1%, while an increase in pork price causes very little effect on beef demand.

5 Conclusions

The results in the long-term indicate that the expenditure elasticity of food is less than one, supporting the idea of a normal good. On the other hand, meat is a luxury good because its expenditure elasticity is greater than one. In the lower level, the cross price elasticities indicate that there is a bigger substitution effect of beef for poultry than beef for pork. Although the total expenditure elasticity of demand for beef is 1.78 in the long-term, the short-term expenditure elasticity is merely 0.034. The smaller short-term reaction of the consumers is also evidenced in price shocks; while the own price elasticity of beef is -0.24 in the short-term, the long-term total elasticity is -1.95. These differences between elasticities obey the small velocities of convergence in the three levels of the model. Specifically, the velocities of convergence are 2%, 10% and 17% on the beef, meat and food demand equations.

Colombian real per-capita total expenditure has grown at 2.1% per annum from 2000 to 2007; therefore, given a 1.5% population growth rate per annum, the total expenditure beef elasticity implies beef demand growing at 5.3% a year.[5] However, Colombian beef production has grown at -0.51% per annum in the same period, this difference has caused Colombian beef price to increase by 14.7% per annum. Recently, Colombia has been negotiating international trade agreements with the United States and the European Union. This implies that the Colombian beef sector would have international competition from countries with high subsidies, and as a consequence, the internal beef price would decrease. These facts would have important effects on domestic producers, which ought to improve productivity in order to stay as an important sector in the Colombian economy and make good use of the new market opportunities.

[5]This is calculated as 1.5% (population growth rate per annum) + 2.1% (per-capita total expenditure growth per annum) * 1.78 (total expenditure elasticity).

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Table 1: Descriptive Statistics.

Variable	Mean	Standard Deviation	Jarque-Bera Test*
	Upper level		
$X_{TotalExpenditure}$	880,923	228,820	0.27
w_{Food}	0.25	0.0068	0.09
p_{Food}	114.42	20.78	0.35
p_{NoFood}	112.53	20.10	0.31
	Middle level		
$X_{FoodExpenditure}$	218,812	50,975	0.33
w_{Meat}	0.30	0.02	0.09
p_{Meat}	128.28	29.87	0.36
$p_{OtherFood}$	104.01	16.28	0.33
	Lower level		
w_{Beef}	0.60	0.27	0.67
p_{Beef}	8,598	2,672	0.15
w_{Pork}	0.08	0.01	0.13
p_{Pork}	8,007	1,802	0.29
$w_{Poultry}$	0.32	0.02	0.71
$p_{Poultry}$	5,299	726	0.15

* p-value

Source: Author's Estimations

Table 2: Unit root test: Colombia, 1998:I-2007:IV.

Variable	KPPS Statistic	Critical Value (5%)
	Upper level	
w_{Food}	0.625	0.463
Δw_{Food}	0.306	0.463
$Log(X/P)$	0.168	0.146
$\Delta Log(X/P)$	0.134	0.146
$Log(p_{Food}/P_{NoFood})$	0.192	0.146
$\Delta Log(p_{Food}/P_{NoFood})$	0.144	0.146
	Middle level	
w_{Meat}	0.482	0.463
Δw_{Meat}	0.288	0.463
$Log(X_{Food}/P_{Food})$	0.173	0.146
$\Delta Log(X_{Food}/P_{Food})$	0.100	0.146
$Log(p_{Meat}/p_{NoMeat})$	0.165	0.146
$\Delta Log(p_{Meat}/p_{NoMeat})$	0.075	0.146
	Lower level	
w_{Beef}	0.667	0.463
Δw_{Beef}	0.096	0.463
w_{Pork}	0.652	0.463
Δw_{Pork}	0.114	0.463
$Log(X_{Meat}/P_{Meat})$	0.185	0.146
$\Delta Log(X_{Meat}/P_{Meat})$	0.089	0.146
$Log(p_{Beef}/p_{Poultry})$	0.660	0.463
$\Delta Log(p_{Beef}/p_{Poultry})$	0.186	0.463
$Log(p_{Pork}/p_{Poultry})$	0.830	0.463
$\Delta Log(p_{Pork}/p_{Poultry})$	0.400	0.463

Source: Author's Estimations

Table 3: Cointegration test (Maximum Eigenvalue): Colombia, 1998:I-2007:IV.

Equation	Ho: CE(s)	Max. Eigenvalue Statistic	Critical Value (5%)
		Upper Level	
Food Demand	r=0*	26.31	22.29
	r=1	6.59	15.89
	r=2	1.82	9.16
		Middle Level	
Meat Demand	r=0*	23.92	21.13
	r=1	12.66	14.26
	r=2	0.01	3.84
		Lower Level	
Beef Demand	r=0*	31.87	28.58
	r=1	12.52	22.29
	r=2	8.47	15.89
	r=3	5.61	9.16
Pork Demand	r=0*	48.55	28.58
	r=1	21.52	22.29
	r=2	5.71	15.89
	r=3	4.13	9.16

* No significant at 5%

Source: Author's estimations.

Table 4: Expenditure elasticities for the three levels. Colombia, 1998:I-2007:IV.

Upper level		
Food	Other goods	
0.76*	1.07*	
(0.034)	(0.011)	
Middle level		
Meat	Other food	
2.16*	0.48*	
(0.291)	(0.129)	
Lower level		
Within meat group		
Beef	Pork	Poultry
1.07*	1.78*	0.64*
(0.145)	(0.367)	(0.268)
Total		
Beef	Pork	Poultry
1.78*	2.95*	1.05*
(0.378)	(0.687)	(0.166)

Standard deviation are calculated with Delta method.
* Significant at 5%
Source: Author's estimations

Table 5: Uncompensated and compensated beef price elasticities. Colombia, 1998:I-2007:IV.

	Marshallian			Hicksian		
	Beef	Pork	Poultry	Beef	Pork	Poultry
Within	-1.17*	-0.04	0.14*	-0.52*	0.04*	0.47*
	(0.142)	(0.033)	(0.043)	(0.063)	(0.001)	(0.003)
Total	-1.95*	-0.09	-0.03	-1.78*	-0.08	8E-03
	(0.278)	(0.047)	(0.111)	(0.262)	(0.045)	(0.103)

Standard deviation are calculated with Delta method.
* Significant at 5%
Source: Author's estimations

Table 6: Short-term beef elasticities: Colombia, 2007:I.

Beef demand			
Total expenditure	Beef price	Pork price	Poultry price
0.034	-0.247	-0.025	0.103

Source: Author's estimations