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A Multi-Stage Almost Ideal Demand System: The Case of Beef Demand in Colombia

Sistema casi ideal de demanda multinivel: el caso de la demanda de carne de res en Colombia

Andrés Ramírez[a]

Departamento de Economía, Universidad EAFIT, Medellín, Colombia

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 parameter 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 elasticity estimates in each stage, but also, total elasticities which incorporate 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.

***Key words*:** Cointegration, Delta method, Demand system, Generalized method of moments, Monte Carlo Simulation.

[a]Associate professor. E-mail: aramir21@eafit.edu.co

Resumen

El objetivo más importante de este artículo es obtener estimaciones confiables de las elasticidades de la demanda de carne de res en Colombia para el largo y corto plazo utilizando información trimestral desde 1998 hasta 2007. Sin embargo, las decisiones que toman los consumidores se enmarcan en un ambiente complejo, puesto que el gasto en un bien particular se realiza de forma secuencial. En el caso particular de la demanda de carne de res en la economía colombiana, se propone un Sistema Casi Ideal de Demanda Multinivel. La novedad econométrica en este artículo es estimar simulatáneamente todos los niveles del modelo mediante el Método Generalizado de los Momentos; esto permite obtener una matriz conjunta de covarianzas de todos los parámetros, y así utilizar el Método Delta para calcular las desviaciones estándar de las elasticidades estimadas de largo plazo. Adicionalmente, este enfoque nos permite obtener estimaciones de las elasticidades en cada nivel, pero también, elasticidades totales que incorporan la interacción entre los niveles. Por otra parte, la dinámica de corto plazo se estudia a través de la estimación conjunta de la versión en Corrección de Errores del modelo; de esta forma, ejercicios de simulación Monte Carlo son reaizados para analizar el impacto sobre la demanda de carne de res debido a perturbaciones en diferentes niveles del proceso de toma de decisiones de los consumidores. Los resultados indican que aunque en el largo plazo la elasticidad estimada de la demanda de carne de res con respecto al gasto total es 1.78, y la elasticidad estimada de la demanda con respecto al gasto en cárnicos es 1.07, la elasticidad de la demanda con respecto al gasto total en el corto plazo es solo 0.03. La reducida reacción en el corto plazo también está presente ante perturbaciones en el precio; mientras que la elasticidad precio propia total de la demanda de carne de res es -0.24 en el corto plazo, las elasticidades total y al interior del grupo de cárnicos para el largo plazo son -1.95 y -1.17, respectivamente.

***Palabras clave*:** cointegración, método delta, método generalizado de los momentos, simulación Monte Carlo, sistema de demanda.

1. Introduction

Colombian beef demand is important for a number of reasons. Historically consumers have generally preferred beef to other types of meat. Beef accounted for approximately 60% of the total meat budget, 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 Gross Domestic Product 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 trading partners. Approximately, 15% of Colombian beef production is exported to Venezuela. Recently, the Venezuelan Government decided to stop imports from Colombia as a result of political tensions. This trade restriction policy of Venezuela has generated preoccupation among specialists due to its consequences for the beef sector. Additionally, 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, given the trading conditions, the internal beef price would decrease. On the other hand, there is an asymmetric aspect that is necessary to take into account, the Colombian beef sector does not have international certification on phytosanitary aspects while the United States and the European Union accomplish this requirement. This implies that Colombia cannot export beef while the latter countries can do it. All 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, Hayes & Williams 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 & Muellbauer 1980*a*, pp 312)*

Specifically, we use a Multi-Stage AIDS model due to consumers following 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 us to estimate a joint covariance matrix which can be used to calculate the 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 to calculate, 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 (Asatryan 2003, Clark 2006, Fuller 1997, Galvis 2000, Holt & Goodwin 2009, Sulgham & Zapata 2006). 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 (Barreira & Duarte 1997, Clark 2006, MAFF 2000, Sulgham & Zapata 2006), while in the poorer countries in the East it is generally above 1.0 (Liu, Parton, Zhou & Cox 2008, Chern, Ishibashi, Taniguchi & Tokoyama 2003, Ma, Huang, Rozelle & Rae 2003, Rastegari & Hwang 2007). The own-Marshallian price demand elasticity is between -1.19 and -0.10, usually less than -1 (Fousekis & Revell 2000, Galvis 2000, Golan, Perloff & Shen 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 -0.52, 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 2 provides the methodology, Section 3 presents the long-term results, Section 4 presents some Monte Carlo simulation exercises, and Section 5 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 (Gao, Eric, Gail & Cramer 1996, Michalek & Keyzer 1992, Shenggen, Wailes & Cramer 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 &

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. Also 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 obtain 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 & 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 allow us to calculate 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 & Muellbauer 1980*a*). 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 $i = 1, 2, \ldots, N$, $j = 1, 2, \ldots, N$ and $t = 1, 2, \ldots, T$ where N is the number of goods, T is the temporal length, and 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 (3) or Laspeyres (4) 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:

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

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

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

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, Marshallian (uncompensated) and Hicksian (compensated) elasticities, respectively.

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:

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

for $i = 1, 2, \ldots, N$, $j = 1, 2, \ldots, N$ y $t = 1, 2, \ldots, T$, 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 & 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) provide expressions to get elasticities associated with the lower level and we adapt these equations as follows:

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

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

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

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 $\theta = (\theta_1, \theta_2, \ldots, \theta_k)$, 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

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

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

It must be observed 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

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

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

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 the covariances between parameters at 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

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

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

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 Federación 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 & Muellbauer (1980*b*) considered Taylor's expansion of the cost function to show that a first order approximation to the True Cost of Living index will be the Paasche like index (see equation 3). 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

Table 1: Descriptive Statistics: Colombian beef demand, 1998:I-2007:IV.

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

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% (see Figures 1 and 2).

Unit root tests (Kwiatkowski, Phillips, Schmidt & Shin 1992, Ng & Perron 2001) were carried out, which indicate 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 cannot reject the null hypothesis of one cointegration vector in each equation. On the other hand, we use Hayes, Wahl & Williams (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 cannot 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.[2] 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

[1]Information criteria was used to select VEC order and deterministic components of the cointegration test.

[2]Residuals are normal and homoscedastic, but because of autocorrelation, we estimate the covariance matrix through consistent process (Newey & West 1987). Outcomes can be seen in Table 4.

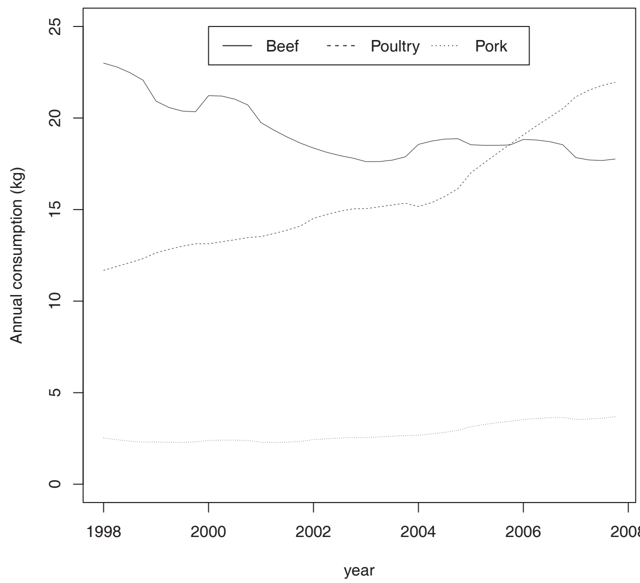

Figure 1: Meat per-capita annual consumption: Colombia, 1998:I-2007:IV.

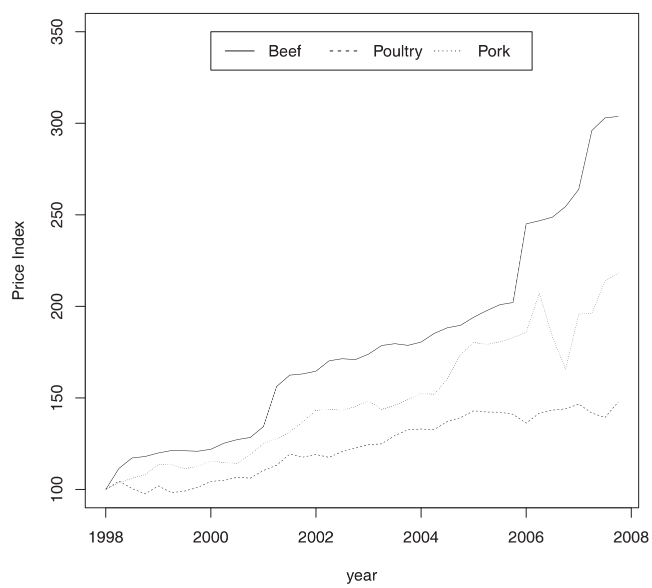

Figure 2: Meat's price index: Colombia, 1998:I-2007:IV.

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).

Table 2: Unit root tests: Colombian beef demand, 1998:I-2007:IV.

Variable	$KPSS^a$	Critical Value (5%)	$Ng - Perron^b$	Critical Value (5%)
		Upper level		
w_{Food}	0.625	0.463	-6.712	-8.100
Δw_{Food}	0.306	0.463	-14.062	-8.100
$Log(X/P)$	0.168	0.146	-2.835	-2.910
$\Delta Log(X/P)$	0.134	0.146	-2.116^c	-2.910
$Log(p_{Food}/P_{NoFood})$	0.192	0.146	-0.886	-2.910
$\Delta Log(p_{Food}/P_{NoFood})$	0.144	0.146	-2.919	-2.910
		Middle level		
w_{Meat}	0.482	0.463	-1.193	-8.100
Δw_{Meat}	0.288	0.463	-13.205	-8.100
$Log(X_{Food}/P_{Food})$	0.173	0.146	-0.363	-2.910
$\Delta Log(X_{Food}/P_{Food})$	0.100	0.146	-3.004	-2.910
$Log(p_{Meat}/p_{NoMeat})$	0.165	0.146	-2.619	-2.910
$\Delta Log(p_{Meat}/p_{NoMeat})$	0.075	0.146	-2.956	-2.910
		Lower level		
w_{Beef}	0.667	0.463	-3.629	-8.100
Δw_{Beef}	0.096	0.463	-18.851	-8.100
w_{Pork}	0.652	0.463	-2.552	-8.100
Δw_{Pork}	0.114	0.463	-13.998	-8.100
$Log(X_{Meat}/P_{Meat})$	0.185	0.146	-1.589	-2.910
$\Delta Log(X_{Meat}/P_{Meat})$	0.089	0.146	-2.713^c	-2.910
$Log(p_{Beef}/p_{Poultry})$	0.660	0.463	-1.760	-2.910
$\Delta Log(p_{Beef}/p_{Poultry})$	0.186	0.463	-3.079	-2.910
$Log(p_{Pork}/p_{Poultry})$	0.830	0.463	-3.566^c	-2.910
$\Delta Log(p_{Pork}/p_{Poultry})$	0.400	0.463	-4.116	-2.910

Notes: [a] Null hypothesis stationarity. [b] Null hypothesis unit root.
[c] We use the MZ_t^d statistic. However, the 5% critical value of the MPT^d statistic is 5.480 while its values are equal to 10.161, 6.205 and 3.754 for $\Delta Log(X/P)$, $\Delta Log(X_{Meat}/P_{Meat})$ and $Log(p_{Pork}/p_{Poultry})$, respectively. Additionally, the 5% critical value of the MSB^d statistic is 0.168 while its values are equal to 0.235, 0.182 and 0.136 for $\Delta Log(X/P)$, $\Delta Log(X_{Meat}/P_{Meat})$ and $Log(p_{Pork}/p_{Poultry})$, respectively.
Source: Author's Estimations

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 (5), 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.

The partial beef expenditure elasticity is 1.07 in the Colombian economy (see Table 5). This value is smaller than the elasticity found in Mexico which is 1.30 (Golan et al. 2000). In general, the wealthier countries in the West have expenditure elasticities of beef below 1.0 (Clark 2006, Barreira & Duarte 1997, MAFF 2000, Sulgham & Zapata 2006), while the poorer countries in the East have elas-

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

Table 3: Cointegration tests: Colombian beef demand, 1998:I-2007:IV.

Equation	Ho: CE(s)	Max. Eigenvalue[a]	Critical Value (5%)	Trace[b]	Critical Value (5%)
		Upper Level			
Food Demand[c]	r=0*	43.72	24.25	57.76	35.01
	r=1	9.85	17.14	14.03	18.39
	r=2*	4.18	3.84	4.18	3.84
		Middle Level			
Meat Demand[c]	r=0*	33.87	24.25	51.82	35.01
	r=1	11.98	17.14	17.94	18.39
	r=2*	5.95	3.84	5.95	3.84
		Lower Level			
Beef Demand[d]	r=0*	36.24	24.15	57.09	40.17
	r=1	13.08	17.79	20.84	24.27
	r=2	5.36	11.22	7.75	12.32
	r=3	2.39	4.12	2.39	4.12
Pork Demand[d]	r=0*	32.51	24.15	51.14	40.17
	r=1	11.86	17.79	18.62	24.27
	r=2	6.20	11.22	6.76	12.32
	r=3	0.56	4.12	0.56	4.12

[a] Null hypothesis: the number of cointegrating vectors is r against the alternative of $r + 1$
[b] Null hypothesis: the number of cointegrating vectors is less than or equal to r against general alternative
[c] There is a constant and a deterministic trend in the cointegrated equations. Schwarz criterion supports these outcomes.
[d] There is not a constant nor a deterministic trend in the cointegrated equations. Schwarz criterion supports these outcomes.
* Denotes rejection of the hypothesis at the 5% level
Source: Author's estimations.

ticities above 1.0 (Chern et al. 2003, Liu et al. 2008, Ma et al. 2003, Rastegari & Hwang 2007).

Table 4: Residuals tests: Colombian beef demand, 1998:I-2007:IV.

Equation	Jarque-Bera[a]	Breusch-Pagan-Godfrey[b]	Breusch-Godfrey[c]
		Upper Level	
Food Demand	1.61	3.31	36.21*
		Middle Level	
Meat Demand	2.34	8.70	27.82*
		Lower Level	
Beef Demand	1.24	6.66	24.53*
Pork Demand	2.75	5.72	30.26*

[a] The null hypothesis is normality
[b] The null hypothesis is homocedasticity
[c] The null hypothesis is not autocorrelation
* Denotes rejection of the hypothesis at the 5% level
Source: Author's estimations.

As can be seen in Table (6), there is substitution of poultry for beef within the meat group, but this effect is not present if taking into account that a change

Table 5: Expenditure elasticities for the three levels: Colombian beef demand, 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

of poultry price implies reallocation effects of meat within food and food within total consumption. With regard to 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.[4]

The partial own-Marshallian price demand elasticity is -1.17 in Colombia (see Table 6). This value is similar to elasticities that are internationally found (Galvis 2000, Golan et al. 2000, Fousekis & Revell 2000). Usually, this elasticity is less than -1. With regard to the partial compensated price elasticity, it is found a value equal to -0.52 in the Colombian economy (see Table 6). The partial own-Hicksian price demand elasticity is -0.59 in Mexico (Golan et al. 2000). This elasticity internationally has a range between -0.23 and -1.63. The highest elasticity in absolute value is found in Nigeria (Osho & Nazemzadeh 2005), while the lowest is found in U.S. (Asatryan 2003).

[4]Uncompensated own-price elasticities of poultry and pork are -1.020 and -0.028, respectively.

Table 6: Uncompensated and compensated beef price elasticities: Colombian beef demand, 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 7: Short-term beef elasticities: Colombian beef demand, 1998:I-2007:IV.

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

Source: Author's estimations

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. 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 different scenarios is based only on differences in the exogenous variables, not on differences in random errors.

The first exercise evaluates 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. It can be seen on Table 7, that 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.

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[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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