Respuestas, 26 (1) January-March 2021, pp. 45-52, ISSN 0122-820X - E ISSN: 2422-5053

Respuestas
Journal of Engineering Sciences

RESPUESTAS

Original Article https://doi.org/10.22463/0122820X.1908

Two-stage least squares simultaneous equation analysis of the demand and supply of chicken meat

Análisis de la demanda y oferta de carne de pollo utilizando ecuaciones simultaneas mediante mínimos cuadrados en dos etapas

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How to cite: : S. Cancino, G. O. Cancino-Escalante, D.F. Cancino-Ricketts, "Two-stage least squares simultaneous equation analysis of the demand and supply of chicken meat". *Respuestas*, vol. 26, no. 1, pp. 45-52, 2021.

Received on June 22, 2020 - Approved on October 23, 2020.

ABSTRACT

Keywords:

Supply, demand, simultaneous equations, two stage least squares

Chicken meat production is one of the fastest growing industries in Colombia with an average per person consumption of 35.6 kg. Due to the increase in demand and to the growing importance of the chicken meat production to the Colombian economy the objective of the study was to estimate the demand and supply response and the short run elasticities for chicken meat using a two-stage least squares technique for simultaneous equations. Results indicated that chicken meat demand was responsive to changes in own and beef prices as well as income. The direction of the independent variables were as expected, with the exception of pork prices. The response of chicken meat supply to own-price changes was found to be inelastic in the short run. Chicken feed and the exchange rate elasticities did not present a great impact on the percentage changes of the quantity offered of chicken meat. The proposed model can be useful for producers, chicken meat companies managers and policymakers as understanding the factors that affect the chicken market can lead to optimal managerial and financial decisions.

RESUMEN

Palabras clave:

Oferta, demanda, ecuaciones simultaneas, mínimos cuadrados en dos etapas

La producción de carne de pollo es una de las industrias de más rápido crecimiento en Colombia con un consumo promedio por persona de 35.6 kg. Debido al aumento de la demanda y la creciente importancia de la producción de carne de pollo para la economía colombiana, el objetivo del estudio fue estimar la respuesta de la demanda y la oferta y las elasticidades a corto plazo utilizando el modelo de ecuaciones simultaneas mediante mínimos cuadrados en dos etapas. Los resultados indicaron que la demanda de carne de pollo respondía a los cambios en los precios propios y de la carne, así como a los ingresos. La dirección de las variables independientes fue la esperada, con la excepción de los precios del cerdo. Se encontró que la respuesta de la oferta de carne de pollo a los cambios en su precio era inelástica a corto plazo. Alimentos para pollo y las elasticidades del tipo de cambio no presentaron un gran impacto en los cambios porcentuales de la cantidad ofrecida de carne de pollo. El modelo propuesto puede ser útil para productores, gerentes de empresas de carne de pollo y formuladores de políticas, ya que comprender los factores que afectan el mercado del pollo puede conducir a decisiones administrativas y financieras óptimas.

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Introduction

Chicken meat is an important source of dietary protein for consumers and their increased awareness and preferences for healthy and balanced food have been a strong driver of growth for the industry. It is one of the most widely animal-source food eaten globally and, over the last fifty years, production has increased more than 12-fold [1].

Furthermore, chickens contribute with 89% of world poultry meat production and the largest producer is the United States of America (18% world production) followed by China and Brazil [2]. The chicken meat chain involves production, processing and retailing and the industry plays a major role in the economy as it provides employment opportunity and income generation.

In Colombia, it is one of the fastest growing industries and over the last ten years chicken meat reached 1,54 million tons, a 52,7% growth, presenting the highest index of the continent. Moreover, the average per person consumption of chicken meat has consistently increased from 14,20 kg (2000) to 35,6 kg (2019) due most probably to prices and income factors [3] [2].

Several studies have concentrated on the variables that affect supply, demand and the elasticities of poultry individually. González, Rebollar and Hernandez [4] assessed the sensitivity of demand for poultry meat in Mexico; Purcell [5] analyzed the changes in demand for beef, pork, and chicken; Kapombe [6] estimated the supply response for broilers in the United Sates; Goodwin, Madrigal and Martin [7] estimated the impact of economic variables on production, consumption, and prices in the U.S. however, only a few have focused on simultaneous estimation using two-stage least squares techniques.

In this respect, due to the rise in demand and to the growing importance of the chicken meat production to the Colombian economy the primary purpose of the study was to estimate the demand and supply response and the short run elasticities for chicken meat using a two-stage least square technique for simultaneous equations.

Materials and Method

A descriptive, correlational and non-experimental design was selected to describe relationships among variables. The historical data used was based on information from secondary sources: Food and Agriculture Organization (FAO) statistics, World Bank, Colombia´s National Poultry Federation and the Ministry of Agriculture. Time series data spanning from 1991 to 2015 were collected. The data and regression model were analyzed using E-views® 9 package.

Unit root tests

The study performed the Augmented Dickey Fuller (ADF), the Phillips Perron (PP) and the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) tests in order to verify the presence of stationarity in the time series. The ADF and the PP approach consists in testing the null hypothesis for the presence of non-stationarity implying that the time series have a unit root, whilst the KPSS, on the other hand, considers as null hypothesis that the series are stationary.

Endogeneity and weak instrument tests

The Durbin-Wu-Hausmann test was also conducted in order to detect the presence of endogenous regressors so as to validate the use of a two-stage least squares regression model. Moreover, the Cragg-Donald F-statistic was applied to evaluate the overall strength and validity of the instruments. In this manner, the null hypothesis assumes that the instrument is weak against the alternative hypothesis of a strong instrument.

Diagnostic tests

The Breusch-Pagan, Godfrey (BPG) and Glejser tests were performed to assess the existence of heteroscedasticity (when the variance of the error term in the regression model varies), whereas the Breusch-Godfrey LM test was conducted to examine the presence of serial correlation.

Demand and supply model

A traditional way to model chicken meat demand and supply is to specify chicken production as a function of a measure of predetermined variables. Thus, based on the classical microeconomic theory, it is assumed that a consumer behaves in such a way to optimize an overall utility function subject to a budget constraint [8]. Therefore, the demand for chicken meat can be written as:

$DC_t = DC\ (PC_t, PP_t, PB_t, PCI,)$

where:

DC_t = Estimated quantity of average per person consumption of chicken meat (Kilogram).
PC_t = Prices paid by consumers for the purchase of chicken meat (USD/ton).
PP_t and PB_t = Prices of pork and beef meat (USD/ton), possible substitutes for chicken meat.
PCI_t = Per capita income (USD).

As for supply, it is a function of chicken meat price, price of chicken feed, lagged chicken meat and feed price (maize) and exchange rate. It is important, however, to note that chicken feed is mostly imported and accounts for an average 70% of farmers production cost, thus exchange rate changes could raise the cost of agricultural inputs affecting farmers profitability [9]. As for the lagged independent variables, it is assumed that the production of chicken meat and feed are determined by the price expected in the current time period and in the previous year [10] [11]. Subsequently, the supply for chicken meat is as follow:

$SC_t = SC\ (PC_t, PC_{t-1}, PM_t, PM_{t-1}, PS_t, PS_{t-1}, EXCRt)$

where:

SC_t = Estimated quantity of chicken meat production (ton).
PC_t = Prices received by farmers for the sale of chicken meat (USD/ton).
PC_{t-1} = Lagged prices of chicken meat (USD/ton).
PM_t = Prices paid by farmers for maize (USD/ton).
PM_{t-1} = Lagged prices of maize (USD).
$EXCR_t$ = Exchange rate defined as the trade value of the Colombian pesos versus the
United States dollar ($/USD).

Econometric model specification

Following previous studies, the model specification was based on [10] with modifications, which consists of two equations - demand and supply of chicken meat - and an identity equating demand and supply. Therefore, the general equations are as follow:

Demand for chicken meat per person
$DC_t = \alpha_1 + \alpha_2 PC_t + \alpha_3 PP_t + \alpha_4 PB_t + \alpha_5 PCI_t + \upsilon$ (1)

Supply of chicken meat

$$SC_t = \beta_1 + \beta_2 PC_t + \beta_3 PC_{t-1} + \beta_4 PM_t + \beta_5 PM_{t-1} + \beta_6 EXCR_t ++ \mu \quad (2)$$

Identity

$$SC_t = DC_t \quad (3)$$

where t is the time subscript; β_1 to β_6 and α_1 to α_5 are the coefficients to be estimated; and μ and υ are error terms.

The model consists of three endogenous (SC_t, DC_t and PC_t), and seven pre-determined variables (PC_{t-1}, PM_t, PM_{t-1}, $EXCR_t$, PP_t, PB_t, PCI_t) consequently, both the demand and supply equations are identified in rank and overidentified in order condition. Moreover, solving the system for either price or quantity both structural equations shows that the error terms are correlated with the endogenous variables indicating that the use of ordinary least squares regression (OLS) would lead to biased and inconsistent coefficients [12]. Therefore, the two stage least squares (2SLS) procedure was used to estimate the structural parameters due to its effectiveness when compared to OLS but also because it is one of the most used technique in the econometric literature for dealing with simultaneous equations [13].

The sign of each coefficient in (1) and (2) indicates the direction of the relationship between the independent and the response variable. From this perspective, as the demand curve is hypothesized to be negatively sloped it is expected an inverse relationship between DC and PC as an increase in chicken price would reduce quantity demand. On the other hand, an increase in PP or PB, potential substitute for chicken meat, would tend to shift the demand for chicken upwards and increase chicken meat production levels. The coefficient on PCI should be positive as chicken meat is considered a normal good in the sense that demand for chicken meat tends to be positively related to consumers' income.

In regards to the supply function, it is expected that an increase in PC and PC_{t-1} will rise SC; however, any changes in PM_t, PM_{t-1} and $EXCR_t$ will shift the supply function. These coefficients are a reflection of an inverse relationship with SC as an increase in chicken feed price and a depreciation in exchange rate will consequently reduce chicken meat production levels. Likewise, the short run demand and supply elasticities were calculated in order to measure the scope of response to changes in the variables.

Results and analysis

The data in table I presents the descriptive statistics of the variables used in the study, specifically focusing on chicken meat price and production, per capita consumption and income, and chicken price feed (maize) for the period 1991-2015. The average price received per ton of chicken meat sold was 1.859 with a minimum of USD 1.214 and a maximum of USD 2.861. Production reached a maximum level of 1.424.388 ton whilst the annual per capita consumption and income were 31 kg/person and 8.213 USD, respectively. As for chicken feed, prices presented an upward trend due to the growing demand from the animal feed industry, specifically the poultry sector that accounts for 66 per cent of total feed imports, reaching a maximum of 433 (USD/ton).

Table I. Mean, Maximum, Minimum and Standard Deviation

Variable	Mean	Max	Min	Standard deviation
DC	18	31	11	5,94
PC	1.859	2.861	1.214	434
PP	2.022	3.313	1.080	759
PB	2.215	3.321	1.477	617
PCI	3.968	8.213	1.457	2.218
SC	768.303	1.424.388	386.100	320.305
PM	266	433	186	74
PS	413	360	278	127
EXC	1.786	2.877	502	675

Unit root, endogeneity and weak instrument tests

According to [12] in order to provide valid statistical inference and avoid problems with spurious results, it is important to examine the stationarity of the variables before proceeding with the estimation of the model. Therefore, all variables were tested using the Augmented Dickey Fuller (ADF) and Phillips Perron (PP) unit root test as well as the Kwiatkowski, Phillips, Schmidt and Shin (KPSS) stationary test.

The results shown in table II indicate that in the level form for the ADF and PP all variables are higher than the critical values with the exception of PM and PMt-1 where they are significant at a 5% level for constant and linear trend. For the KPSS test, all series have a stationary property, even at a 10% level of significance. In the first difference, all variables are stationary around a constant, constant and linear trend mostly at 5% and 10% (ADF and PP) and 1% (KPSS) significance level therefore, as a whole the results suggest that the series used are integrated of order one I(1).

In regards to the Durbin-Wu-Hausmann endogeneity test the null hypothesis is rejected which confirms the assumption that PC is an endogenous variable. Furthermore, when testing for weak instruments the Cragg Donald F-statistic (F= 33,43 for demand; F = 24,18 for supply), were well above the rule of thumb guideline (F > 10), implying that the instruments are relevant.

Table II. Unit Root and Stationary Test Results

		Level			First difference		
Variable	**Model**	**ADF**	**PP**	**KPSS**	**ADF**	**PP**	**KPSS**
DC	Constant	-1,37	-1,29	0,70*	-3,37**	-3,34**	0,38*
	Constant & trend	-0,78	-0,99	0,17*	-3,78**	-4,01**	0,05*
PC	Constant	-2,12	-1,57	0,34*	-2,68***	-2,64***	0,10*
	Constant & trend	-2,02	-1,71	0,13*	-2,13	-2,21	0,11*
PC_{t-1}	Constant	-0,55	-0,55	0,22*	-3,38**	-3,34**	0,19*
	Constant & trend	-1,23	-1,23	0,15***	-3,04	-3,21	0,08*
PP	Constant	-1,51	-1,53	0,58*	-3,96*	-3,94**	0,14*
	Constant & trend	-1,71	-1,71	0,09*	-3,82*	-3,80*	0,13*
PB	Constant	-1,33	-1,33	0,54	-3,11**	-3,04*	0,14*
	Constant & trend	-1,41	-1,41	0,12*	-2,99	-2,93	0,14*
PCI	Constant	-1,69	-0,88	0,61*	-2,65***	-2,65***	0,12*
	Constant & trend	-2,04	-1,66	0,15*	-3,32***	-3,34***	0,11*
SC	Constant	-1,91	-3,53	0,70*	-3,55*	-3,51*	$0,52^{**}$
	Constant & trend	-0,70	-0,37	0,18*	-4,19*	-6,15*	0,15*
PM	Constant	-1,14	-1,14	0,49*	-3,66**	-3,61**	0,09*
	Constant & trend	-4,26**	-1,56	0,17*	-3,58**	-3,53**	0,09*
PM_{t-1}	Constant	-1,07	-1,07	0,45***	-3,38**	-3,30**	0,08*
	Constant & trend	-4,09**	-1,59	0,12**	-3,24	-3,16	$0,09^{*}$
EXC	Constant	-1,41	-1,48	0,45**	-2,95**	-2,98**	0,15*
	Constant & trend	-3,05	-1,62	0,15*	-2,00	-2,00	0,11*

ADF and PP uses the null hypothesis of non-stationary (there is unit root) while KPSS uses the null hypothesis of stationary (no unit root).
*, ** and *** indicate rejection of non-stationary at 1%, 5% and 10% significance level, respectively.

Estimated models

Table III provides the 2SLS estimated results of the demand and supply proposed models as specified previously in (1) and (2).

Table III. Demand and Supply Estimated Equations

			Demand	Equation		
DC =	16,49535	- 0,007587PC	- 0,00130PP	+ 0,00370PB	+ 0,003844PCI	
t =	(0,000)	(0,000)	(0,081)	(0,0184)	(0,000)	
R^2 =	0,94					
			Supply	**Equation**		
SC =	4.446	+ 245PC	+ 365PC_{t-1}	- 686PM	- 3.823PM_{t-1}	- 120,87EXC
t =	(0,000)	(0,039)	(0,111)	(0,048)	(0,693)	0,000)
R^2 =	0,81					

Results showed that the p-values ($p < 0,05$) associated to the t-statistic of the explanatory variables are significant, with the exception of PP, PCt-1 and PMt-1. The coefficients of determination (R-squared values) for the demand and supply function were high however, [14] [15] argue that in system equations, it is not well defined; therefore, it is not a goodness-of-fit indicator (Table III).

The demand equation generated coefficients with the expected signs for PC, PB and PCI and are theoretically correct; however, this was not the case for PP. This suggests that an increase in own-prices will have a negative impact on demand; on the other hand higher beef prices as well as rising consumers´ incomes will lead to an increase in chicken meat production levels. For the estimated supply quantity-dependent equation, all variables bear right signs. This indicates a direct relationship between production levels and own and lagged-prices and an inverse one with exchange rate and chicken feed prices, therefore, if chicken feed prices decreases the production of chicken meat should increase and vice-versa.

The Breusch-Pagan, Godfrey (BPG) and Glejser tests were applied on the two-equations´ residuals and the null hypothesis for no heteroscedasticity was not rejected. Moreover, there is a lack of evidence of serial correlation as the chi-squares and p-values of the Breusch-Godffrey test are not significant suggesting the non-presence of autocorrelation (Table IV).

Table IV. Heteroscedasticity and Serial Correlation Tests

Test	Demand function		Supply function	
Heteroscedasticity	Chi-square	p-value	Chi-square	p-value
Breusch-Pagan, Godffrey	7,062	0,132	8,173	0,084
Glejser	5,158	0,271	8,157	0,086
Breusch-Godffrey Serial Correlation	3,780	0,151	0,344	0,841

The short run elasticities calculated for the proposed demand and supply model are shown in table V. The own-price demand elasticity for chicken meat indicates that if chicken meat price increase 1%, production will decrease 0,77 %. As for the cross-price elasticity ($\varepsilon dcp = 0,476$), the study indicates that beef meat is a substitute for chicken meat and changes in prices will lead consumers to shift toward a lower cost product. However, the cross-price elasticity of demand for chicken and pork had unexpected opposite signs therefore, a concrete conclusion on the degree of competition or complementarity between both variables could not be reached. Likewise, the value of income elasticity ($\varepsilon di = 0,84$) was quite high suggesting that chicken meat is sensitive to changes in income.

Concerning the own-price supply elasticity of chicken meat an increase in price will induce producers to supply larger quantities, thus a price increase of 1% will rise production in 0,59%. It is important to highlight that in related studies supply response also showed an inelastic response to market prices [6] [16]). With regards to chicken feed and the exchange rate elasticities both were low (-0,23 and -0,27, respectively) which would imply that they do not present a great impact on the percentage changes of the quantity offered of chicken meat.

Table V. Short Run Elasticities of Demand and Supply

	Demand	Elasticity
Own-price	Cross-price	Income price
(PC)	(PB)	(PCI)
- 0,77	0,47	0,84
	Supply	Elasticity
Own-price	PM	Exchange rate
(PC)		
0,59	-0,23	-0,27

Conclusion

In conclusion, a simultaneous equation model of chicken meat demand and supply was specified and estimated using two-stage least squares. The overall fits of the demand and supply equations were generally good.

Results indicated that chicken meat demand was responsive to changes in own and beef prices as well as income. The direction of the independent variables were as expected and in accordance with the economic theory, with the exception of pork prices. On the other hand, the response of chicken meat supply to own-price changes was found to be inelastic in the short run. Concerning chicken feed and the exchange rate elasticities, they did not present a great impact on the percentage changes of the quantity offered of chicken meat.

Consequently, the proposed supply and demand model for chicken meat can be useful for producers, chicken meat companies managers and policymakers as understanding the factors that affect the chicken market can lead to optimal managerial and financial decisions.

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