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Brazilian sawn wood price and income elasticity

BRAZILIAN SAWN WOOD PRICE AND INCOME ELASTICITY

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ABSTRACT: This study estimated the sawn wood demand price and income elasticity. Specifically it was estimated the price elasticity of sawn wood, the cross price elasticity of wood panels and the income elasticity of Brazilian GDP. A *log-log* model with correction through outline of the mobile average (*MA(1)*) was used, adjusted for the period of 1971 to 2006, which showed to be stable, with satisfactory significance levels. It was observed that sawn wood demand is inelastic in relation to price and elastic in relation to income.

Key words: Forest economy, sawn wood demand, income maximization.

ELASTICIDADE PREÇO E ELASTICIDADE RENDA DA MADEIRA SERRADA BRASILEIRA

RESUMO: Conduziu-se este estudo, com o objetivo de estimar as elasticidades preço e renda da demanda por madeira. Especificamente estimou-se a elasticidade preço do m³ de madeira serrada, a elasticidade preço cruzada do m³ de painéis de madeira e a elasticidade renda do PIB da nação. Fez-se uso de um modelo log-log com correção por meio de esquema de media móvel (MA(1)), ajustado para o período de 1971 a 2006 que se mostrou estável e com níveis de significância satisfatórios. Observou-se que a demanda de madeira serrada é inelástica em relação a preço e elástica em relação à renda.

Palavras-chave: Economia florestal, demanda de madeira serrada, maximização da renda.

1 INTRODUCTION

The acquisition and merger process of the organizations is intensified by Globalization, because of the largest capital mobility and information due to the market integration which accelerated the technological development and it improved the efficiency of the productive chains, turning the competition more accentuated in quality and cost, in internal and external markets. This scenery includes the productive chains of forest based products (GARCIA, 2002).

Due to the internationalization of the economy, the consumers become more concerned with environmental issues and sustainability, placing in prominence the forest sustained management and the origin of raw materials (CHIPANSKI, 2006).

Brazil was shown competitive in the international scenery considering products as sawn wood, plywood and furniture in spite of the high inequality indexes and of monopoly verified at the markets of these products (COELHO & BERGER, 2004; NOCE et al., 2003, 2007a,b).

The wood price has strong influence in different aspects of importance for the forest sector and for the nation. It is important in the valorization of forest areas front the possibility of conversion to agricultural use, viability of activities of the forest key industry and the possibilities of social insert of fomentation programs. In that way it is reflected as much in the context of native forest as in the ones of fast growth.

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The conception of the market economy presupposes intimate relationship between price and demand. Therefore, this study aimed at estimating the demand elasticity of sawn wood. Specifically, it aimed to estimate the price elasticity of sawn wood, cross price elasticity of wood panels and income elasticity of Brazilian GDP.

2 MATERIAL AND METHODS

2.1 Proposed model

Initially it was estimated the following model:

$$ln\,Y_t = \beta_0 + \beta_1\,ln\,X_1 + \beta_2\,ln\,X_2 + \beta_3\,ln\,X_3 + u_t$$

being:

Y_t: sawn wood demand in m³;
X_1: price in dollars for m³ of sawn wood;
X_2: price in dollars for m³ of wood panels;
X_3: Gross Domestic Product (GDP) in thousands of dollars;
β_0: intercept;
β_1, β_2, β_3: angular coefficients;
u_t: error term.

The use of a *Log-Log* model allows scale problems to be overcome among the variables as well as the direct obtaining of the elasticities that determine the percent variation of the demand in relation to 1% variation in prices and in GDP (GUJARATI, 2006).

The apparent consumption of Brazilian sawn wood in the period 1971-2006 was used as proxy for representing the demand of sawn wood. It was obtained by the sum of the production values and import, minus exports. The data related to the production, export and import, as well as the ones of price is available in the Food and Agriculture Organization of the United Nations - FAO (2007) website. The relative data to the Brazilian Gross Domestic Product in the referring period is available in the website of the Institute of Applied Economical Researches - IPEA (2007).

Due to the autocorrelation of the error terms of the first estimated regression model, a term of movable average (*MA*) was inserted, envisaging the representation of the average of the recent past observations. Thus, the proposed model was:

$$ln\,Y_t = \beta_0 + \beta_1\,ln\,X_1 + \beta_2\,ln\,X_2 + \beta_3\,ln\,X_3 + MA(1)u_t$$

where:

β_1: price elasticity;
β_2: cross price elasticity;
β_3: income elasticity;
MA(1): movable averages.

The term of movable average (*MA*) was included in the regression model, considering that the flotation in the past values represent aleatory flotation around a "soft" curve. The larger the number of observations included in the average movable, the higher the smoothness effect in the forecast (WHEELWRIGHT & MAKRIDAKIS, 1989).

The movable averages also represent the error of aleatory events that cannot be explained by the model, i.e., the foreseen value for the observation depends on the error values observed in each past period. Besides, it can be used to soften seasonal effects (MADDALA, 2003).

The correction through the movable average to temporal series was used to estimate the *ARIMA* model, which made possible to distinguish the price behavior related to the wood origin, if from native or from fast growth forest (COELHO JÚNIOR et al., 2006).

2.2 Statistical analysis

The stationary stochastic process, or estacionarity of the temporal series, was tested through the test of unitary root of *Dickey-Fuller*. The increased *Dickey-Fuller* procedure tests the null hypothesis of unitary root or non stationary temporal series ($\delta = 0$) for the three possibilities: (a) aleatory walk without displacement ($\Delta Y_t = \delta Y_{t-1} + \alpha \Delta Y_{t-1} + u_t$), (b) aleatory walk with displacement ($\Delta Y_t = \beta_1 + \delta Y_{t-1} + \alpha \Delta Y_{t-1} + u_t$) and (c) aleatory walk with displacement surrounding a stochastic tendency ($\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \alpha \Delta Y_{t-1} + u_t$). Under the null hypothesis, the value of t of *Student* estimated by the coefficient Y_{t-1} followed the statistics τ (tau) and the probability of maximum error allowed was of 5%. The inclusion of lag values of the dependent variable ΔY_t allowed the possibility of u_t present autocorrelation (GUJARATI, 2006).

Due to the situation of estacionarity of order 1, the number of co-integration vectors was tested shared by the series through the *Johansen* test. It was assumed that the existence of a co-integration vector indicates that there is balance or long run relationship among the variables (JOHANSEN, 1995).

The method to estimate the regression models used was the *Minimum Ordinary Square* (*MQO*) and the result of the estimated regression was evaluated by the following criteria:

a) Determination Coefficient (R^2)

The determination Coefficient (R^2) is considered as a measure of the regression adjustment quality. It measures

the proportion or percentage of the total variation of Y explained by the regression model (GUJARATI, 2006). R^2 was calculated by the equation:

$$R^2 = \frac{SQE}{STQ} = 1 - \frac{SQR}{STQ}$$

being:
SQE: sum of the explained square of the regression;
SQR: sum of the square of the residue of the regression;
STQ: sum of the total square of the regression.

b) Test of general significance or F test

The general significance test (F test) was accomplished to test the null hypothesis that all the estimated coefficients are the same and equal to zero ($\beta_2 = \beta_3 = ... = \beta_i = 0$) (HOFFMANN & VIEIRA, 1998). The calculated value of F was obtained by the equation:

$$F = \frac{SQE / k - 1}{SQR / n - k}$$

being:
SQE: sum of the explained square of the regression;
SQR: sum of the residue square of the regression;
k = number of estimated variables in the regression;
n = number of observations.

The statistics of the test follows the distribution F, with ($k–1$) degrees of freedom for the numerator and ($n–k$) degrees of the denominator and maximum error probability allowed of 5%. If the value of calculated F overcomes the value of critical or controlled F, the null hypothesis is rejected.

c) Test of individual significance of the coefficients or t test

Through the test t the statistical significance of the regression coefficients was verified, considering the null hypothesis that each estimated coefficient is individually equal to zero ($\beta_i = 0$) (GUJARATI, 2006). The calculated value of t was obtained by the equation:

$$t = \frac{\hat{\beta}_i - 0}{ep(\hat{\beta}_i)}$$

being:
$\hat{\beta}_i$ = estimated coefficient;
ep = standard error of the estimated coefficient.

The statistics of the test follows the distribution t, with ($n–2$) degrees of freedom with maximum error probability allowed of 5%. If the value of calculated t overcomes the value of critical or tabled t, the null hypothesis is rejected.

d) Test of residues normality

The normality of the residues was verified through the graphic of distribution of the residues and of the *Jarque-Bera* test, that considers the united hypothesis that the asymmetry (S) and the kurtosis (K) are same to zero and three, respectively (MADDALA, 2003). In that way, the test considers the null hypothesis that the residues are usually distributed. The value of *Jarque-Bera* was calculated by the equation:

$$JB = n\left[\frac{S^2}{6} + \frac{(K-3)^2}{24}\right]$$

being:
n: size of the sample;
S: asymmetry coefficient;
K: kurtosis coefficient.

The asymmetry coefficients (S) and kurtosis (K) are given by:

$$S = \sum_{i=1}^{n}\left(\frac{u_i - \bar{u}}{\hat{\sigma}}\right)^3 \quad \text{e} \quad K = \sum_{i=1}^{n}\left(\frac{u_i - \bar{u}}{\hat{\sigma}}\right)^4$$

being:
u_i = error;
$\bar{u}$ = average error;
$\hat{\sigma}$ = estimated standard deviation.

The statistics of the test follows the distribution of χ_2 (qui-square), with 2 degrees of freedom and maximum error probability allowed of 5%. If the calculated value goes superior to the critical value or tabled, the null hypothesis is rejected.

e) Autocorrelation Test

The verification of the autocorrelation presence of the error terms was accomplished through the correlogram observation and through the *Breusch-Godfrey's* test (*LM test*) (GUJARATI, 2006).

In *Breusch-Godfrey's* test the residues ($\hat{u}_t$) of the regression are obtained and estimated as dependent variable in an auxiliary regression against the independent variable X_t and its own dephased values:

$$\hat{u}_t = \alpha_1 + \alpha_2 X_t + \hat{\rho}_1\hat{u}_{t-1} + \hat{\rho}_2\hat{u}_{t-2} + ... + \hat{\rho}_p\hat{u}_{t-p} + \varepsilon_t$$

The determination coefficient (R^2) of the estimated auxiliary regression multiplied for ($n - p$) follows the distribution χ^2 (qui-square), with p degrees of freedom.

being:

n: number of observations;

p: number of diphase of the error term ($û_t$).

If $(n-p)R^2$ is superior to the critical or tabled value at the level of maximum significance of 5%, the null hypothesis of autocorrelation absence, or that at least one ρ is different from zero, it is rejected.

3 RESULTS AND DISCUSSION

It was observed through the test of Dickey-Fuller that the temporary series used in the study were not stationary in level, being just stationary in first difference. The use of temporary series in first difference suggests the validity of the results only for the short run temporal horizon, in case it is not verified that the variables are co-integrated. It was rejected that the series presents number of vectors of co-integration inferior or superior to two for the test of Johansen, as well as it was identified that the dependent variable regression residue by the explanatory variables is stationary (I(0)), procedure used by Mattos (2005). In that way the model was adjusted in first difference esteeming the elasticities of short run and in level to indicate the elasticities in the long run horizon, presupposing that the temporary series tend to the balance in the long run once they show co-integrated.

3.1 Short run results

The hypothesis of absence of serial autocorrelation is not rejected by *Breusch-Godfrey's* test (Table 1). It stands out that the graphic analysis of the correlogram converges for the same result of non rejection of the hypothesis of autocorrelation absence (Figure 1).

The hypothesis of normality of the residues is not rejected through the test of *Jarque-Bera* (Figure 2).

It was admitted that the variables are stationary in the first difference, without correlation absence and normal distribution of residues, which justified the discussion of the adjustment of the regression under a short run perspective (Table 2).

The proposed model was statistically significant by the test *F* (general significance) and the null hypothesis that the coefficients are jointly equal to zero was rejected at 1% of probability. The price coefficients of the sawn wood and GDP presented significant values in the test *t* of *Student* at 1% of probability, rejecting the null hypothesis of β_1 e β_3 equals to zero, while the price coefficients of wood panel and of the intercept didn't show significance at 5% probability, not rejecting the hypothesis of they be equal to zero. The value of adjusted *R* indicated that 96.2% of the sawn wood demand variation occurred in function of the alterations in the price of the

**Table 1** – *Breusch-Godfrey* (*LM*) Test of Serial Autocorrelation.

Tabela 1 – *Teste Breusch-Godfrey (LM) de autocorrelação Serial.*

F–statistical	0.348	Probability	0.708
Corrected R	0.844	Probability	0.655

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.088	0.088	0.2926	
		2	0.106	0.099	0.7338	0.392
		3	-0.234	-0.256	2.9535	0.228
		4	-0.021	0.014	2.9725	0.396
		5	-0.273	-0.237	6.1918	0.185
		6	0.129	0.143	6.9390	0.225
		7	-0.018	-0.006	6.9541	0.325
		8	-0.099	-0.271	7.4275	0.386
		9	-0.130	-0.023	8.2638	0.408
		10	-0.157	-0.229	9.5383	0.389
		11	-0.040	0.017	9.6256	0.474
		12	0.015	-0.023	9.6375	0.563
		13	0.130	-0.070	10.635	0.560
		14	0.090	0.107	11.129	0.600
		15	0.093	-0.052	11.694	0.631
		16	0.057	0.110	11.916	0.685

Figure 1 – Correlogram for absence of serial autocorrelation hypothesis.

Figura 1 – *Correlograma para a hipótese de ausência de autocorrelação serial.*
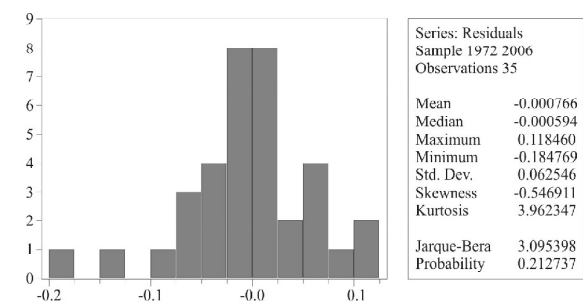
Figure 2 – *Jarque-Bera* test of normality of the residues.

Figura 2 – *Teste Jarque-Bera de normalidade dos resíduos.*

sawn wood and in GDP during the period from 1971 to 2006 (Table 2).

The coefficient of -0.143 for the price of the sawn wood indicated that the demand is inelastic in relation to price, so that if the prices of the wood varied in 10% the demand would alter in 1.43% in inverse sense. As well as the coefficient of 1.326 of GDP indicated that the demand was elastic in relation to the income, presupposing that for alterations of 10% in GDP the demand would vary in 13.26% in same sense.

Table 2 – Adjustment of the proposed model.

Tabela 2 – Ajuste do modelo proposto.

Dependent variable	Ln(Demand(-1))			
Explanatory variable	Coefficient	Pattern error	Test t	Probability
Intercept	-1.311	2.810	-0.466	0.644
Ln(price of sawn wood (-1))	-0.143	0.055	-2.591	0.014
Ln(price of wood panel (-1))	-0.053	0.064	-0.835	0.410
Ln(GDP of Brazil (-1))	1.326	0.195	6.768	0.001
MA(1)	0.651	0.109	5.934	0.001
Statistics of the adjustment				
R^2	0.966	F-statistic		217.775
Adjusted R^2	0.962	Prob(F-statistic)		0.001

3.2 Long run results

Through *Breusch-Godfrey's* test the hypothesis of absence of serial autocorrelation is not rejected (Table 3). This result is confirmed by the correlogram graphical analysis (Figure 3).
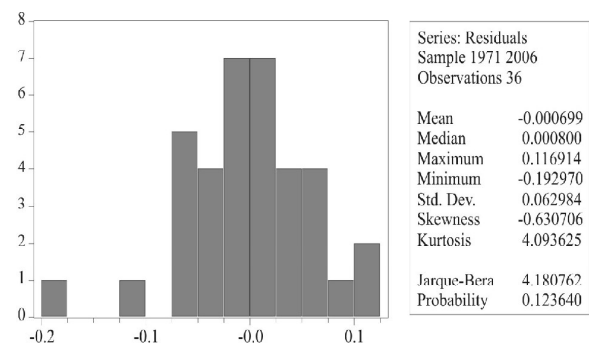
Table 3 – *Breusch-Godfrey* Test (*LM*) for long run Serial Autocorrelation.

Tabela 3 – Teste Breusch-Godfrey (LM) de Autocorrelação Serial para longo prazo.

F–statistical	0.453	Probability	0.640
Corrected R	1.086	Probability	0.580

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.088	0.088	0.3056	
		2	0.110	0.103	0.7913	0.374
		3	-0.218	-0.240	2.7592	0.252
		4	-0.006	0.026	2.7609	0.430
		5	-0.248	-0.213	5.4715	0.242
		6	0.146	0.160	6.4460	0.265
		7	-0.013	-0.002	6.4544	0.374
		8	-0.083	-0.236	6.7940	0.451
		9	-0.114	-0.001	7.4565	0.488
		10	-0.161	-0.221	8.8126	0.455
		11	-0.014	0.079	8.8226	0.549
		12	0.020	-0.008	8.8462	0.636
		13	0.128	-0.037	9.8212	0.632
		14	0.088	0.145	10.304	0.669
		15	0.079	-0.069	10.712	0.709
		16	0.031	0.133	10.777	0.768

Figure 3 – Correlogram for the hypothesis of absence of long run serial autocorrelation.

Figura 3 – Correlograma para a ausência de autocorrelação de longo prazo.

The hypothesis of normality of the residues was not rejected by *Jarque-Bera* test (Figure 4).

Series: Residuals	
Sample 1971 2006	
Observations 36	
Mean	-0.000699
Median	0.000800
Maximum	0.116914
Minimum	-0.192970
Std. Dev.	0.062984
Skewness	-0.630706
Kurtosis	4.093625
Jarque-Bera	4.180762
Probability	0.123640

Figure 4 – *Jarque-Bera* Test of long run normality of the residues.

Figura 4 – Teste Jarque-Bera de normalidade dos resíduos para longo prazo.

It was admitted that the variables are co-integrated, with autocorrelation absence and normal distribution of residues, justifying the discussion of the regression adjustment, in a long run perspective (Table 4).

The proposed model was statistically significant for the test *F* (general significance), rejecting the null hypothesis that the coefficients are jointly equal to zero at 1% of probability. As well as in the adjustment in first difference, the price coefficients of the sawn wood and of GDP presented significant values in *Student t* test at 1% of probability, while the price coefficients of the wood panel and of the intercept weren't significant. It stands out that the significance of the price coefficient of the wood panel presented improvement in of long run perspective. It was

Table 4 – Adjustment for the long run proposed model.

Tabela 4 – Ajuste do modelo proposto para longo prazo.

Dependent variable	Ln(Demand(-1))			
Explanatory variable	Coefficient	Pattern error	Test t	Probability
C	-0.889	2.817	-0.315	0.754
Ln(price of sawn wood)	-0.140	0.056	-2.485	0.018
Ln(price of wood panel)	-0.063	0.062	-1.018	0.316
Ln(GDP of Brazil)	1.298	0.197	6.589	0.001
MA(1)	0.662	0.105	6.260	0.001
Statistics of the adjustment				
R^2	0.965	F-statistic		220.005
Adjusted R^2	0.961	Prob(F-statistic)		0.001

observed through the value of adjusted *R* that 96.1% of the variations of the demand were explained by the changes in sawn wood prices and by the GDP, in the period of 1971 to 2006 (Table 4).

As well as in the short run analysis, the demand was inelastic due to the coefficient of -0.140 for sawn wood price, i.e., for a 10% price variation of the sawn wood, the demand would change by 1.40% in a contrary way. The demand was elastic in relation to income, as can be observed in the coefficient of 1.298 for GDP, which indicates that a 10% change in the demand would change GDP by 12.98% in the same direction.

The demand price inelasticity presupposes that the revenue of the production would be maximized with increases of price of the sawn wood, once the demand has a reaction less than proportional to the variation of the prices. This is a coherent result with the low elasticity observed in the aggregation of wood manufactured products which includes sawn wood (CALDERON & ÂNGELO, 2006). Excessive increases of wood production would alter the offer, generating price reduction, which would reduce the income due to the inelasticity of the demand, result that confirms what would happen in the scenery of inelastic offer (ÂNGELO, 1998).

Increases in the GDP causes reactions more than proportional in the sawn wood demand, fact also observed for agglomerate panels and plywood by Brasil et al. (2003).

4 CONCLUSIONS

For the conditions in which this study was accomplished, it was concluded that:

- the increase of price favors the income maximization of sawn wood producers, both in short and long run. This is important for the sustainable use of the renewable resources, once it would be possible to combine reduction of the production with the increases of price and revenue;

- the more than proportional response of sawn wood demand to income, gives to sawn wood the status of superior good, being sensitive to structural variations;

- the values of short and long run elasticities were relatively close, as well as the significance and the coherence of the signs observed in the coefficient values.

5 ACKNOWLEDGEMENTS

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