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The Roundwood Market from the Amazon Forest and the Impacts on the Socio-Economy of the State of Pará

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ABSTRACT

The objective of this research was to analyze the timber market in five mesoregions of the Amazon forest in the state of Pará, in the period from 2000 to 2013, to determine the influence of deforestation under the market's regulation and to estimate the monetary value of the timber forest activity. The panel data analysis was applied and the demand and supply equations's parameters were estimated by the generalized method of moments. The results indicated that the demand and supply of timber are inelastic to the price and significantly influenced by

deforestation. The impact of deforestation was positive for demand and higher, in absolute terms, to the negative impact in the supply; resulting in an increment in the market equilibrium price. The socioeconomic and environmental average benefits of timber extraction was US$137.73 million per year by mesoregion, amounting US$688.65 million per year for the state of Pará. From this total, producers appropriated 21.8% and consumers 78.2%. The timber's equilibrium price was higher than the average prices utilized in forest valuation for the compensations purposes and for the public forest concession projects, indicating an underestimation of the socioeconomic and environmental value of the timber forest capital.

Keywords: Valuation of natural resources, forest management, deforestation, timber forest capital.

INTRODUCTION

Timber extraction of the Amazon forest in the state of Pará has a significant participation in the State's economy through labor occupation, income generation and foreign exchange by exports. For this reason, the region is rapidly moving towards the last forest's occupation areas of public domain in the state of Pará and Amazon, with concessions given for exploitation by the private initiative and the local communities.

Despite the socioeconomic and environmental importance of the Amazon Forest, the environmental value of this asset (i.e. wood and non-timber products, and ecosystem services) is unknown. This article aims to estimate the value of the socioeconomic and environmental benefit of timber extraction and commercialization of five mesoregions in the state of Pará from 2000 to 2013, as well as their distribution among consumers and producers.

From this value, the unitary benefit that the extraction of each cubic meter of wood generates for the Pará's state economy is determined. It serves as a parameter for comparison with other productive activities that compete with the forest areas in Pará. In fact, it is possible to plan the use of land systems in the Amazon, combining extractive activities with agricultural and cattle activities in the form of private and /or collective programs.

The value of the socioeconomic and environmental benefits generated by the extraction and sale of timber from settlement areas and management projects was based on the fundamentals of the neoclassical theory applied to the economy of natural resources. Timber has a market value and represents the main commercial product of the Amazon forest, so a market model was used to estimate the supply (or social marginal cost) and demand (or social marginal benefit) equations and to determine the economic surplus, or total socioenvironmental benefit [21; 20, 26], in the Para's state mesoregions where wood exploitation continues to interface with authorized and unauthorized deforestation areas and with legal extraction in private and collective forest management areas of settlement projects, conservation units, national and state forests.

Economic surplus is a measure of the consumer's marginal benefit, or consumer surplus, given the difference between the value people want and can pay for the product and the price actually paid (area limited between demand and market equilibrium price) and the producer's marginal

benefit or producer surplus is represented by the difference between the price received and the cost of producing an additional unit of output [19, 22].

This concept, initially used to determine the returns of investment [8, 1, 14]. Was first used to estimate the social cost of the Brazilian's tree-nut depredation in the state of Pará and the entire North region [21, 27, 18]. This article, the integral calculation is applied to determine the economic surplus or socioenvironmental benefit of the extraction of timber in the state of Pará and its distribution between producers and consumers.

In general, the existent extractivism is inadequate, not concerned with sustainable exploitation, since the stock of commercial species is completely extracted and the rest of the forest is cut and burned for the implantation of pastures for the extensive cattle creation and/or for the implantation of crops with technologies. Thus, there is no concern to domesticate the species for reforestation, and neither the sustainable management for the permanent exploitation of wood and non-timber products by the traditional populations and by forest's concession projects to the private initiative.

In this context, what is the value of the socioeconomic and environmental benefits of extraction and commercialization of timber under the influence of deforestation in the five mesoregions in the state of Pará, from 2000 to 2013?

To answer this question, a dynamic data panel model was specified to represent the timber market, with the parameters estimated by the generalized moments method. From the estimation of the parameters of this model, the value of the socioeconomic and environmental benefit of the timber extraction is determined.

The first objective of the research was to estimate the parameters of demand and supply models of timber from the five mesoregions in the state of Pará and to determine the influence of deforestation on the regulation of the timber market. The second objective was to estimate the total value of the socioeconomic and environmental benefit of the extraction and commercialization of timber, and to analyze its distribution among producers and consumers. Following, the text contemplates in the methodology the theoretical foundations about the market and the determination of the value of the socioeconomic and environmental benefit of the extraction and commercialization of timber. Afterwards, an analysis and a discussion of the results of the research is presented. Finally, the conclusions of the work are presented.

MATERIAL AND METHODS

The researched área, from the state of Pará, in the Brazilian Amazon, included five mesoregions where timber production is still active, involving the various forms of exploitation of this natural resource; namely: Lower Amazonas, Marajó, Northeast Paraense, Southeast Paraense and Sudoeste Paraense. In 2010, they accounted for 99.16% of the timber production and marketing in the State of Pará. The Belém mesoregion was excluded because the wood extraction activity practically exhausted, representing only 0.84% of total production in 2010. Currently, the extraction of wood takes place in the following areas: private areas with legalized management projects; in areas of collective exploitation; in areas authorized for deforestation; and in unauthorized areas where the extraction occurs illegally.

Data on wood production, wood and firewood prices and per capita GDP values were obtained from the Brazilian Institute of Geography and Statistics (IBGE). The value of the Circulation of Goods and Services Tax (ICMS) collected from the logging activity was obtained from the Secretariat of Finance of the State of Pará (SEFA) [12]. From the Getúlio Vargas Foundation (FGV), the IGP-DI as obtained and, from the National Institute of Space Research (INPE), all data on deforestation.

Specification of the Timber Market

The timber market-operates with characteristics that are close to perfect competition, due to the large number of managed units and establishments licensed to carry out deforestation within the 20% allowed in the Amazon biome, which offer timber and by the large number of companies that purchase wood in the mesoregions of Para [22, 32]. The wood in logs, considered by species, is a homogeneous product in the vision of the buyers. Thus, wood's prices and quantities are determined by the interaction between demand and supply, according to the adjustment process of a dynamic recursive model.

The amount of timber demanded tends to vary inversely with market prices and presents a direct correlation with the consumers per capita income, represented by sawmills, wood extractors and carpenters [22]. Thus, in response to increases in price and/or decrease in income, consumers tend to adjust their purchasing plans for a smaller quantity of the high-cost products and maintain the same level of satisfaction. For the variable deforestation, it is observed that for each km^2 of deforested area, the demand for wood tends to increase in response to the companies' needs of increasing their stocks for they processing purposes [22, 28].

An increase in demand is also expected with regard to the quantity of timber lagged one period, since a higher demand in one period tends to maintain consumption expectations in the subsequent period. Currently, deforestation in rural settlement projects, as well as the extraction of wood in private areas, in conservation units for sustainable use (national and state forests) and in forest concession areas tend to make legal timber trade viable, together with illegal timber extracted from unmanaged areas in the vicinity of private and/or community areas.

The amount of wood supplied tends to vary in the same direction as the prices of the previous harvest, according to the Northern Constitutional Fund (FNO), and in the opposite direction of the state's ICMS tax. Before the generalized and more effective action against deforestation in the Amazon biome, the supply of wood evolved in the same direction as deforestation, due to the greater quantity of the product available in the deforested mesoregion [22, 32]. In the post-2005 period, deforestation and the supply of timber decreased due to the greater effectiveness of the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA), the Chico Mendes Institute for Biodiversity Conservation (ICMBio) and the Environmental Secretaries (SEMA).

With regard to the amount of timber lagged one period, it is expected to obtain a positive correlation with supply, given that the stability of the timber supply in one year creates an expectation of expansion in the following period. The price of firewood, since it is a product

generated from logging waste from fallen trees and without commercial value to the industry, tends to present a positive correlation with the timber supply.

In addition to the endogenous and exogenous variables, category of instrumental variables were included; though not considered directly in the structural equations, their effects will be captured in the structural model. These variables present strong correlation with the exogenous variables and absence of correlation with the error term. Thus, the GDP per capita lagged one period (GDPpct-1) and the goods circulation tax lagged one period (ICMSt-1) tend to present correlation with some of the exogenous variables, but should be orthogonal to the error terms [22, 20,18].

In addition, the quantity of timber lagged one period (QMt-1) gather information of the market forces that acted in the previous harvest, whose effects may influence market performance in the current period. The Hansen J statistic was used to test the adequacy of these variables in the model [22, 3, 18].

The dynamic recursive model was specified in the data panel form, combining the cross-section information from the five mesoregions of the state of Pará with the time series data from 2000 to 2013, given the advantages of increasing the number of observations, avoiding multicollinearity problems and increasing the efficiency of parameter estimators.

The recursive model:

$$QM_{dit} = a_0 + a_1 PM_{it} + a_2 PIBpc_{it} + a_3 DMT_{it} + a_4 DMT_{it-1} + a_5 QM_{it-1} + u_{dit} \quad [1]$$

$$QM_{oit} = b_0 + b_1 PM_{it-1} + b_2 DMT_{it} + b_3 ICMS_{it} + b_4 PLEN_{it} + b_5 FNO_{it} + b_6 QM_{it-1} + u_{oit} \quad [2]$$

$$u_{jit} = \mu_{ji} + v_{jit}, i = 1, \dots, N; t = 1, \dots, T; j = d, o \quad [3]$$

Where:

Endogenous variables: QM_{it} is the amount of timber (demanded and supplied) of the mesoregion i of the state of Pará, in period t, in m^3; PM_{it} is the real price of timber from the mesoregion i of the state of Pará, in period t, in US\$/m^3;

Exogenous variables: QM_{it-1} is the amount of timber of mesoregion i of the state of Pará, in period t-1, in m^3; PM_{it-1} is the real price of timber from the mesoregion i of the state of Pará, in period t-1, in US\$/m^3; DMT_{it} is the deforestation of the mesoregion i, in period t, in km^2; DMT_{it-1} is the deforestation of the mesoregion i, in period t-1, in km^2; $ICMS_{it}$ is the marketing tax on timber in US\$ of mesoregion i, in period t; PIBpcit is the real per capita gross domestic product of mesoregion i, in period t, in US\$/inhab; PLEN*it* is the real price of wood of the mesoregion i, in period t, in US\$/m^3.

Instrumental variables: GDP_{pcit-1} is the real gross domestic product per capita of mesoregion i, in period t-1, in US\$/inhab; $ICMS_{it-1}$ is the marketing tax on timber in US\$ of mesoregion i, in period t-1**.**

Parameters and error terms: $\boldsymbol{a_0}$ and $\boldsymbol{b_0}$ are the values of the intercept for the dynamic demand and supply equations, which are the same for all mesoregion; $\boldsymbol{a_p}$ and $\boldsymbol{b_q}$ are the parameters that capture the effect of the exogenous variables on the endogenous variables of the dynamic

equations of demand and supply of timber in the state of Pará; μ_{ji} are the individual and specific unobservable effects that affect each equation; v_{it} is the remaining random error, with independent and normal distribution.

The demand and supply equations were considered overidentified by the order and rank conditions. Therefore, the model parameters were estimated by the Generalized Method of Moment (GMM) including the instrumental variables and the treatment for heteroscedasticity and autocorrelation [30, 22, 17, 5]. Details on the specification and estimation of parameters of panel data models involving fixed effects, random effects, and dynamic models are anchored in the specialized literature [3, 5, 22, 17]. The choice of the fixed effect model is due to the fact that the data come from five fixed mesoregions and the standardization by the Hausman test [3]. Thus, the model is a balanced panel of data with fixed effects, including the same intercept, with 14 observations (2000 to 2013) from five mesoregions; totaling 70 observations. Differences between mesoregions or cross-sectional units can be captured in the intercept term, and are kept constant over time.

Socioeconomic and Environmental Benefit

From the econometric results, the value of the total socioeconomic and environmental benefit of timber (VBSTM) from five mesoregions of the state of Pará is estimated, given by the sum of the benefits of the producer (PSPM) and the consumer (BSCM). The VBSTM is given by the sum of the integral of the timber supply equation, defined in the range of price zero at the equilibrium price PMe, with the integral of the demand equation, defined between the PMe and the price PMd, which makes the quantity demanded equal to zero. Therefore, the VBSTM is estimated by:

$$VBSTM_t = BSPM_t + BSCM_t = \int_0^{PMe} (\mu + vPM) dPM + \int_{PMe}^{PMd} (a - bPM) dPM \quad [4]$$

Finally, assuming a scenario in which the benefit of timber extractivism becomes a compensation for the damages caused to the environment and society, through deforestation for the implantation of agricultural activities and the suppression of the forest to enable the mining and the production of electricity as a fixed amount and in the form of a perpetual annuity, assuming a discount rate *r* equal to 4% per year, applied by the ICMBio for the mineral extraction projects in the Amazon, it is obtained the present value of the compensation (VPCOMP) given by equation 5 [9, 20,26]:

$$VPCOMP_t = \sum_{t=0}^{\infty} BSTM_t \, (1 + r)^{-t} = \frac{BSTM_t}{r} \quad [5]$$

RESULTS AND DISCUSSION

This section presents the econometric results of the demand and supply equations, the total value of the socioeconomic and environmental benefit of timber extraction and the distribution of the benefits to the mesoregions of the state of Pará.

Supply and Demand of Wood

The demand model for timber was adequately specified to explain the consumer behavior of the product in the mesoregions of state of Pará. The Hansen J statistic confirmed that the vector

of exogenous and instrumental variables is orthogonal to the errors and that the model is correctly specified. The exogenous variables explained 97.86% of the variations in the quantities demanded. There is also no problem of first-order autocorrelation (Table 1).

Table 1: Demand for timber in the mesoregions of the state of Pará: 2000 to 2013.

Variable	Coefficient	Standard Error	t-Statístics	Probab.	Elasticity
Constant: a	69,418.23	64,144.54	1.082216	0.2845	-
Timber Price: TP	-572.4433	157.7429	-3.628964	0.0007	-0.1814
GDP *per capita*: GDPpc	0.620871	0.579408	1.071561	0.2893	0.0114
Deforastation: DMT	46.92358	20.17485	2.325845	0.0242	1.0481
Deforestation (t-1): DMT(-1)	-41.37692	17.98627	-2.300473	0.0257	-0.9242
Quant. Timber (t-1): QT(-1)	0.788499	0.084815	9.296735	0.0000	0.7881
R^2	0.982214	J Statistics			0.27525
Adjusted R^2	0.978584	Probability (J Statistics)			0.59983
Average of depend. var.	374,779.9	Durbin-Watson Statístics - d			1.48443
Exogenous and Instrumental variables: *PIBpc, DMT, DMT (-1), ICMS (-1), PIBpc (-1), QM (-1)*					

The estimated parameters are correct and significant at 5%, except for the GDP *per capita* variable that was significant at 28.9% (Table 1). The amount demanded had an inverse and significant relation to prices, and positive relation with the income variable. The contemporary deforestation and quantity of lagged timber variables had a positive relation with demand, indicating that the increase in deforestation of 1.0 km^2 tended to produce a displacement of 46.92 m^3 of timber in demand, and a fall of 41.38 m^3 the following year. The demand response to the quantity in the previous year is positive and less than proportional; that is, with each increase of 1.0 m^3 in the demand for wood in one year, a magnitude of 0.79 m^3 should be reproduced for the demand of the following year (Table 1).

Following, the timber's supply model was correctly specified to explain the behavior of the producers in the mesoregions of the state of Pará. The Hansen J statistic was not significant, which indicates the acceptance of the hypothesis that the vector of exogenous and instrumental variables is orthogonal to errors. The variables included in the model explained 94.96% of the variations in the quantities offered and there is no problem of first order autocorrelation (Table 2).

The results are in accordance with the microeconomic theory and presented statistical significance at 5%, except the FNO credit that was significant at 8.16% (Table 2). Thus, the quantity of wood is positively influenced by: variations in the price of one year; in the quantity offered in the previous year; in the price of firewood; and in the FNO credit. And negatively in relation to contemporary deforestation and state´s tax ICMS.

Table 2: Supply of timber in the mesoregions of the state of Pará: 2000 to 2013

Variable	Coefficient	Standard Error	t-Statístics	Probab.	Elasticity
Constant: b	-281,288.9	71,053.73	-3.95882	0.0002	-
Timber Price: TP(t-1): PM(-1)	1,502.309	422.7544	3.553622	0.0009	0.4754
Deforestation: DMT	-17.99119	7.170734	-2.508975	0.0155	-0.4019

Quant. Timber (t-1): QM(-1)	0.993053	0.125658	12.36767	0.0000	0.9925
FNO Credit: FNO	1.355366	0.67186	1.77902	0.0816	0.0502
State Tax: ICMS	-0.004794	0.001904	-2.517279	0.0152	-0.0313
Firewood Price: PLEN	1,596.172	787.5627	2.026723	0.0483	0.0649
R^2	0.959025	J Statistics			0.022803
Adjusted R^2	0.949635	Probability (J Statistics)			0.879969
Average of depend. var.	374,779.90	Durbin-Watson Statístics - d			2.200694
Exogenous and Instrumental variables: *PIBpc, PIBpc(-1), DMT, PM(-1), ICMS, QM(-1), FNO, PLEN*					

Supply and Demand Elasticities

The price elasticity of demand for timber with a value lower than one in absolute terms allows it to be classified as inelastic at price. This result indicates that, in response to unit price increases, the quantity demanded tends to vary in the opposite direction of -0.181%, *ceteris paribus*. This shows that timber presents low sensitivity to changes in price, given the high perishability of the product to pest and fungus attack and cracks from sun exposure, a certain abundance of supply for the domestic market and the absence of close substitutes from planted forests. This result was more inelastic than the one obtained for the mesoregions of the Southwest Paraense and Lower Amazon, equal to -0.221 [32].

This characteristic of low inelasticity-price of demand makes the spending of the timber's buyers unstable due to the small changes in the quantity demanded that requires great changes in prices and, in turn, in the expenses incurred in the purchase of wood.

With respect to income elasticity, timber can be classified as a "normal good" for the Pará's timber merchants, since the low aggregated value, the relative abundance of the product in several species makes the product with a relatively low participation in the budget. For 10% increases in income, demand tends to increase by only 0.11%; that is, it practically remains at the same level. This result indicates that the demand does not change with the politics of increase and distribution of the income.

The elasticity of demand in relation to present and past deforestation presented a net result in the order of 0.1239 (= 1.0481 - 0.9242), indicating that deforestation tends to increase demand strongly in the same year that deforestation occurs, and negatively in the following period; this is due to the environmental regulation that acts *ex-post* and inhibits the action of buyers of wood originating from the place. A previous study found a deforestation elasticity of 0.576 for some municipalities in the Southwest Paraense and Lower Amazon mesoregions [32]. The performance of the regulatory agencies increased the effectiveness of combating deforestation and illegal timber trade in these mesoregions, especially since 2007.

Finally, the demand for wood from the state of Pará tends to increase following the consumption trend of sawmills, wood extractors and carpenters. Thus, a 10% increase in the consumption of timber in one year tends to boost the next year´s demand by the magnitude of 7.88%, *ceteris paribus.*

With respect to supply, a price elasticity of 0.4754 was obtained (Table 2). This result confirms the hypothesis that timber has a supply inelastic to price, given the low value added, the limited

stock of domesticated species and the propagation in commercial plantations. In the state of Pará, as in the Amazon, there is no way to increase production without forest management for the rational exploration and inclusion of new species in the market, combined with the plantations of species of high commercial value. The imprecision of the control with respect to the number of species to be explored per hectare, the insertion in the market of the known major species and those with market value yet not known, contributes to the exhaustion of the trees of greater commercial value despite management plans. Therefore, forest concessions tend to make the supply of the main commercial species perfectly inelastic by establishing the support capacity of this forest asset [25, 28]. At this point, the inelasticity of supply and demand is the main problem of producers' income sustainability, given that environmental policy can not neutralize the effects of failures in forest product markets.

The cross-elasticity of supply of timber with respect to firewood showed that the products are not competitive with respect to the use of the factors of production, especially the labor and forest area, since both are produced together. In this case, in response to a 10% increase in the price of firewood, the supply of timber tends to increase by 0.649%, *ceteris paribus.* That is, the increase in the production of firewood for coal, for example, makes possible the extraction of timber.

The tax-elasticity indicated a weak sensitivity of the timber supply to increases in the value of the merchandise circulation tax, since supply tends to decrease -0.313% in response to a 10% increase in the value of ICMS. A tax-elasticity of -0.652 for timber supply in the mesoregions of Sudoeste Paraense and Baixo Amazonas, from 2000 to 2007 [32].

The elasticity-deforestation was -0.402, indicating that with each 10% increase in the deforested area in the mesoregions, the supply of timber tended to decrease -4.02%, *ceteris paribus*. This result was different from that found for the municipalities of the mesoregions of Southwest Pará and Lower Amazon, in the period from 2000 to 2007, whose value was 0.476 [22, 32]. The explanation for the result obtained for the mesoregions is linked to the response given by the responsible organisms in the control of the logging activity in the Amazon, and to the reflection of the world economic crisis. Thus, areas where there are increases in deforestation, especially with suspected illegality, the inspection increases and inhibits the supply of timber. This effect has proved to be the main cause for the closure of sawmills in all mesoregions, with a greater impact on those located in the "deforestation arc" area.

With respect to the elasticity of adjustment, it is estimated that the increase in the supply of timber of one year tends to be completely transferred to the next year, given the coefficient being 0.992. This result suggests that the regulation of the supply of timber through a management plan and deforestation tends to ensure its natural increase over time, according to the capacity of supply of the wood stocks.

Socioeconomic and Environmental Benefit

In order to express the quantities demanded and offered for timber based on prices alone, the average value of the exogenous variables in each equation is substituted and the result is added to the intercept.

Demand: QMdt = 415,638.84 - 527.44 PMt [6]

Supply: QMot = 181,925.22 + 1,502.31 PMt [7]

Equilibrium: QMe = QMd = QMo = 351,155.09 m^3/year; PMe = US$ 112.65/m^3 [8]

From the solution of the system, the average of the annual quantities of timber transacted in each mesoregion was of 351.16 thousand m^3 at an average price of US$112.65/$m^3$.

The monetary value of the socio-environmental benefit is given by the sum of the integral of the supply equation, defined in the price range between zero and US$ 112.65/m^3, representing the surplus or profit of the producer, with the consumer surplus determined by the integral of the demand equation, defined as the average equilibrium price of US$112.65/$m^3$ and the price of US$726.08/$m^3$, which makes demand equal to zero. This price range represents the limits between the maximum price, the equilibrium price and the price not expected by consumers to maximize their utility functions, adopting the criteria of rationality in the commercial transactions of buying and selling wood in each mesoregion of the state of Pará.

The value of the total socioeconomic and environmental benefit of timber (VBSTM), including the effects of deforestation, is the sum of the benefit of the timber producer (BSPM) with the benefit of the timber consumer (BSCM). The result was obtained as follows:

$$VBSTM_t = BSPM_t + BSCM_t$$

$$= \int_0^{112.65} (181{,}925.22 + 1{,}502.31\text{PM})\text{dPM} + \int_{121.65}^{726.08} (415{,}638.84 - 527.44PM)dPM$$

$$VBSTM_t = (181{,}925.22\ PM + 751.155\ PM^2)_0^{112.65} + (415{,}638.84\ PM - 263.72\ PM^2)_{112.65}^{726.08}$$

$$VBSTM_t = 30{,}024{,}819.82 + 107{,}704{,}903.21 = US\$\ 137{,}729{,}723.03/\text{year}$$

The monetary value of the producer's benefit was US$30.02 million per year and the timber's consumer benefit of US$107.70 million per year for each mesoregion. Thus, the total value of the benefit generated by the extraction and sale of timber from each of the five mesoregions of the state of Pará reached US$137.73 million per year, equivalent to US$ 688.65 million per year for all five mesoregions. Of this total, 21.8% was for the extractivists, while 78.2% of the total was appropriated by the consumers. Therefore, most of the benefit generated by the extraction of wood was appropriated by sawmill owners and woodworkers, who do the industrial treatment of the wood, and by a small portion of agents who act as wood extractors and intermediaries in the activity.

The obtained VBSTM represents the average social value of each mesoregion of US$392.22/$m^3$, which is 3.842 times higher than the market equilibrium price of US$112.56/$m^3$. That is, by private evaluation, which considers only the benefit or profit of the producer, there is an average gross value of timber production per mesoregion of only US$39.56 million per year (= 351.155 m^3 x US$ 112.65/m^3).

The value of R$392.22/$m^3$ requires a higher demand to reach the equilibrium quantity of 771,159.54 m^3 of wood supply. Due to the great informality in the production and commercialization of timber in the state of Pará, this volume of wood represents 45.54% of the total produced and is consistent with previous results [31, 25, 32].

Subtracting from the value of the equilibrium production the BSPM, we obtain the average cost of production of US$9.54 million (= US$ 39.56 - R$ 30.02), equivalent to US$ 27.17/m^3 of Timber. This unitary social cost is equivalent to 24.10% of the equilibrium price of the timber market (R$ 112.65/m^3).

The difference between the value of logging from the point of view of the producer and the value of the activity from the point of view of society represents the socio-environmental value for the timber's consumption. Therefore, in terms of valuation of timber forest resources for the purpose of compensation under the forestry concession, mineral extraction, hydroelectric energy production and other projects that use the forest areas, the average value of the timber of these mesoregions should be US$392.22/$m^3$. This value makes the production of 1.0 m^3 of wood per ha and per year, relatively more profitable than extensive livestock and soybean [25, 24, 29].

In addition, considering the case of forest management projects with extraction of 30 m^3/ha, a socioeconomic and environmental value of US$11,766.67/ha is obtained from the forest area to be eliminated. This value exceeds the present gross value of the standing forest production estimated for the Saracá-Taquera National Forest valuation [16]. The value found by these authors, based on the average volume of wood of 84.68 m^3/ha and considering the horizon of 100 years, represents only 43.82% of the value of the socioeconomic and environmental benefit estimated in this work.

On the other hand, an annual exploitation of 0.677 m^3 per hectare per year for forest concession projects makes the activity relatively less profitable than livestock and soybeans [15, 2, 22, 32]. In this sense, it is possible to expand the most profitable activities.

In addition, since the extraction of forest resources in the management plans, in general, do not contemplate the exploitation of non-timber products, in addition of not considering, effectively, the biodiversity value of the area exploited and the minimum conditions of survival for the local population, it must be considered the total value of the ecosystem services of this environmental asset and adopt a perpetual annuity flow to generate the monetary value of the resource that reflects the opportunity cost of the Amazon forest.

Applying equation 5, the present value of the socioeconomic and environmental benefit of logging in the mesoregions of the state of Pará is obtained, we obtain:

$$VPEMP_t = \frac{US\$\ 137{,}729{,}723.03}{0.04} = US\$\ 3{,}443{,}243{,}075.75/cycle$$

The amount of US$3,443.25 million is equivalent to the net present value of the forest capital of each mesoregion, or the opportunity cost to conserve the forest standing, considering the

conditions captured in the model and the timber's extracting and marketing conditions from 2000 to 2013. In the five mesoregions, the value of the timber forest capital would be US$17,216.22 million. In this case, the effective conditions of the stocks of commercial species are still unknown, since forest management is in the experimental phase, and there are no known management cases that have completed the initial stage of the 25-30 years of sustainable exploitation.

Finally, the results of the research, besides presenting the socioeconomic and environmental value of the timber market and its distribution among the agents of society, are the basis for some research on the problems caused by illegal logging and the effects of other activities with respect to the deforestation in the Amazon. Some studies link deforestation to the expansion of beef and dairy farming activities and also to soybean production [4, 6]. Additionally, the study shows that managed logging, even without incorporating social and environmental effects, exceeds the return from extensive livestock farming and grain production in the Amazon [25, 26, 28].

CONCLUSIONS

The demand and supply of timber from the five mesoregions of the state of Pará are inelastic in price, which tends to generate strong instability in producers' income and consumer spending. Deforestation strongly influences the supply and demand of timber and, consequently, determines the formation of the equilibrium price and the distribution of income between extractivists and wood processing units.

The amount of timber traded in the mesoregions studied, in a given period, tends to produce positive adjustments in demand and supply in the following period, with a major impact on supply than on demand. This result points to the effects that the regulatory conditions has on the equalization of the market for the sustainable extraction of natural resources.

The total value of the average socioeconomic and environmental benefits of timber extraction per mesoregion was US$ 137.73 million per year in the period studied, or US$ 688.65 million per year for the state of Pará. From the benefits, producers tend to take 21.8% and consumers 78.2%. Therefore, sawmills, wood extractors and carpenters who exert the demand for timber are the main beneficiaries of the activity.

The value of the timber forest capital of the mesoregions of state of Pará, considering 25-year extraction cycles for a sustainable exploration over an infinite horizon, would reach the value of US$ 3,443.24 million per mesoregion or US$ 17,216.22 million for the state of Pará. This justifies the policy of sustainable management of the use of forest resources for timber and non-timber in the Amazon.

Finally, it is concluded that the valuation of the standing forests for the purpose of compensation by the mining companies and for the purpose of the forest concession projects underestimate the socioeconomic and environmental value of the timber forest capital. Thus, for products that exist in the market, the parameters of the supply and demand equations must be estimated and the producer and the consumer surplus considered.

Thus, it is suggested that forestry concessions projects, as well as agricultural and forestry development projects, energy production, roads and mineral extraction projects that, directly or indirectly, cause damage to the natural resources and to society of the state of Pará and the Amazon should bear with the compensation value of the socio-environmental opportunity cost. These resources must form a special fund whose earnings are applied in local development projects.

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