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RESEARCH ARTICLE

An Econometric Study of Deforestation in the Brazil's Amazonian Municipalities

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Abstract

Using both analytical and econometric frameworks, this paper evaluates the causes of deforestation in the Brazilian Amazonian municipalities from 2000 to 2004. Starting with an analytical framework, the main causes that led farmers to cut down forests and convert the soil use to other activities are highlighted. Basing on the analytical framework, an equation is developed and estimated using a dynamic panel data model. Agricultural prices, rural credit and government expenditure on transport have played important roles as stimulators for deforestation as well as an inertial process of deforestation has taken place. The article ends by suggesting some policies to restrain deforestation without reducing the income of farmers and the accessibility of the local population.

Keywords: *Amazonian region, Brazil, Deforestation, Panel data.*

Introduction

Most of the land currently occupied by human beings has undergone deforestation, and the later remains an ongoing process. According to a study conducted by the Food and Agriculture Organization (FAO), between 1990 and 2005 the average deforested area in some tropical countries[1] was as high as 9,464,067 hectares per year. Brazil stands out with 2,821,933 hectares of deforested land per year, followed by Indonesia, with an average deforestation of 1,871,467 hectares per year, and Myanmar, with 466,467 hectares per year.

On the African continent, there is an annual deforestation of 650 million hectares. The growing demand for farmland, land for raising livestock and building infrastructure, increased demand for energy products from forest lands (such as firewood and charcoal), the growing need for construction inputs and other needs result in approximately 5.3 million hectares of deforestation in Africa every year [1].

In Asian countries the scenario is similar. Thailand, for instance, between 1976 and 1989, lost around 28% of its forest land [2]. In Indonesia, due to the country's major insertion on the world wood-based product trade, around 300 thousand hectares of land were deforested per year during the 1970s. This number rose to 600 thousand per year in the 1980s and reached the one million hectares mark in the 1990s [3].

The situation in Latin America is no different from the other tropical regions. The growing levels of deforestation in the region resulted in an average loss of 0.4% of forest land per year during the 1990s [4].

Focusing specifically on South America, deforestation continues to grow. In the countries that form the Amazon Basin[2], for example, between 1990 and 2005, 3,429,066 hectares of forest land were lost every year[3].

Particularly in Brazil, the rate of deforestation is growing and suggests that the large area of native forest, the Amazon, will see its landscape transformed.

Although deforestation enables economic growth due to log extraction and the alternative use of the soil for agriculture, it has negative impacts on the local, regional and global environments. On the climate aspects, deforestation changes the carbon cycle and rainfall patterns. On the soil

[1] Brazil, Indonesia, Myanmar, the Democratic Republic of the Congo, Zambia, Tanzania, Nigeria, Mexico, Zimbabwe, Venezuela, Bolivia, the Philippines, Cameroon, Ecuador, Honduras, Cambodia, Papua New Guinea, Ghana and Angola.

[2] The countries that make up the Amazon Basin area are Bolivia, Brazil, Colombia, Ecuador, Guiana, French Guiana, Peru, Suriname and Venezuela.

[3] Calculated from FAO data, available at <http://www.fao.org>. Retrieved on 10 February, 2007.

aspects, deforestation increases the potential for erosion, reduces the capacity to retain sediments, and drops the formation of soil and causes an unbalanced nutrient cycle. In terms of biological elements, deforestation leads to the elimination of pollinating agents, biological control agents and a reduction in genetic resources.

In Brazil, and more precisely in the Legal Amazon region[4], in addition to the environmental problems outlined above, there are also social problems that stem from deforestation or are concomitant with it, such as seizure of land, expropriation and marginalization of persons, including native Brazilians. Other problems include endemic diseases and land concentration.

Many papers and reports have explained the causes of deforestation using a variety of focuses and procedures and among them the economic papers stand out. These generally relate deforestation to the economic behavior of different agents who are either directly or indirectly involved in the process. Despite the causes of deforestation have been pointed out, little has been researched about what are the impacts of each cause on deforestation.

Inspired by what has been outlined above, the objective of this article is to quantify and evaluate the causes of deforestation in the Legal Amazonian municipalities using a dynamic panel data. The period of 2000-2004 is the focus of the article. In addition to this introduction, there is a review of the literature in Section 2. The analytical framework and methodological procedures are presented in Section 3, and the analysis of the results is showed in Section 4. The final considerations are presented in Section 5.

Review of the Literature

In the wide range of works on deforestation, most have sought to explain the reasons behind this process. Some authors have emphatically pointed to specific factors as the cause of deforestation in the Amazon, such as construction or the paving of roads or other works of infrastructure [5-7], the growth of livestock [8], soybean expansion [9,10] or even the growing population. However, the factors are actually multiple and are plainly related to one another. In addition to seeking the causes of deforestation, a further challenge in the empirical papers is to measure their impact on the generation of deforestation.

In the following paragraphs, some of the main works performing econometric analysis of the cause of deforestation, both in the Amazon and other countries, are analyzed. It is worth mentioning that these papers are important to provide guidelines for and justify the choice of the variables that make up the econometric model that is proposed and estimated in this paper.

In general, the works measure deforestation using the area of forest land that was lost between two time different years [11-15] Another possibility, however much more complex and to date seldom considered in empirical works, is using a measurement of the quantity of biomass that is eliminated during the removal of the natural cover [16,17]. Another method is the one employed by Young [18], which used the increase of farming land as a proxy of deforestation.

In all the reviewed works that analyze deforestation through economic models, population is the factor that is mentioned most when attempting to explain deforestation [2,11,15,19,20]. As Tanaka and Nishii [19] point out, the population variable implicitly incorporates other variables, making them unnecessary. Furthermore, population is easy to measure, which facilitates works of an empirical nature. However, considering population as the only variable for explaining deforestation does not capture the true reasons for it. For example, there are also economic actions [21] and the policies that encourage deforestation.

The works agree that deforestation takes place due to the presence of the human population and the activities substituting forest provide food and raw materials for human subsistence inside the deforested area or far way. All the empirical works agree that the larger the population or the higher its growth rate, the more pressure there will be for deforestation in a given region.

The roads variable, measured by the cost of transport or the distance between a certain place and a commercial center or a place where supplies can be acquired or goods can be exported, was also identified in the empirical works on deforestation [2,7,13]. Cropper, Griffiths and Mani [2] examined the impact of the pressure of roads and the population on deforestation in Thailand between 1976 and 1989. The model takes into account, using the above variables as a basis, that the land market in the short term is balanced. However, in the long term, deforestation depends on the profitability of farming and the costs of deforestation.

[4] The Brazilian Legal Amazon accounts for 5.2 million km^2, equal to 61% of Brazilian territory. This region encompasses the total area of Acre, Amapá, Amazonas, Pará, Rondônia, Roraima and Tocatins plus the Center-west part of Mato Grosso and the Northeast part of Maranhão.

Arima et al. [22] used a combination of the consumer behavior theory and the geographical information system to analyze the spatial decisions of the economic agents. Their results showed that deforestation increased as the number of roads grew. Similar results are found by Pfaff et al. [12]. They analyzed the impact of more roads on deforestation in the Amazon region and concluded that the growing number of roads, whether paved or not, helped to increase deforestation. Weinhold and Reis [7] analyzed the connection between population growth and growth in infrastructure in 295 towns in the Amazon region from 1975 to 1985. The differential in this work was that infrastructure was incorporated as an endogenous variable in the model, unlike the other works, which indicated their exogeneity, i.e., it is a growth in infrastructure that leads to a growth in population which, in its turn, leads to deforestation.

Intergovernmental Panel on Climate Change – IPCC (2000), showed that there is a correlation between income levels and the rate of deforestation. Young [18] found positive correlations between deforestation, agricultural prices, amount of available credit, the number of roads and the price of land. Pffaf et al. [23] found results that were different from those of other works on the relationship between income and deforestation in Costa Rica between 1963 and 2000. After isolating areas with higher and lower income levels, the authors found that there is a higher rate of deforestation in lower income areas. Andersen and Reis [11] estimated a deforestation model based on the demand for farming land.

They sought to evaluate the different instruments used for development policies from 1970 to 1985. The model takes into account the level of urbanization in the town, the growth rate of the local market, land prices and government actions. Ferraz [24] analyzed deforestation in eight states in the Amazon region between 1980 and 1998, linking it to the expansion of farming and the breeding of livestock. The expansion of crops correlates positively with the presence of roads, rural credits and land prices. Livestock has a positive relationship with roads and a negative relationship with cattle prices. As both crop and cattle require open land, they have an impact on the deforestation rate.

Pfaff [23] analyzed the determiners of deforestation in the Brazilian Amazon from 1978 to 1988. The econometric model that was adopted consists of determining a representative equation of the possible factors that lead to deforestation.

The assumptions are that the land is allocated to alternative uses in order to maximize profits. The results are in accordance with the economic theory and with the other empirical studies: more roads have a positive impact on deforestation; government development programs also speed up deforestation; areas that are far from the markets are less susceptible to deforestation; and areas with more fertile soil are also more likely to be deforested. The author highlights that no relationship was found between the population size and deforestation when this variable is analyzed along with the others.

Ferraz [25] analyzed the reasons for growth in agriculture and the raising of livestock in the Amazon region between 1980 and 1995 using multiple regression models. The dependent variables “conversion of forests into farming areas and livestock areas” was run against to the value of production, cost of inputs (land prices and wages), extended paved and unpaved roads and rural credits. All the independent variables were positively related to deforestation.

Reis [26] applied an econometric model to evaluate the indirect effects of the Carajás Steelworks (Pólo Siderúrgico do Carajás, in Portuguese) on deforestation. The explanatory variables used were farming and livestock, urbanization and industrialization. The results showed that the steelworks had no impact on deforestation in the region. Barcellos [27] reached the same conclusion of Reis [26], pointing out that the impact of mining on deforestation is minor in comparison with crops and livestock expansion.

Arcand, Guillaumont and Jeanneney [28] used a dynamic model to evaluate deforestation among developing countries and using interest rates, exchange rates, per capita GNP, the price of wood, population growth rate and rural population density rates as explanatory variables. The authors conclude that short-term economic policies affect deforestation levels.

The aforementioned literature spawned new researches that simultaneously took into consideration the different causes of deforestation in a theoretical model and more disaggregated data, at the municipal level, for instance, for estimating the equation resulting from the theoretical model, which has so far received little attention.

Analytical and Methodological Framework

Analytical Framework

In order to systematize the debate on deforestation, a theoretical model concerning deforestation is presented. The model is based on one of the models developed by Angelsen [29] and adapted by Silva [30].

The paper assumes that the agent responsible for deforestation is the farmer, who is interested in maximizing the income generated by each unit of land. The base for comparison is the expected profit (receive minus costs) of the non-sustainable use of the soil $(R^d - C^d)$ in relation to the profit expected from the sustainable use of the soil $(R^s - C^s)$. The latter is based on extraction and other forms of generating income that do not include eliminating the natural cover. Therefore, expected deforestation is calculated by the difference between income derived from activities that exclude natural cover or do not:

$$D = fE[(R^d - C^d) - (R^s - C^s)] \quad (1)$$

The expected income from the non-sustainable use of the soil $(E(R^d))$ includes the wood obtained from deforestation (R^m) and the income from the economic activities that are possible after deforestation $(E(R^{\dagger}a))$, which means activities with crops and livestock. In its turn, the growth in farming depends on exogenous factors such as the price index of crops (P^a), the price of meat (P^c), and the specific conditions of the farming area (CP), e.g., the natural characteristics of the land (types of landform, types of soil, level of deforestation, predominant types of economic activity and distance between the producer and consumers). It is assumed that the specific conditions of the farm are constant over time, but they are different from one town to another and are homogeneous inside them.
Summarizing, we have:

$$E(R^d) = f(R^m + E(R^a)) \quad (3)$$
$$E(R^a) = f(P^a, P^c, CP) \quad (4)$$

The non-sustainable use of land implies costs, including the cost of log exploitation (C^m) and the costs of planting and harvesting crops and breeding livestock (C^a). Furthermore, it also depends indirectly on the economic policies for agriculture, such as government expenditure to encourage farming (GA) and rural loans (CR). Furthermore, government policies that impact the cost of production also constitute subjacent factors to deforestation, as is the case of government expenditure on the transport networks (GT), which reduces logistical costs and increases profit. Thus, the cost of the non-sustainable use of the soil (C^a) is determined by:

$$C^d = f(C^m, C^a, GA, CR, GT) \quad (5)$$

A deforested area is connected to the problem of the farmer and this problem, in turn, has to do with maximizing profits, given the parameters of decision making, and is subjected to the restrictions of production (costs). The aim of the farmer is to maximize his profits (π) given the crop prices (P^a) and meat prices (P^c) and subject to the cost elements in Equation (5), plus the specific conditions of the farmland (CP). Therefore:

$$Max: \pi(P^a, P^c)$$
$$Sujeito\ a:\ C^m, C^a, GA, CR, GT, CP \quad (6)$$

The above equation is in accordance with the first of the three perspectives established by Kaimowitz and Angelsen [31], i.e., the scale of the individual farmer, the regional scale and the national scale. Therefore, it is a return to the classic problem of the microeconomics of maximizing a function with imposed restrictions. Generally, restrictions on the agent are exogenous, such as prices, resource endowment, preferences, economic policies, institutions and alternative technologies. It is worth pointing out that the decision-making parameters of the farmer are determined on broader scales that depend on the conditions of the market and public and private institutions, as well as policies that are positively correlated with agriculture.

Basing on the above framework and the main explanatory variables suggested by the empirical studies reviewed in the prior section, the following equation is suggested for estimating deforestation:

$$\ln Desmat_{it} = \alpha_{it} + \beta_1 lnIPBA_{it} + \beta_2 lnIPS_{it} + \beta_3 PC_{it} + \beta_4 lnGA_{it-1} + \beta_5 lnCR_{it-1} + \beta_6 \ln GT_{it-1} + e_{it} \quad (7)$$

P^a is evaluated by PBA (crop prices, excluding soybeans) and PS = soy prices; PC is the price of meat; GA = government expenditure on crops and livestock; CR = rural credits; and GT refers to government expenditures with transport networks. It is assumed that the values of $GA, CR\ e\ GT$ in one year affect deforestation in the next year and agricultural prices will be in line with deforestation.

Subscripts i and t, respectively, represent the town under study and the year of observation. There is information available on 782 municipalities for 2000 to 2004.

Thus, $i = 1, \ldots, 782$ e $t = 2000, \ldots, 2004$.
α and the βs are the set of coefficients to be estimated.

Therefore, there is a panel of data considering the 782 municipalities for 2000 to 2004 in the nine states that make up the region.[5] The signs of the coefficients are all expected to be positive.
To directly obtain the elasticities, Equation 7 is expressed in logarithms.

The econometric model used here is on the scale of the farmer [31]. The farmer is the agent who carries out the deforestation, but the variables that affect the farmer's decision to deforest are determined on an external scale, and these variables, in turn, are also determined on a broader scale, which is denominated by variables that are subjacent to deforestation. Therefore, a model that captures the effect of the different types of determining variables of deforestation may be preferable to the alternative models. Thus, the results presented here attempt to establish these relationships through a dynamic model that adequately captures this functional form.

The importance of a dynamic model to explain deforestation is justified by the fact that deforestation cannot be seen as a contemporaneous phenomenon of the activities or factors related to it. Furthermore, a dynamic specifically for deforestation (inertia effect) can be conceived because in the short term, the substitution of activities such as timber is not fully possible. Therefore, the structure that has been erected leads to the continuation of deforestation, even when there are no factors to account for it.

The Data

Using data concerning Production Value (*VP*) and Amount Produced (*QP*) for both temporary and permanent crops, a price index was generated for each of the 782 municipalities for each year analyzed (from 2000 to 2004). The price of soybean was calculated using this same procedure.

The rural credit data were obtained on a municipal scale from the website of the Brazilian Central Bank. The data on Government Expenditure on Agriculture and the transport networks were collected from the website of the National Treasure Secretariat, also on a municipal scale.

The price of meat was calculated based on the price published in Annual pec and on the Arima et al. [32] and Silva [30] papers, which adopted a procedure based on transport costs to determine the average price that livestock breeders received in each city.

Population and income level for each municipality were retrieved from the ipeadata website (http://www.ipeadata.gov.br).

Econometric Procedures

The dynamic model for panel data proposed by Arellano and Bond [33] may be expressed as:

$$\mathbf{Desmat_{it}} = \boldsymbol{\gamma}\mathbf{Desmat_{it-1}} + \mathbf{x'_{it}}\boldsymbol{\beta} + \boldsymbol{\varepsilon_{it}} \quad (8)$$

where $\mathbf{x}$ is the matrix containing all the explanatory variables and ε is the random error. In this model, the dynamic of the model is given by including the lagged explanatory variable among the independent variables. This procedure includes the inertia effect [34] because it can be understood that the invalidation of the exogenous variables still causes deforestation.

The model assumes that the explanatory variables are contemporaneous with deforestation. However, there is empirical evidence that some of the factors that affect deforestation are not contemporaneous with it [35]. Thus, the new version for Equation (8) is:

$$\mathbf{Desmat_{it}} = \boldsymbol{\gamma}\mathbf{Desmat_{it-1}} + \mathbf{x'_{it-1}}\boldsymbol{\beta} + \mathbf{z'_{it}}\boldsymbol{\delta} + \boldsymbol{\varepsilon_{it}} \quad (9)$$

In other words, in addition to the inclusion of the dependent lagged variable in one period ($\mathbf{Desmat_{it-1}}$) among the explanatory variables, there is also a set of lagged explanatory variables in a period ($\mathbf{x'_{it-1}}$) added to the inclusion of contemporaneous explanatory variables ($\mathbf{z'_{it}}$) to the dependent variable.
The variables Population, Municipal Income, Rural credit, Agricultural Costs and Transport Costs are also treated as endogenous in the adopted model, i.e., they constitute a set of instruments utilized in the regression. The fact that they are included in the model as endogenous variables means that they also determine the other variables that are considered contemporaneous to deforestation. The inclusion

[5] For each variable there may be as many as 3,910 observations.

of instrumental variables in a dynamic panel data model interferes crucially with the generated estimates. To test the joint pertinence of the instrumental variables incorporated into the model, the Hansen J statistic was used, which proved to be effective in the presence of heteroscedasticity. The non rejection of the null hypothesis indicates that the instruments used are valid.

The autocorrelation of the residue was also tested, in other words, $E[\varepsilon_{it}\varepsilon_{is}] = 0$, for $i = 1, \dots, N$ e $s \neq t$. As the term ε_{it} represents the sum of two terms of error ($\varepsilon_{it} = u_i + v_{it}$), u_i is, by definition, autocorrelated, due to its characteristic of representing fixed effects of status. However, it is worth pointing out that the method described by Arellano and Bover [33] eliminates this problem source.

Results

There is a consensus that until the early 1970s only 1% of the Legal Amazon Region had been subjected to deforestation. As shown in Table 1, 67.54% of the area had forest coverage in 2000. This shows that between the early 1970 and the year 2000 not only was deforestation accelerated but it also became more widespread, reaching into extensive areas of the region.

Between 2000 and 2004 (the period under study in this paper) the deforested area rose from 18,226 Km^2 a year to 27,429 Km^2, a growth rate of over 50%. In global terms, this meant 1.76%-reduction of the remaining forest coverage.

Table 1: Evolution of forest coverage and deforestation in the Amazon

Year	Estimated remaining forest coverage in the Amazon (Km^2)	Percentage of forest coverage*	Deforested area(Km^2)
2000	3,524,097	67.54	18,226
2001	3,505,932	67.2	18,165
2002	3,484,727	66.79	21,205
2003	3,459,576	66.31	25,151
2004	3,432,147	65.78	27,429

Source: INPE (2006)

However, deforestation is not homogenous among the states that make up the region. Table 2 shows that the deforestation is more widespread in some states, while in others it is less so or even almost non-existent, such as the case of State of Amapá.

The deforested area in the states of Mato Grosso and Pará correspond to over 70% of all the deforested area in the Legal Amazon Region. Only the state of Mato Grosso is responsible for around 40% of the total deforestation in the nine states analyzed. This is because Mato Grosso is the southernmost state in the Amazonian Region. As it is near to the most dynamic states, there is an intense flow of occupation and, consequently, deforestation.

Table 2: Deforested area in the states of the Legal Amazon Region: 2000-2004 (km^2/year)

States	2000	2001	2002	2003	2004
Acre	547	419	730	885	769
Amapá	n/a	7	0	25	46
Amazonas	612	634	881	1,632	1,221
Maranhão	1,065	958	1,014	993	755
Mato Grosso	6,369	7,703	7,892	10,405	11,814
Pará	6,671	5,237	7,324	6,996	8,521
Rondônia	2,465	2,673	3,067	3,620	3,834
Roraima	253	345	84	439	311
Tocantins	244	189	212	156	158
Legal Amazon Region	18,226	18,165	21,205	25,151	27,429

Source: INPE (2006)
n/a = not available.

Table 3 shows the descriptive statistics concerning deforestation and variables that cause it. The average area of deforestation per municipality during the period under study was 735.99 Km^2. From this value it is possible to obtain the mean deforestation per city for each year, which is 147.19 Km^2.

Table 3 shows that some variables in the equation (7) are null in some cities of the Amazon, including the deforestation (the interested variable in this paper). The non-existence of deforestation in unthinkable, but we can imagine that there are deforested areas that are not detected by satellites because the areas are relatively small. Furthermore, in accordance with Homma [36], in some districts of the Amazon there is a practice known as "quebradão" (breakage), which consists of removing vegetation that lies closer to the soil, thereby leaving the taller trees intact. This is another instance that the satellite sensors do not detect, thereby underestimating the extent of deforestation.

Table 3: Descriptive Statistics of the Variables of the Model (given at a municipal level)

Variable		Mean	Standard Deviation	Minimum	Maximum
Deforestation (Km^2)	Overall	735.9908	1064.669	0	12,194.9
	Between		1057.464		
	Within		128.1961		
Municipal income (R$)	Overall	40534.64	195701.4	67.42	3,951,822
	Between		194919.9		
	Within		14842.46		
Population (unities)	Overall	27198.3	85783.82	697	159,255
	Between		85513.76		
	Within		5251.312		
Rural credit (R$)	Overall	4534868	1.36E+07	500	2.12e+08
	Between		1.16E+07		
	Within		6384994		
Expenditure on Agriculture (R$)	Overall	195828.6	608304.2	0	1.41e+07
	Between		467184.5		
	Within		323082.8		
Expenditure on transport networks ($)	Overall	671350.3	2485601	0	6.93e+07
	Between		1949565		
	Within		1221277		
Price of crops - excluding soybeans (price index)	Overall	1.42953	1.041368	0	33.5054
	Between		0.828447		
	Within		0.631536		
Price of soybean (price index)	Overall	0.089066	0.190782	0	0.79002
	Between		0.149376		
	Within		0.118774		
Price of meat (price index)	Overall	659.49	104.05	49.75	789.55
	Between		99.328		
	Within		75.55		

Source: Data generated in this research

The Dynamic model (GMM) and the Fixed Effect model were run and the results appear in Table 4. The reason for running the Fixed Effect model is the fact that Chow test proves the existence of unobservable individual effects among the cities where deforestation is increasing. The test was significant, thus assuming the presence of fixed effects, which are the specific conditions of the production area. These are not observed and have a direct effect on deforestation. However, most of the coefficients estimated by the Fixed Effect model are not statistically significant. Besides the constant term, the only statistically significant variables are the expenditure on transport and the price of meat. As the fixed effect model shows the short term effects, it may be that the other estimated variables actually have a long term relationship. Thus, the dynamic model appears to be of a greater explanatory capacity.

Table 4: Result of estimated parameters

	Model	
	Dynamic (GMM)	Fixed Effects
Deforestation$_{t-1}$	0.75204* (3.57)	
Rural credit$_{t-1}$	0.087292* (5.10)	-0.0026262 (-0.08)

Expenditure on Agriculture $_{t-1}$	-0.04347* (-4.51)	-0.0085942 (-0.57)
Expenditure on Transport $_{t-1}$	0.088637* (7.11)	0.0559308* (2.94)
Price of Meat	0.343815* (12.94)	0.233301* (3.12)
Price of Crops (excluding soybean)	0.69604* (8.08)	0.0903304 (0.92)
Price of Soybean	0.502222* (7.03)	0.1643029 (1.75)
Constant		3.244669* (3.17)
Chow Test		47.82*
Hansen J Statistic	4.27	
Serial Correlation AR (1)	-5.02 (0.000)	
Serial Correlation AR (2)	2.21 (0.027)	

Note:***, ** and * mean a significance of 10%, 5% and 1%, respectively.

Based on the Dynamic Model results, the first step is to analyze the Hansen J Statistic. This shows whether the instrumental variables used in the regression are valid. If they are, the null hypothesis is rejected; if not, it is accepted. The third line from bottom to up in Table 4 shows that the Hansen J Statistic is not statistically significant. Therefore, the null hypothesis is rejected. Thus, the instruments included in the regression are valid. In their turn, the first and second order serial correlation tests indicate that the instruments are valid because they are not correlated with the term of error.

As shown in the literature, there are several causes of deforestation, with the caveat that some of them are more common in some states than in others. However, there is a common denominator that lends support to this study: deforestation occurs because farmers wish to use the land for crops and livestock. Furthermore, the estimated coefficient for lagged deforestation is statistically significant, suggesting that the dynamic model is appropriate. This shows that there is inertia in deforestation, what may be directly linked to the fact that deforestation is an activity that requires few resources and that there is a local population that specializes in doing it. Thus, irrespective of the stimuli of prices and policies, deforestation exists. Moreover, there is a tradition embedded in the culture of the local population that ownership of the land is not recognized until the forest has been removed, and this encourages deforestation.
The estimated coefficients concerning public policies (rural credits, government expenditure in agriculture and transport) are statistically significant. However, the negative sign of the coefficient for government expenditure in agriculture is not in accordance with the one expected. As stated by Gasques [37] this form of expenditure comprises many functions, which impact the behavior of the farmer differently, and one of the farmer's many activities is deforestation. In addition, other papers, such as Prates and Serra [38], have found no relationship between government expenditure on agriculture and deforestation, which leads one to believe that this expenditure, given its many forms and functions, does not encourage deforestation. Meanwhile, the signs of the coefficients concerning rural credits and government expenditure in transport are in accordance with expectations. The amounts allocated both for credits and the transport networks make feasible the deforestation. But the government expenditure in transport impacts deforestation with a two-pronged effect. Firstly, it offers access to previously isolated or inaccessible areas; secondly, it results in a fall in the logistical cost of transporting both materials and crops and livestock. The result of these two vectors is expansion into new areas and to maintain or intensify deforestation.

The coefficients concerning the price variables are also statistically significant and all the signs are as expected. As can be seen from the model, these variables are contemporaneous with deforestation. This is justified by the fact that the farmer decides to deforest the area when he plans to expand his activities, because deforestation precedes planting crops or raising livestock on that land. Thus, when the farmer learns of prices that will encourage him to expand agriculture, he begins to clear the land in order to obtain a profit in the future.

As the coefficients were estimated by the variables in logarithmic form, their estimates supply the elasticities. Among prices, the one with most impact was the crops index, followed by soy and finally meat prices.

As the scale of analysis is the Legal Amazon region, not all the states that make up this region are planting soybean. Therefore, its impact is lower than the impact of crop prices. This result could be different if the scale of analysis is at the state level, because the price of soy would have a higher impact in some states. The same could be said for the price of meat[39-42].

Conclusion

This study analyzed deforestation from the perspective of the farmer, who is a maximizing agent and therefore will react to incentives. The farmer makes his decision to deforest land based on the parameters of choice, such as the prices of the goods to be produced (crops and livestock) and production costs, in addition to other incentives that will lead him to produce agricultural goods.
As the behavior of the farmer is based on the price system, he will continue deforestation as long as the market is favorable. The adoption of such policies only makes sense if the financial rewards are equivalent to other economic activities that the farmer might undertake after deforesting the land. If he is unable to make a profit, all attempts will be in vain.
Concerning public environmental policies, the government has control of elements that indirectly affect deforestation. This is not the expenditure on agriculture but rather rural credits and expenditure on the transport networks. As for rural credits, the government can limit them to activities that do not result in increased deforestation by stimulating the reoccupation of degraded areas.

Finally, by not investing in the transport system in order to slow down deforestation, the government would be neglecting the infrastructure of communities and the people who live there, and this is inconceivable. Even now in the twenty-first century access to many areas of the Amazon is extremely precarious and undoubtedly the transport system required many improvement to increase the standard of living of the people who inhabit the region. To say that the Amazon is a demographically empty space is not to know the actual conditions of the region, although it is true to say that a large area of the region is sparsely populated. This means that it is possible to choose where to build roads taking environmental criteria into account, reducing the environmental impact of deforestation in comparison with other areas. On this subject, it is worth pointing out the importance of the Ecological Economic Zoning project in the region and its execution at various government levels.

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