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ON

ENVIRONMENT

ALEXIS TORÍBIO DANTAS

WALDEMAR KOZIOŁ

RENATA SIUDA-AMBROZIAK (EDS.)

UNIVERSITY OF WARSAW

UNIVERSITY OF WARSAW
FACULTY OF MANAGEMENT

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DEFORESTATION AND VIOLENCE IN BRAZIL[1]

Carlos Eduardo Frickmann Young[*]
André Albuquerque Sant'Anna[**]

INTRODUCTION

Deforestation in Brazil is deeply rooted in the process of land property accumulation that, in Latin America, is strongly correlated to rural conflicts and the expansion of agricultural settlements in what is the so-called "agricultural frontier". However, in the academic literature, deforestation and rural conflicts tend to be dealt with separately, despite both being linked to a fundamental feature of the institutional framework of Brazilian land: the poor definition of property rights.

The literature on deforestation usually focuses on its economic causes. On the one hand, there are perverse incentives caused by public policies aiming at the "development" of the region: fiscal incentives, credit subsidies, infrastructure investments, privatization "for free" of extensive public lands. On the other hand, there are economic incentives provided by the increasing profitability of activities associated with deforestation (unsustainable logging, cattle ranching, cultivation (Fearnside, 1992; Schneider, 1994; Ozorio de Almeida, Campari;

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[*] Carlos Eduardo Frickmann Young – PhD in Economics, Associate Professor at the Institute of Economics of the Federal University of Rio de Janeiro (IE/UFRJ) and researcher at the National Science and Technology Institute on Public Policies, Strategies and Development (INCT-PPED). Coordinator of the Environmental Economics Research Group (GEMA) at the Federal University of Rio de Janeiro.
E-mail: carloseduardoyoung@gmail.com.

[**] André Albuquerque Sant'Anna – PhD student at the Federal University of Rio de Janeiro and economist at the National Bank of Economic and Social Development (BNDES).
E-mail: andre.santanna@bndes.gov.br.

1995; Young, 1997; Margulis, 2003; Nepstad *et al.*, 2006, 2009; Celentano, Veríssimo, 2007; Sant'Anna, Young, 2010).

One possible way to theoretically link rural conflicts and natural resource depletion in the same model is given by Hotte (2001). In that paper, a Stackleberg game is proposed, where each agent makes an effort to evict/expropriate each other. The central argument in this paper is the role of distance to the state capital city, allegedly, where the courts are. It is shown that conflicts related to land property rights play a major role in the exhaustion of a natural resource. Another model of rural conflict is presented by Alston *et al.* (1999). The outcomes, violence and expropriation efforts are a result of a game played by farmers and squatters. These authors do not neglect these effects on forests. As it is clearly stated, "some landholders deforest as a means to better secure their land" (Alston *et al.*, 2003: 22).

In this paper, we propose an empirical model that aims to test whether deforestation is linked to violence in Brazil. In section 2, we discuss how the process of deforestation is linked to violence. More specifically, we show that an institutional framework conducive to the lack of well-defined property rights leads to a process of land accumulation that is prone to the occurrence of deforestation as well as land conflicts. In order to empirically test this relationship, section 3 presents an analysis crossing data for deforestation and homicide rates, used as *proxy* for land tenure conflicts in the Brazil. The results carried out using an instrumental variable for deforestation showed that these two variables are highly associated, independently of the functional forms tested for the regression analysis, providing robust support for the model's predictions. Section 4 presents the main conclusions of this paper.

THE PROCESS OF DEFORESTATION AND VIOLENCE

Historically, the evolution of Brazilian rural sector was marked by two distinguished features. On the one hand, land is highly concentrated. Since colonial times, agriculture in Brazil has been established mainly by plantation cultures that require vast amounts of land. Furtado (1959) describes how the Brazilian economy evolved along the different cycles of resource exploration. According to Engerman and Sokoloff (1997), factor endowments available in the country are central to explaining structural inequality, which is a determinant of bad ins-

titutions, low human capital investment and, therefore, underdevelopment. On the other hand – and related to high land inequality – the rural sector's expansion in Brazil has been mainly over an extensive margin. Despite productivity gains observed in the last years, the process of rural extension has followed the same path since colonial times: the expansion of the agricultural frontier into forest areas has been used as a 'safety valve' to accommodate landless farmers. Therefore, forest areas have been reduced considerably in the South-East, South and part of the North-East regions, where agricultural activities have been established for a long time[2]. Nowadays, the frontier of expansion is mainly in the Amazon forest.

This process is generally driven by squatters that deforest areas in order to transform them into pasture. It happens because the legal and institutional framework that deals with land occupation in Brazil is flawed. As property rights are ill defined, especially at the frontier, there are perverse incentives to clear land. As a cleared plot of land is transformed into pasture, it is possible to claim for land titling on the basis of a productive use of land. Therefore, the issue of the privatization of land ownership is particularly important, and is a major issue in the debate about the institutional causes of deforestation.

In such an institutional environment, a plot of pasture land has a higher probability of being titled than a plot of forest. Therefore, the private value of a forest is much less than that of a pasture. Thus, the possibilities of capital gains with re-selling the land add fuel to the race for property rights, and deforestation is a main source of enforcing land claims: the actual productivity of the economic activity carried out after deforestation may be low, but the asset value increases by the expectation of higher land prices (Ozório de Almeida, Campari, 1994). In other words: "Rather than the agricultural suitability of land and settlers, the problem is better understood by focusing on the supply and demand for property rights" (Mueller *et al.*, 1994: 274).

Hence, when squatters go into the forest, clear land and start cattle ranching, there is an overall expectation of an increase in land prices. By that time, a conflict is established over who is to appropriate this surplus: farmers and/or *grileiros* are attracted by this expectation of capital gains. At this moment, con-

[2] Dean (1997) describes in details how this process leads to Mata Atlântica (Atlantic rainforest) devastation.

flicts over land claims arise: "The movement of expansion of [rural] firms pushes small producers to less fertile or less accessible land through a violent process of expulsion and expropriation" (Becker, 1991: 30).

This process is more violent the lower the presence of the state, in the sense of law enforcement and institutional capacity[3]. Where the state is more present, there is less deforestation because it is foreseen that the creation of property rights is not so feasible and even when it occurs, the process of land acquisition might happen through market transaction and not with the establishment of violent conflicts.

In short, the process of deforestation occurs because there is a lack of institutional governance that gives possibilities to claim for land titling by clearing land. This gives rise to an expectation of an increase in prices that attracts farmers or *grileiros*, giving rise to violent conflicts in order to expel squatters. This framework allows us to test empirically the relation between deforestation and violence in Brazil.

VIOLENCE AND DEFORESTATION IN THE BRAZILIAN AMAZON: EMPIRICAL ANALYSIS

Methodology

The focus of this section is to analyze the relation between deforestation and homicide rates in the Brazilian municipalities between 2005 and 2008. In the previous section, it is argued that violence, as measured by homicide rates[4], should be related to deforestation, as measured by homicide rates. Thus, the basic model can be described by the following equation:

$$\text{Homic}_i = \beta\ \text{Deforest}_i + \alpha' X_i \varepsilon_i$$

The parameter of interest is β. If the coefficient is positive and statistically significant, it should be interpreted as evidence that deforestation and violence are indeed linked in Brazil. However, there is a potential endogeneity between

[3] This argument links with Besley and Persson's (2011) analysis of development giving a central role to state capacity.

[4] Alston and Mueller (2010) present a related argument and use the presence of priests as an instrument to identify potential conflicting areas.

these variables. It is hard to assess causality and also there is a potential omitted variable bias. Moreover, OLS estimation would be biased in such a situation.

Potential Endogeneity and Instrumental Variable

In order to address this problem, we suggest the mean altitude of a municipality as an instrument for deforestation. Brazil has an old Forest Code that dates back to 1934 and reformed after that in 1965 and 2012.

The Brazilian Forest Code introduces a concept of Permanent Preservation Area (PPA), where landowners are forbidden to suppress vegetation. Among these areas, every hill with slopes above 45^{o} is considered a PPA and therefore it is not legal to deforest. It is must be remarked that this legal restriction dates back to 1965, when deforestation was not seen as a major problem by any sector of society.

Although average altitude does not necessarily translates into hills with high slopes[5], Figure 1 shows that there is a negative relationship between altitude and deforestation. There is no *a priori* reason to believe that altitude is related to violence by any channel other than deforestation. Thus, in this paper it is believed altitude is a good instrument for deforestation in order to address endogeneity problems with homicide rates.

Data and Summary Statistics

In order to evaluate the theoretical prediction, we use five different sources of information. The data on deforestation were collected at the Ministry of Environment, for the period between 2005 and 2008. Data on deforestation were divided by the total area of the municipal unit. As such, it is an alternative to control for the total area instead of inserting this measure in the regression.

Homicide rates in each municipality, measured as a proportion of 100,000 inhabitants, were used as proxies for rural violence. The data was collected at the site of the Health Ministry of Brazil. The quantity of rural conflicts, as published by the Catholic Church Land Commission (Comissão Pastoral da Terra), should be a more realistic proxy of the rural violence in the Amazon. Nevertheless, as shown by Araujo *et al.* (2009), homicide rates and rural conflicts are

[5] Indeed, a significant part of Brazil is in high and relatively flat, as the Planalto Central.

positively and significantly correlated. Moreover, homicide rates are considered a better proxy of *potential* conflicts in a given county than actual rural conflicts (Alston & Mueller, 2012). Thus, in this paper, we decided to use the homicide rates, because they are more widespread both geographically and temporally, allowing for a more complete database. Besides, we use other data as control variables: initial land distribution, measured by the Gini index from the Agricultural Census of 1996; initial income *per capita*; population density (both evaluated at 2000); a variable associated with land reform (from 1998 to 2008) and ratio of families ran by women (in 2000)[6].

The final data basis consists of 5,505 municipalities in Brazil (Table 1), which depicts the main statistical values.

TABLE 1. DESCRIPTIVE STATISTICS

	Homicides	Deforestation	House_ Woman	Density	Gini	Land_ref	Ln_income
mean	13.09	0.02	5.01	96.11	0.56	0.02	4.98
p50	9.29	0.00	4.90	23.25	0.56	-	5.07
p10	-	-	2.87	3.94	0.49	-	4.19
p90	30.80	0.05	7.23	113.42	0.63	0.06	5.69
p99	65.46	0.17	9.49	1,657.88	0.72	0.39	6.10
N	5564	5507	5507	5507	5505	5507	5505

As can be seen from Table 1, there is a sizeable degree of heterogeneity for deforestation and homicide rates across Brazil's counties. The average deforestation rate is 2% of a county's total area, whereas the 99th percentile for deforestation rate was 17% in a single year. As for homicide rates, one can find more than 10% of municipalities with zero murders and the p99 with more than 65 people out of 100,000. Figure 2 plots homicide rates and deforested area. It is clear that there are important outliers.

Empirical Results

Due to the above endogeneity problems, OLS estimators would be biased and thus we adopt a two least squares estimation with altitude as an instrumental variable for deforestation. The first two columns of results on Table 2 show

[6] See the appendix for details on data description.

TSLS results. In (2), we introduce dummies for the different biomes that exist in Brazil: Amazonia, Cerrado, Caatinga, Mata Atlântica, Pampa and Pantanal, in order to test if there are sub-national specificities.

TABLE 2. EMPIRICAL RESULTS

Dependent Variable: HOMICIDE RATE			
Methods: Two Least Squares (TSLS) and Tobit with Endogenous regressors			
Variable	(1) - TSLS	(2)-TSLS	(3) - Tobit
C	-197.80	-180.47	-210.90
	(20.36)*	(15.74)*	(19.21)*
DEFORESTATION	479.15	297.16	348.46
	(65.49)*	(50.74)*	(61.75)*
LN_INCOME	69.60	57.22	62.54
	(8.17)*	(6.11)*	(7.45)*
LN_INCOME^2	-6.05	-4.82	-5.12
	(0.81)*	(0.61)*	(0.74)*
HOUSE_WOMAN	1.61	1.25	1.63
	(0.19)*	(0.14)*	(0.17)*
GINI	0.09	30.26	41.29
	(8.44)	(4.79)*	(5.85)*
LAND_REF	-13.15	-5.21	-5.37
	(3.59)*	(2.36)**	(2.87)***
DENSISTY	0.006	0.004	0.004
	(0.001)*	(0.0004)*	(0.001)*
Biomes Dummy	No	Yes	Yes
Obs	5505	5268	5268
F-statistic	54.81	54.93	
Prob(F-statistic)	0	0	
Wald			657.71
Prob>Chi			0

Instrumented: Deforestation.
Instruments: Ln_Income; Ln_Income^2, House_woman, Gini, Land_Ref, Altitude.
* significant at the 1% level, ** significant at the 5% level, *** significant at the 10% level. The values in parentheses are the standard errors.

In column (3), we present a Tobit estimation with endogenous regressors as there is a significant number of zeros in the homicide rates, as can be seen in Figure 2.

Thus, a model was developed, based on more than 5,200 *municípios* in all Brazilian states, and the dependent variable was the average homicide rate between 2005 and 2008. The results of the regressions are presented below.

All estimated models have evidenced a positive relation between deforestation and homicide rates, even after controlling for a number of variables. The coefficient on deforestation is statistically and economically significant in the three results presented above. Taking the coefficient on equation (2) and evaluating at the sample mean, for example, it implies that average deforestation – 2% – is associated with a homicide rate of 5.11 murders per 100,000 inhabitants. This represents 39% of the average homicide rate.

Aside from deforestation, control variables present expected signs and are statistically significant for the range of equations with biome dummies. Income per capita corresponds to the behaviour predicted by the theory; the positive and negative coefficients for the linear and quadratic variables respectively correspond to the fact that, as pointed out by Fajnzylber and Piquet (2001), income has positive effects on crimes against property and negative on crimes against individuals. The fraction of households ran by women is positively associated with homicides, as also stated by Fajnzylber and Piquet (2001). Land inequality has a positive coefficient that gains significance with the introduction of biome dummies. It has a high economic significance. An evaluation at the sample mean show that average Gini is associated with a homicide rate of 16.9 murders per 100,000 inhabitants. The amount of families in expropriated land (divided by total municipality area), as a measure of land reform, has negative coefficients. It may be associated with a reduction in rural violence once the process of land reform has been established. Finally, population density is introduced in order to control for more urban municipalities that have high homicide rates, which are not related to land property rights disputes. Its coefficients are also positive and robust, though with small economic significance.

As shown in Figure 2, there are large outliers both in average homicide rates and in deforestation. Thus, as an additional check of our results, Table 3 shows the same models as in Table 2 with the exception that we drop outliers above the top percentile for homicide rates and deforestation.

TABLE 3. EMPIRICAL RESULTS

Dependent Variable: HOMICIDE RATE			
Methods: Two Least Squares (TSLS) and Tobit with Endogenous regressors			
Variable	(1) - TSLS	(2)-TSLS	(3) - Tobit
C	-162.88	-152.90	-178.20
	(17.39)*	(13.05)*	(16.15)*
DEFORESTATION	509.78	268.13	320.91
	(80.39)*	(55.58)*	(68.51)*
LN_INCOME	57.44	48.66	52.79
	(6.97)*	(5.10)*	(6.31)*
LN_INCOME^2	-4.94	-4.13	-4.33
	(0.69)*	(0.51)*	(0.63)*
HOUSE_WOMAN	1.39	1.08	1.40
	(0.16)*	(0.12)*	(0.15)*
GINI	-2.71	29.03	38.80
	(8.37)	(4.21)*	(5.21)*
LAND_REF	-6.77	-1.63	-1.37
	(2.88)**	(1.88)	(2.33)
DENSISTY	0.005	0.004	0.004
	(0.0004)*	(0.0004)*	(0.001)*
Biomes Dummy	No	Yes	Yes
Obs	5399	5171	5172
F-statistic	53.42	58.52	
Prob(F-statistic)	0	0	
Wald			683.60
Prob>Chi			0

Instrumented: Deforestation.
Instruments: Ln_Income; Ln_Income^2, House_woman, Gini, Land_Ref, Altitude
* significant at the 1% level, ** significant at the 5% level, *** significant at the 10% level. The values in parentheses are the standard errors.

As can be seen from Table 3, the main results remain essentially the same. The coefficient on deforestation is slightly reduced, without a significant loss of economic significance. The only variable that shows difference is land reform that loses confidence.

Regional Results

In the previous section, it has been shown that there exists in Brazil a robust relation between deforestation and violence, as measured by homicide rates. In this section, we provide evidence for each Brazilian biome. Table 4 presents the main results based on Two Least Squares Estimation. Although only deforestation coefficients are presented here, the same control variables have been utilized.

TABLE 4. EMPIRICAL RESULTS BY BIOMES – OLS ESTIMATION

Dependent Variable: Homicide Rate						
Variable	Amazonia	Pantanal	Mata Atlântica	Caatinga	Cerrado	Pampa
DEFORESTATION	30.23	-785.50	-4423.34	-219.09	181.14	188.75
	(7.12)*	(1315.85)	(2516.76)***	(224.85)	(28.44)*	(352.18)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Obs	768	25	2813	1165	1289	161
F-statistic	83.72	0.86	4.84	25.43	40.87	3.85
Prob(F-statistic)	0.00	0.54	0.0001	0.00	0.00	0.0013

* significant at the 1% level, ** significant at the 5% level, *** significant at the 10% level. The values in parentheses are the standard errors.

The results above point to different dynamics according to the region. As expected, biomes located at the agricultural frontier (Amazonia and Cerrado) are those where deforestation implies a positive and statistically significant relation with violence. The region surrounded by Mata Atlântica biome, where the relation is negative, is, in fact, the most urban region in Brazil. Then, the main drivers of violence are not related to agriculture and hence to deforestation. Interestingly, except for Pantanal, which has a very small sample, in every biome

there is a positive and strong relation between land inequality and violence. This is a remarkable result that has much to say about the historical pattern of land occupation in Brazil.

CONCLUSION

Brazil has many challenges concerning the improvement of living conditions of its poor population, especially the rural poor ("the poorest of the poor"). However, the expansion of the agricultural frontier cannot be perceived as a solution for that, not only because this would endanger even further the richest biodiversity on the planet but also because deforestation is not a source of development. Previous studies have shown that income per capita and the Human Development Index are either negatively or non-significatively associated to deforestation (Young, 2006). Other studies have shown other social and economic problems linked to the conversion of forests into pasture or agricultural land (UNDP, 2010).

This paper examined one of these issues: the violence associated with the deforestation process. To halt the process of deforestation is also to impose governance in the frontier areas. After all, both derive from the historical process of land occupation in Brazil: as property rights are not well defined, deforestation arises as a measure to acquire property rights that could be efficient from the private perspective, but that causes profound social and environmental externalities.

The lack of a good structure of governance to reduce uncertainties regarding property rights is also a main cause for the country's high rate of homicides. As there is not a good definition in relation to property rights, there is an incentive for different groups to organize in order to claim for land titles. Such a situation is prone to generate violent conflicts over land.

As the Brazilian legislation favours "productive" (i.e., cattle ranching or cultivation) use of land when conceding land titles, and the conservation of native forests and associated ecosystem services are not yet recognized as productive use, the decision to clear land is strategic to acquire property rights. Thus, the decision to deforest arises as a rational response to the incentives provided by the institutional framework. Additionally, for the landholder, cleared land

indicates to possible squatters that it is of their interest to keep the property, even with the use of force. On the other hand, squatters perceive deforested areas to have more value than forested ones and, given their opportunity cost – agricultural wages – they are also more prone to act violently in cleared lands.

It is this process of land occupation, based on poor property rights, that creates a positive association between deforestation and violence in rural Brazil. Clearly, it is a case of negative externalities where there is much room for efficiency gains. Thus, it is urgent to improve the design of the institutional framework, reducing the incentives to clear land that are linked to speculative behaviour looking for land price increases.

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Data description

The variables that were introduced in the database are:

GINI – LAND GINI INDEX: This index measures the concentration of the land distribution. Source: Naritomi *et al.* (2009).

INCOME PER CAPITA: Estimated GDP per capita, per municipality, at 2000 prices. Source: IPEADATA – Database maintained by the Institute of Economic Applied Research.

HOMICIDE RATE: Number of homicides per 100.000 inhabitants. Source: DATASUS - Database maintained by the Ministry of Health.

SINGLE MOTHERS (WOMEN WHO ARE THE HEAD OF FAMILY, NO SPOUSE, AND WITH CHILDREN UNDER 15 YEARS OLD): Number of women who run a family, being the main source of income, no spouse and with children under 15 years old. Source: IPEADATA – Database maintained by the Institute of Economic Applied Research.

NUMBER OF FAMILIES IN LAND REFORM SETTLEMENTS: Total number of families in settlements during the whole year in the municipality. Source: IPEADATA – Database maintained by the Institute of Economic Applied Research.

ALTITUDE OF THE MUNICIPALITY: Source: IPEADATA – Database maintained by the Institute of Economic Applied Research.

BIOME AREA DEFORESTED FROM 2002 TO 2008: This data represents the yearly deforestation from 2002 until 2008. Source: Ministry of Environment.

Figure 1

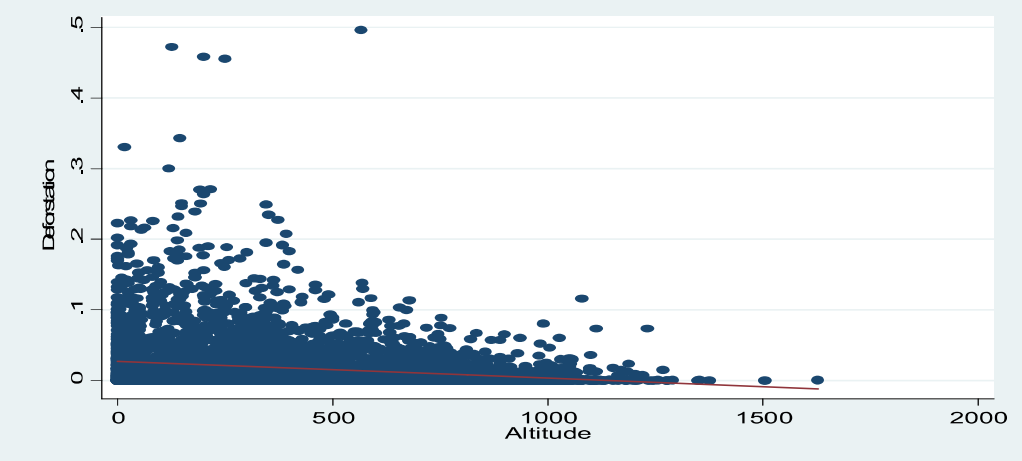

Figure 2

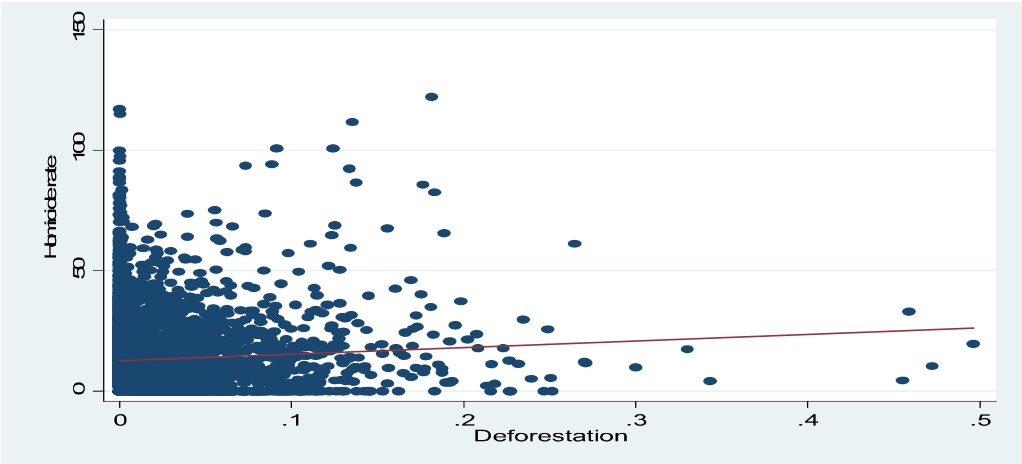

Figure 3