Amazon Monitoring and Deforestation Slowdown: The Priority Municipalities

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Abstract

This paper measures the impact of the Priority Municipalities, a policy that increases monitoring on municipalities listed, on Brazilian Amazon deforestation. This policy, theoretically, applies a cost to bad environmental behavior in a more centralized way, as the sanction shifts from the household to the municipality level. Anecdotal evidence also suggests that priority status may have generated political pressure for politicians, credit agents, and commodity industry agents. We find an important and negative effect of Priority Municipalities on deforestation. We also find that, when controlling for the monitoring intensity, the priority status has zero effect, which means that the other mechanisms (such as political pressure and other economic sanctions) seem to have no significant effect on deforestation.

RESUMO

Este trabalho mede o impacto dos Municípios Prioritários, uma política que aumenta a fiscalização nos municípios listados, sobre o desmatamento da Amazônia. Esta política, em tese, aplica um custo para desvios de conduta ambiental de uma forma mais centralizada, já que a sanção passa do nível do estabelecimento ao nível do município. Evidências anedóticas também sugerem que o status de prioridade pode ter gerado pressão política para os políticos, agentes de crédito, e os agentes do setor de commodities. Encontramos um efeito importante e negativo dos municípios prioritários em desmatamento. No entanto, ao controlar pela intensidade no monitoramento, o efeito sobre o desmatamento passa a ser zero, o que significa que os outros mecanismos (como pressão política e outras sanções econômicas) parecem não ter qualquer efeito significativo.

Keywords: Deforestation, Priority Municipalities, Monitoring
Palavras-Chave: Desmatamento, Municípios Prioritários, Fiscalização
JEL codes: Q23, Q24, Q28
Área Anpec: Economia Agrícola e do Meio Ambiente

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1. Introduction

The Amazon is the world's largest rainforest, stretching over an area of more than 5 million square kilometers. In Brazil, the forest originally occupied over 4 million square kilometers – an area equivalent to almost half of continental Europe. Today, around 80% of the Brazilian Amazon remains covered by native vegetation, making it an important carbon sink. Moreover, the Brazilian Amazon holds unique biodiversity and 20% of the planet's fresh water (MMA (2012)). Protecting the Amazon from illegal deforestation and enforcing environmental regulation in the region is a challenge as immense as the forest itself. Yet, the pace of forest clearings appears to have lost momentum in recent years. Amazon deforestation rates escalated in the early 2000s, but after peaking at over 27,000 square kilometers in 2004, decreased sharply to about 5,000 square kilometers in 2011 (INPE (2012)).

There is a substantial stream of literature documenting the drivers of deforestation in the Amazon, such as population, road density, and agroclimatic characteristics (Pfaff (1999), Chomitz and Thomas (2003), Reis and Guzmán (1994), Reis and Margulis (1991)). However, there is scarce empirical evidence on the immediate drivers of the recent Amazon deforestation slowdown. Assunção et al. (2012) show that, even when controlling for commodity prices and relevant fixed effects, conservation policies introduced in the second half of the 2000s helped avoid over 60,000 square kilometers of forest clearings. Hargrave and Kis-Katos (2012) and Assunção et al. (2013) find a negative relationship between the number of fines and deforestation in the Amazon. We contribute to this literature by focusing on the effect of a specific monitoring and law enforcement policy.

This paper evaluates the impact of the priority municipalities policy introduced in the late 2000s. Implemented by the Ministry of the Environment (MMA) as a means to target law enforcement efforts, this policy introduced differential treatment in terms of economic and political sanctions for municipalities that exhibited a recent history of intense deforestation activity. Priority status was determined based on three municipality-level criteria: (i) total deforested area; (ii) total deforested area over the past three years; and (iii) increase in the deforestation rate in at least three of the past five years. The priority municipalities policy was implemented as part of the second phase of the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (PPCDAm), the pivotal governmental conservation policy effort of the mid-2000s. Launched in 2004, the PPCDAm integrated actions across different government institutions and proposed novel procedures for monitoring, environmental control, and territorial management.

The decree establishing the legal basis for the priority municipalities policy was passed in December 2007, and the first thirty-six municipalities to be added to the priority list were announced in January 2008. In March 2009, seven municipalities were added to the list, and, in March 2011, seven others were also added.

The priority municipalities were intended as targets for a more stringent system of deforestation monitoring and environmental law enforcement. Any rural establishment located within these municipalities could be called upon for registry update by the National Institute for Colonization and Agrarian Reform (INCRA), the agency responsible for rural households land titles. The Brazilian Institute for the Environment and Renewable Natural Resources (Ibama), which operates as the national environmental police and law enforcement authority, focused law enforcement activities on priority municipalities, combining information obtained from INCRA with satellite data on deforestation activity.

In addition, although there is no explicit mention of this type of administrative sanction in the legislation that regulates the implementation of the priority municipalities policy, anecdotal evidence suggests that priority status may have generated political pressure for politicians, credit agents, and commodity industry agents operating in priority municipalities. These pressures would result from changes in economic and political decisions related to deforestation activity. Examples include, but are not limited to, politicians pressuring farmers to comply with environmental legislation, big slaughterhouses refusing to buy meat from irregular producers, and bank managers facilitating access to credit to producers who comply with environmental legislation.

This paper aims at not only assessing the impact of the creation of priority municipalities on deforestation, but also identifying the mechanism through which the implemented policy was most effective. Did the policy affect deforestation solely through intensified monitoring and law enforcement, or did other political and economic sanctions also play a significant role?

We address these questions using a municipality-by-year panel data set from 2002 through 2011. Deforestation data is obtained from processed satellite imagery made publicly available by the National Institute for Space Research (INPE). We use a municipality fixed-effect model using the priority municipality status dummy as the independent variable of interest. We control for agricultural commodity prices, as well as for other relevant conservation policies, such as the extent of protected areas and the number of environmental fines applied by Ibama at the municipality level.

Results indicate that the priority municipalities policy significantly contributed to reduce deforestation after 2008. The effect is statically significant in most specifications, even when controlling for a municipality-specific time trend and other policies (except the number of fines applied by Ibama). Quantitatively, the policy avoided the clearing of 11,218 km^2 of forest area from 2008 through 2011. Total deforestation observed in the same period was 20,689 km^2, 35.1% smaller than in the absence of the policy.

However, when adequately controlling for the number of fines applied by Ibama, the effect of the priority municipalities disappears. We interpret this as an indication that the relevant mechanism for the priority municipalities policy impact is improved monitoring and targeting of law enforcement. Other potential mechanisms, such as political pressure and economic sanctions, seem to have no significant effect on deforestation when we adequately control for the sanctions directly applied by monitoring and law enforcement agents.

Our paper is related to two other branches of the economic literature. First, our results contribute to the literature on the evaluation of effectiveness of environmental monitoring and law enforcement. Gray and Shimshack (2011) provides a recent survey of this literature. Most studies refer to plant-level environmental performance, as captured by standard emissions or accidental discharges (see, for example, Epple and Visscher (1984), Magat and Viscusi (1990), Anderson and Talley (1995), Eckert (2004), Gray and Shadbegian (2005), Shimshack and Ward (2005), and Earnhart and Segerson (2012)). Our paper addresses a different dimension of environmental monitoring and law enforcement, focusing on the impact of a targeted law enforcement policy on deforestation.

Second, there is an important literature that discusses decentralized versus centralized provision of public goods (see Lockwood (2002), Knight (2002), Bardhan and Mookherjee (2000), and Besley and Coate (2003)). In this paper, we analyze a policy that, theoretically, applies a cost to bad environmental behavior in a more centralized way, as the sanction shifts from the household to the municipality level.

The rest of this paper is organized as follows: Section 2 discusses the institutional context in the time of the implementation of priority municipalities; Section 3 provides a detailed description of the data used in the paper; Section 4 explains the empirical strategy used to calculate the impact of priority municipalities on deforestation; Section 5 discusses the results of the paper; and Section 6 addresses the conclusions and policy implications of our results.

2. Institutional Context

Monitoring and law enforcement in the Brazilian Amazon is traditionally based on legislation written establishing rules to rural households. For example, farmers are required to keep at least 80% of their lands with native vegetation and to keep at least 15 meters os permanent protected areas near to rivers. Ibama uses these rules to classify certain deforested area as legal or illegal. The priority municipalities were the first attempt to shift the unit of analysis in the monitoring system and in the Ibama's law enforcement actuation from the household level to the municipality level, a more centralized way.

Since its creation in February 1989, Ibama has been responsible for environmental monitoring and law enforcement in Brazil. It both operates as an environmental police force, investigating environmental infractions and applying administrative sanctions, and executes environmental policy actions concerning environmental licensing, quality control, and impact, as well as the generation and spread of environmental information. As the country's leading figure in environmental monitoring, Ibama plays a central role in the control and prevention of Amazon deforestation.

The strengthening of command and control has been a key policy effort of the MMA since the launch of the PPCDAm in the mid-2000s. The creation of the priority municipality targeting system was an important component of the second phase of the PPCDAm. The signing of Presidential Decree 6,321 in December 2007 established the legal basis for singling out municipalities with intense deforestation activity and taking differentiated action towards them. These municipalities, classified based on their recent deforestation history, were marked as in need of priority action to prevent, monitor, and combat illegal deforestation. Any Legal Amazon municipality could be added to what became known as the "list of priority municipalities". Municipality-level selection criteria for this list were: (i) total deforested area; (ii) total deforested area over the past three years; and (iii) increase in the deforestation rate in at least three of the past five years. Exiting the list of priority municipalities was conditioned upon significantly reducing deforestation. Issued in January 2008, MMA Ordinance 28 listed the first thirty-six priority municipalities. Seven municipalities were added to the list in 2009, and another seven in 2011.

Differential action taken in priority municipalities largely consisted of more rigorous environmental monitoring and law enforcement. Ibama monitored the municipalities more closely and dedicated a larger share of its resources to them. Licensing and georeferencing requirements for rural establishments were harsher in priority municipalitites, and, in an effort to identify fraudulent documents and illegal occupations, private land titles were to be revised.

In addition to concentrating a large share of Ibama's attention and monitoring efforts, priority municipalities also became subject to a series of other administrative measures that did not necessarily stem from command and control policy. Although not officially established through legislation, these measures imposed an additional cost to being in the MMA's priority list. Examples include, but are not limited to, compromised political reputation for mayors of priority municipalities and economic sanctions applied by agents of the commodity industry.

3. Data, Descriptive Statistics, and Stylized Facts

This section introduces the data used in our empirical evaluation of Resolution 3,545, presents descriptive statistics, and discusses stylized facts to characterize aggregate trends for our variables of interest.

3.1. Deforestation

Data on deforestation is built from satellite-based images that are processed at the municipality level and publicly released by PRODES/INPE. Because PRODES data is reported annually, we first convert our municipality-by-month credit panel into a municipality-by-year credit panel. We define deforestation as the annual deforestation increment, that is, the area in square kilometers of forest cleared over the twelve months leading up to August of a given year.[1]

For any given municipality, cloud cover during the period of remote sensing may compromise the accuracy of satellite images, requiring images to be produced at a different time. As a result, image records for different years may span from less to more than twelve months. To control for measurement error, variables indicating unobservable areas are included in all regressions. This data is also publicly available at the municipality-by-year level from PRODES/INPE.

To smoothen the cross-sectional variation in deforestation that arises from municipality size heterogeneity, we use a normalized measure of the annual deforestation increment. The normalization ensures that our analysis considers relative variations in deforestation increments within municipalities. The variable is constructed according to the following expression:

$$Deforest_{it} = \frac{ADI_{it} - \overline{ADI}_{it}}{sd\left(ADI_{it}\right)} \tag{1}$$

[1]More precisely, the annual deforestation increment of year t measures the area in square kilometers deforested between the 1[st] of August of $t-1$ and the 31[st] of July of t.

where $Deforest_{it}$ is the normalized annual deforestation increment for municipality i and year t; ADI_{it} is the annual deforestation increment measured in municipality i between the 1st of August of $t-1$ and the 31st of July of t; and $\overline{ADI}_{it}$ and $sd\,(ADI_{it})$ are, respectively, the mean and the standard deviation of the annual deforestation increment calculated for each i over the 2002 through 2011 period. The variable ADI_{it} replaces $Deforest_{it}$ in robustness checks. Our sample does not include municipalities that showed no variation in deforestation throughout the sample years, as this variation is needed to calculate the normalized variable.

The final data set containing information on deforestation, rural credit, time, and geographic variables at the municipality-by-year level is used to estimate the effects of the credit restriction on deforestation. Again, we do not include municipalities crossed by the biome frontier. The full sample comprises X Amazon Biome municipalities.

3.2. Law Enforcement

We use the total number of fines applied as sanctions for environmental crimes in each municipality as a measure of the intensity of monitoring and law enforcement at the municipality level. The data are publicly available from Ibama.

It is worth highlighting that the knowingly low collection rates for environmental fines applied in Amazon municipalities do not interfere with our analysis (Hirakuri (2003), Brito and Barreto (2008), **?**, Brito (2009)). These fines are often accompanied by other sanctioning instruments that are more binding, such as seizure and destruction of production goods, tools and materials, and embargoes of production areas. Because panel data for the use of these instruments are not available, we use the number of fines as a proxy for command and control efforts as a whole. Essentially, we are interested in exploring fines as a means of capturing the effect of environmental police (Ibama) presence – not of the sanctioning instrument itself – on deforestation.

To maintain consistency across our panel data, we consider the PRODES year – August 1st, $t-1$ through July 31st, t – as the relevant unit of time in our sample. Thus, for each municipality, the total number of fines in a given year captures all fines applied in that municipality in the twelve months leading up to August of that year.

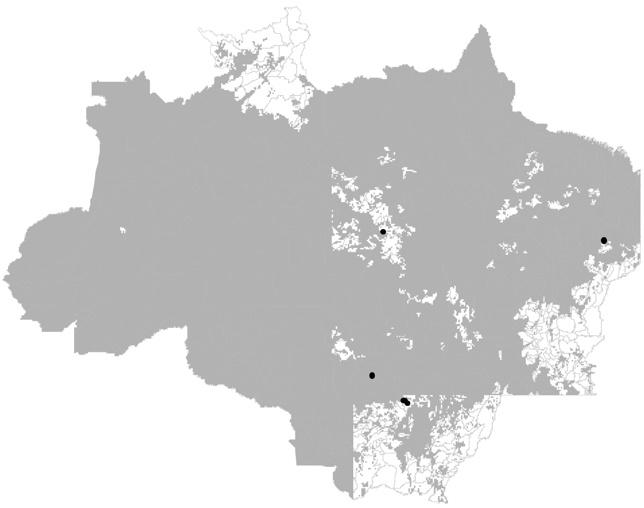
3.3. Cloud Coverage

Georeferenced data on deforestation activity produced by the satellite-based Real-Time Detection of Deforestation (DETER) system are used to identify deforestation hot spots and issue alerts that serve to target law enforcement activity. Figure 1 shows examples of maps containing both cloud coverage and alerts captured by DETER. In addition to portraying the high degree of within-year variation in DETER cloud coverage, the figure also clearly illustrates DETER's inability to detect land cover pattern in areas covered by clouds – typically, no deforestation activity is captured and no deforestation alerts are issued in these areas. This supports the perception that the allocation of Ibama personnel is directly affected by DETER cloud coverage, such that law enforcers are less likely to be present in areas that are systematically under greater cloud coverage.

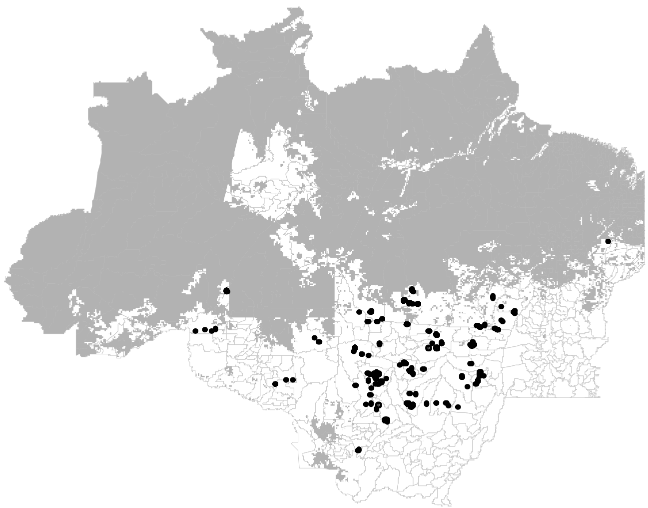
We are, then, interested in exploring how DETER cloud coverage affects Ibama presence in the Amazon. To do this, we use georeferenced data from DETER/INPE that map cloud coverage over the Amazon throughout the year. When visibility is at least partial, these maps show exactly which areas were covered by clouds (see Figure 1). When visibility is too precarious to derive information about land cover, however, no map is produced – we assume DETER cloud coverage to be complete in this case. We use the 15-day periodical data to calculate, for each sample municipality and year, average DETER cloud coverage for that municipality and year both in absolute (square kilometers) and relative (share of total municipality area) terms. Again, the relevant unit of time is the PRODES year. We use this constructed variable as an instrument for the number of fines applied to each Amazon municipality.

Figure 1: DETER Cloud Coverage and Deforestation Alerts

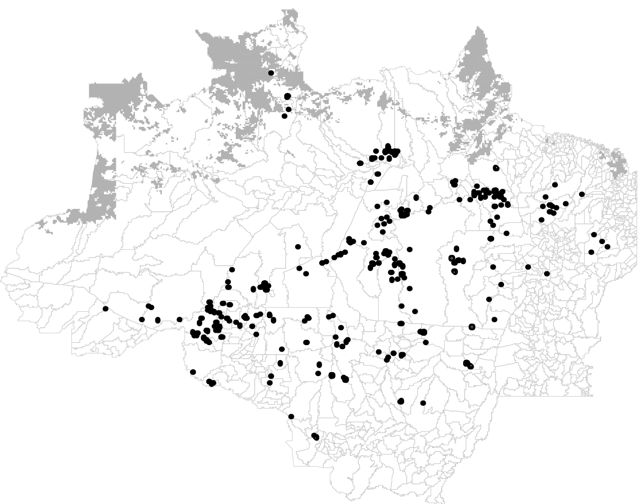
(a) January 2011



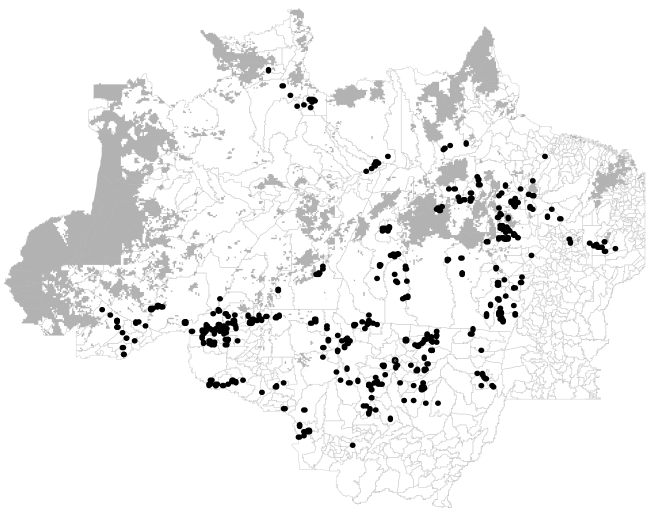
(b) April 2011

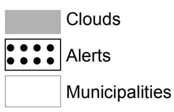


(c) July 2011



(d) October 2011





Notes: The figure illustrates the high degree of within-year variation in DETER cloud coverage and shows that, typically, no alerts are issued in areas covered by clouds.

Source: DETER/INPE.

3.4. Agricultural Output Prices

Agricultural prices are endogenous to local agricultural production. Thus, to control for fluctuations pressuring deforestation at the municipality level, we must construct output price series that capture exogenous variations in the demand for agricultural commodities produced locally. As argued in **?**, agricultural commodity prices recorded in the southern Brazilian state of Paraná are highly correlated with average local crop prices calculated for the Legal Amazon sample municipalities. Hence, we use the Paraná agricultural commodity price series as exogenous indicators of local market conditions within our empirical context. Prices for beef cattle, soybean, cassava, rice, corn, and sugarcane were collected at the Agriculture and Supply Secretariat of the State of Paraná (*Secretaria de Agricultura e do Abastecimento do Estado do Paraná*, SEAB-PR). Soybean, cassava, rice, and corn are predominant crops in the Legal Amazon in terms of harvested area. Although not a predominant crop in the region, sugarcane is also included to take into consideration the recent expansion of Brazilian ethanol biofuel production. Together, the five crops account for approximately 70% of total harvested area averaged across sample years.

The Paraná price series are used to build two variables of interest. The first of these variables, an annual index of crop prices, is constructed in three steps. First, we calculate nominal monthly price series for each calendar year-month and culture. Annual prices are deflated to year 2011 BRL and are expressed as an index with base year 2011.

Second, we calculate a weighted real price for each of the crops according to the following expression:

$$PPA_{itc} = PP_{tc} * A_{ic,2000-2001} \tag{2}$$

where PPA_{itc} is the weighted real price of crop c in municipality i and year t; PP_{tc} is the Paraná-based real price of crop c in year t expressed as an index with base year 2000; and $A_{ic,2000-2001}$ is the share of municipal area used as farmland for production of crop c in municipality i averaged over the 2000 through 2001 period.[2] This latter term captures the relative importance of crop c within municipality i's agricultural production in the years immediately preceding the sample periods. It thus serves as a municipality-specific weight that introduces cross-sectional variation in the commodity price series.

Third, we use principal component analysis on the weighted real crop prices to derive the annual index of crop prices. This technique allows the price variations that are common to the five selected crops to be represented in one single measure. The resulting index of crop prices captures the first principal component of the five weighted real prices. As the index maximizes the price variance, it represents a more comprehensive measure of the agricultural output price scenario for this analysis than the individual prices themselves. Moreover, by using the index of crop prices, which absorbs both cross-sectional and time-specific trends at the municipality level plausibly correlated with credit demand, we overcome an important empirical limitation.

The second variable of interest is an annual index of cattle prices, which is derived analogously to PPA_{itc}. However, as land pasture is not observable, in this case $A_{ci,2000-2001}$ is the ratio of heads of cattle to municipal area in municipality i averaged over the 2000 through 2001 period.

3.5. Rain and other policies

We include a series of variables to control for other potentially relevant determinants of deforestation, namely rainfall, and other conservation policies.

First, there is no consensus in the literature as to how deforestation and precipitation are related. On the one hand, forest clearings are often concentrated in dry seasons, when it is easier to penetrate and burn the forest. On the other hand, the cutting down of forests may itself affect the region's microclimate and precipitation patterns (Negri et al. (2004), Aragão et al. (2008), Saad et al. (2010)). Although understanding

[2] Variables on annual municipality crop production (harvested area, *quantum*, or value in current prices) are based on data originally from the Municipal Crop Survey of the Brazilian Institute for Geography and Statistics (*Pesquisa Agrícola Municipal do Instituto Brasileiro de Geografia e Estatística*, PAM/IBGE).

this relationship in detail is out of the scope of this paper, we include a measure of total precipitation in each sample municipality to account for the effect of rainfall on forest clearing activities. We do so by using annual precipitation data compiled by Matsuura and Willmott (2012), who draw on worldwide climate data to calculate a regular georeferenced world grid of estimated precipitation over land. Their estimations are based on a variety of sources for geographic extrapolations of rainfall data collected at weather stations. Using this georeferenced grid, we estimate total precipitation in each municipality according to the following rule: (i) for municipalities that overlap with only one grid node, we use the precipitation value for that grid node as municipality precipitation; (ii) for municipalities that overlap with two or more grid nodes, we consider all node values and use their average precipitation as municipality precipitation; (iii) for municipalities that have no overlap with any grid nodes, we take the area of a 28-kilometer buffer around the municipality and consider the average precipitation of all grid nodes that fall within this buffer area as municipality precipitation; and (iv) for the few municipalities whose 28-kilometer buffer do not overlap with any grid nodes, we use the precipitation value for the nearest grid node as municipality precipitation.[3]

Finally, we include controls for other relevant conservation policies implemented during the sample period. In particular, we account for total protected area in each municipality, including both conservation units and indigenous lands.

4. Empirical Strategy

This section describes the empirical strategy used to identify the causal effect of the priority municipalities policy on Amazon deforestation. As municipalities are included in the list of priority municipalities in different years, we use a municipality fixed-effects strategy with a dummy indicating if municipality i was a priority municipality in year t as the independent variable of interest. We also control for year fixed-effects, for agricultural commodity prices, rainfall, and other relevant conservation policies. We restrict our sample to municipalities within 300km of the Amazon biome frontier to focus our analysis on the areas where agricultural development and, consequently, deforestation are most relevant. The main specification is:

$$Deforestation_{it} = \gamma_1 Priority_{it} + \sum_k \gamma_k X_{itk} + \psi_i + \lambda_t + \epsilon_{it} \tag{3}$$

where $Deforestation_{it}$ is the normalized measure of deforestation; $Priority_{it}$ is a dummy indicating if municipality i had priority status on year t; X_{itk} is a vector of controls; ψ_i is the municipality fixed effect; λ_t is the year fixed effect; and ϵ_{it} is the idiosyncratic error.

There are some econometric issues that we must account for to ensure validity of our main assumption that priority municipalities are comparable to non-priority ones. They refer to the criterions used to determine priority status: first, total deforested area within a municipality since its creation; second, total deforested area over the past three years; and, third, increase in the municipality-level deforestation area in at least three of the past five years. The way the municipalities are chosen, however, also give us an opportunity. The criteria of total deforested area over the last 3 years take into account the whole deforested area. However, the size of the territory within municipality is not token into account. Therefore, we have to check whether after normalized the deforestation variable is comparable between groups or not.

We address these issues as follows. First, we include fixed effects, such that we only consider variations in deforested area and account for past deforestation. We also conduct an exercise in which we restrict our sample to municipalities having at least half of their territory covered by native vegetation in the initial sample year.

Second, we normalize the deforestation variable, such that the scale of the variation is the same for all municipalities. Because total deforested area over the last three years is directly influenced by the absolute size of the municipality, the normalized variable should be comparable between groups in our specifications.

[3]Buffer size was chosen based on the size of grid nodes – 28 kilometers is equivalent to half the distance between grid nodes.

Third, we check if there are differences in pre-trends between treatment and control groups when using the normalized deforestation variable. We address this question in two ways. First, we build dummy variables signaling whether each municipality was attributed priority status in each year. We do it fixing the year before the priority status be attributed as year zero. Then, the dummy indicating one year before the year zero is labeled as "1 year before the program" and so on. The same logic is used for the dummies after the program. The pre-treatment dummies are expected to have no significant effect if the pre-trends are alike, and the post-treatment dummies are expected to be negative and significant if the policy had a significant effect. To ensure we are not capturing some pre-trend pattern, we also run the main specification controlling for municipality-specific time trends.

We are also interested in the mechanism through which priority municipalities could have an effect on deforestation. Thus, we conduct an exercise in which we adequately control for deforestation monitoring intensity and law enforcement activity following Assunção et al. (2013). The authors instrument the number of fines applied by Ibama using DETER cloud coverage. DETER cloud coverage seems to affect the allocation of law enforcement efforts, but not deforestation directly (except through the rain channel, which is controlled for). The idea is to check whether, after controlling for law enforcement activity, priority status will still have an impact on deforestation. If the effect is still present, this means that the other political and economic sanctions applied in priority municipalities (political pressure, slaughterhouses refusing to buy meat, and bank managers hampering access to credit) are relevant elements of the policy. On the other hand, if the effect is no longer present after controlling for the number of fines, this suggest that priority status only affects deforestation through improved monitoring and targeting of law enforcement.

5. Results

Table 1 shows the effect of the priority municipalities policy on Amazon deforestation. Column 1 presents coefficients for our main specification, as described in Section 4. Column 2 uses a restricted sample of municipalities with more than half of their territory covered by native vegetation in the first sample year. Column 3 uses total deforested area instead of normalized deforestation as the dependent variable. Column 4 restricts the sample to the years after 2006, to allow for comparison with the regressions we later run using the number of fines and DETER cloud coverage (as data on DETER cloud coverage is only available starting in 2006).

Priority municipalities appears to have a negative and significant impact on deforestation. Results are robust to all specifications. Quantitatively, counterfactual analysis shows that the policy avoided the clearing of 11,218 km^2 of Amazon forest area in our sample from 2008 through 2011. Total deforestation observed in the sample in the same period was 20,689 km^2, 35.1% smaller than in the absence of the policy.

Table 2 suggests that our results are not coming from differences in pre-policy trends. In Column 1, we see that only the dummies indicating post-policy priority status have a significant effect on deforestation. The pre-treatment dummies are not statistically significants, indicating that different pre-policy trends are likely not a concern for our specifications. Even so, in Column 2, we run the main specification controlling for municipality- specific time trends. The priority municipalities policy still appears to have a significant negative effect on deforestation. Thus, it seems that we are really capturing the policy effect on deforestation, and not that of unobservables or pre-policy trends.

Finally, we want to investigate the mechanism through which the policy was most effective. To do this, we run the same regressions as in the Table 1, but control for the number of fines applied by Ibama, as instrumented by DETER cloud coverage. Table 3 shows that, when adequately controlling for law enforcement, the priority municipalities policy has no significant impact on deforestation. The only specification in which there is still a significant policy effect is the one that uses non-normalized deforestation variable – as we mentioned before, this variable is not reliable, due to large municipality size heterogeneity.

Taken together, these results suggest that the impact of the priority municipalities policy stems from increased monitoring and improved law enforcement in these municipalities. All other potential consequences of being classified as a priority municipalities, including political and economic sanctions, appear to have had no significant effect on Amazon deforestation.

6. Final Remarks

Overall, our results show that changing the unit of analysis in Amazon monitoring and law enforcement from the household to the municipality level appears to have an important negative impact on deforestation. Moreover, our findings suggest that the driving force behind this effect is not related to political or economic sanctions applied in targeted municipalities, but rather to improved monitoring and better targeting of law enforcement activities in the Amazon.

This is important because is saying that change the way of monitoring and law enforcement activity from a less centralized to a more centralized and target way produces good results. Also, as the monitoring is targeted, the cost is also smaller, you don't need concentrate resources in areas with few deforestation. But, at the same time, is also true that is not possible to use this policy as a stamp policy. Deforestation will probably not decrease because the municipality is in the "black list", if the intensity of monitoring does not increase, as the reputation effect does not hold (priority municipality is not significant when we control for the number of fines). That means, the increase in the monitoring seems to be the essential part of the priority municipalities policy.

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Table 1: The Effect of Priority Municipalities on Deforestation in the Amazon Biome

VARIABLES	(1) Normalized Deforestation	(2) Normalized Deforestation	(3) Deforestation	(4) Normalized Deforestation
Priority Municipalities	-0.545**	-0.558**	-125.3**	-0.374**
	(0.0629)	(0.0700)	(14.42)	(0.0820)
Rain in t-1	-3.88e-05	0.000104	0.00915*	0.000130
	(7.59e-05)	(0.000107)	(0.00382)	(6.91e-05)
Cloud Prodes	-6.78e-05	-5.09e-05	-0.00861	-0.000166*
	(3.95e-05)	(3.56e-05)	(0.00633)	(7.28e-05)
Non-Observed Prodes	0.000176	0.000216**	0.00547	-0.000394*
	(0.000151)	(6.25e-05)	(0.00629)	(0.000179)
Protected Areas	-0.371	-0.135	-306.6	7.249**
	(0.598)	(0.671)	(156.3)	(2.209)
Crop Prices 1st Semester	0.469**	0.244*	13.05	-0.406**
	(0.142)	(0.0990)	(7.891)	(0.111)
Cattle Prices 1st Semester	-0.0291**	-0.0549**	-0.0156	-0.0135**
	(0.00394)	(0.0127)	(0.141)	(0.00454)
Crop Prices in t-1	0.240*	0.434**	20.90	0.184
	(0.114)	(0.126)	(13.29)	(0.0989)
Cattle Prices in t-1	0.0266**	0.0485**	-0.781**	0.00716
	(0.00506)	(0.0156)	(0.226)	(0.00428)
Observations	2,853	1,368	2,853	1,585
Number of municipalities	317	152	317	317
Municipality and Year FE	Yes	Yes	Yes	Yes
Municipality Time Trend	No	No	No	No

Notes: Significance: ** p<0.01, * p<0.05.

Table 2: Pre-Trend Regressions

VARIABLES	(1) Normalized Deforestation	(2) Normalized Deforestation
1 Year Before the Program	-0.180	
	(0.0965)	
2 Year Before the Program	0.130	
	(0.141)	
3 Year Before the Program	0.320	
	(0.168)	
4 Year Before the Program	-0.0284	
	(0.151)	
5 Year Before the Program	-0.331	
	(0.294)	
6 Year Before the Program	0.606	
	(0.544)	
7 Year Before the Program	0.342	
	(0.630)	
1 Year After the Program	-0.471**	
	(0.124)	
2 Year After the Program	-0.435**	
	(0.118)	
3 Year After the Program	-0.586**	
	(0.0995)	
4 Year After the Program	-0.550**	
	(0.107)	
Priority Municipalities		-0.285*
		(0.130)
Observations	2,853	2,853
Number of municipalities	317	317
Municipality and Year FE	Yes	Yes
Municipality Time Trend	No	Yes

Notes: Significance: ** p<0.01, * p<0.05.

Table 3: The Effect of Priority Municipalities on Deforestation in the Amazon Biome

VARIABLES	(1) Normalized Deforestation	(2) Normalized Deforestation	(3) Deforestation	(4) Normalized Deforestation
Number of Fines in t-1	-0.0537	-0.100	-0.903	0.199
	(0.0628)	(0.0695)	(1.723)	(0.483)
Priority Municipalities	0.0410	0.436	-48.32*	-2.559
	(0.510)	(0.684)	(20.76)	(5.253)
Rain in t-1	-3.16e-05	-0.000257	0.00387	0.00214
	(0.000214)	(0.000503)	(0.00649)	(0.00442)
Cloud Prodes	9.61e-05	0.000296	0.000606	-0.000952
	(0.000456)	(0.000690)	(0.0132)	(0.00214)
Non-Observed Prodes	-0.000432*	-0.000644	0.00534	-0.000958
	(0.000219)	(0.000431)	(0.00560)	(0.000724)
Protected Areas	-8.666	-27.66	-404.7	-71.97
	(26.74)	(48.06)	(766.1)	(191.6)
Crop Prices 1st Semester	-0.420**	-0.752	-5.579	-0.948
	(0.152)	(0.406)	(4.884)	(1.395)
Cattle Prices 1st Semester	0.00220	0.0122	-0.548	-0.0834
	(0.0185)	(0.0572)	(0.586)	(0.151)
Crop Prices in t-1	0.486	-0.184	16.19	0.157
	(0.473)	(0.569)	(12.08)	(1.093)
Cattle Prices in t-1	-0.0132	-0.145	0.462	0.103
	(0.0245)	(0.125)	(0.715)	(0.220)
Observations	1,585	760	1,585	1,585
Number of municipalities	317	152	317	317
Municipality and Year FE	Yes	Yes	Yes	Yes
Municipality Time Trend	No	No	No	Yes

Notes: Significance: ** p<0.01, * p<0.05.