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Environmental enforcement, property rights, and violence: evidence from the Brazilian Amazon

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Abstract

Conflicts over resources with poorly defined property rights have fuelled both deforestation and violence in the Brazilian Amazon. However, what happens when the State enhances its ability to monitor and enforce existing environmental laws? We study the case of the list of *Municípios Prioritários*, a policy that allocates additional resources to verify compliance with environmental laws in municipalities with high deforestation rates. Employing a difference-in-differences approach, our findings suggest that an improvement in the ability of the State to monitor and enforce environmental laws can reduce conflicts over the appropriation of value from resources with poorly defined property rights. Consistent with existing studies, we also find that the policy led to a reduction in deforestation rates in the Brazilian Amazon. Finally, we discuss the limitations of the current approach to curb violence in a region where the activity of mafias has considerably grown since the turn of the twenty-first century.

Keywords: blacklist; Brazilian Amazon region; deforestation; Municípios Prioritários; priority list; property rights; violence

Introduction

The imagery of burning rainforests has significantly influenced global perceptions of Brazil's ability to combat deforestation in the Amazon. Often overlooked in these accounts are the high violence rates in the region: while Brazil's homicide rate increased by 85% between 1980 and 2018, the Brazilian 'Northern' region experienced a more staggering surge of 260% (BFPS, 2021). Different studies show that both deforestation and violence are employed to secure control over resources with poorly defined property rights in the Brazilian Amazon. First, scholars emphasize the difficulty of the Brazilian government to enforce existing environmental laws due to high monitoring costs. For example, Brazil designed a policy in the 1990s to limit the exploitation of mahogany. An illegal market then flourished, leading to outbursts of violence in mahogany-rich areas (Chimeli and Soares, 2017). Second, researchers describe many institutional voids and contradictions that impair the protection of property rights in the region. For example, environmental rules mandating that 80% of a property must be covered by forest contrast with ownership rules which may classify these areas as 'unproductive', rendering them vulnerable to expropriation for agrarian reform purposes (Oliveira, 2008). Deforestation and violent actions are thus employed by both farmers and squatters to influence expropriation decisions (Alston *et al.*, 1999; Alston *et al.*, 2000).

The available evidence suggesting that deforestation in the Brazilian Amazon complements violent actions aligns with a consistent body of literature showing that conflicts are a likely by-product of illegal activities (e.g., Angrist and Kugler, 2008; Berman *et al.*, 2017; Idrobo *et al.*, 2014). After all, parties engaged in conflicts over resources with poorly defined property rights often have a limited access

to State-based dispute settlement systems. However, it is not entirely clear whether an improvement in the State-based ability to monitor and enforce the existing environmental 'rules of the game' can impact outcomes other than deforestation rates. Much of the deforestation in the Brazilian Amazon takes place either in State-owned 'undesignated lands' or in areas with overlapping claims between landowners, squatters, and land grabbers (Alston *et al.*, 1996; Moutinho and Azevedo-Ramos, 2023). Deforestation is thus seen as a 'pre-emptive' strategy, intended to signal the productive use of the land and increase the likelihood of seizing its property rights (Aldrich *et al.*, 2012; Brown *et al.*, 2016). Given the pervasive challenges to property rights claims in the region, violence inevitably emerges as a complementary method to assert dominance over competing individuals and groups. The close link between deforestation and deadly conflicts in the Brazilian Amazon raises an important question: can environmental policies play a role in reducing violence rates in the region?

The purpose of this paper is to study how the creation of the list of *Municípios Prioritários* by the Brazilian government in 2007 has impacted homicide rates in the Brazilian Amazon. As Assunção and Rocha (2019) explain, the policy has two main policy tools. First, it enhances the monitoring ability of the State by enabling a better targeting of enforcement resources. In practice, additional law enforcement officers are dispatched to municipalities with high deforestation rates and the available data from georeferencing systems and land title registries are analysed more closely. Second, it closes institutional loopholes by restricting access to public credit and authorizations for clearing rainforest areas in listed municipalities. Our empirical analysis relies on a difference-in-differences approach to analyse annual data between 2004 and 2016 from municipalities in the entire Brazilian *Amazônia Legal* region. Previous studies show that the list of *Municípios Prioritários* has contributed to reduce deforestation (Arima *et al.*, 2014; Assunção and Rocha, 2019; Assunção *et al.*, 2015; Cisneros *et al.*, 2015). We go one step further, arguing that, by limiting the ability of individuals to engage in illegal economic activities, an improvement in the capacity of the State to monitor compliance with environmental laws should be followed by a reduction in violence levels.

Institutional context

Deforestation in the Brazilian Amazon has intensified since the building of Brasília in the 1950s and the subsequent expansion of Northern Brazil's road network (Fearnside, 2005; Moran, 1996). From the 1990s on, the growing international demand for agricultural commodities spurred another wave of deforestation (Morton *et al.*, 2006). Most deforestation in the Brazilian Amazon occurs in State-owned 'undesignated' lands whose legal status has not been fully clarified (Moutinho and Azevedo-Ramos, 2023; Pacheco and Meyer, 2022). Despite successive State-led attempts to legalize land tenure in the Brazilian Amazon (see Barreto *et al.*, 2008; Lipscomb and Prabakaran, 2020), the existence of a huge stock of 'undesignated' lands – more than 52 million hectares, according to Sparovek *et al.* (2019) – provides a strong incentive for the continuous expansion of the agricultural frontier towards areas with poorly defined property rights. Using data from the Brazilian Agricultural Census, Araujo *et al.* (2009) estimate that around 30% of all landholdings in the region were not attached to a legal title in the 1990s. In turn, Barreto *et al.* (2008) show that uncertainty over property rights still affected more than 50% of the territory of the *Amazônia Legal* region even after three State-led initiatives to regularize land tenure between 1999 and 2004.

Violence has been a pervasive by-product of the advance of the agricultural frontier in the Brazilian Amazon. Different actors compete for resources with poorly defined property rights in the region, motivating a broader spectrum of conflicts (see Fearnside, 2008). Squatters ('*posseiros*', term in Portuguese) and land grabbers ('*grileiros*', term in Portuguese) have historically been the first to arrive to undesignated lands, cleaning forest areas and filling the land with cattle to claim property rights. Squatters may arrive either spontaneously or responding to State-based incentives, such as the creation of settlement projects for small farmers. Land grabbers, in turn, employ violent methods and corruption to seize large areas and then sell the land. These actions may target either undesignated lands or areas not employed in commercial farming, such as designated indigenous lands. As the frontier

consolidates, the existence of overlapping land titles or unrecognized claims continues to affect inter-actions among different groups. For example, conflicts between landholders and squatters are common in Southern Pará (see Alston *et al.*, 1996). Fearing expropriation for agrarian reform purposes, farmers in the region have adopted the practice of 'pre-emptive deforestation' to signal that the land is used for economic purposes (Aldrich *et al.*, 2012; Brown *et al.*, 2016). Uncertainty over property rights remains though, helping to explain multiple outbursts of violence since the 1990s (Alston *et al.*, 2000).

In an attempt to curb deforestation in the Brazilian Amazon, the Brazilian government created in 2004 the Action Plan for Prevention and Control of Deforestation in the *Amazônia Legal* (PPCDAm, acronym in Portuguese). The PPCDAm provides a framework for establishing financial and market-based incentives for deforestation control. A specific measure from the PPCDAm is the Presidential Decree 6,321/2007, which creates the list of *Municípios Prioritários* – i.e., municipalities with high deforestation levels. As Assunção and Rocha (2019) show, the policy has two main tools. First, it enhances the monitoring and enforcement ability of the State. By facilitating the targeting of interventions, the 'list of *Municípios Prioritários*' policy has enabled government officials to allocate additional human and financial resources to monitor the rural areas of targeted municipalities. The inclusion to the list also means the adoption of stricter georeferencing and licensing requirements. Second, it closes institutional loopholes. State officials have reviewed the private land titles of *Municípios Prioritários* to curb unlawful practices. Moreover, the policy aims to restrict access to public credit and authorizations for clearing rainforest areas for farmers and firms in the municipalities included in the list.

Three major criteria determine the inclusion of municipalities in the list of *Municípios Prioritários*: (i) high rates of deforestation over the preceding three years; (ii) the cumulative amount of area deforested; and (iii) an increase in forest loss in three out of the five most recent years. Published in 2008, the initial version of the list comprised 35 municipalities. Eight municipalities were added to the list in 2009, followed by seven more in 2011, and two more in 2012. To be excluded from the list, a *Município Prioritário* should register 80% of rural properties in the Brazilian Rural Environmental Registry (CAR, acronym in Portuguese) and reduce annual deforestation to less than 40 square kilometres.

Several studies estimate the effect of the creation of the list of *Municípios Prioritários* on deforestation rates within the Brazilian Amazon, showing a cautious optimism (see Nepstad *et al.*, 2014). Employing a difference-in-differences approach to analyse data on forest loss from 2006 to 2011, Arima *et al.* (2014) find that the creation of the list of *Municípios Prioritários* in 2008 resulted in an average annual decrease of 82 km^2 deforestation per municipality. Other studies reach similar conclusions. Cisneros *et al.* (2015) find a policy-induced decrease in deforestation of 4022 km^2, on average, between 2008 and 2012. In turn, Assunção and Rocha (2019) estimate that the publication of the list of *Municípios Prioritários* led to a reduction in deforestation of 11,218 km^2 between 2008 and 2011. Adopting a broader perspective, Assunção *et al.* (2015) argue that the creation of the PPCDAm contributed to the protection of over 73,000 km^2 of forests in the Brazilian Amazon.

But an environmental policy can influence outcomes other than the depletion of ecosystems (Dechezleprêtre and Sato, 2017). A growing literature has scrutinized how the list of *Municípios Prioritários* affects a broader set of socioeconomic variables. Damm *et al.* (2024) investigate the effects of the policy on land use decisions, showing that the creation of the list of *Municípios Prioritários* led farmers to convert extensive grazing areas into higher productivity crops. Specifically, while soybean crop area increased 102.9% in the region after the creation of the list, only 1.2% of this expansion occurred in forested areas. On a similar note, Koch *et al.* (2019) show that the creation of the list of *Municípios Prioritários* incentivized the adoption of agricultural intensification techniques in the Brazilian Amazon. The study finds a significant increase in cattle productivity within *Municípios Prioritários* – i.e., an increase in the number of animals without an equivalent increase on pasture area. Adding to this growing literature, we further explore the idea that the potential influence of an environmental policy goes way beyond its original goals. Specifically, we take inspiration from the principles of institutional analysis to investigate whether and how the creation of the list *Municípios Prioritários* has affected homicide rates in the Brazilian Amazon.

Theoretical background

Scholars have long acknowledged the importance of institutions in reducing uncertainty in society. North (1991) explains that institutions are humanly devised constraints – or prescriptions, to use Ostrom's (1986) terminology – that, with varying degrees of effectiveness, specify property rights. Property rights theory has traditionally maintained that the ownership of property rights entails the ability of using a resource, appropriating the returns from using it, and transferring these rights (see Libecap, 1989). Schlager and Ostrom (1992) further disentangle the term, identifying five dimensions within the notion of property rights, i.e.: access rights, withdrawal rights, management rights, exclusion rights, and alienation rights. Irrespective of the definition chosen, the idea that property rights are 'well-defined' reflects a social consensus that certain types of action can be carried out, helping to solidify expectations on how people can benefit from using an asset (Alchian and Demsetz, 1973; Demsetz, 1967).

The consolidation of a property rights regime that effectively influences human behaviour is fraught with difficulties though. Since resources are typically composed of multiple attributes (Paavola, 2007), the property rights over some attributes may be better defined than over others. After all, the costs of enforcing property rights may considerably vary depending on the features of each attribute (McCann, 2013). Design issues affect the definition of property rights as well. As von Jacobi (2018) remarks, property rights ensue from the coexistence of multiple rules and structural factors, which may contradict each other. Institutional rules can also be too complex, demanding the design of specialized organizations dedicated to translating them into intelligible prescriptions (Ménard, 2014; Oliveira et al., 2023). Finally, the coexistence of different rules in a world of positive transaction costs may create gaps and loopholes that inadvertently legitimize the actions of opportunistic actors (Miranda and Oliveira, 2023). We should not take for granted the State capacity to enforce property rights either. Indeed, state officials may lack the resources and capabilities to deter unlawful behaviours. In extreme cases, the State may even lose the monopoly over the systematic use of coercion, competing with mafia or paramilitary groups over the control of the territory (Böhm and Pascucci, 2020).

While the establishment of formal laws is not a necessary condition for the materialization of order (see Ellickson, 1994), the lack of State-based guarantees over property rights may give room to highly unstable patterns of competition and cooperation (Cole, 2015; Hodgson, 2015). The basic argument is that the existence of 'well-defined' property rights can channel potential conflicts into rule-based dispute settlement systems. But the establishment of formal laws is not a sufficient condition for the materialization of order either. Whenever the State loses the ability to enforce the property rights over the relevant attributes of a resource, competition may lead to the use of violence as a method of dispute settlement (Castillo et al., 2020; Jensen and Ramey, 2020). Once again, it is important to remark that private attempts to capture the value from resources do not necessarily entail the employment of violent methods (see Allen, 2023; Barzel, 1997). However, the degree of clarity surrounding property rights strongly influences the potential value that can be captured from unlawful activities (Bandiera, 2003). In other words, the costs of engaging in illegal actions in societies where the State is unable to monitor the compliance with the 'law of the land' are lower than in societies where such enforcement is effective (Becker, 1968).

In this sense, we expect that effective State-based attempts to better enforce a property rights regime will lead to a reduction of violence levels, *ceteris paribus*. This may occur, for example, if the State designs a policy that enhances the ability to monitor compliance with the existing 'rules of the game'. It may also occur if the State is able to clarify the relationship between two or more prescriptions within a given property rights system, increasing the likelihood that courts will address complex conflicts. With the design of the 'list of *Municípios Prioritários*' policy in 2007, the Brazilian government expected to better target the deployment of monitoring activities across the region. The decision should thus affect the balance of the costs and benefits of engagement in unlawful activities (e.g., the appropriation of 'undesignated' lands) and, consequently, the costs and benefits of adopting violent methods to capture value from resources in the region.

Methods and procedures

We adopt a difference-in-differences strategy to assess whether the creation of the list of *Municípios Prioritários* affects homicide rates in the Brazilian Amazon. Our empirical analysis uses data collected at the municipality level, covering a period of 13 years between 2004 and 2016. We analyse municipalities from the *Amazônia Legal* region, an administrative area delimited by the Complementary Law 124/2007 which covers 59% of the Brazilian territory.

Variables

We use two dependent variables. First, the variable *Homicides* (mean: 10.29; standard deviation: 46.06) measures 'violence' as the annual number of homicides per household at the municipality level according to the Brazilian Institute for Applied Economic Research (IPEA, acronym in Portuguese). Second, the variable *Firearms-Homicides* (mean: 6.01; standard deviation: 31.45) uses data from Brazil's Mortality Information System (SIM/DATASUS, acronym in Portuguese) to measure the annual number of firearms-related homicides per municipality i. Two reasons justify our choice of dependent variable. The first refers to the quality of the available data. Although the employment of violence can lead to negative outcomes other than a homicide, data on homicides has been reported in a more accurate way than other manifestations of violent behaviour in Latin American countries (Buvinic and Morrison, 1999). The second refers to the nature of the social relationships in the Brazilian Amazon. As a broad literature shows, the frontier between rural and urban realities in the region is porous (e.g., Brondízio *et al.*, 2002; Ludewigs *et al.*, 2009). Or, to use the definition of Becker (1995), the Brazilian Amazon is essentially an 'urbanized forest' with a dynamic agricultural frontier. To encapsulate these complex interactions, the use of total number of homicides is thus advised.

The variable *Deforestation* (mean: 1,765.65; standard deviation: 5,855.01) is built with data on annual net forest loss, in hectares, at the municipality level from the Mapbiomas (2021) database. Moreover, we use three control variables at the municipality-year level. Two control variables are taken from the Mapbiomas (2021) database: the variable *Soy* (mean: 10,943.31; standard deviation: 47,009.97), i.e., the number of hectares of soy crop production; and the variable *Pasture* (mean: 104,000; standard deviation: 130,000), i.e., the number of hectares of pasture. The addition of these two control variables accounts for the fact that the diffusion of a specific economic activity in the Brazilian Amazon is associated with different degrees of property right protection. Loggers are the first to come, followed by ranchers who fill the land with cattle to secure property rights. Soybean production tends to gain steam only after property rights are relatively well defined either due to effective public or private protection efforts. Based on data from the Brazilian Institute of Geography and Statistics (IBGE), the third variable, *PopDensity* (mean: 17.462; standard deviation: 92.642), represents the population density, measured as the total number of inhabitants per square kilometre in municipality i during year t.

Identification strategy and difference-in-differences specification

Previous research shows that the creation of the list of *Municípios Prioritários* has contributed to reduce deforestation rates in the Brazilian Amazon (Arima *et al.*, 2014; Assunção and Rocha, 2019; Assunção *et al.*, 2015; Cisneros *et al.*, 2015). Since deforestation in the region mostly occurs in State-owned 'undesignated' lands (Moutinho and Azevedo-Ramos, 2023), a potential explanation for this outcome is that the public policy enhances the monitoring and enforcement ability of the State. In other words, the State can better enforce – albeit still imperfectly – property rights in the region (see Assunção and Rocha, 2019). But we also know from the literature that violence in the Brazilian Amazon has traditionally ensued from conflicts over resources with poorly defined property rights (e.g., Alston *et al.*, 2000; Chimeli and Soares, 2017). Therefore, our hypothesis is that *by influencing deforestation rates, the 'list of Municípios Prioritários' policy has influenced violence patterns*

in the Brazilian Amazon as well. We use a panel data structure to test this hypothesis, which allows us to control for time fixed effects to identify the effect of the 'list of *Municípios Prioritários*' policy on both deforestation rates and violence rates. We also control for municipality fixed effects to account for time-invariant heterogeneity, such as the proximity to international borders.

We are particularly interested in estimating the effects of the 'list of *Municípios Prioritários*' policy on homicide rates, measured as the inverse hyperbolic sine of *Homicides* or *Firearms-Homicides*. The inverse hyperbolic sine function transformation offers several advantages. It is defined at zero and produces values closer to zero, while still enabling the interpretation of coefficients in a manner similar to a log transformation (Bellemare and Wichman, 2020). Hence, it allows us to deal with highly skewed outcomes that also have zeros instead of using variables in the form 'log ($y + 1$)'. We employ the same transformation to examine whether variations in deforestation rates help to explain the potential effects of the public policy on homicide rates. Specifically, we first normalize deforestation as the proportion of net forest loss relative to the total hectares of forest cover in a particular municipality during the first year of our sample – i.e., the year of 2004. We then employ the inverse hyperbolic sine transformation.

We adopt the following difference-in-differences approach to estimate these effects:

$$Y_{it} = \alpha_i + \delta_t + \beta MP_{it} + cX_{it} + \sigma_{it}$$

where Y_{it} is the inverse hyperbolic sine of *Homicides or Firearms-Homicides* by municipality i at year t. The terms α_i and δ_t are, respectively, municipality and year fixed effects. The variable MP_{it} characterizes the treatment effect from the 'list of *Municípios Prioritários*' policy by municipality i at year t. Finally, X_{it} is a vector of control variables by municipality i at year t and σ_{it} is the error term.

Results

Table 1 summarizes the results of our difference-in-differences analysis. All models incorporate every control variable as well as fixed effects. Overall, our analysis shows that *the establishment of the 'list of Municípios Prioritários' policy led to a decrease in homicide rates in the targeted municipalities*. Model 1 shows a decrease of 16.9% in the overall number of homicides in municipalities that were added to the list of *Municípios Prioritários*. In turn, Model 2 shows a decrease of 14.6% in firearms-related deaths.

To further validate our identification strategy and test the robustness of our findings, we (i) check the parallel trends assumption; (ii) investigate the spatial range of the effects of the public policy on violence; (iii) examine the results using an alternative estimator; and (iv) assess the direct relationship between deforestation and violence.

Parallel trends

We devise two strategies to check the parallel trends assumption. To account for the fact that the inclusion of all municipalities in the list of *Municípios Prioritários* did not occur in the same year, we incorporate interactions between time dummies and treated observations during the period before the inclusion of any municipality in the list of *Municípios Prioritários* to account for time-varying 'pretreatment effects' (i.e., before 2008). A standard practice in placebo tests (see Fredriksson and Oliveira, 2019), this strategy demands the use of the years when the policy still did not exist. We find no differences between the 'treatment' group and the control group in the 'pretreatment' period for any of the two outcome variables (i.e., homicides and homicides with firearms), a result that strengthens the credibility of our baseline results (see Table 2).

We also use an event-study approach to check for parallel trends. This strategy allows us to visualize and estimate treatment effects for multiple periods before and after the creation of the list of *Municípios Prioritários*. Using the estimator described by De Chaisemartin and d'Haultfoeuille

Table 1. Baseline models

Variables	(1) *Homicides*	(2) *Firearms-Homicides*
MP list	−0.169** (0.082)	−0.146* (0.085)
PopDensity	1.003*** (0.324)	1.652*** (0.495)
Soy	−0.151*** (0.050)	−0.149*** (0.056)
Pasture	0.145* (0.081)	0.205* (0.114)
Observations	7,254	7,254
Number of municipalities	558	558
Municipality FE	YES	YES
Year FE	YES	YES

Notes: *** $P < 0.01$, ** $P < 0.05$, * $P < 0.1$. Robust standard errors in parentheses and clustered at the municipality level. Municipalities analysed have at least 1% of forest cover detected by PRODES/INPE in 2004.

(2020), Table 3 shows that the reduction in homicides started after four years of the implementation of the public policy. Remarkably, the result holds for both overall homicides and firearms-related homicides. On the other hand, we observe a slightly weak 'anticipation effect' that reinforces the need for a cautious interpretation of our difference-in-differences findings. We also test whether the placebo effects are jointly equal to 0. We cannot reject this hypothesis for both outcome variables (*P*-value = 0.489 and *P*-value − 0.338), a result that provides further support for our parallel trends assumption. Finally, we present the average 'treatment effect' for our two outcome variables. The results show a 21.1% decrease in the number of overall homicides and a decrease of 27.5% in the number of firearms-related homicides.

Staggered nature: changes-in-changes as an alternative estimator

To provide a more comprehensive picture of our empirical analysis, we now test the robustness of our findings using the changes-in-changes model proposed by Athey and Imbens (2006). While standard

Table 2. Parallel trends

Variables	(1) *Homicides*	(2) *Firearms-Homicides*
MP list × 2004	0.197 (0.167)	0.094 (0.194)
MP list × 2005	0.128 (0.123)	0.097 (0.126)
MP list × 2006	−0.038 (0.111)	−0.046 (0.128)
PopDensity	0.275 (0.399)	0.201 (0.327)
Soy	0.062 (0.133)	0.050 (0.120)
Pasture	0.127 (0.200)	0.186 (0.189)
Observations	2,232	2,232
Number of municipalities	558	558
Municipality FE	YES	YES
Year FE	YES	YES

Notes: *** $P < 0.01$, ** $P < 0.05$, * $P < 0.1$. Robust standard errors in parentheses and clustered at the municipality level. Municipalities analysed have at least 1% of forest cover detected by PRODES/INPE in 2004.

difference-in-differences focuses on the adjustments to the average, the changes-in-changes model examines the distribution functions of possible outcomes for both groups. Using the changes-in-changes estimator described by De Chaisemartin and d'Hautlfoeuille (2018), we find a decrease of 20.2% in overall homicides and a reduction of 22.4% in firearms-related homicides after the implementation of the 'list of *Municípios Prioritários*' policy (Table 4).

Neighbouring effects

Starting from our difference-in-differences analysis, we now examine the impact of the public policy on both overall homicides and firearms-related homicides in the areas neighbouring the *Municípios Prioritários*. Two new outcome variables are created (Table 5). While Column 1 displays an outcome variable representing the number of overall homicides in neighbouring municipalities, Column 2 shows a variable representing firearms-related deaths in neighbouring municipalities. Table 5 shows that the effect of the policy on homicides is not limited to the boundaries of a *Município Prioritário*, extending to the surrounding areas.

The relationship between deforestation and homicides

Our results so far indicate that the establishment of the list of *Municípios Prioritários* has indeed affected homicide rates in the Brazilian Amazon. But how exactly has this public policy contributed to reduce violence levels in the region? To answer this question, we explore the direct relationship between deforestation and homicides in the Brazilian Amazon.

The first step is to assess the effects of the 'list of *Municípios Prioritários*' policy on deforestation rates. Our goal is to test whether our empirical analysis delivers results that are similar to those

Table 3. Event study approach

	(1)	(2)
Variables	*Homicides*	*Firearms-Homicides*
Average effects	−0.211* (0.10)	−0.275** (0.117)
Eight years after MP list	−0.293* (0.151)	−0.378** (0.178)
Seven years after MP list	−0.221* (0.125)	−0.356*** (0.131)
Six years after MP list	−0.244*** (0.145)	−0.390*** (0.150)
Five years after MP list	−0.354** (0.119)	−0.390*** (0.119)
Four years after MP list	−0.273** (0.121)	−0.261** (0.121)
Three years after MP list	−0.048 (0.092)	−0.083 (0.113)
Two years after MP list	−0.182 (0.114)	−0.204 (0.135)
One year after MP list	−0.039 (0.112)	−0.112 (0.123)
Year of MP list	−0.068 (0.103)	−0.089 (0.123)
One year before MP list	0.0361 (0.103)	0.026 (0.126)
Two years before MP list	0.030 (0.112)	0.056 (0.108)
Three years before MP list	0.000 (0.124)	0.019 (0.108)
Four years before MP list	−0.372* (0.219)	−0.258 (0.184)
Five years before MP list	−0.482 (0.406)	−0.407* (0.210)

Notes: *** $P < 0.01$, ** $P < 0.05$, * $P < 0.1$. Robust standard errors in parentheses and clustered at the municipality level. Municipalities analysed have at least 1% of forest cover detected by PRODES/INPE in 2004.

Table 4. CIC estimator

Variables	(1) *Homicides*	(2) *Firearms-Homicides*
Wald-CIC	−0.202** (0.080)	−0.224** (0.112)
Observations	7,254	7,254
Number of municipalities	558	558
Municipality FE	YES	YES
Year FE	YES	YES

Notes: *** $P < 0.01$, ** $P < 0.05$, * $P < 0.1$. Robust standard errors in parentheses and clustered at the municipality level. Municipalities analysed have at least 1% of forest cover detected by PRODES/INPE in 2004.

found in the existing literature. The results are summarized in Table 6. In Column 1, we estimate how the public policy affected deforestation rates in the *Municípios Prioritários*. We find a 57.9% decrease in deforestation after the inclusion of a municipality in the list of *Municípios Prioritários*. Column 2 displays the results for neighbouring municipalities, showing a decrease of 55.2% in deforestation rates in municipalities that are neighbours of *Municípios Prioritários*. Taken together, these results reinforce the main conclusions found in the literature (Arima *et al.*, 2014; Assunção and Rocha, 2019; Assunção *et al.*, 2015; Cisneros *et al.*, 2015).

The second step is to scrutinize the relationship between deforestation rates and violence in the Brazilian Amazon. Our empirical findings suggest that the creation of the list of *Municípios Prioritários* has affected homicide rates by reducing deforestation. We further explore this rationale by using the list of *Municípios Prioritários* as a source of exogenous variation in a two-stage least squares approach. For our two-stage least squares approach to be valid, we must assume that the public policy impacts homicides only because it impacts deforestation rates. In the first stage (Table 7, column 1), we find that 'the list of *Municípios Prioritários*' policy led to a decrease of 57.9% in deforestation. Different weak identification tests, such as the Cragg-Donald Wald F statistics, the Kleibergen-Paap Wald F-statistics, and the Stock-Yogo weak ID test demonstrate that our instrument is sufficiently strong for predicting variations in the first stage of the model. In Columns 2 and 3, we observe a positive relationship between deforestation and our two measures of violence, i.e., overall homicides and firearms-related homicides.

Table 5. MP effects on neighbouring areas

Variables	(1) *Neighbours_Homicides*	(2) *Neighbours_Firearms-Homicides*
MP list	−0.131*** (0.047)	−0.179*** (0.068)
PopDensity	1.053*** (0.145)	1.630*** (0.194)
Soy	−0.176*** (0.032)	−0.222*** (0.048)
Pasture	−0.077 (0.052)	−0.085 (0.066)
Observations	7,254	7,254
Number of municipalities	558	558
Municipality FE	YES	YES
Year FE	YES	YES

Notes: *** $P < 0.01$, ** $P < 0.05$, * $P < 0.1$. Robust standard errors in parentheses and clustered at the municipality level. Municipalities analysed have at least 1% of forest cover detected by PRODES/INPE in 2004.

Discussion and concluding remarks

Both deforestation and violence have been employed to control resources with poorly defined property rights in the Brazilian Amazon (Alston *et al.*, 2000; Chimeli and Soares, 2017). Would a policy intended to improve the monitoring of compliance with environmental rules contribute to reduce violence rates as well? We study how the creation of the list of *Municípios Prioritários* (i.e., municipalities with high deforestation rates) affected homicide rates in the Brazilian Amazon between 2004 and 2016. Instead of fundamentally changing Brazilian environmental laws, the 'list of *Municípios Prioritários*' policy reallocates additional resources in an attempt to enhance the State-based enforcement ability of existing institutions (see Assunção and Rocha, 2019). In this sense, an effective implementation of the policy should mean an enhanced enforcement of legal property rights in the targeted municipalities. Overall, our results highlight the close link between deforestation and violent actions in the Brazilian Amazon region. First, we show that the implementation of the 'list of *Municípios Prioritários*' policy led to a decrease of 16.9% in the overall number of homicides and a decrease of 14.6% in firearms-related deaths between 2004 and 2016. Consistent with other studies (Arima *et al.*, 2014; Assunção and Rocha, 2019; Assunção *et al.*, 2015; Cisneros *et al.*, 2015), we also find that the policy reduced deforestation.

Could we then argue that the 'list of *Municípios Prioritários*' policy is sufficient to curb both deforestation and violence in the Brazilian Amazon? As the available success cases suggest, the full story is more complex. The available evidence describes the existence of an effective orchestration between the Federal government and multiple local stakeholders (Massoca and Brondízio, 2022). The most widely discussed case is Paragominas, a city in the state of Pará which was excluded from the list of *Municípios Prioritários* in 2010 after successfully reducing deforestation rates. Farmers and civil leaders received the news that Paragominas had become a *Município Prioritário* with great sense of urgency – a reaction that reflected the fear that such classification would threaten long-standing business relationships. The full collaboration of authorities at the municipality level allowed not only reinforcement in monitoring activities, but also the interest in the creation of innovative tool for reinforcing the 'list of *Municípios Prioritários*' policy. In 2014, Paragominas became the first municipality in the Brazilian Amazon region to have a 'compensation market' in which farmers could buy or rent forested land to compensate for a deficit in the protected area within their properties (see Brito, 2020). Remarkably, local leaders saw the pursuit of an ambitious environmental agenda also as an opportunity to leave behind a past of high violence levels. Perhaps the best example of such ambition is found in the words of Flexa Ribeiro, then Senator of the state of Pará, who gave a speech in the Brazilian Senate in March 2010 to celebrate the exclusion of Paragominas from the list of

Table 6. MP effects on deforestation

Variables	(1) *Deforestation*	(2) *Neighbours_Deforestation*
MP list	−0.579*** (0.100)	−0.552*** (0.152)
PopDensity	2.191*** (0.325)	4.842*** (0.846)
Soy	−0.093 (0.087)	−0.248* (0.129)
Pasture	0.427** (0.168)	0.377** (0.175)
Observations	7,254	7,254
Number of municipalities	558	558
Municipality FE	YES	YES
Year FE	YES	YES

Notes: *** $P < 0.01$, ** $P < 0.05$, * $P < 0.1$. Robust standard errors in parentheses and clustered at the municipality level. Municipalities analysed have at least 1% of forest cover detected by PRODES/INPE in 2004.

Table 7. 2SLS estimates

Variables	(1) 1st stage *Deforestation*	(2) 2nd stage *Homicides*	(3) 2nd stage *Firearms-Homicides*
MP list	−0.579*** (0.100)		
Deforestation		0.291** (0.146)	0.252* (0.152)
PopDensity	2.191*** (0.324)	0.364 (0.411)	1.099** (0.555)
Soy	−0.093 (0.086)	−0.124** (0.053)	−0.125** (0.059)
Pasture	0.427** (0.168)	0.020 (0.079)	0.097 (0.092)
Cragg-Donald Wald F stat.		19.32	
Kleibergen-Paap Wald F-stat.		33.50	
Stock-Yogo weak ID test (10%)		16.38	
Observations	7,254	7,254	7,254
Number of municipalities	558	558	558
Municipality FE	YES	YES	YES
Year FE	YES	YES	YES

Notes: *** $P < 0.01$, ** $P < 0.05$, * $P < 0.1$. Robust standard errors in parentheses and clustered at the municipality level. Municipalities analysed have at least 1% of forest cover detected by PRODES/INPE in 2004.

Municípios Prioritários: '[…] *starting today, Paragominas is no longer considered a municipality with deforestation* […] *That was not easy to achieve. If we go back in time, the friends of Paragominas who watch us, listen to us, not only from Paragominas but from the entire state of Pará, know that, for almost 18 years, the municipality was known in Pará as Parago'bullet' because it was a stage for multiple crimes, a true Far West*' (Anais do Senado, 2010).

Since the days of optimism in cities such as Paragominas, an additional threat to the authority of the State has gained space in the Brazilian Amazon, i.e.: criminal organizations specialized in drug trafficking have increasingly attempted to capture value from resources with poorly defined property rights in the region (see Human Rights Watch, 2019; UNODC, 2023). While the 'list of *Municípios Prioritários*' policy appears to enhance the ability of the State to address historical conflicts in the Brazilian Amazon, its tools may prove insufficient to deter the action of these criminal groups and mafias. Indeed, accounting for the multiple interactions that explain the success of a policy is not enough though. Any changes in the preferences of the different groups involved in deforestation activities can impact the effectiveness of the 'list of *Municípios Prioritários*' policy as much as variations in the ability of the State to monitor and enforce a given property rights system. We should not take for granted that everyone will respond identically to reinforcement in the monitoring ability of the State. The actual effect of such reinforcement should depend on how different individuals guarantee their livelihoods. After all, individuals weight the costs and benefits of an illegal activity before deciding to act (Becker, 1968). Given the limitations of our dataset, we could not assess how the 'list of *Municípios Prioritários*' policy has affected the behaviour of the diverse groups that carry out deforestation activities (i.e., smallholders, large farms, loggers, and organized crime groups) and how these changes affect variables such as homicide rates. Diversity may exist even within the same group. For example, although soybean production has been highlighted as a key driver in the increase of deforestation rates in the *Amazônia Legal*, Rajão *et al.* (2020) show that a relatively small number of farms is responsible for a high percentage of the total illegal deforestation in the region. Studies may shed additional light on the indirect effects of environmental policies in the Brazilian Amazon by exploring the role of different patterns of deforestation in the region.

Another important aspect to be stressed is that property rights protection and the reduction of conflicts may ensue from diverse social equilibria. As Cai *et al.* (2020) explain, titling is only one of the potential ways to effectively control the use of land. From a broader perspective, North *et al.* (2009) contend that the features of a social order determine how violence is controlled. While institutions and the rule of law limit violence in 'open access societies', elites from 'natural states' tend to establish coalitions rooted in intertwined privileges (see also van Besouw *et al.*, 2016). Furthermore, alternative groups may compete with the State for the provision of services such as private protection (Böhm and Pascucci, 2020; Gambetta, 1993). Apparent peace in several regions of the Brazilian Amazon may be embedded in tacit agreements among members of local and regional elites that establish a *de facto* control over natural resources. Further research may investigate to what extent pockets of relative stability in the region depend on the existence of a 'natural state' equilibrium or the action of groups that illegitimately deploy means of coercion.

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