The Brazilian administrative law enforcement process and its effects on environmental recidivism

AREA ANPEC: Área 11 - Economia Agrícola e do Meio Ambiente

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Abstract

The Brazilian enforcement process is regarded as inefficient and weak concerning administrative sanctions appliance on environmental violations. Our main goal is to analyze the effect of processing status of administrative infraction perception of the defendant on the recidivism behavior of environmental offenders. We employ a unique dataset of infraction notices registered by IBAMA, for the years 2000 to 2010, at the individual level, within the Brazilian territory, through the Survival Analysis methodology. This paper contributes to the international literature on the rarely addressed subject of recidivism by providing new and strong evidence on the enforcement effects of the environmental law. The results shows that the delays in the legal process increase the risk of recidivism against the environment in Brazil.

Keywords: environmental violations; recidivism; enforcement; administrative sanctions; Brazil
JEL: K32, K41, Q58

Resumo

O processo de execução brasileiro é considerado ineficiente e fraco em relação às sanções administrativas aplicadas às violações ambientais. Nosso principal objetivo é analisar o efeito do status de processamento da percepção de infração administrativa do réu sobre o comportamento reincidente dos infratores ambientais. Empregamos um conjunto de dados inédito de notificações de infração registradas pelo IBAMA, para os anos de 2000 a 2010, em nível individual, dentro do território brasileiro, através da metodologia de Análise de Sobrevivência. Este artigo contribui para a literatura internacional sobre o tema da reincidência de infrações ambientais, fornecendo novas e fortes evidências sobre os efeitos da aplicação da lei ambiental. Os resultados mostram que os atrasos no processo legal aumentam o risco de reincidência contra o meio ambiente no Brasil.

Palavras-chave: violações ambientais; reincidência; execução; sanções administrativas; Brasil

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1. Introduction

In Brazil, the Institute for the Environment and Renewable Natural Resources (IBAMA) exerts the power of environmental police in Federal cases as part of the Brazilian Environmental Protection System (SISNAMA), is also performs the role of judging authority in administrative environmental law, as it is responsible for enforcing administrative sanctions within its competence. IBAMA was created in 1989, and it is linked to the country's Ministry of Environment (MMA). The agency can propose and edit environmental norms to the Environmental Council (CONSEMA), establish criteria for managing the use of natural resources, and regulate its procedure for investigating environmental infractions and imposing penalties on offenders. According to the IBAMA normative instruction No 10/12, when a violation is verified, a notice of infringement is issued by the inspection agent, and administrative sanctions are indicated to the transgressor following the legislation. In this "investigation phase," the assessed is given the possibility of defense. After that, IBAMA will proceed with a trial, and the offender may appeal the decision to superior officials in the SISNAMA's hierarchy. Once the notice of infraction has its final approval (after all appeals have been decided), then the law enforcement stage begins. At this point, the offender is ordered to pay the fine assigned to him at the time of notice of infraction, being the value increased or reduced by mitigating or aggravating circumstances if any is applicable. Additionally, IBAMA must inform the Public Ministry if the violator's conduct also configures environmental crime. If it is the case, alongside the administrative investigation, the criminal prosecution will take place, as civil liability procedures may also apply according to article 225, § 3rd.

The country has seen immense advances in monitoring technology, mainly concerning deforestation in the Amazon region. According to IBAMA (2010), inspections are planned and directed using remote sensing, satellite images, and geo-referenced location, acting throughout the country. Instead of pulverized actions, monitoring operations became larger and focused on "major violators" and critical areas. Also, the electronic assessment of infractions is making possible for IBAMA to track all current and past notifications, therefore the efficiency of the Institute in enforcing the law is increasing, as demonstrated by the higher rates of collected charges (IBAMA, 2010). Administrative sanctions are far more common than civil or criminal suits in Brazil, as it happens in other countries, fines are the most frequent sanctions[1] (Levia et al., 2004; Billiet and Rousseau, 2011; Alm and Shimschak, 2014; Uhr et al., 2018). Previous studies, such as Assunção et al. (2013), Uhr and Uhr (2014), and Uhr et al. (2018) appoint that fact for Brazil, as fine charges became, thus, essential to discourage deforestation and further environmental offenses.

However, the Brazilian enforcement process is often regarded as inefficient and weak concerning administrative sanctions (Hochstetler, 2002; Kirchhoff, 2006; McAllister, 2008; Barreto and Mesquita, 2009; Rooij and McAllister, 2014; Souza, 2016; Da Silva and Bernard, 2016; Garcia and Fonseca, 2018). Barreto and Mesquita (2009) point that the effectiveness of administrative sanctions is diminished by IBAMA's failure to comply with the legal deadlines for the investigation/ratification of infraction notices, there is a high rate of cases with long processing periods until final judgment, which leads to statutory limitations, and non-compliance to the imposed fines. The authors conclude that the current impunity perception favors new offenses[2]. Da Silva and Bernard (2016), for instance, show that over a span of twelve years only 1% of fines applied for wildlife-related infractions were actually paid in the state of

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[1] Souza (2016) states that there are three main administrative penalties at the disposal of IBAMA: the application of sanction charges, the imposition of embargoes, and the confiscation of the means used for illegal purposes. As pointed by Uhr et al. (2018), fines are issued with or without other sanctions, therefore being applied to all administrative infractions in every case. That is not the case for the remaining penalties.

[2] In another paper, Barreto et al. (2009) focus on criminal prosecution. Analyzing data from 51 violations against protected areas in the state of Pará, the authors concluded that the criminal liability was ineffective: only 14% of criminals were punished and 15% of all cases prescribed. Among the cases concluded, there was rarely a requirement to repair or compensate for environmental damage associated with the application of other restrictive penalties.

Pernambuco. Souza (2016) also points that an increasing in the collection of sanctions charges should be the main topic to improve efficiency in this field. In a more recent article, Garcia and Fonseca (2018), evaluating mining companies, suggest that the impact of administrative sanctions is likely reduced for two main reasons. The first being that, fines are disproportionally under evaluated considering the size of non-compliant companies and, the second, that issued penalties tend to go through several years of processing span. The authors also state that, even when recidivism is identified, fine values do not change much (Garcia and Fonseca, 2018). Therefore, being a continental country, Brazil faces enormous challenges not only to monitor offenders in a Federal level, but also to enforce environmental legislation.

The international literature on environmental infractions and recidivism is very scarce concerning empirical evidence[3] mainly because data on such cases is almost non-existent (Levia et al., 2004)[4]. Levia et al. (2004), analyzing data for the European Union, indicate that the benefits of administrative sanctions, such as being faster and less costly compared to criminal proceedings, are compromised by the application of low fine values, a lack of aggravation in the case of recidivism, among other issues. The authors also stress the importance of sanctioning recidivism with higher severity and in creating a central and public available register of recidivist companies. By comparing the effects of civil, criminal, and administrative lawsuits on recidivism rates for US companies, Miller (2005) have concluded that criminal trials significantly reduce recidivism among environmental perpetrators. Also, that civil lawsuits are not more effective than administrative actions. However, civil lawsuits against firms with one or more incidents significantly reduce recidivism by carrying stronger punishments due the punitive damages legal institute. In that way, Miller (2005) emphasizes the central issue of continuing enforcement to assure compliance with the environmental law. In a literature survey of empirical studies regarding the determinants of imposed fines for the USA, Canada, and the European Union, Rousseau (2009) point that sanction charges tend to be higher for repeat offenders. Blondiau and Rousseau (2011) test how punishment decisions are taken in Belgium by using a dataset of criminal and administrative enforcement cases. They find that repeat offenders have a higher sanction probability and are consistently given stricter penalties than first-time violators. Additionally, firms receive stringent punishments than individuals.

Our primary goal is to analyze the effect of the Brazilian administrative law enforcement process on the recidivism behavior of environmental offenders[5]. We focused on the processing status of administrative infraction notices, with emphasis on the actual payment of imposed fines[6] as an index of efficacy. We also consider a comprehensive set of 53 control variables that are related to the possibility of criminal prosecution, offender characteristics, local environmental monitoring, and socioeconomic, geographical, and institutional aspects of the municipality where the infraction took place. To do that we employed a unique dataset of infraction notices registered by IBAMA, for the years 2000 to 2010, at the individual level, within the Brazilian territory, and applied the Survival Analysis methodology. We contribute, therefore, to the international literature on environmental policy enforcement, on the rarely

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[3] The theoretical framework on recidivism and enforcement is well established. Examples include Endres and Rundshagen (2016), Mungan (2010), Emons (2003, 2007), Chu et al. (2000), Polinsky and Shavell (1998), and Polinsky and Rubinfeld (1991).

[4] Current international research on environmental violations and deterrence focuses on aspects other than the imposition of administrative fines: criminal prosecution, threat of imprisonment, spillover effects, corruption, the importance of local governments, and decentralized monitoring and enforcement (Almer and Goeschl, 2010; Billiet and Rousseau, 2011; Gray and Shimshack, 2011; Faure and Svatikova, 2012; Aklin et al., 2014; Blondiau et al., 2015; Sjöberg, 2016, Lynch et al., 2016).

[5] We use a broad concept of recidivism, which refers simply to the commitment of a new environmental infraction without considering specific legal aspects. In this way, recurrence may include general (the practice of new environmental infringement of diverse nature) or specific cases (same nature).

[6] Information on the current situation of each process, which comprises a total of one hundred and one possibilities, has been subdivided into seven status categories: (i) paid fines; (ii) assessments in progress; (iii) converted into other minor sanctions; (iv) payment of the fine in installments; (v) fine values enrolled in the active debt of the Union; (vi) prescribed cases; and (vii) canceled, suspended, or deleted records. We possess data on sanction charges indicated at the time of assessment by the inspection agent, however, at that point, fine values do not consider the offender's recidivism, if any. Monetary values may be increased or reduced later by the judging authority, and we lack that information. Therefore, we decided not to employ fine values in the analysis.

addressed topic of recidivism. In this sense, we provide new and strong evidence on the effects of administrative sanctions and the enforcement of environmental legislation in Brazil.

The results indicate that the highest risk of recidivism occurs when the process is extinguished. The second major effect on the risk of recidivism occurs when the legal process is subjected to statutory limitations. Thirdly, fact that the process is placed in the official active debtors list of the state, and, finally, the fact that the proceeding takes too much time to be concluded.

The remainder of this paper is organized as follows. Firstly, we present the Brazilian environmental legislation regarding recidivism in the next section. Data and descriptive statistics are discussed in part three. Section four describes the applied methodology (Survival Analysis Models). Empirical results are discussed in part five. In the part six we analyzed the sensitivity of the coefficients of the section five. Final thoughts are presented under Conclusions.

2. Brazilian Environmental Legislation, Recidivism and Legal Procedure[7]

Brazilian Environmental Law is organized in Constitutional, Legal and Normative rules. Being the most important rule in this matter regarded in article 225 of the Federal Constitution that considers the Right to an Equilibrated Environment a Fundamental Right for all. The paragraph third of article 225 also predicts the administrative, criminal and civil liability as applicable for damages to the environment.

The Administrative Environmental Law is organized under the Environmental Protection System's - SISNAMA Act (Lei 6.938/81) which is composed by the Environmental Ministry (MMA), which is responsible for the administration of all Environmental Policies under the Federal Jurisdiction, the Federal Environmental Council (CONSEMA), and the Federal Environmental Agencies IBAMA (responsible for environmental compliance in general) and ICMBIO (specialized in the protection of biodiversity and the control of Federal Preservation Areas) responsible for environmental compliance and licensing in the Federal level. In State level this structure is repeated being the State's Office for Environmental affairs the equivalent to the MMA, the State's Environmental Council to CONSEMA and the State's Agencies usually comprises the roles of IBAMA and ICMBIO, the same is true for the Municipalities level as the County's Environmental Office is a counterpart to MMA and CONSEMA and a local Agency is usually equivalent to IBAMA and ICMBIO. Along with the agencies, offices and councils, SISNAMA also is helped to investigate environmental non-compliance occurrences by the local Police Departments with special environmental squads.

The Environmental Offences and Administrative Infractions are consolidated in the Environmental Crimes Act (Lei 9.605/98) which predicts sanctions divided by themes such as Crimes against the Fauna and Flora, Biodiversity, National Parks, etc. In this law, any environmental crime can be regarded as an Administrative Infraction, though administrative infractions can be predicted in other acts, as the Criminal offenses are restricted to actions previously specified in Law. As for the Civil Liability for environmental damages, it is predicted in the Paragraph Third of the article 225 of the Federal Constitution as it is also mentioned in article 14 of the SISNAMA Act and is one of the exceptional cases of strict liability under Brazilian torts law.

Finally, concerning the institute of recidivism, Law 9.605/98 does not mention the administrative consequences for this matter, although it does predict Criminal consequences in article 15, I as an aggravation or qualification circumstance to environmental penalties. Law 6.938/81 mentions recidivism in administrative sanctions as a measure to aggravate fines, as it is often regarded as a way to chose between different administrative sanctions given by Environmental Law (Lei 6.938) such as simples fine versus daily fine (article 14, I); restriction or loss of tax benefits of licenses conceded by the State (article 14, II); suspension or loss of participation in financial modalities in state-owned credit establishments (article 14, III); suspension of the firm activity (article 14, IV).

[7] Uhr et al. (2018) do an extensive review of the current Brazilian environmental regulation concerning the general legislation on environmental infractions and the administrative process for monitoring and enforcement. Here, our focus is specifically on recidivism aspects.

As for the Brazilian Administrative Procedure, its length can vary according to specific normative for each Agency. Though the Administrative Procedure Act (Lei 9.784) gives its general lines. The procedure will follow phases such as installment, instruction and trial to reach a decision about the appliance of the administrative section according to the stances presented by the State and the Defendant, though differently from the Civil and Criminal procedures, if the defendant do not pose its defense acts, the procedure will follow automatically by the State thus the will of the people should prevail on private ones, being any abnormally extended procedure length thus attributed to the State's lack of interest or capacity to continue the procedure itself. Though if the Administration fails to present documents, notices or data require, the procedure could be subjected to archival (extinction without a final decision) according to article 40. Article 51 predicts the causes of extinction without a final decision, which are the desistance of the plea of disposable rights or when its object is considered impossible, useless or harmed by a future event. In addition, the Administration can void its own acts when based upon legality issues, and can revoke them by opportunity and convenience, respected acquired rights. The right to void administrative acts are limited to 5 years by the law. Finally, article 56 states that the administrative decisions are subjected to appeals which can be imposed upon three Administrative stances according to the hierarchy of the Administrative Agency (article 57). In addition, Administrative decisions are subjected to Legal Courts control according to article 5th XXXV of the Constitution.

If an administrative sanction is applied to environmental infractions, it can be done throughout simple fines, daily fines, activity suspension, detainment of actives such as machines and other goods necessary to production and the license of operation's extinction, being the sanctions applied accordingly to the magnitude of the consequences of the infringement (article 72 and 6th of Lei 9.605/98). Though if the sanction applied is the simple fine, it could be converted to lesser sanctions such as preservation of green areas, improvement of the environmental quality and other actions given by the State (article 72, §4th), though, if the procedure takes a time span larger than 3 years, it can be subjected to the extinctive effects of the statutory limitations of article 1st, § 1st of Lei 9.873/99 which established the statutory limitations on the Acts of the State.

The same rational about the Administrative Procedure can be applied to the Civil and Criminal procedure, thus both can be archived by a lack of procedure acts due to the plaintiff or the State as extinguishment of the procedure can be made regarding formalities required to perform procedure acts, although in Civil procedure the latest reforms restricted extinguishment possibilities to a complete lack of performance of the plaintiff since article 76 of the Civil Procedure Code requires that the judge ask for the party to redo any act that may extinguish the procedure without a final decision. The Statutory Limitations for the Civil Liability lawsuits are 3 years counting from the act itself, according to the article 206, § 3rd of the Civil Code. As for the Criminal Procedure, the phases before the presentation of a denounce from the Public Ministry, such as the investigation can bring possibilities of archival, firstly by the Police Authorities that declares a lack of interest of factual possibilities of continuing the investigation or later by the Public Ministry in its appreciation of the Police's report. Though if made by the Public Ministry, the decision must be reviewed by a judge according to article 28 of the Criminal Procedure Code, who will confirm or deny the archival of the procedure. The Criminal Procedure Code can be suspended to resolve any controversy about facts and proofs needed for the decision of the judge to apply or not a sanction to the defendant, as the judge can also suspend the penalty itself from 2 to 6 years on penalties of reclusion and detention lesser than 2 years if the defendant has good precedents, and the circumstances shows that it will not be subject of recidivism. The article 8 of the Environmental Criminal Act also predicts the conversion of the penalty to services provided to the community to compensate the damages caused; the Statutory Limitations in Criminal Cases are variable according to the Penalty Applied, according to article 109 of the Criminal Code, though since the penalties of Environmental Crimes vary from 1 to 5 years mostly, from 4 to 12 years before the final sentence, although there are more cases of statutory limitations in Criminal Law which can be studied further through the Criminal Procedure Code, the Criminal Enforcement Act and other legislations on the subject.

3. Data

The main dataset on infraction notices in administrative federal circuit is available for download at IBAMA's website[8]. The employed data covers administrative infractions against the Brazilian flora, for the years between 2000 and 2010[9], at the individual level totaling 127,873 records and 98,006 violators. Raw data contains information about the infringement record number, the violator's information (if physical or legal persons, if public or private firms, including their names and social registry number), the date and municipality of the fact, the magnitude of the applied fine, the status of the administrative procedure[10], and the legal basis of the assessment, indicating violations that can also give rise to criminal proceedings (potential environmental offense).

Table 1 shows how infraction records behave concerning recidivism. The amount of data censored by the right (no recurrence) is 76.64%, and the average number of violations is 1.3047 per violator. The average time to failure or censorship is 2,309.58 days (counted from the first record, that is, after the occurrence of the first offense, or after the appearance of a new infringement event for the same violator, if more than one case of recurrence). Recidivism cases correspond to 23.36% of the total infringements, that is, 29,867 occurrences and the violators who experience this event are 14,791, or 15.1% of the total number of offenders. Of these, 62.67% recidivate once, 16.92% recidivate twice, 7.53% recidivate three times, and 12.88% four times or more.

Table 1 – Descriptive statistics for offense records, violators, and recidivism rates

	Total	Mean	Median	Min	Max
Offense Records	127,873 (100%)	1.3047	1	1	34
Recidivism cases	29,867 (23.36%)	0.3047	0	0	33
Time to failure (days)	-	2,309.58	2,471	1	4,017
Violators	98,006 (100%)	-	-	-	-
Repeat Offenders	14,791 (15.09%)	-	-	-	-
Recidivate once	9,269 (62.67%)	-	-	-	-
Recidivate twice	2,503 (16.92%)	-	-	-	-
Recidivate thrice	1,114 (7.53%)	-	-	-	-
Four times or more	1,905 (12.88%)	-	-	-	-

Notes: Recidivism rates in parentheses; data collected in May 2016. **Source:** Records of administrative infraction notices against flora collected from IBAMA, with occurrence between 2000 and 2010.

Table 2 shows the description and descriptive statistics on our essential variables, which relate to the processing status of administrative infraction notices, with emphasis on the payment of imposed fines. Information on the current situation of each record, comprising a total of one hundred and one possibilities in the dataset, was subdivided into seven great categories: (i) actually paid fines; (ii) assessments in progress, including notified cases that are under analysis/investigation, awaiting approval/ratification, etc.; (iii) sanction converted into other lesser sanctions, which include simple warnings (no fine charged), community service performance or social compensation for the environmental damage; (iv) payment of the fine in installments; (v) fine values enrolled in the active debt

[8] The information provided by IBAMA contained some issues that had to be addressed, such as duplication of records, fines with lower values than allowed by law, errors in the description of the municipalities where the violations took place, as well as missing data. For the latter case, the records were removed from the analysis.

[9] After the publication of Complementary Law 140 of 2011 by the Federal Government, it is the municipalities that have, through their environmental secretaries, the prerogative to supervise administrative issues within their area. This competence is absorbed by the regional entities when the municipality does not have its own secretariat and by IBAMA only when they are linked to national parks or when they are of federal competence. Therefore, as of 2011, the records registered by IBAMA reflect only part of the total administrative infractions.

[10] Data were collected in May 2016; therefore, the current situation of the infringement processes may be different from the ones in our database.

of the Union blacklist; (vi) cases subjected to statutory limitations; and (vii) extinguished, suspended, or deleted records for any reason.

Table 2 – Descriptive statistics for the processing status of offense records

	Description	Mean	SD	Min	Max
QUI	1 for fine paid, 0 otherwise	0.3761	0.4844	0	1
TRA	1 for assessments in progress, 0 otherwise	0.4066	0.4912	0	1
CEO	1 for converted into other lesser sanction, 0 otherwise	0.0058	0.0762	0	1
SPA	1 for fine payment in installments, 0 otherwise	0.0177	0.1320	0	1
IDA	1 for enrolled in the active debt of the Union, 0 otherwise	0.0588	0.2353	0	1
PRE	1 for subjected to statutory limitations, 0 otherwise	0.0641	0.2449	0	1
CBS	1 for extinguished, suspended, or deleted, 0 otherwise	0.0676	0.2512	0	1

Notes: Data collected in May 2016. **Source:** Records of infraction notices against flora collected from IBAMA, with occurrence between 2000 and 2010.

Records with paid fines (QUI) correspond to 37,61% of total offenses and infraction notices with the debt negotiated in installments (SPA) matching only 1,77% of the data, giving an overall of 39,38% of fines paid or in the course of payment. Only 0,6% of violations were converted into simple warnings or other lesser sanctions (CEO). The other main category, assessments in progress (TRA), shows that 40,66% of the records in 2016 are still under analysis/investigation or awaiting approval/ratification. That represents a minimum of 6 years for the processing time of this phase, supposing the infringement occurred in 2010. Other categories favoring impunity are cases enrolled in the active debt of the Union (IDA), subjected to statutory limitations / “*prescrição*” (PRE), and extinguished, suspended, or deleted (CBS), corresponding to almost 20%. Therefore, we can consider that roughly 40% of infraction records were actually an administrative sanction in the analyzed period.

For the empirical analysis, we also considered a comprehensive set of 53 control variables, which are organized into eight categories plus the possibility of criminal prosecution. They are: (i) offender characteristics, regarding the violation performance by individuals or private/public entities; (ii) municipal environmental monitoring, including the existence of an environmental police station, presence of IBAMA superintendence or separate technical unit, and the number of environmental NGO; (iii) municipal geographical characteristics; (iv) local agricultural production and fire outbreaks; (v) other municipal socioeconomic variables; (vi) local institutional aspects, including the existence of specific environmental legislation and municipal council for the environment, among others; (vii) other municipal characteristics; and (viii) local expenses with environmental control, management, preservation, and recovery. The full set of control variables and descriptive statistics is available in Appendix A.

Concerning the possibility of criminal prosecution, the legal basis of assessment in the dataset indicates if the offender violated articles 38 to 53 of the Environmental Crimes Act (Lei 9.605/98). In these cases, IBAMA must inform the Public Ministry and, alongside the administrative investigation, the criminal prosecution might take place. Those cases correspond to 25.9% of the violations, or 33,117 records. Appendix B shows how criminal records in our dataset behave concerning recidivism.

4. Method[11]

Survival Analysis is concerned with assessing the expected span of time of the occurrence of an event, or the amount of time until a failure (Cleves et al., 2004). In social sciences these methods are also called "Duration Analysis". In our case, the event in question is recidivism, and failure denotes reoffending. According to Monnery (2013), since the seminal work of Schmidt and Witte (1989), a large amount of studies employ such methods instead of binary or linear models to study recidivism. Our interest is, therefore, not only in the occurrence, or the probability of reoffending, but also when it takes place. The most important functions in the analysis are the Survival Function, $S(t)$, and the Hazard Function, $h(t)$, where $T = 1,..,t$ is a non-negative random variable denoting time to failure. $S(t)$ denotes the probability of surviving beyond time t and $h(t)$ is the instantaneous rate of failure, conditional on having survived to that time (Cleves et al., 2004). The Hazard Function, along with the Cumulative Hazard Function[12], $H(t)$, help to answer what is the risk – the intensity with which recidivism occurs - of the event at time t. According to Cleves et al. (2004), hazard functions give an easier way to understand how the co-variables affect the risk and the process that generates failure (reoffending).

Traditionally, subjects are followed over time until the first failure, and the observation on that individual stops at that point. However, in our case, data collection does not stop when the violator recidivates, and we consider the possibility of repeatable events, that is, multiple reoffences. We worked with longitudinal data on infringements in the span of 11 years and violators could join the study at any time, from 2000 to 2010. Also, we had access to the precise number of days between the subject's first violation and the date of the following infractions, if any. Therefore, we dealt with repeated event models to investigate the process that generates recidivism. The large time-span and number of events of our dataset, along with the "fail precision", improve the consistency of our estimates and provide satisfactory statistical power.

The recurrent event analysis with multiple co-variables imposes some particularities. Non-parametric models[13] do not provide effect estimates for multiple variables of interest. In that case, semi-parametric[14] or parametric models[15] allow for the analysis of recidivism with respect to our focus variables simultaneously, which is, they provide estimates for the effect of each category of the processing status of infraction notices. Also, repeated event data is correlated thus we considered multiple recurrences for the same offender (repeated measures for an individual). Frailty models, which account for unobservable heterogeneity or random effects (the violator's own disposition to recidivate) consider the presence of correlation and were used to model dependence in multi-variables survival data[16]. The first are termed "Unshared Frailty Models" and the latter are referred to as "Shared Frailty Models" (Cleves et al., 2004). We assume frailty to be a characteristic of the infringer, that is, frailty is not a

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[11] The "Columbia University Mailman School of Public Health" provides and overview on survival analysis data, methods, and main questions, along with a comprehensive list of further readings. This section is largely based on their website. It can be accessed at https://www.mailman.columbia.edu/research/population-health-methods/time-event-data-analysis

[12] Usually, the relationship among these functions translates as: an increase/decrease in h(t) will lead to an increase/decrease in H(t), which translates into a decrease/increase in S(t).

[13] Nonparametric approaches do not rely on assumptions about the parameters in the underlying population. The most well-known estimators are the Kaplan-Meier and the Nelson-Aalen (Kaplan and Meier, 1958, Aalen, 1978, Nelson, 1969, Nelson, 1972). These methods are generally used to describe the data with respect to the factor under analysis by estimating S(t).

[14] The Cox Proportional model is the most commonly used multivariable semi-parametric approach in Duration Analysis. The model consists of a non-parametric element, represented by the baseline hazard, $h_0(t)$, and a parametric module comprising the covariate vector, $g(X'\beta)$. The proportional hazards (PH) hypothesis presumes that the covariate vector multiples $h_0(t)$ by the same amount regardless of time, that is, risk rates (hazard ratios) are proportional and constant among individuals for the entire period of analysis (Cox, 1972).

[15] In parametric models the distributions of the covariate vector and the hazard function are both stipulated based on assumptions about the underlying population. In that case, the estimation of the baseline hazard is of interest. The PH approach can also assume the parametric form. Parametric models, when correctly specified, are more efficient and have more power than semiparametric counterparts, providing smaller standard errors and more precise estimates (Cleves et al., 2004). The most frequently used distributions for the hazard function are: the Gompertz, the Exponential, and the Weibull.

[16] Vaupel et al. (1979) are among the firsts to suggest an individual random effects model for time-to-event analysis with the notion of frailty, meaning that subjects with shorter times to failure are more "frail" than others (Cleves et al, 2004; Gutierrez (2002).

specific observation but causes of violation for the same subject who are correlated. The Shared Frailty controls this latent individual effect.

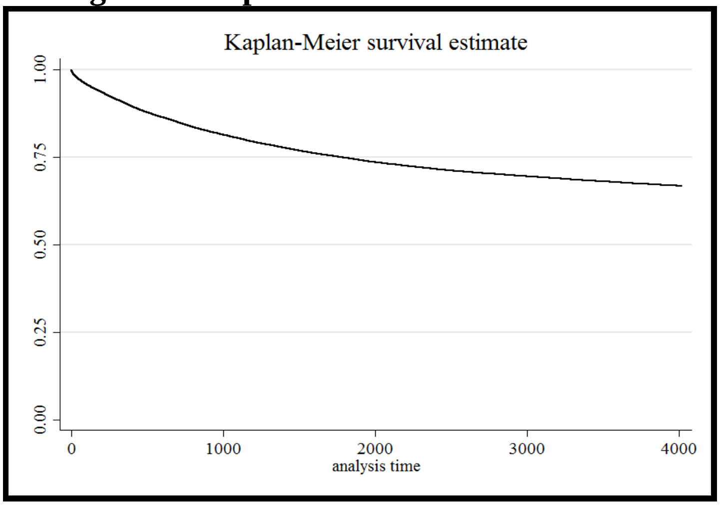
Therefore, frailty is shared at the violator level and can be assumed to follow either a gamma or inverse-gaussian distribution (Vaupel et al., 1979; Hougaard, 1984; Cleves et al., 2004). In this case, the hazard ratio's[17] interpretation will be conditional on frailty (Gutierrez, 2002). Therefore, $h(t_{ij}|x_{ij}, \alpha_i) = \alpha_i h(t_{ij}|x_{ij})$, for data consisting of n groups, with the ith group comprised of n_i observations. The index i denotes the offenders ($i = 1, \ldots, n$), and j denotes the observation within groups, for $j = 1, \ldots, n_i$, where "group" represents a single subject for which multiple offense episodes may be observed, α_i are the individual frailties and t is the time period (Cleves et al., 2004; Gutierrez, 2002).

Therefore, to analyze the effect of processing status of administrative infraction notices on the recidivist behavior from environmental violators we employed the semi-parametric approach of the Cox Proportional Model, the parametric versions of the Proportional Hazards (PH) Models considering different distributions (Gompertz, Exponential, and Weibull)[18], and the Shared Frailty Approach. The Kaplan-Meier and the Nelson-Aalen non-parametric approaches are also presented as a form to describe the data. To compare models run with different parametric forms, we use the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). Sensitivity analysis is done by the evaluation of two measures: the pseudo R^2 (Cox and Snell, 1989) and the Log-Pseudolikelihood.

5. Results

In this section we will present the results of the application of survival analysis models to assess the effects of the Brazilian administrative procedure on the recidivism of environmental violators. The analysis is structured in two phases, the non-parametric analysis of Kaplan-Meier and Nelson-Aalen and the application of proportional risk models.

Figure 1: Kaplan-Meier Survival function



In order to illustrate failure time we chose to use the Kaplan-Meier Survival Graph, whereby one can observe how individuals experience recurrence over time. Figure 1 shows that the probability of survival declined by approximately 30% during the analyzed period, and this decrease occurs more sharply in the first quarter of the time analyzed.

Table 3 presents the results of the survival function given by Kaplan-Meier non-parametric

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[17] In a simple form, HRs reflect the relationship between the instantaneous hazards for two groups of covariates, describing the differences in the relative hazard, and are often treated as a ratio between failure probabilities.

[18] The exponential distribution assumes that the hazard depends only on model coefficients and covariates and is constant over time. The Weibull distribution assumes a monotonic hazard that can either be increasing or decreasing. The Gompertz distribution is a PH model that is equal to the log-Weibull distribution, so the log of the hazard function is linear in t.

estimation. In the first column is the variable time, subdivided into categories, the second and third column, presents the number of recurrences in the period and their accumulated number and from the fourth column, the value of the Kaplan-Meier function and its statistics.

Table 3 - Kaplan-Meier Estimation

Categoria de Tempo	Reincidências no período	Reincidência Acumulada	Survival Function	Error	Confidence Interval (95%)	
De 0 a 1 mês	2125	2125	0,9785	0,0005	[0,9776	0,9794]
De 1 a 6 meses	4001	6126	0,9387	0,0008	[0,9372	0,9402]
De 6 a 12 meses	3762	9888	0,9018	0,0009	[0,8999	0,9036]
De 1 a 2 anos	5747	15635	0,8426	0,0011	[0,8439	0,8484]
De 2 a 3 anos	4218	19853	0,8049	0,0012	[0,8024	0,8073]
De 3 a 5 anos	5468	25321	0,7475	0,0014	[0,7448	0,7502]
De 5 a 8 anos	3722	29043	0,6980	0,0015	[0,6950	0,7009]
De 8 a 11 anos	824	29867	0,6663	0,0025	[0,6614	0,6711]

From Table 3 can be inferred that the value of the survival function decreases at decreasing rates over time. The value of this function reflects the probability of occurrence of recidivism not happening until a certain period. For the first year, after the basic registration, 90.18% of the cases do not present recurrence, for the second year this value decreases to 84.26% and in the third year to 80.49%, decreasing at ever lower rates until arriving in 66.63% for the eleventh year.

Table 4 presents the results according to Nelson-Aalen's non-parametric estimation. Following the same structure as the previous table, in which the first column represents time, subdivided into categories, in the second and third column, the number of recurrences in the period and its cumulative number and from the fourth column, the value of the Nelson-Aalen function and its Statistics.

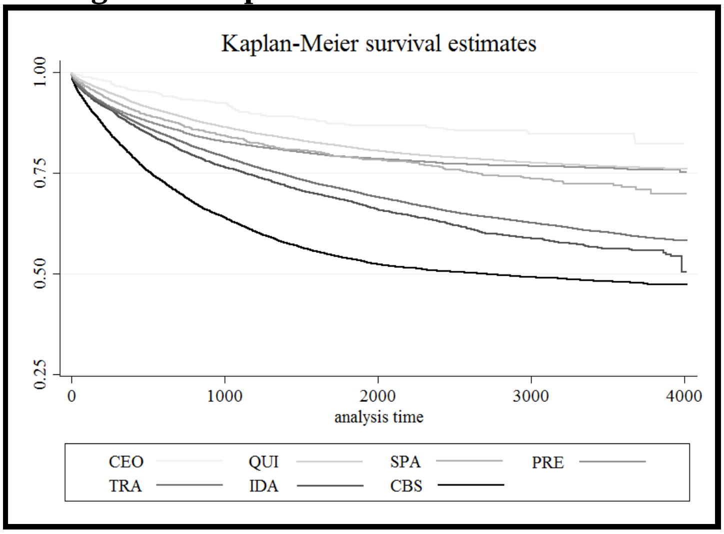
Table 4 - Nelson-Aalen Estimation

Categoria de Tempo	Reincidências no período	Reincidência Acumulada	Função de Risco Acumulada	Erro	Intervalo de confiança Coeficiente de 95%	
De 0 a 1 mês	2125	2125	0,0217	0,0005	[0,0208	0,0226]
De 1 a 6 meses	4001	6126	0,0632	0,0008	[0,0617	0,0648]
De 6 a 12 meses	3762	9888	0,1033	0,0010	[0,1013	0,1054]
De 1 a 2 anos	5747	15635	0,1670	0,0013	[0,1644	0,1697]
De 2 a 3 anos	4218	19853	0,2171	0,0015	[0,2141	0,2201]
De 3 a 5 anos	5468	25321	0,2909	0,0018	[0,2874	0,2946]
De 5 a 8 anos	3722	29043	0,3595	0,0022	[0,3553	0,3638]
De 8 a 11 anos	824	29867	0,4060	0,0037	[0,3988	0,4134]

The value of the accumulated risk function grows at decreasing rates over time. As the value of the function reflects the cumulative risk of recidivism after a certain period. For the first year after the basic registration, the cumulative risk of recurrence is 10.33%, for the second year the cumulative risk is 16.7%, this accumulated risk increases at ever lower rates until reaching 40.6% % for the eleventh year.

Now, if we look at Kaplan-Meier's survival function for the categories of the legal process situation (Figure 2). Which is, the procedural situation of the infraction that caused the entry of the individual in the analysis affects the function of recidivism that he observes for the next periods. In all seven categories the survival function is decreasing with decreasing rates over time and categories intensify this decrease.

Figure 2: Kaplan-Meier Survival function



The lighter survival function is the base records categorized as CEO, and below it are the survival curves for the records categorized as QUI, SPA and PRE. These curves are close to each other. Registries categorized as TRA and IDA present near survival curves and slightly above the survival curve for records categorized as CBS, which has its survival function with the highest intensity of decrease. Thus, the records categorized as CBS have a probability of experiencing the recidivism event close to 45%, in the half of the analyzed period, for those categorized as QUI, the probability falls close to 20%.

It is important to emphasize that to correctly evaluate the effect of the variables of the administrative procedure situation on the risk of recidivism of infractions against the environment in Brazil we must use correctly the sample that we have. The sample is structured as follows, we have multiple records per violators on failures that may happen repeatedly. In addition, co-variables of interest change over time. Then, with this "complex" structure, we must specify strong standard errors thus the data follow the violator identity variable, and this implies in the estimation that clustering will be defined by the violator. So, all estimates consider this structure for analysis. And in order to control the heterogeneity between individuals we added the shared fragility component. Therefore, in Table 5 we present the results for the proportional risk (PH) models (Cox, Gompertz, Exponential and Weibull, respectively). When the estimators allow[19] us to add regressions containing both the shared frailty with the Gamma distribution and the shared frailty with the Inverse Gaussian distribution. The estimates were performed using all control groups described in the data section.

The coefficients presented in Table 5 should be interpreted as follows: when they are represented by a number below zero, the risk of recidivism of infraction decreases. In contrast, if the coefficient is given by a number above zero, the risk of recurrence increases. As for the set of variables regarding the process status, the difference between their risk rates is obtained through their coefficients, and the basis of comparison between them is the QUI variable. To derive the variation on the risk of recidivism we should apply the exponential to the estimated value, subtract one unit and multiply by 100, for all coefficients found in Table 7. For example, consider the Cox semi-parametric model in the first column. In this model, the SPA variable has a coefficient of 0.153, so by applying the exponentiation to this value, we have $exp(\beta) = exp(0{,}153) = 1{,}165$, so the risk ratio for the SPA category in relation to the risk of QUI is 16.5% greater than that of the base variable.

The Cox proportional hazards model presents a negative coefficient for the CEO variable and positive for the variables SPA, PRE, IDA, TRA and CBS. These positive variables are statistically significant, the first at least 10% and the others at 1% in significance level. In the parametric model of proportional risks with Gompertz distribution we have the negative coefficient for the CEO variable and positive for the other variables. The coefficients of SPA, PRE, IDA, TRA and CBS are statistically

[19] The stcox stata package is not able to run the cox model with frailty due to the large number of offenders contained in the database.

significant, being the first two at least 5% and the other at 1%. Then, the model with Gompertz distribution and shared frailty with Gamma distribution was estimated and, later, the model considering the shared fragility with Inverse Gaussian distribution. The coefficients of both models presented negative values in the CEO variable, and positive in the variables SPA, PRE, IDA, TRA, CBS. In both models, the coefficients of the CEO and SPA variables were not significant, while for the others, they were statistically significant at least 1% significance level.

We follow the same rationale for proportional hazards model with Exponential distribution, the coefficients were negative for the CEO variable and positive for the SPA variable, the first being not significant and the second significant with at least 10% of significance level. For the variables PRE, IDA, TRA, CBS the coefficients are positive and significant to at least 1% of significance level. Considering the frailty shared with Gama distribution and with Inverse Gaussian distribution, the models presented coefficients with negative values in the CEO variable, and positive in the variables SPA, PRE, IDA, TRA, CBS. In both models, the coefficients of the CEO and SPA variables were not significant, while for the others, they were statistically significant at least 1% of significance level.

Finally, we considered the parameterization with Weibull distribution. When frailty is disregarded, the SPA variable is significant at least 10% confidence level. When considering the shared frailty, for both models the coefficients presented negative values in the CEO and positive variables in the variables SPA, PRE, IDA, TRA, CBS, with the variables CEO and SPA not significant and the other coefficients significant at least 1% of significance.

In general, we can conclude that the variables PRE, IDA, TRA and CBS are significant in all proportional risk models utilized. The coefficients appoints to the same direction, which means that they all increase the risk of recidivism of the violators. The selection of the most appropriate model is performed by the AIC and BIC criteria, in which smaller values indicate which modeling is most appropriate. The model selected by these criteria is the Weibull with Inverse Gaussian Shared Frailty. This model presents the lowest values for both criteria, which are respectively: 71245.2 and 71775.9. In addition, the LR statistic referring to the theta parameter indicates rejection of the null hypothesis, so the unobserved heterogeneity is statistically significant at 1% of confidence and should be considered.

The parametric model of proportional hazards with Weibull distribution and shared Inverse Gaussian frailty shows that PRE, IDA, TRA and CBS significantly affect the risk of recidivism of infringements against the environment. The results indicate that the components of the law enforcement process increase the risk of recidivism of violators against the environment. The highest risk of recidivism occurs when the process is extinguished (CBS), with effect of approximately 79.9%. The second major effect on the risk of recidivism occurs when the legal process is prescribed (PRE), with effect of approximately 33.4%. The fact that the process is recorded in the active debt increases the risk of recurrence by approximately 29.7%. Finally, the fact that the proceeding remains in progress increases the risk of recidivism by approximately 29.1%.

These results suggest that both the delays in the legal process and the eventual ability of the offender to be assisted by lawyers who can extend the process in court, possibly resulting in cancellation or limitation, increase the risk of recidivism of these offenders against the environment. Therefore, institutional policies that stimulate both the settlement of fines and acceleration of the judgments would reduce the risk of recidivism of environmental infractions in Brazil.

Table 5 – Proportional Hazards (PH)

	Cox	*Gompertz*			*Exponencial*			*Weibull*		
	Without Frailty	*Without Frailty*	*Frailty Gama*	*Frailty Inv Gaus*	*Without Frailty*	*Frailty Gama*	*Frailty Inv Gaus*	*Without Frailty*	*Frailty Gama*	*Frailty Inv Gaus*
CEO	-0.133	-0.127	-0.0679	-0.122	-0.134	-0.0876	-0.138	-0.130	-0.0692	-0.116
	(-0.62)	(-0.59)	(-0.35)	(-0.63)	(-0.62)	(-0.45)	(-0.71)	(-0.61)	(-0.36)	(-0.60)
SPA	0.153*	0.173**	0.113	0.115	0.210**	0.134	0.135	0.146*	0.0910	0.0928
	(1.84)	(2.05)	(1.29)	(1.30)	(2.48)	(1.54)	(1.56)	(1.75)	(1.05)	(1.07)
PRE	0.366***	0.370***	0.291***	0.285***	0.336***	0.253***	0.233***	0.374***	0.299***	0.288***
	(5.96)	(5.98)	(4.81)	(4.74)	(5.34)	(4.17)	(3.90)	(6.11)	(4.98)	(4.84)
IDA	0.400***	0.417***	0.293***	0.291***	0.405***	0.211***	0.199***	0.403***	0.268***	0.260***
	(9.39)	(9.70)	(7.07)	(7.06)	(9.29)	(5.12)	(4.83)	(9.48)	(6.56)	(6.37)
TRA	0.400***	0.416***	0.288***	0.286***	0.408***	0.198***	0.186***	0.402***	0.263***	0.255***
	(14.81)	(15.29)	(10.81)	(10.79)	(14.78)	(7.44)	(7.03)	(14.94)	(10.00)	(9.74)
CBS	0.672***	0.665***	0.547***	0.534***	0.630***	0.576***	0.560***	0.680***	0.599***	0.587***
	(14.98)	(14.74)	(13.18)	(12.96)	(13.79)	(13.81)	(13.65)	(15.23)	(14.59)	(14.45)
Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Likelihood[1]										
Null	-160788.8	-51634.4	-40509.3	-40387.7	-51661.6	-41406.4	-41387.4	-51039.7	-39859.0	-39782.5
Model	-149529.5	-40019.1	-36207.2	-36178.6	-40500.7	-37181.3	-37191.3	-39316.0	-35569.8	-35564.6
LR	-	-	7623.80	7680.98	-	6638.71	6618.71	-	7492.45	7502.83
AIC	299169.0	80152.2	72530.4	72473.2	81113.4	74476.7	74496.7	78746.0	71255.5	71245.2
BIC	299672.3	80673.7	73061.1	73003.9	81625.8	74998.3	75018.3	79267.6	71786.3	71775.9
R-squared[2]	0.276	0.284	0.116	0.114	0.274	0.114	0.114	0.286	0.116	0.114
N	69582	69582	69582	69582	69582	69582	69582	69582	69582	69582

Estatísticas t entre parênteses, * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$, [1]Log pseudo Likelihood, [2]Cox & Snell's pseudo R-squared

6. Sensitivity Analysis

In this section we analyze the sensitivity of the coefficients of the parametric model of proportional hazards with Weibull distribution and shared Gaussian inverse frailty. The Table 6 presents ten different strategies for this parametric model. The first modeling considers only the variables of interest and disregards all controls.

The results of this strategy are reported in column (01) and indicate that all variables of interest are statistically significant, CEO, PRE IDA TRA and CBS at 1% level of significance, while SPA is significant at 5% confidence. The magnitudes of the coefficients are close to those found in the previous section. The largest difference occurs in the significance of the CEO and SPA variables. The first indicates that the conversion of the process into other sanctions reduces the chance of recidivism by approximately 30.8%. The debt installment would increase the risk by approximately 15.3%.

The estimation (02) considers as control in the empirical model only the variable that characterizes if the infraction is considered a crime. The results remain close to those of the estimation (01). In addition, in the estimation (03) is added the group of controls associated with the characteristics of the violators (Control Group 1), and the statistical significance of the CEO variable is lost, the magnitudes of the coefficients associated with SPA and PRE are close to those found previously.

In the estimation (04) the municipal characteristics of monitoring and facing environmental infractions are considered (Control Group 2), and the coefficients also remain close to those of the previous equations. Following this logic, subsequent estimates consider, respectively, controls of geographical characteristics (Control Group 3), agricultural production and burnings (Control Group 4), socioeconomic variables (Control Group 5), institutional aspects (Control Group 6) and other municipal characteristics (Control Group 7). Even so, the magnitudes of the variables of interest remain statistically significant and with magnitudes close to each other.

It should be noted that in the estimations of (03) to (09) the effect of the debt installment increases the risk of recurrence by approximately 27.6%. When we add the last group of controls related to local expenditures on environmental control (Control Group 8), the debt repayment loses statistical significance. But the variables PRE, IDA, TRA, and CBS remain strongly significant, with coefficients close to those previously found.

The analysis of column (10) is the same found in the previous section. From Table 6, we can assess that when the control group 8 is added in the analysis, the estimate (10) has its sample reduced to 69582. This is due to missing data in the controls regarding local expenditures on environmental control. Even with a smaller sample size, the value for the Log-Pseudolikelihood in (10) was the largest among the estimates in Table 8, that is, -35564.6. In addition, the highest value of Cox & Snell's Pseudo R-Squared is also that of the estimation (10), with 0.114. Then, we can conclude that specification (10) presents the best fit for the model. In addition, the LR test indicates that consideration of heterogeneity is required in all estimated models, therefore shared frailty must be considered for correct inference.

The purpose of this article was to analyze the effect of the Brazilian administrative procedure on the recidivist behavior of environmental offenders. The results were robust for all estimation strategies in Table 8, showing that the coefficients were not significant due to chance, nor were their magnitudes influenced by the strategy used. Thus, we are confident about the results found.

Table 6 – Sensitivity Analysis

	Proportional Hazards Weibull with Inverse Gaussian Frailty Model									
	(01)	**(02)**	**(03)**	**(04)**	**(05)**	**(06)**	**(07)**	**(08)**	**(09)**	**(10)**
CEO	-0.368***	-0.374***	-0.110	-0.103	-0.0906	-0.0611	-0.0587	-0.0541	-0.0484	-0.116
	(-2.78)	(-2.83)	(-0.88)	(-0.83)	(-0.74)	(-0.50)	(-0.48)	(-0.44)	(-0.40)	(-0.60)
SPA	0.142**	0.121*	0.252***	0.258***	0.235***	0.238***	0.249***	0.247***	0.244***	0.0928
	(2.14)	(1.83)	(4.04)	(4.13)	(3.83)	(3.88)	(4.06)	(4.02)	(3.97)	(1.07)
PRE	0.165***	0.166***	0.287***	0.282***	0.329***	0.324***	0.319***	0.319***	0.318***	0.288***
	(4.85)	(4.89)	(8.94)	(8.79)	(10.35)	(10.16)	(10.00)	(10.00)	(9.95)	(4.84)
IDA	0.358***	0.335***	0.386***	0.388***	0.234***	0.223***	0.230***	0.229***	0.224***	0.260***
	(11.19)	(10.41)	(12.47)	(12.52)	(7.61)	(7.24)	(7.45)	(7.42)	(7.25)	(6.37)
TRA	0.380***	0.357***	0.415***	0.413***	0.266***	0.258***	0.269***	0.269***	0.267***	0.255***
	(20.87)	(19.17)	(23.35)	(23.27)	(15.01)	(14.50)	(14.89)	(14.89)	(14.73)	(9.74)
CBS	0.609***	0.599***	0.600***	0.599***	0.557***	0.552***	0.552***	0.547***	0.546***	0.587***
	(23.37)	(22.91)	(24.11)	(24.07)	(22.69)	(22.46)	(22.40)	(22.20)	(22.18)	(14.45)
Crime	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C. Group 1	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C. Group 2	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
C. Group 3	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
C. Group 4	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
C. Group 5	No	No	No	No	No	No	Yes	Yes	Yes	Yes
C. Group 6	No	No	No	No	No	No	No	Yes	Yes	Yes
C. Group 7	No	No	No	No	No	No	No	No	Yes	Yes
C. Group 8	No	No	No	No	No	No	No	No	No	Yes
Likelihood[1]										
Null	-87459.7	-87459.7	-87341.5	-87338.8	-87338.8	-87338.8	-87329.0	-87317.1	-87317.1	-39782.5
Model	-87101.6	-87085.9	-82407.8	-82336.4	-81004.2	-80932.0	-80906.4	-80855.7	-80829.3	-35564.6
LR	3.9e+04	3.9e+04	2.2e+04	2.1e+04	1.6e+04	1.5e+04	1.5e+04	1.5e+04	1.5e+04	7502.83
AIC	174221.2	174191.8	164839.5	164704.9	162064.5	161938.0	161898.8	161813.4	161766.6	71245.2
BIC	174309.1	174289.4	164956.6	164860.9	162337.6	162298.9	162318.3	162310.9	162293.3	71775.9
R-squared[2]	0.00558	0.00583	0.0746	0.0756	0.0947	0.0957	0.0960	0.0965	0.0969	0.114
N	127873	127873	127338	127334	127334	127334	127314	127308	127308	69582

Coeficientes hazard ratios; estatísticas t entre parênteses. [1]Log pseudo Likelihood, [2]Cox & Snell's pseudo R-squared. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

7. Conclusions

This work aimed at analyzing the effects of the Brazilian administrative law enforcement procedure on the recidivist behavior of environmental violators. We focused on the legal processing of administrative infractions registered by IBAMA, with emphasis on the payment status of the fines imposed by the agency. Additionally, we considered as controls a large set of variables related to the possibility of criminal prosecution, offender characteristics, local environmental monitoring, and socioeconomic, geographical, and institutional aspects of the municipality where the infraction took place.

This paper contributes to the international literature on environmental enforcement, on the rarely addressed subject of recidivism. As seen, data on this topic is almost inexistent and most studies work with restrict datasets, accompanying a limited number of infringements for a specific region during a short period of time. We are the first to provide empirical evidence for a large database disaggregated at the individual level, spanning the whole Brazilian Federation, spanning for several years. In this sense, we provide new and robust evidence on the enforcement effects of the environmental law, considering the processing status of administrative violation records. Therefore, this research fits in the field of Empirical Law and Economics.

Evidence regarding the effectiveness of enforcement efforts in Brazil is mingled. Some studies point that administrative fines are essential to discourage deforestation and further environmental offenses, while others emphasize that impunity favors new infringements insofar that IBAMA fails to comply with legal deadlines, processing times are too long, and favor the incidence of statutory limitations as fines are seldom collected (Barreto and Mesquita, 2009; Assunção et al., 2013; Uhr and Uhr, 2014; Da Silva and Bernard, 2016; Garcia and Fonseca, 2018; Uhr et al., 2018).

Our results show that the delays in the legal process do increase the risk of recidivism of these offenders against the environment. That is, the results indicate that the highest risk of recidivism occurs when the process is extinguished. The second major effect on the risk of recidivism occurs when the legal process is subjected to statutory limitations. Thirdly, fact that the process is placed in the official active debtors list of the state, and, finally, the fact that the proceeding takes too much time to be concluded. Therefore, we highlight that IBAMA has a low capacity to guarantee compliance to environmental standards, particularly when it comes to recurrence. As shown, even if the efficiency of the Institute in collecting fines is increasing (IBAMA, 2010), 60% of offense records in the analyzed period were still not sanctioned in a span of a minimum of six years (supposing that the infringement occurred in 2010). Souza (2016) points that increasing the collection of sanction charges is the main issue for improving law enforcement.

Future researches could test the hypothesis that treating repeat offenders more harshly encourages compliance or if such remedy is inefficient due to higher obedience costs. Our dataset shows that the sanction fine is significantly higher for recidivists (2,6 times) than for non-recidivists, as is the percentage of offenders facing the possibility of criminal prosecution (from 23% to 31%). However, the percentage of fines paid, with debt in installments or converted into warnings or lesser punishments, is considerably lower for the group with repeated violations (dropping from 51% to 31%). On the other hand, categories favoring impunity, such as assessments in progress and extinguished, suspended, or deleted cases, rise from 43% to 57%. Such evidence seems to favor the hypothesis of high compliance costs regarding environmental law in a Federal level.

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