Open investigation: a quasi-experiment on the impact of public participation in the fight against environmental crimes through satellite monitoring of mining polygons in Brazilian Northeast

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Abstract

The objective is to measure the impact of public geospatial monitoring in environmental crimes related to mining explorations. Powered by open data and freeware, people will be stimulated to investigate crimes against Nature through satellite surveillance using a Web-Based GIS platform. After exploring the imagery for eventual unauthorized explorations, both miner (or applicant) and governmental agencies will be informed of the inspection. The hypothesis that satellite surveillance of mining polygons made with public participation has a deterrence effect in crimes against Nature will be tested by a panel data econometric model. The initial step would cover approximately 10,192 mining polygons in three Brazilian states: Rio Grande do Norte, as treatment group and its neighbors, Ceará e Paraíba as control and placebo group. If the expected effect is observed, this model of environmental governance can be expanded to other states, countries and types of crimes.

INTRODUCTION

From the limitation of scientific management (Taylor, 1998) to the range of systemic models (Capra & Luisi, 2016), organizational theory evolved to recognize the inherent complexity of human relationships of collaboration, ethics, conflict, and resistance, which became object of academic study and practical management. Skills linked to learning, creativity and innovation have become critical success factors and technology, the means by which all solutions are made feasible, especially those involving complex or wicked problems (Hawryszkiewycz, 2016), such as crime.

From the organizational perspective, it seems to have been a convergence between political evolution – which crowned democracy as model of government– and scientific – which brought the concept of power to the center of the debates (Clegg, 2009). According to Rose e Miller (1992), modern democratic states have abandoned the utopia of complete social control, accepting that human organizations have their own naturalities, rules, processes and internal forms of self-regulating power.

In liberal states, power is confronted by human rights and the government, by a handful of processes outside its reach, beyond politics, which can only be administered by a complex network of relationships. Hence, as democracy advanced in the world, traditional control mechanisms became obsoletes (Rose & Miller, 1992). This applies particularly to positivist governance system based on binomials such as hierarchy and discipline.

Social governance extrapolates political actions (bureaucracy, policing, surveillance). Given the impossibility and ineffectiveness of direct external control, the govern is forced to develop technologies to exercise power at a distance over the private sphere of the modern world. In the field of public administration, there is a growing need to invest in agile organic structures, capable of using technology, creativity, learning and innovation to keep up with social evolution rhythm.

Complex phenomena like crime require holistic comprehension and management. This implies to transcend the mechanicist paradigm and to adopt the ecologic premise that the living beings nature is not on the matter but in their connections , which form an inseparable web of relations (Capra, 1997). It is necessary to attack the causes of the problem, which are multifactorial, controlling the risk of the factors that create it in each level of the social ecosystem[1]. This demands efforts to develop tools of governing at a distance capable of promoting self-regulation and engagement.

Inside this new paradigm, security solutions must be built together with civil society, not for them – risking to fail due to detachment of reality – or for them – because, paraphrasing Garriott (2013), in criminal societies, crime is seen as much as problem as solution. Police governance has, indeed, evolved towards the narrowing of ties with the community and the strengthen of public participation. Community policing initiatives around the world support this impression (Lum, 2009; Goldstein, 1987; MacDonald, 2002; Adams, Rohe, & Arcury, 2002; Gill, Weisburd, Telep, Vitter, & Bennett, 2014).

Factor (2019) performed an experiment to evaluate public participation in the fight against traffic violations in Israel. The intervention effect was measured by 12,236 field observations. Among the treatment group, there was a significant reduction of the violations, while the control group presented a discrete increase. The study concluded that public participation in the prioritization of specific criminal spots and in the construction and application of security solutions has a positive effect in driver's behavior, reducing traffic violations.

Based on this research, it can be argued that police work, more than open itself, must encourage social participation in favor of a more just and peaceful society. To be effective,

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[1] As described by Ferreto & Romero (2009), which defend an ecological model to approach violent behavior.

policing has to adapt to the reality of the region and be seen as legitime and fair, as well as involve community members (Factor, 2019).

Garnier, Caplan & Kennedy (2018) analyzed the relation between environmental and social factors of criminal activities estimated by *Risk Terrain Modelling* (RTM). In a quantitative study, the authors investigated spatiotemporal correlations of successive robberies controlling for these variables through RTM. Results showed that the combination of environmental and social characteristics increase the precision of RTM estimation alone.

According to them (Garnier et al., 2018), there is a relation between the environmental and social factors geographic distribution that promotes crime recurrence. Immediately after a crime is committed, the recurrence probability increases, diminishing exponentially with time, in an inversely proportional function of the distance from the original event. With RTM, it is possible to evaluate the contribution of this geographic distribution to environmental crimes involving mining.

In their turn, Entorf & Spengler (2000) revisit Becker-Ehrlich criminal dissuasion model to include current discussion factors, like demographic changes, youth unemployment and income inequality. In a criminometric study using panel data, the authors explored highly and sparsely and densely populated areas in Germany, contrasting the east and west of the country. Results confirmed the hypothesis of criminal dissuasion related to age an employment, reveling important influences of demographic and economic factors.

Hence, in a rereading of Becker-Ehrlich model (Becker, 1968; Ehrlich, 1973), incorporating, among other variables, geographic controls estimated by RTM, this study intends to teste the effectiveness of popular participation in the fight against crime, particularly environmental crimes performed by applicants of mining authorizations. Uniting elements from the theory of governmentality (Foucault, 1991, 2003, 2009) and living systems, it proposes to evaluate how social participation in satellite surveillance of mining polygons (exploration areas defined in formal processes with the National Mining Agency - ANM[2]) impacts environmental criminality.

To this new investigation model, centered in e-government (Jamil Marques & Abilio Pereira, 2016), transparency and social engagement, it is given the name “Open Investigation”, in honor of the academic movement called “open science” (García Peñalvo, García Figuerola, & Merlo, 2010; Jhangiani & Biswas-Diener, 2017; Kraker, Leony, Reinhardt, & Beham, 2011; Schroeder, 2007)

The idea is to merge and replicate the works of Factor (2019), Entorf & Spengler (2000) e Garnier et al. (2018), combining mining crimes interdependence, socio-environmental influences and satellite surveillance made by public participation in a quasi-experiment with three Brazilian states as control, treatment and placebo groups. The central hypothesis is that public participation would have a negative effect on crimes involving environmental crimes involving mining explorations.

The variable of interest is a dummy whose value is one if the mining polygon had been object of public investigation through satellite surveillance. To do that, a geospatial web platform, with open data about mining processes, will be built. Through it, anyone interested in protecting Nature against illegal mining will be able to gather proves and make a denunciation to the authorities.

The awareness of the responsible for the exploration is indispensable to the experiment, whereas it is because of it that a potential criminal can reevaluate de cost-benefit of his endeavor and decide to interrupt the undertaking of future crimes (Entorf & Spengler, 2000). On that account, every public access to the mining polygons will be registered, published on the project web platform e informed to the applicants.

[2] Available in https://app.dnpm.gov.br/DadosAbertos/SCM/

Among the main obstacles for oversighting mining activities in Brazil, Arcoverde (2015) highlighted the huge territorial extension, the difficulty to reach some isolated areas, lack of technological solutions and shortage of personnel. Perhaps if the government could afford to pay enough men to visit every mining polygon periodically, we would see a reduction in environmental crime rate. Nevertheless, besides being impracticable in rural Brazil, Factor (2019) states that while massive law enforcement in minority communities might temporally reduce crime, it tends to increase levels of alienation, resentment, perception of paternalism and social resistance.

The solution proposed in this paper would circumvent these problems, contributing to the creation of a generalized surveillance power based on social engagement. In a digital panopticon (Han & Gabás Pallás, 2016), apart from civil society, mining entrepreneurs would supervise their competitors certain that they were also being observed. Beyond the fear of being arrested, this would also incentivize compliance with labor laws, avoiding the degradation of the working conditions of poor people that is already subjected to an exhausting, dangerous and, in most cases, unprofitable work.

The article is divided into four sections. The second describes the theory of criminal deterrence used in this paper, detailing the methodology of the study, especially the econometric model developed for this particular object. The third section discusses the data and the fourth, the results and conclusions of the analysis.

MINING ENVIRONMENTAL CRIMES

According to the International Council on Mining and Metals - ICMM (2018), Brazil is the ninth largest mining producer on the planet in value of metallic minerals and coal. On the other hand, in the ranking of importance of the mining activity for the national economy, the country occupies the 65th position, the activity being responsible for 2% of the Gross Domestic Product in 2016.

Many countries that depend economically on mining activities have natural resources as the main responsible for economic activity, but, like Brazil, have deficient governance systems. According to the National Mining Plan 2030 - PNM 2030 (Brasil, 2011), effective governance and sustainability are two of the three guidelines that should guide actions for the Brazilian mining sector by the year 2030.

The dynamics of the world mining activity is to concentrate the activities that are most harmful to the environment, which produce outputs of lower value added, in peripheral countries (Penido, 2018). In central countries, where governance systems are more rigid and effective, less polluting transformations are made and more valuable items are produced. This socio-environmental inequality produces poverty, destroys territories and generates risks and disasters, such as the ones caused in Mariana, by Samarco, in 2015, and in Brumadinho, by Vale, in 2019 (Freitas, Barcellos, Asmus, Silva, & Xavier, 2019; Penido, 2018), killing hundreds of people.

Large mining companies can afford environmental specialists and, because of their level of exposure, must have deeper concerns about complying with laws and regulations. Despite that, it should be noted that 87% of the mining activity in Brazil is carried out by micro and small companies (IBRAM, 2018).

For many towns, the mining industry represents the main economic activity, generating employment and income for populations with few opportunities for human development. As it produces inputs for several segments, mining activities generate a multiplier effect on labor in other sectors. In Brazil, the mineral extraction sector, excluding oil and natural gas, was responsible for employing 179,000 workers in the first half of 2018, indirectly generating 651,000 jobs in the mineral processing industry (ANM, 2018).

The fact that mining is an important source of income for governments and entire communities, allied with the inherent challenges of mining control (Arcoverde, 2015), can contribute to the creation of dark spots, defined by Factor (2019, p. 2) as geographic regions where communities suffer with crimes, but these are not reported to the police and do not appear in criminal statistics because of government inefficiency or because members of the community do not report them. In this sense, popular participation appears as a cheap and effective alternative to “illuminate” these regions and, consequently, improve mineral production instruments of governance.

According to articles 20 and 176 of the Brazilian Constitution (Brasil, 1988), all mineral resources, including those of the subsoil, belongs to the State. The person interested in mining must obtain a governmental authorization or concession. It is a federal crime to do it without permission or in disagreement with what was allowed by the State. The crimes are described in art. 55 of Law nº 9,605/1998, "performing research, mining or extraction of mineral resources without the competent authorization, permission, concession or license, or in disagreement with that obtained", and in art. 2 of Law nº 8,166/1991, "producing goods or exploiting raw materials belonging to the Union, without legal authorization or in disagreement with the authorizing title".

Environmental damage is inherent to mining activity. It is through it that mining becomes possible. Therefore, even if performed in the most perfect legal compliance, mineral exploration generates significant environmental impacts. Due to this characteristic, mining legal procedures require intensive studies and investments, lengthy processes and numerous bureaucratic steps. Such long waiting times can encourage entrepreneurs to start exploring only with an application protocol for mining authorization. In addition, geographic isolation, characterized by low demographic density and difficult access, common features of many exploration sites, can give the miner a false sense of invisibility, strengthening the hope of impunity in the eventual practice of an environmental crime.

Pursuant to §1, art. 144 of the Federal Constitution (Brasil, 1988), the Federal Police, with the diminutive staff of only 12,913 active employees (Brasil, 2019), is the sole responsible for the investigation of criminal offenses involving Union assets and, therefore, mining activities.. With 8,516 million km² of territorial area, it appears that even if every federal policeman could be ordered to investigate only environmental crimes, staff would remain in shortage. Brazil's land cover and land use, however, has been completely monitored by satellite in projects such as MapBiomas[3], which annually monitors changes in Brazilian territory from open data provided through Google's Earth Engine platform.

According to data from the Mining Geographic Information System (ANM, 2019), the states of Rio Grande do Norte (RN), Ceará (CE) and Paraíba (PB) have almost five thousand km² of mining area, which need to be carefully monitored. Combined, these federative units have a larger area (258,171 km²) than the United Kingdom (242,514 km²). RN has the largest territorial proportion of mineral exploration among the states and the largest number of mining applicants per 100 thousand inhabitants.

The chosen states have similar demographic densities and sand as the main mineral explored, with granite, limestone and clay following behind (ANM, 2019). RN and CE have similar rates of applicants per km², contrasting with PB, which has almost twice the density. Given these numbers magnitude, the range and availability of remote satellite surveillance can be used often as a free alternative to on-site inspections, or at least, direct investigations for polygons with higher crime possibilities.

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[3]"The MapBiomas is a multi-institutional initiative involving universities, NGOs and technology companies that have come together to contribute to the understanding of the transformations of Brazilian territory through annual mapping of the land cover and land use" (http: // mapbiomas .org).

Table 1. Relevant data from the chosen states

	RN	CE	PB
TERRITORIAL AREA (KM²)	52.809,60	148.894,76	56.467,24
SUM OF MINING AREA (KM²)	18.606,28	33.348,13	15.418,11
AREA EXPLOITED BY MINING (%)	35,23	22,40	27,30
MINING POLYGONS (UND)	3.203	5.410	2.723
POPULATION (PEOPLE)	3.479.010	9.075.649	3.996.496
MINING APPLICANTS (UND)	969	1.468	840
NUMBER OF APPLICANTS PER 100 THOUSAND HAB.	27,85	16,18	21,02
DEMOGRAPHIC DENSITY (HAB / KM²)	65,88	60,95	70,78
APPLICANTS PER KM² OF POLYGONS	0,052	0,044	0,054

Source: Territorial area, population, IBGE (2019); Mining polygons, holders of polygons, ANM (2019); population density, number of owners per 100 thousand inhabitants, percentage of land use, owners per km², sum of the area of the polygons, the Author, with assistance, in this last variable, of QGIS (2019).

THE MODEL

According to Spengler & Entorf (2000), the economic view of crime originated in Becker's 1968 article "Crime and Punishment: An Economic Approach". Becker (1968) was interested in estimating the extent to which the benefits of a crime should exceed the return of time and resources employed in legal occupations to be able to motivate criminal activities. The author proposed that investment in the public security system, as well as the size and form of punishments, directly affect the occurrence of crimes, since changing these variables alters criminal's perception about the probability of success of his future endeavors.

To Becker's model, Ehrlich (1973) added controls for legal and illegal income opportunities, creating the so-called Becker-Ehrlich model, described below in its usual logarithmic form (Entorf & Spengler, 2000):

$$\ln(\text{crime rate}) = \beta_0 + \beta_1 \ln(\text{deterrence}) + \beta_2 \ln(\text{income}) + \beta_3 \ln(\text{other influences}) + u$$

In this line, for the purposes of this work, we will measure crime by the ratio between active investigations involving mining explorations within the Federal Police units responsible for that area and open mining processes (iaxpm). Deterrence will be measured by the ratio between finished investigations involving mining activities and active mining processes (irxpm), as well as by popular surveillance under the "Open Investigation" project. The deterrence variables are expected to have a negative sign, but the latter will gain significance and magnitude as the project matures.

As suggested by Entorf & Spengler (2000), since income opportunities cannot be directly measured, we will use proxies. In order to measure illegal income prospects, we will use the variable GDP per capita (pibpc), as specified by Ehrlich (1973). Although it is not a pacified subject in academia, results in Entorf & Spengler (2000) point to the fact that GDP per capita is, in fact, an indicator for illegal income. Legal income will be evaluated by the "relative distance to the average income" (dppcm), calculated by [("GDP per capita of the respective state" - "Brazilian GDP per capita") / ("GDP per capita of the respective state")]. The variable measures the difference between the states and not within them, which is in line with our sample choice.

Other controls used in the model are the risk of crime estimated by RTM (certm), unemployment rates (desem) and social inequality (desoc). As alternative variables, it is considered to include population, age and educational level.

The starting econometric model can be described as:

$$\mathbf{ln(iaxpm)=\beta_0 + \beta_1 ln(irxpm) + \beta_2(inabe) + \beta_3 ln(pibpc) + \beta_4 ln(dppcm) + \beta_5(certm) +}$$

$$\mathbf{\beta_6(desem) + \beta_7(desoc) + \boldsymbol{a} + \boldsymbol{u}}$$

The data structure is cross-sectional, corresponding to two periods: one initial, before the beginning of the experiment, and one twelve months after. Panel data methodology requires that each unit composing the initial sample be analyzed later in two or more periods. Thus, each mining polygon *i*, which constitutes the sample in the initial period, will be re-analyzed twelve months after the start of the "Open Investigation" project.

Since the intervention will be carried out through popular participation using a Web-Based GIS platform, it is believed that the choice of investigating a mining polygon will be carried out randomly, promoting independence and identical distribution. In spite of this, the choice of the treatment group – RN – was performed for convenience, since the author resides and works in the state. Consequently, both control group – PB – and placebo – CE – were selected because of the choice of treatment group, since they are neighbors. Because mining control institutions (ANM and PF) have state or intra-state districts, despite being federal agencies, the division by state seems more accurate.

There are some variables (such as the number of federal police officers stationed at the district's specialized environmental police stations, population, and average levels of gender, age, color, religion, education, and nuptiality) that may be contained in the error, but their variation over the twelve-month period is small or nonexistent. The panel data allow us to control for these unobserved characteristics, solving some possible biases, since we consider that they are fixed in time, which is very useful in the analysis of public policies.

Assuming that the explanatory variables vary in time, even if they are related to a_i, it is possible to correct eventual heterogeneity biases through the artifice of differentiation. Since a_i is constant in time, we can eliminate it (including this error) by subtracting one equation from the other, which allows us to have unbiased estimators.

The initial panel data econometric model is defined as:

$$\mathbf{ln(iaxpm)=\beta_0 + \delta_0 \boldsymbol{d}21_{it} + \beta_1 ln(irxpm_{it}) + \beta_2(inabe_{it}) + \beta_3 ln(pibpc_{it}) + \beta_4 ln(dppcm_{it})}$$

$$\mathbf{+\beta_5(certm_{it}) + \beta_6(desem_{it}) + \beta_7(desoc_{it}) + \boldsymbol{a_i} + \boldsymbol{u_i}}$$

Where δ_0 represents the change between the two periods (time dummy for the year 2021) without the effect of the explanatory variables.

In order to capture causal effects even in the presence of endogeneity, as long as it is invariant in time, the panel data structure uses the first-differenced (FD) estimator, transposing only the difference between the periods studied. Accordingly, the differentiation equation of the proposed econometric model can be written as:

$$\mathbf{ln(\Delta iaxpm) = \delta_0 + \beta_1 ln(\Delta irxpm_i) + \beta_2(\Delta inabe_i) + \beta_3 ln(\Delta pibpc_i) + \beta_4 ln(\Delta dppcm_i) +}$$

$$\mathbf{\beta_5(\Delta certm_i) + \beta_6(\Delta desem_i) + \beta_7(\Delta desoc_i) + \Delta \boldsymbol{u_i}}$$

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