Violence and homicides in rural areas: An analysis of the homicide differential between rural and urban municipalities in Brazil

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Abstract

This study investigated the impacts of water scarcity and/or periods of extreme drought on homicide rates in Brazilian municipalities, particularly rural ones. Using a survey of 769,774 data points that combined climate information, socioeconomic data of victims, homicide rates, and municipal socioeconomic variables as controls, between 2002 and 2020. The study also outlined a profile of homicide victims in rural municipalities for a deeper understanding of the issue. The results show that water scarcity and/or periods of extreme drought increase firearm homicide rates in rural municipalities of Brazil, with higher homicide rates in the region leading to greater observed effects. In summary, there are indications of a phenomenon of crime interiorization, especially in predominantly rural municipalities.

Keywords: Violence in Rural Areas. Homicide Rates. Crime Interiorization. Rural Municipalities.

JEL Classification: I3, J1, R1.

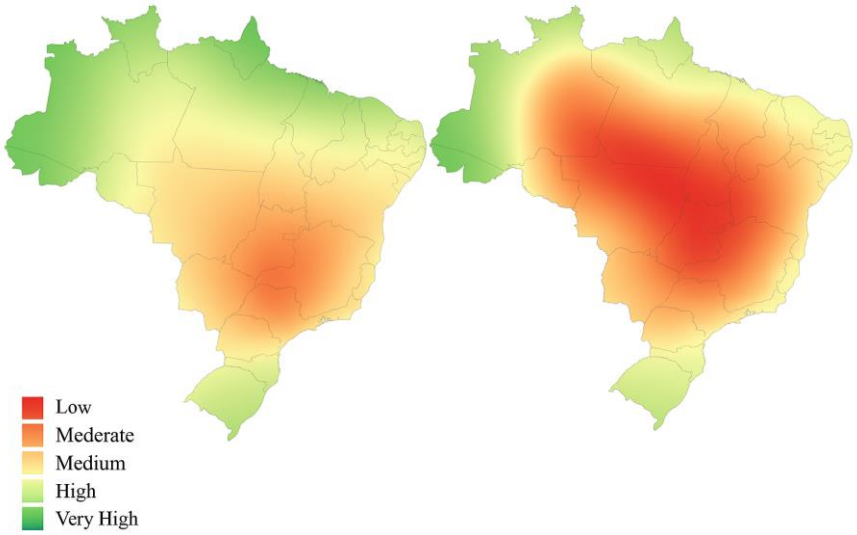
1. INTRODUCTION

The interiorization of crime is a phenomenon highlighted in the literature, in which criminal activities, previously concentrated in urban areas, expand into rural and remote regions. This shift can be driven by various factors, such as urbanization, forced migration, lack of social and economic infrastructure, absence of public policies, deficiencies in policing, and the vulnerability of these areas to criminal activity due to resource scarcity and limited law enforcement. This process challenges traditional conceptions that associate urban areas as the primary loci of crime, thereby requiring targeted policing and prevention strategies for rural regions (Andrade; Diniz, 2013; Steeves; Petterini; Moura, 2015; Ferreira; Marcial, 2015; Soares Filho; Merchan-Hamann; Vasconcelos, 2020).

"Figure 1 presents the evolution of the homicide rate in Brazil over time, highlighting regional trends and the potential spread of crime into rural areas. The North and Northeast regions stand out as the most affected by violence and criminality. While the average homicide rate in the other regions is approximately 23.10, in the North and Northeast these average rises to around 33.10 from the 2000s onward. In 2022, the average homicide rates in these regions were 36.

According to the Brazilian Yearbook of Public Security (ABSP, 2023), the North and Northeast regions of Brazil are home to the ten states with the highest homicide rates recorded in 2022. Furthermore, among the twenty most violent cities in the country, seventeen are located in these regions. In numerical terms, the average homicide rates in the North and Northeast have increased by more than 600% at their peak compared to the initial year of the historical series (IPEA, 2023). It is also important to note that the majority of municipalities in these regions are predominantly rural. According to the classification by the Brazilian Institute of Geography and Statistics (IBGE), approximately 60.4% of Brazilian municipalities are categorized as either remote rural or adjacent rural. These areas face challenges such as low population density, lack of infrastructure, and limited access to services, making them heavily dependent on traditional economic activities such as agriculture, livestock farming, and extractivism. In contrast, only 26.16% of the country's 5,570 municipalities are classified as essentially urban according to this methodology. This distribution highlights the predominance of rural areas and the socioeconomic disparities among regions in Brazil

Figure 1 – Evolution of the Interiorization of Homicides in Brazil – 2000 to 2022



Source: Elaborated by the authors based on the dataset.

On the other hand, analyses centered on the "economics of crime" start from the premise that individuals make decisions rationally, always seeking to optimize their gains. Within this context, the choice to engage in illegal or criminal activities is largely determined by the evaluation of the cost-benefit relationship associated with such violent or delinquent behaviors (Becker, 1968). Therefore, when analyzing social environments with low probabilities of punishment, especially in predominantly rural areas characterized by high inequality in economic and educational opportunities, scarce investments in public security, and/or challenges in law enforcement, among other potential determining factors, a conducive environment for the increase in criminal activities is observed. These aspects give rise to a scenario that facilitates the recruitment of individuals into the world of crime, particularly young people with considerably low opportunity costs (Lochner; Moretti, 2004; Lochner, 2004; Lochner, 2011; Carneiro; Loureiro; Sachsida, 2005; Khan *et al*., 2015).

There are studies that link the increase in crime to periods of water scarcity and/or extreme drought. For instance, Ishak (2022) examines the effect of climate shocks on violent crime using disaggregated data from Brazilian municipalities during the period 1991–2015. The main findings document that adverse climate shocks in the form of droughts lead to a significant increase in violent crime in rural areas. In this context, agencies such as the United Nations (UN), the African Union (AU), and the European Union (EU) have identified climate shocks as a factor that increases insecurity and vulnerability, particularly in regions where mitigation and adaptation measures have not been implemented. The impacts of climate change are increasingly recognized as global security threats, although research on climate variables and violence and/or crime is mainly concentrated on African countries (Couttenier; Soubeyran, 2014; Nordqvist; Krampe, 2018; Bayas; Grau, 2023).

Given the above, the primary objective of this study was to examine how water scarcity and/or periods of extreme drought affect homicide rates in Brazilian municipalities, with a special focus on rural areas. Additionally, the phenomenon known as the interiorization of crime was investigated, which is linked to the significant increase in victims of firearm-related homicides in rural areas compared to urban areas. This phenomenon is presumed to occur due to the fact that rural municipalities tend to attract individuals, especially younger ones, because of limited educational and economic opportunities—factors that may be exacerbated during periods of water scarcity and/or extreme drought. To this end, the entropy balancing method,

as proposed by Hainmueller and Xu (2013), was employed, along with quantile regression estimates literally adopting the approach by Chernozhukov, Fernández-Val, and Melly (2013), comparing urban and rural municipalities. Additionally, a profile of homicide victims in rural municipalities was developed for a deeper understanding of the particularities of the problem under study.

The approach adopted in this study seeks to differentiate itself from the focus present in previous studies, which generally limit themselves to describing the problem, often restricted to a specific region or type of locality. Instead, this study details the profile of victims in rural municipalities and compares it with that observed in urban centers. Moreover, and equally importantly, it investigates the impacts of water scarcity and/or extreme drought on the phenomenon of the interiorization of crime, that is, on homicide rates in the Brazilian rural context.

2. REFERENCIAL TEÓRICO

2.1 Economics of Crime: The Rationality Behind Criminal

The seminal work of Becker (1968) introduced an economic theory of crime by proposing that individuals make rational choices when deciding whether to engage in criminal behavior. According to this framework, people weigh the expected gains from committing a crime against the probability of punishment and the severity of its consequences. In contexts where state capacity is weak—particularly in rural areas with limited law enforcement and judicial infrastructure—the perceived cost of crime decreases. This leads to a distorted cost-benefit calculation, making criminal activity relatively more attractive.

Empirical evidence supports this theory. Levitt (1997), analyzing variations in police hiring driven by electoral cycles in the U.S., showed that increasing the perceived probability of apprehension significantly reduces crime. In rural settings, where institutional presence is minimal, the deterrent effect is substantially weaker. Similarly, Machin and Meghir (2004) demonstrated that in the UK, investment in education and policing had differentiated impacts across regions, with stronger effects in areas with weaker institutions—conditions that resemble rural Brazil.

This rational-choice perspective provides a critical lens through which the interiorization of crime can be interpreted. As criminal organizations expand into rural zones, they exploit the absence of deterrents and reduced monitoring. Furthermore, the structure of rural labor markets—often characterized by informal or seasonal employment—lowers the opportunity cost of engaging in illicit activities. Thus, the economic logic of crime in rural areas is reinforced by structural vulnerabilities that are less pronounced in urban centers.

2.2 **Inequality of Opportunity as a Driver of Criminality**

Beyond simple income disparities, inequality of opportunity has emerged as a robust explanatory factor in crime studies. Roemer (1998) argued that individuals should not be penalized for outcomes driven by circumstances beyond their control, such as family background, region of birth, or ethnicity. These structural inequities lead to stratified access to education, healthcare, and employment, creating fertile ground for criminal behavior. Lefranc, Pistolesi, and Trannoy (2008), studying European countries, found that higher inequality of opportunity is significantly associated with higher crime rates, particularly among the youth.

In rural settings, these inequalities are intensified. Limited schooling infrastructure, scarcity of formal jobs, and lack of public investment perpetuate intergenerational poverty. Bayas and Grau (2023), using microdata, revealed that disadvantaged youth are far more likely to engage in delinquency in regions with systemic deprivation and institutional neglect. Their

findings reinforce the idea that, especially in non-urban areas, criminality becomes a mechanism of social compensation where legitimate upward mobility is unattainable.

Ferreti, Pozza and Coluccia (2019) further showed that recidivism is more prevalent in rural Italian provinces marked by high levels of opportunity deprivation. Their study highlights how a combination of social exclusion and economic marginalization fosters cycles of violence and incarceration. For Brazil and other developing countries, this suggests that the interiorization of crime may be less about spatial displacement and more about longstanding structural inequities in rural territories.

2.3 Climate Shocks and Violence: Evidence from Developing Countries

The relationship between climate shocks and violence has gained prominence in recent years, particularly in the context of the Global South. Couttenier and Soubeyran (2014) provide compelling evidence that extreme droughts in Sub-Saharan Africa are strongly associated with the outbreak of civil conflict. In agricultural economies, reduced rainfall compromises food production and income stability, which in turn escalates tensions and violent outcomes. Their work underscores how environmental variables must be integrated into economic models of conflict and crime.

Similar patterns emerge in Brazil. Ishak (2022) demonstrates that rural municipalities affected by droughts show significantly higher homicide rates compared to non-affected areas. These shocks disrupt rural livelihoods, increase migration pressure, and weaken social cohesion—all of which are known drivers of violence. Importantly, these effects are not observed in urban areas, indicating a specific vulnerability of rural regions to climatic stress. These findings align with global assessments by the UN and World Bank that classify climate insecurity as a key threat to stability in underdeveloped regions.

Burke et al. (2015), in a meta-analysis published in Nature, support this view by finding consistent links between climate variability and intergroup conflict. Their results show that temperature increases and rainfall deviations exacerbate economic insecurity and institutional fragility—two core predictors of violence. Thus, any attempt to understand crime in rural areas of Brazil must consider the ecological-economic dynamics that shape residents' risk exposure and behavioral incentives.

2.4 Internal Migration and the Interiorization of Violence

The phenomenon of internal migration plays a crucial role in explaining the spatial redistribution of violence, particularly in developing countries. As individuals or families are displaced due to economic hardship, environmental stress, or urban violence, they often move toward smaller municipalities or rural areas in search of security or livelihood. However, these destinations frequently lack the institutional capacity to absorb new populations, creating social tension and exacerbating crime rates. In Brazil, Steeves, Petterini, and Moura (2015) demonstrated that the expansion of violence into rural and mid-sized municipalities is strongly associated with population shifts and the migration of criminal networks from metropolitan centers to interior regions with limited state presence.

International evidence reinforces this dynamic. Brown et al. (2011), analyzing internal displacement in Mexico, showed that the escalation of drug-related violence in rural municipalities coincided with waves of forced migration from urban centers. The redistribution of violence was not random but followed clear patterns of institutional vacuum and economic vulnerability. Similarly, Barnes and Curtis (2021) found that gangs in El Salvador strategically relocated their operations to rural areas as a response to heightened law enforcement pressure

in large cities. These new territories provided safe havens with minimal state oversight and opportunities for recruitment among impoverished rural youth.

The interiorization of violence should thus be interpreted not only as a geographical phenomenon but also as a structural consequence of failed urban security policies and uneven development. As Davis (2018) argues in the context of the United States, organized crime adapts to repression by shifting to less regulated regions. This migration of violence is often facilitated by weak rural governance and unregulated land use, enabling the entrenchment of criminal economies in peripheral areas. In Brazil and other countries facing similar challenges, the convergence of internal migration, inequality, and fragile rural institutions fuels a self-reinforcing cycle of violence that undermines social cohesion and economic development in the countryside.

3. METHODOLOGICAL PROCEDURES

3.1 Data Description

The dataset employed in this study comprises a comprehensive collection of information from various sources, covering the period from 2002 to 2020 for all Brazilian municipalities. More specifically, it includes socioeconomic characteristics of 769,774 victims of firearm homicides, obtained from the Mortality Information System (SIM/DATASUS). Additionally, municipal firearm homicide rates per 100,000 inhabitants were collected from the Institute for Applied Economic Research (IPEA).

These data were supplemented with municipal indicators obtained from the Brazilian Institute of Geography and Statistics (IBGE) and the Ministry of Labor (MT), including information such as population, population density, GDP per capita, number of security agents per inhabitant, average income, unemployment rates, occurrences of traffic-related deaths and drug-related deaths, as well as income inequality indices. Table 1 presents a summary of all variables used in this study.

Table 1: Description, Details, and Source of the Information

Variable	Description
Outcome Variable	
Firearm Homicide Rate	Firearm homicides per 100,000 inhabitants.
Climate Variables of Interest	
Total Precipitation	Log of total annual rainfall volume.
Rainfall Deviation	Log of annual rainfall deviations relative to the historical average.
Drought	Dummy: drought = 1, otherwise 0.
Municipality Type	Dummy: rural = 1, otherwise 0.
Individual Socioeconomic Variables – Victims	
Age	Dummy: young = 1 (up to 29 years old), otherwise 0.
Education	Dummies: low and high educational level.
Marital Status	Dummy: single = 0; married = 1.
Race	Dummy: non-white = 0; white = 1.
Occupation	Dummy: low skilled = 0; high skilled = 1.
Sex	Dummy: male = 0; female = 1.
Native Status	Dummy: native = 0; migrant = 1.
Local/Regional Socioeconomic Variables	
Population	Estimated resident population.
Density	Population density (population per Km^2).
GDP	GDP per capita (in 1000 Brazilian Reais).
Inequality	Proxy measure for income inequality.
Traffic Death Rate	Traffic-related deaths per 100,000 inhabitants.
Drug-related Death Rate	Drug-related deaths per 100,000 inhabitants.

Unemployment	Proportion of total population without formal employment.
Security Agents	Total number of formal employment links in the security sector.
Average Remuneration of Security	Average formal remuneration in the security sector.

Source: Elaborated by the authors based on the dataset.

In addition to these, three main variables of interest were included: i) a dummy variable classifying municipalities according to the occurrence of homicides, distinguishing between urban and rural areas based on the IBGE classification; ii) a climate variable identifying water scarcity in rural areas, which may become potential settings for involvement in criminal activities. This is because water scarcity can reduce employment opportunities, income, and/or food availability, thereby lowering the opportunity cost in the cost-benefit relationship of crime, as discussed in the literature. Finally, iii) a dummy variable identifying periods of extreme drought according to the historical series, which may exacerbate the aforementioned problem.

The study adopted criteria based on the classification of municipalities as rural or urban, according to the IBGE proposal, which considers five distinct typologies based on population density, proximity to urban centers, and population size. These criteria result in the categorization of municipalities as urban, rural, or intermediate, in line with international standards such as those of the European Union and the United States. More specifically, for this study, a dummy variable was created that classifies a municipality as urban if it meets the IBGE's urban criteria, and as rural otherwise.

In turn, the climate variables of interest are based on the study by Rocha and Soares (2015), differing in some aspects, particularly regarding the temporal scope and certain specific features in the construction of the variables. The total period used spans from 1901 to 2020. In summary, the following is considered:

i. **Log of annual rainfall deviations:** logarithmic annual deviation of average precipitation:

$$P_{it} = ln\left(\sum_{m=1}^{12} p_{im}\right) - \ln\left(\overline{p_i}\right) \quad (1)$$

Where p_{it} denotes the logarithm of the annual total rainfall recorded in municipality i during year t; $\overline{p_i}$ represents the historical annual average precipitation, calculated based on monthly data m from 1901 to 2020, for municipality i; t indicates the year.

ii. **Drought:** a dummy variable that takes the value 1 if there was a drought in year t , and 0 otherwise. In summary, it aims to capture extreme conditions of water scarcity:

$$S_{it} = 1 \Leftrightarrow \sum_{m=1}^{12} p_{im} < (\overline{p_i} - p_i^{\sigma}) \quad (2)$$

Let p_i^{σ} be the historical annual standard deviation, considering the monthly period analyzed between 1901 and 2020. In summary, the drought dummy variable ($S_i = 1$) takes the value one when the total annual precipitation volume is more than one standard deviation below the historical average for municipality i.

3.2 Model and Method

To compare the observed difference in homicide rates between the control group (urban municipalities) and the treatment group (rural municipalities), and thus the potential effects of the phenomenon known as the interiorization of crime, the Entropy Balancing Method,

hereafter EBM, originally proposed by Hainmueller (2012) and updated by Hainmueller and Xu (2013), was employed. The decision to use this matching method was mainly motivated by its simplicity and effectiveness in making the control and treatment groups similar, highlighting only the characteristic of interest in a significant manner.

In summary, the Entropy Balancing Method (EBM) aims to correct bias arising from unbalanced data in classification problems. It is based on entropy theory to assess uncertainty in the data. EBM reweights the information so that the distributions of covariates satisfy certain statistical conditions, such as mean, variance, skewness, and covariance. This procedure balances samples in observational studies, allowing control group data to be adjusted to match those of the treatment group. Moreover, EBM can be used to reweight samples based on known characteristics of a specific population.

In brief, Equation 3 describes the average treatment effect on the treated individuals. This occurs in the most common case, where the treatment effect is calculated as the average difference in observed outcomes between the treatment group and the adjusted control group.

$$E[Y(0)|\widehat{D=1}] = \frac{\sum_{\{i|D=0\}} Y_i d_i}{\sum_{\{i|D=0\}} d_i} \quad (3)$$

Where the counterfactual mean is estimated by Equation 3, and each individual in the control group is assigned a weight determined by $d_i = \frac{\hat{p}x_i}{1-\hat{p}x_i}$. Where $\hat{p}x_i$ a propensity score used to ensure that the distribution of individuals' characteristics in the control group matches that of the treatment group. However, this approach may fail to balance all data characteristics, especially due to endogeneity issues in the model. To overcome these challenges, EBM generalizes the propensity score weighting approach by estimating weights directly from a broad set of balancing constraints that consider various sample moments. In summary, the counterfactual mean is obtained through Equation 4.

$$E[Y(0)|\widehat{D=1}] = \frac{\sum_{\{i|D=0\}} Y_i w_i}{\sum_{\{i|D=0\}} w_i} \quad (4)$$

Where w_i represents the entropy balancing weight assigned to each individual in the control group. These weights are calculated using Equation 5, which describes the reweighting process to minimize the entropy distance metric.

$$\min_{w_i} H(w) = \sum_{\{i|D=0\}} w_i \log(w_i/q_i) \quad (5)$$

Subject to balancing and normalization constraints. Where $q_i = 1/n_0$ is a base weight and $C_{ri}(X_i) = m_r$ refers to a set of balancing constraints R, which are applied to the moments of the covariates in the control group after reweighting. It is important to highlight that, after balancing between the control and treatment groups, estimations will be performed using the quantile treatment effects method, aiming to understand differences across various points of the homicide rate distribution.

$$\sum_{\{i|D=0\}} w_i C_{ri}(X_i) = m_r \text{ com } r \in 1, \cdots, R \quad (6)$$

4. PRESENTATION AND DISCUSSION OF RESULTS

The results obtained are presented and examined in two distinct sections. First, a descriptive analysis of firearm homicide victims is conducted, outlining the main

socioeconomic characteristics of the victims and distinguishing between urban and rural municipalities. Subsequently, the empirical results of the estimated models are discussed, especially regarding water scarcity and/or extreme drought and their influences on firearm homicide rates.

4.1 Descriptive Analysis

A priori, Table 1 presents some of the main individual descriptive socioeconomic information of firearm homicide victims during the analyzed period. The total number of homicide victims comprising the sample is 769,774 individuals. Of this total, 128,710 firearm homicide victims (16.72%) resided in predominantly rural municipalities, compared to 641,064 (83.28%) who lived in areas classified as essentially urban.

Table 1 – Descriptive Statistics by Socioeconomic Aspects – Rural versus Urban

Variables	*Dummies: I/II*	Type of Municipality – Homicides			
		Rural (128,710)		Urban (641,064)	
Educational Level	Low/Medium	80.19%	19.81%	75.63%	24.37%
Professional Occupation	Low/Medium	89.88%	10.12%	78.04%	21.96%
Age	Young/Adult	48.37%	51.63%	62.23%	37.77%
Race/Ethnicity	Non-White/White	76.27%	23.73%	71.01%	28.99%
Sex	Female/Male	6.27%	93.63%	5.75%	94.25%
Marital Status	Single/Married	73.22%	26.78%	84.81%	15.19%
Nativity	Native/Migrant	31.22%	68.78%	35.98%	64.02%

Source: Elaborated by the authors based on the dataset.

In summary, the results from Table 1 reveal that firearm homicide victims in Brazil frequently come from highly vulnerable socioeconomic backgrounds, characterized by low educational attainment, precarious occupations, youth, single marital status, non-white ethnicity, and migration. However, notable distinctions emerge when analyzing the profile between rural and urban areas, such as the incidence of female victims in rural areas, which is 9.04% higher than in urban areas, possibly due to greater exposure to violence faced by women in these regions. Regarding educational level, 80.19% of victims in rural municipalities did not complete even the first cycle of elementary school, compared to 75.63% in urban areas. Concerning professional occupation, nearly 9 out of 10 victims in rural settings hold low-ranking positions in the labor market, reflecting the victims' low education levels and aligning with seminal works in the literature, such as Rawls (1971), Roemer (1998), and Lefranc, Pistolesi, and Trannoy (2008).

An important distinction arises with respect to race: 5.26% more non-white individuals, primarily black and brown, die compared to otherwise similar individuals in urban municipalities. This is among the most alarming findings, as race is a characteristic unrelated to individual agency, and thus any disadvantage stemming from exogenous attributes should, in principle, be offset. Conversely, urban areas exhibit a significantly higher incidence of deaths among young and single individuals relative to rural municipalities. In absolute terms, there is a 13.86% increase in mortality among young individuals and an 11.59% increase among single individuals in urban areas.

Following a synthesis of the socioeconomic profile of firearm homicide victims in Brazil—across both rural and urban areas—and the key distinctions therein, a simple analysis of average differences in these characteristics is now undertaken, disaggregated by type of municipality. The results presented in Table 2 corroborate the inferences drawn from Table 1 and are consistent with findings in the existing literature, such as those reported in the Brazilian Yearbook of Public Security (ABSP, 2023).

Table 2 – Homicide Rate Differentials by Characteristics – Rural versus Urban

Variables	Municipality Type – Homicides

	Rural (128.710)			Urban (641.064)		
	Treated	**Control**	**Diff. %**	**Treated**	**Control**	**Diff. %**
Educational Attainment (Low/Medium)	28.02	24.71	3.31***	37.35	31.65	5.70***
Occupational Status (Low/Medium)	27.48	24.92	2.56***	35.36	34.83	0.53***
Age (Young/Adults)	28.76	26.11	2.65***	37.22	33.87	3.35***
Race/Ethnicity (Non-White/White)	28.86	22.96	5.90***	38.68	27.63	11.05***
Sex (Female/Male)	26.61	27.44	-0.83***	34.95	36.02	-1.06***
Marital Status (Single/Married)	28.14	26.08	2.06***	36.45	32.60	3.84***
Place of Birth (Native/Migrant)	26.26	27.90	-1.64***	35.20	36.38	-1.18***

Source: Elaborated by the authors based on the dataset.
Notes: $***p < 0{,}01$; $** p < 0{,}05$.

As shown in Table 2, the discrepancies between the treatment and control groups (i.e., socioeconomic characteristics) are more pronounced in urban municipalities than in rural ones, with the exception of occupational status and place of birth. In summary, the effect of low-level occupations on the likelihood of becoming a homicide victim in rural areas is 4.83 times greater than in urban areas. This result may be attributed to the fact that even modest improvements in occupational status in rural regions substantially reduce the probability of becoming a victim of firearm-related homicide. Regarding place of birth, being a migrant in rural municipalities increases the likelihood of being a homicide victim by approximately 39% compared to urban municipalities.

For the other individual characteristics, the differential effect is significantly higher in urban areas than in rural ones. For instance, having a low level of education (i.e., not completing the first cycle of primary education) increases the firearm homicide rate by a factor of 1.72 in urban municipalities compared to rural areas. It is worth noting, as indicated in Table 1, that the educational attainment of homicide victims in rural Brazil tends to be uniformly low, which helps explain this result. The effect of firearm homicide rates on the youth population (individuals up to 29 years of age) is 26.42% higher in urban areas than in rural areas. This finding is also corroborated by the evidence presented in Table 1.

Another noteworthy result concerns race. On average, being non-white in urban municipalities increases the probability of becoming a homicide victim by a factor of 1.87 compared to rural municipalities. With respect to marital status, simply being single in urban areas increases the probability of being a homicide victim by 86.4% relative to rural areas. In contrast, rural women appear to be considerably more vulnerable, with a 27.71% higher likelihood of becoming firearm homicide victims compared to men, relative to the pattern observed in urban municipalities. These findings underscore the additional challenges faced by rural municipalities in addressing this issue, as socioeconomic differences appear to matter less in urban settings.

It is essential to emphasize that the results reported in Table 2 do not imply causal inference. Nonetheless, regardless of the method employed, there is strong evidence of a marked disparity in the impact of firearm homicide rates across different social groups. This differential reflects not only outcome inequality, but also inequality of opportunity. The fact that individuals are more susceptible to violence and/or homicide based on their social background highlights the deep divisions within the Brazilian social structure. These findings are frequently cited in the literature as emblematic of unfair inequality, largely rooted in initial conditions. As such, it is the government's social responsibility to address and mitigate these

disparities, in line with modern theories of justice and equality of opportunity (Rawls, 2017; Roemer, 1998).

4.2 Empirical Results – Water Scarcity and Drought

To investigate the effect of climatic variables—essentially represented by water scarcity and/or periods of extreme drought—a quantile treatment effects model was employed, combined with an entropy balancing approach. Prior to this, however, Table 3 presents descriptive statistics for the climatic variables of interest.

Table 3 – Descriptive Statistics of Climatic Variables – Rural versus Urban

Variables	Municipality Type					
	Rural			Urban		
	Min.	Mean	Max.	Min.	Mean	Max.
Annual Total Precipitation (mm)	156.66	1.264.96	4.130,10	148,25	1.499.10	4.130,10
Annual Rainfall Deviation	-1.134	-0.066	0,674	-1,131	-0,027	0,697
Drought	Proportion of Drought Periods					
	22.37%			19.58%		

Source: Elaborated by the authors based on the dataset.

According to the adopted methodology, the average precipitation for rural and urban municipalities is observed to be 1,264.96 mm and 1,499.10 mm, respectively. In practice, urban municipalities received on average 18.51% more rainfall than rural ones. Furthermore, deviations in rainfall relative to the municipality's historical average are 2.44 times greater in rural areas compared to urban locations. Lastly, periods of extreme drought were 2.79% more frequent in rural municipalities than in urban ones. In summary, water scarcity and/or drought periods have significantly impacted rural municipalities to a greater extent. Therefore, the main results of the estimates related to the interactions between climatic variables and firearm homicide rates are presented in Table 4.

Based on the observations, the estimated coefficients (β_i) related to periods of extreme drought exhibit a distinct relationship depending on the type of municipality. In practice, it is observed that during drought periods, the effect on firearm homicide rates is positive, with an increase of 14.44 in rural municipalities. Conversely, the effect of drought on crime rates is negative, showing a reduction of -21.14 in urban municipalities. In summary, drought periods increase homicide rates in rural areas while decreasing them in urban zones. This finding is intriguing, as the estimated coefficients for the total annual rainfall volume are rather negligible and positive for both urban and rural municipalities.

Table 4 – Treatment Effect – Periods of Extreme Drought – Rural versus Urban

Variables of Interest	Municipality Type – Homicides					
	Rural (128.710)			Urban (641.064)		
	β_i	σ	t	β_i	σ	t
Periods of Drought	14.44	0.89	16.15***	-21.14	0.65	-32.17***
Total Annual Precipitation (Volume of Rainfall)	0.00	0.00	4.69***	0.00	0.00	45.29***
Annual Rainfall Deviation (Historical Mean)	-10.46	1.94	-5.38***	-25.35	0.42	-59.85***
Educational Level (Low/Medium)	-1.91	0.69	-2.76***	-2.39	0.13	-17.48***
Occupational Status (Low/Medium)	0.01	0.96	-0.02	0.76	0.18	4.22***
Age (Young/Adults)	-2.93	0.61	-4.75***	-1.20	0.54	-2.23**

Race/Ethnicity (Non-White/White)	-6.06	0.80	-7.55***	-5.51	0.61	-8.98***
Sex (Male/Female)	-2.03	1.22	-1.66***	-0.75	0.17	-4.20***
Marital Status (Single/Married)	-1.68	0.61	-2.74***	0.69	0.88	0.79
Place of Birth (Native/Migrant)	3.73	0.62	5.94***	1.59	0.09	16.78***

Source: Elaborated by the authors based on the dataset.
Notes: $***p < 0{,}01$; $**\ p < 0{,}05$.

In turn, deviations in rainfall relative to the historical average exhibit negative effects of -10.46 and -25.32, respectively. These results indicate that the greater the positive deviations, the lower the observed homicide rates in both rural and urban municipalities. However, this effect is 2.42 times stronger in urban municipalities than in rural ones. This may be explained by the possibility that excessive rainfall adversely affects rural inhabitants less favorably in terms of homicide rates compared to those living in urban areas.

All other observed determinants have the expected effect, although they vary between rural and urban municipalities, with the exception of occupational status, which shows no influence on homicide rates in rural municipalities, and marital status, which shows no significant difference in urban municipalities. Numerically, the higher the individual's educational level, the lower the homicide rate tends to be. However, this effect is 25.15% more pronounced in urban municipalities compared to rural ones. This disparity can be attributed to the potentially greater economic dependence in rural areas and/or the scarcity of opportunities for upward mobility in the labor market. This perspective aligns with the results of the occupational status analysis, as significant effects of this variable are only found in urban municipalities. In other words, there is an increase of 0.76 in homicide rates for individuals employed in lower-skilled jobs in urban environments.

Intriguing results arise when analyzing the age, race/ethnicity, sex, and place of birth of homicide victims. For example, it was found that in rural municipalities, being non-white increases the likelihood of being a homicide victim by about 10% compared to individuals of the same race/ethnicity in urban areas. Furthermore, the difference is even more striking regarding the age of victims, where being young in non-urban areas increases the probability of being a homicide victim by 144.16% relative to individuals of the same age group in urban areas.

Regarding sex, the results are concerning, especially in urban areas. Although firearm homicide rates predominantly affect men compared to women, there is a possible inversion of this trend in urban centers. Indeed, the gender disparity is 64% smaller in urban areas than in rural ones. This suggests that firearm homicide rates affect women living in urban areas more severely. This finding aligns with the increase in femicide cases in urban areas, as indicated by the Violence Map published by ABSP in 2023.

Marital status only affects homicide rates in rural areas, where being married reduces the likelihood of becoming a firearm homicide victim by 1.69. Regarding place of birth, migrants from rural areas have a much higher probability of becoming victims of firearm homicide than those from predominantly urban areas. On average, rural migrants are affected 2.36 times more than urban migrants. These findings, together with data on water scarcity and periods of extreme drought, likely reflect two of the main challenges faced by the rural sector: rural exodus and forced migration.

Last but not least, Table 5 presents the quantile treatment effect of extreme drought periods on firearm homicide rates exclusively in rural municipalities. This aims to investigate whether the impact caused by adverse climatic and/or economic conditions remains constant or varies across the distribution of homicide rates in rural areas of Brazil. The results indicate that

the effects on homicide rates in Brazilian rural municipalities are positive throughout the distribution. In other words, there is strong evidence that drought periods generate higher homicide rates in these regions.

Table 5: Homicide Rates versus Extreme Drought

Rural Municipalities	
Decile	β_i
0.10	1.75***
0.25	2.90***
0.50	5.10***
0.75	5.42***

Source: Elaborated by the authors based on the dataset.
Notes: $***p < 0{,}01$; $** p < 0{,}05$.

Another crucial finding is that the effect intensifies considerably across the entire distribution of firearm homicide rates. In summary, the higher the total number of homicides, the more pronounced the effect of extreme water scarcity. Specifically, the impact in the top 25% of municipalities with the highest firearm homicide rates is 3.15 times greater than that observed in the bottom 10% of municipalities with the lowest homicide rates, although the average effect is very close to the maximum recorded values. In other words, the more violent the municipality in terms of homicide rates, the more severe the problems caused by extreme drought. This phenomenon may be linked to the fact that regions with more conflicts have a greater potential for experiencing drought periods. In sum, there is strong evidence of the interiorization of crime phenomenon in the so-called rural municipalities of Brazil.

5. CONCLUDING REMARKS

The primary objective of this study was to investigate the impacts of water scarcity and/or periods of extreme drought on homicide rates in Brazilian municipalities, particularly those classified as rural by the IBGE. To this end, a dataset comprising 769,774 observations was assembled, combining climatic information, socioeconomic characteristics of victims, homicide rates, and selected municipal socioeconomic control variables over the period 2002 to 2020. To achieve this objective, the entropy balancing methodology proposed by Hainmueller and Xu (2013) was employed, along with quantile regression estimates as suggested by Chernozhukov, Fernández-Val, and Melly (2013), comparing urban and rural municipalities. Additionally, a profile of homicide victims in rural municipalities was developed to provide a more detailed understanding of the issue at hand.

The main findings indicate that periods of water scarcity and/or extreme drought contribute to an increase in firearm homicide rates in rural Brazilian municipalities, whereas the effect is reversed in urban areas. Traditional determinants found in victimology literature yielded expected results. Notably, low educational attainment, youth, non-white race, single marital status, male sex, and migration exert a more significant influence in rural areas compared to urban areas regarding firearm-related homicides.

These results can be explained by the economic vulnerability of regions dependent on natural resources, such as water scarcity in rural areas, which may lead to reduced production and/or income, increased unemployment, and worsening poverty and inequality, among other social stressors. This amplifies existing structural problems in these regions. This conclusion is supported by the data in Table 5, which shows that the greater the violence (measured by firearm homicide rates), the greater the impact of water scarcity and/or extreme drought periods on these indicators. In summary, the higher the homicide rate, the stronger the negative effect of water scarcity. In other words, the findings allow for the acknowledgment of the phenomenon of crime interiorization in the so-called rural municipalities of Brazil.

Finally, it is crucial to highlight the need for a deeper understanding of certain issues, such as why the observed effects in urban areas differ from those found in rural municipalities. Some limitations warrant attention in the analysis, including the lack of consideration of regional idiosyncrasies, such as: i) potentially smaller effects in regions without reservoirs or irrigation systems; ii) possible neutralization or reduction of effects in more developed and less economically vulnerable regions, such as the Central-West, Southeast, and South, where homicide rates have stabilized or declined over the years; iii) among other considerations.

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