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JOÃO VICTOR BATISTA LOPES

THE BRAZILIAN ARMED FORCES AND PUBLIC SECURITY ON THE BORDER: A SPATIAL REGRESSION DISCONTINUITY DESIGN APPROACH

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Dissertation submitted to the Graduate Program in Economics of the School of Economics, Business Administration, Actuarial Science and Accounting of the Federal University of Ceará, as a partial requirement for obtaining the title of Master in Economics. Concentration Area: Economics

Advisor: Prof. Dr. José Raimundo de Araújo Carvalho Junior

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To Brazilian and other South American citizens living in the border region.

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"The real contribution of statistics to society is primarily moral, not technical."

(Max Morris)

ABSTRACT

Brazil's Border Strip plays a strategic role in national defense, public security, and regional development and is the target of various control and patrol policies. This study investigates the impact of the Armed Forces' actions on public security in municipalities within the Border Strip. To achieve this, we analyzed the variation in municipal homicide rates between 2010 and 2019 and applied the regression discontinuity design (RDD) to estimate the effects of the Armed Forces' presence by comparing municipalities inside and outside the strip. The results indicate that the presence of the military affects violence; however, these effects are not spatially uniform. In the Northern Arc, there was a significant reduction in homicide rates in municipalities within the Border Strip compared to those outside this region. In contrast, in the Central and Southern Arcs, the estimates were either not statistically significant or, in some years, counterintuitive. Furthermore, we tested alternative classifications for treatment and control groups, including cut-off points that consider the location of the municipal seat and differentiated exposure to the national security apparatus. These tests corroborate the positive impact of homicide reduction exclusively in the Northern Arc. The analysis supports the hypothesis that the presence of the Armed Forces has a positive effect on public safety, though this impact is concentrated in the northern arc municipalities.

Keywords: Public security. Border Strip. Armed Forces. Regression Discontinuity Design.

RESUMO

A Faixa de Fronteira do Brasil desempenha um papel estratégico na defesa nacional, na segurança pública e no desenvolvimento regional, sendo alvo de diversas políticas de controle e patrulhamento. Este estudo investiga, portanto, os impactos da atuação das Forças Armadas sobre a segurança pública dos municípios da Faixa de Fronteira. Para isso, analisamos a variação das taxas de homicídios municipais entre 2010 e 2019 e aplicamos o método de Regressão Descontínua (RD) para estimar os efeitos da presença das Forças Armadas, comparando municípios dentro e fora da faixa. Os resultados indicam que há efeitos da presença militar sobre a violência, no entanto, esses efeitos não são espacialmente generalizados. No Arco Norte, observa-se uma redução significativa das taxas de homicídio nos municípios pertencentes à Faixa de Fronteira vis a vis municípios fora dessa região; enquanto no Arco Central e no Arco Sul, as estimativas não foram estatisticamente significativas ou, para alguns anos, foram contraintuitivas. Além disso, testamos classificações alternativas dos grupos de tratamento e controle, incluindo recortes que consideram a localização da sede municipal e a exposição diferenciada ao aparato de segurança nacional, corroborando o impacto positivo de redução de homicídios somente para o Arco Norte. A análise dá suporte à hipótese de que a presença das Forças Armadas exerce um efeito positivo sobre a segurança pública, porém esse impacto se concentra nos municípios do Arco Norte.

Palavras-chave: Segurança pública. Faixa de Fronteira. Forças Armadas. Regressão Descontínua.

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1 INTRODUCTION

In 2023, at the launch ceremony of the Plano Amazônia: Segurança e Soberania (AMAS, Amazon Plan: Security and Sovereignty), the Minister of Justice and Public Security at the time, Flávio Dino, indicated that the government was evaluating the possibility of expanding Brazil's Border Strip within the Legal Amazon (Moreno, 2023). The proposal involved extending this strip from 150 km to 250 km from the border, allowing the Armed Forces to engage more intensively in the area. The rationale for this initiative was rooted in the objective of improving national security and addressing illegal activities, such as drug trafficking and environmental crimes, which are prevalent in this particularly vulnerable region.

In light of this possibility, fundamental questions arise: Is there empirical evidence to suggest that the presence of the Armed Forces within the Border Strip improves public safety? Should the strip be expanded, would the municipalities newly encompassed within it achieve heightened security? Furthermore, is there a measurable difference in the incidence of violence between cities located within the Border Strip and those that, despite their geographical proximity, fall outside its boundaries?

This study seeks to address the aforementioned questions by analyzing the potential effects of the Armed Forces' presence within the Border Strip, with a particular focus on the legal frameworks governing their actions. The central hypothesis posits that the military presence positively influences public safety in the border strip region by decreasing the occurrence of homicides and other violent crimes. To empirically test this hypothesis, a Regression Discontinuity Design (RDD) was employed to contrast municipalities situated within and outside the strip, thereby isolating the impact of the Armed Forces' actions from other socioeconomic factors. In addition, the study explores alternative classifications of the treatment and control groups to verify the robustness of the findings and discern potential heterogeneities in the observed impacts.

The estimated results suggest that the municipalities that make up the border strip are linked to a substantial decrease in homicide rates within the Arco Norte region. For example, in 2014, the projected effect was a reduction of 39.8 homicides per 100,000 inhabitants, and by 2018, this reduction had increased to 53.4 homicides per 100,000 inhabitants. These findings imply a favorable impact of the policy on public safety. However, this pattern was not observed in the other arcs.

In addition to the introductory section, the dissertation is divided into five additional

sections. The second section of the study presents the motivation for the study, contextualizing the importance of the Border Strip and the security policies aimed at this region. The third section delineates the objectives. The subsequent literature review discusses academic works and regulatory frameworks that support the analysis of the role of the Armed Forces. In the subsequent section, entitled "Methodology," we delineate the empirical design that was employed in this study. This section includes a detailed description of the data used in the study, the econometric modeling that was implemented, and the strategies that were employed to identify the effects. Finally, the final consideration section offers a summary of the primary findings of the investigation, a discussion of their implications for the formulation of public policies, and a suggestion of directions for future studies.

2 MOTIVATION

2.1 Recent Dynamics of Violence and Economic Development on the Border Strip

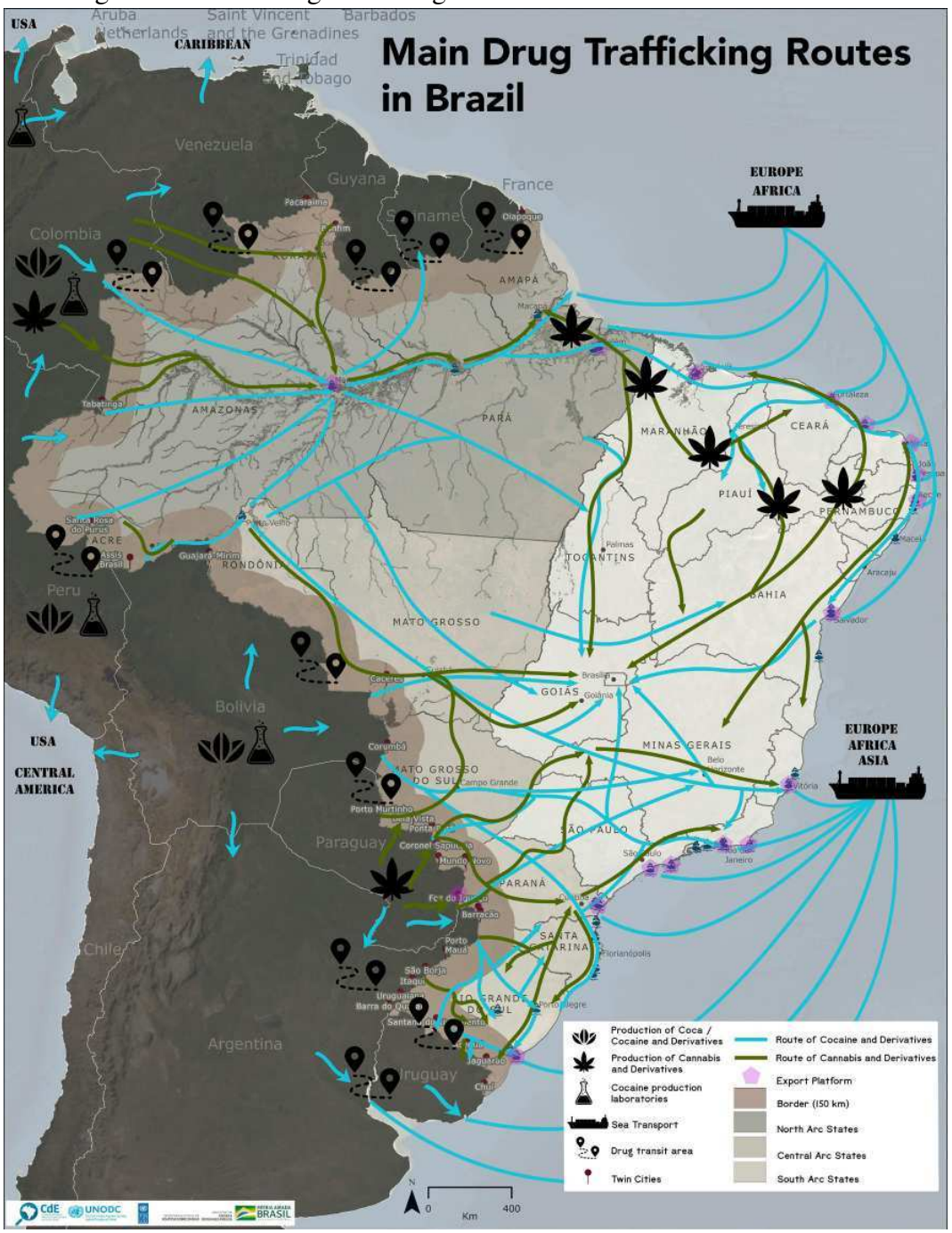
A detailed examination of the issue of public security along the border strip demands a preliminary consideration of the substantial expansion of the region. In its current configuration, the border strip occupies 27% of Brazilian territory, extending along 16,886 kilometers of land border. The border strip is home to 588 municipalities that are located within 11 states.

This expansive geographical region is characterized by a high degree of heterogeneity, which is a natural consequence of its substantial size and diversity. The various sections of the border strip exhibit distinct characteristics, which in turn influence the nature of the public security challenges they face. The existing literature indicates that specific crimes are favored by the geographical and socioeconomic conditions of the location, although it is generally agreed that drug trafficking, smuggling, and environmental exploitation are common in all regions.

The Brazilian border plays a crucial role as a gateway for the transnational flow of drugs, since it connects the main producing countries of South America, such as Colombia, Peru, Bolivia and Paraguay, to national and international consumer markets. This illicit traffic is not restricted to border regions; rather, it spreads extensively throughout Brazil, as illustrated in Figure 1. The North, Northeast and Southeast regions are particularly affected, given the strategic importance of these regions as the main ports utilized for the exportation of illicit substances. As detailed in the CoE Brazil report (2021), trafficking routes exhibit an intricate pattern of internal distribution, utilizing roads, rivers, and airways to supply major metropolitan areas and strategic outlets to Europe, Africa, and Asia. This phenomenon underscores the necessity for an integrated approach to public security, encompassing not only border control but also the oversight of the logistical infrastructures utilized for international trafficking.

In the Northern Arc, comprising the states of Amapá, Pará, Roraima, Amazonas, and Acre, Dias (2024) examine the dynamics of violence and the role of criminal factions in the macroregion. This article delineates the manner in which proliferation and confrontation between factions, including the First Command of the Capital (Primeiro Comando da Capital, PCC) and the Red Command (Comando Vermelho, CV), have influenced criminal activity and violence in the northern region. In addition, it explores the direct impact of these factions in specific locales, establishing a correlation between their presence and the escalation of violence. The text explores how factions associate themselves with typical illegal activities in the region,

Figure 1 – Main drug trafficking routes in Brazil



Source: CoE Brazil (2021)

such as drug trafficking and environmental crimes, including illegal logging and mining. The various factions establish alliances and rivalries with local and regional groups, contributing thus to an increasing state of instability.

In the context of the preceding discussion on the activities of criminal organizations, Couto (2024) focuses on cross-border drug trafficking in the Amazon region. The study emphasizes the intricate interconnection between drug trafficking networks and ancillary activities, such as illegal mining, emphasizing their direct impact on regional security. As Couto (2024)

emphasizes, drug trafficking not only utilizes the Amazon territory as a transit route, but also integrates itself into the local economy, exploiting natural resources and contributing to the increase in violence and crime in the region.

This insight is pertinent to public security in the Northern Arc, as it demonstrates how the region is susceptible to vulnerability due to the presence of criminal factions that compete for control of trafficking routes and exploitation areas. It also addresses the need for pan-Amazonian cooperation, involving Brazil and neighboring countries, to implement an integrated and coordinated security strategy capable of responding to transnational threats that directly affect local sovereignty and development.

The Central Arc, comprising Rondônia, Mato Grosso, and Mato Grosso do Sul, encompasses a region characterized by significant geographical diversity, located at the intersection of the Amazon and the Center-South of the country. As demonstrated in Moura and Oliveira (2018), when analyzing Brazilian cross-border arrangements, it becomes evident that the central arc has undergone significant changes due to the advancement of the economic frontier, particularly in the agricultural sector, and the subsequent relocation of major companies from the southern region to the area. However, the character of this border strip is predominantly defined by a widespread combination of illicit activities and acts of violence. In the states of Mato Grosso and Mato Grosso do Sul, the highest number of drug seizures is recorded, indicating the presence of extensive "corridors" utilized by major trafficking networks. In other border states, "ant" trafficking can predominate, which is more difficult to recognize due to the multiplicity of routes and small amounts of trafficked goods.

The Southern Arc, which includes the states of Paraná, Santa Catarina, and Rio Grande do Sul, exhibits distinct economic and urban performance characteristics that surpass those observed in the other two regions. The border region exhibits a significantly elevated presence of security forces and is subject to stringent regulations. As with the Central Arc, the country is faced with challenges related to trafficking, a phenomenon exacerbated by its extensive integration with neighboring states. This challenge is further compounded by the increase in smuggling activities. As Andrade *et al.* (2019) points out, the characteristics of the region are notable, particularly with regard to the potential to advance public security measures along the Brazilian border.

The existing literature that addresses the relationship between violence and social development in the Brazilian border strip highlights the complexity and challenges facing this

region in terms of public safety and socioeconomic progress. As indicated in seminal studies such as Krüger *et al.* (2017) and Castro (2011), it is imperative to understand the dynamics that shape the scenario of violence and its impact on human development.

As Krüger *et al.* (2017) demonstrates in her analysis of public policies, a focal point of the discussion are the strategies used to encourage sustainable development in the Border Strip. The study's findings underscore the critical need for well-integrated and effective policies in the border strip, a region characterized by pronounced socioeconomic and environmental vulnerabilities. Development initiatives, including the Border Strip Development Program (Programa de Desenvolvimento da Faixa de Fronteira, PDFF) and the North Belt Program (Programa Calha Norte, PCN), have focused primarily on improving socioeconomic factors such as employment, health, and education. However, these initiatives have overlooked the environmental dimension, which is imperative for the sustainability of the region. However, despite certain advances in education and health indicators, employment and income indicators have exhibited a decline in certain regions. This observation suggests a disconnection and absence of continuity in the public policies implemented.

Castro (2011) offers a comprehensive exploration of the impact of external cause mortality, such as homicides and traffic accidents, on human development in border areas. A quantitative analysis of mortality data from 2000 to 2005 reveals that violence and accidents are responsible for a significant proportion of deaths in these regions, with particularly severe impacts observed in the North. The demographic most affected by this phenomenon is young men between the ages of 20 and 49, a group that experiences a considerable loss of potential years of life and productivity. Although the direct impact of mortality from external causes on the Human Development Index (HDI) is limited, the study demonstrates that the resulting economic and social losses are substantial, particularly with regard to gross production and social development.

These studies reveal an interdependence between violence, public safety, and socio-economic development in border regions. The absence of continuity in public policies, in conjunction with the high mortality rate from external causes, underscores the need for more integrated and sustainable strategies. The prevalence of violence in these regions not only undermines security, but also exerts a direct and substantial influence on social development. This underscores the imperative for policies that integrate security, social development, and environmental protection to catalyze transformative change in these areas.

2.2 The Armed Forces and Security in the Border Strip

The Border Strip is defined as the strip extending up to 150 kilometers wide along the land borders, as delineated in the regulation. According to Article 20 of the 1988 Brazilian Federal Constitution (Brasil, 1988), the region is of particular interest to the Brazilian state, from the perspectives of public security, national defense, and sustainable development.

In view of the above, from a legal perspective and with regard to the regional context of public security, the presence of the Armed Forces along the border strip has the potential to affect public security and local development. As Andrade *et al.* (2019) explain, the Army is engaged in operations that go beyond the scope of conventional national defense. These operations encompass public security initiatives and border security measures, among others. The article emphasizes that military operations are not only intended to ensure security, but also to promote social and economic development in border regions. This perspective offers insights into the indirect consequences of military presence, extending beyond the immediate impact of reducing violent crime.

In the study of Andrade *et al.* (2019) the contemporary operational framework is categorized into two distinct classifications: defense policies and public security policies. In terms of defense, the article presents PCN, the Integrated Border Monitoring System (Sistema Integrado de Monitoramento de Fronteiras, Sisfron), Operation Ágata, and the National Defense Policy (Política Nacional de Defesa, PND), which accompany the National Defense Strategy (Estratégia Nacional de Defesa, END). The PCN is the oldest of these organizations, having been established in 1985 by the federal government. Initially, its military aspect was more relevant. Social assistance actions are also carried out in the context of Operation Agata, in civic-social actions (ações cvico-sociais, ACISO) (Andrade *et al.*, 2019, p.394). In these actions, the population is attended by a variety of professionals, including doctors, dentists, social workers, and barbers. In addition, border crossings receive essential supplies such as medicines, documents, haircuts and schools and health centers in localities undergo painting and renovation (Figueredo, 2017, p.77).

In the domain of public security policies, Andrade *et al.* (2019) presents the Specialized Border Units Project (Projeto Unidades Especializadas de Fronteiras, Pefron) and the Strategic Border Plan (Plano Estratégico de Fronteiras PEF), the National Border Public Security Strategy (Estratégia Nacional de Segurança Pública nas Fronteiras, Enafron) and the Integrated Border Protection Program (Programa de Proteção Integrada de Fronteiras, PPIF). The Perfon

initiative was established in 2008 as a pioneering effort to promote and enhance public security agencies' efforts. Subsequently, in 2011, the project was closed and incorporated into Enafron within the framework of the PEF. At the end of 2016, the PEF underwent an update with the initiation of the PPIF. The evolution of the programs presented in the paper indicates that public security along the border is characterized by a lack of cohesion. The authors observe that the absence of a national public security plan with clearly defined objectives and guaranteed resources undermines the efficacy of policies, particularly in border regions. The absence of continuity in policy and the distressing prevalence of violence are presented as consequences of this disarticulation.

Despite the legal certainty that governs the public security situation, the primary necessity is a clear and organized implementation of the objectives to reduce public security problems on the border. This execution could be guided by indicators produced and monitored by various bodies in addition to the Armed Forces. Performing in concert, these entities possess the capacity to effect improvements in this aspect of social development. The Brazilian Public Security Yearbook, in conjunction with the National Public Security Secretariat (Secretaria Nacional de Segurança Pública, Senasp), has already demonstrated its capacity to generate data on criminal activity in all municipalities, including those located within the border strip. Quantitative and empirical studies are imperative for the implementation of public security policies. These studies provide concrete data that facilitate the identification of pertinent issues and the development of effective solutions.

3 STUDY OBJECTIVE

The objective of this study is to assess the impact of policies applied in the border region on public security, paying particular attention to the role of the Armed Forces. To this end, the work aims to consolidate and analyze data on homicides in the region over the period 2010 to 2019, allowing for a more in-depth understanding of the dynamics of violence in this region.

Initially, the number of homicides per municipality will be systematized, providing a detailed overview of the evolution of this phenomenon over time. Subsequently, the variation in the homicide rate per 100,000 inhabitants across the various regions of the Border Strip will be examined, thus facilitating the identification of regional patterns and potential discrepancies between areas.

The analysis will investigate the effects of the geographical discontinuity generated by the Border Strip on homicide rates, exploring the hypothesis that this delimitation directly impacts the levels of violence in municipalities close to the established boundary. To this end, the differences in homicide rates between municipalities belonging to the control and treatment groups will be estimated to measure the effects of belonging to the Border Strip.

Furthermore, the study will seek to identify heterogeneities in the effects of the Border Strip on violence, considering socioeconomic factors that may influence this relationship. A comparative analysis of the impact of the Armed Forces' presence during different periods will be conducted, enabling the assessment of temporal variations and the potential evolution of this policy's impact.

Finally, to ensure the robustness of the results, different sample configurations will be tested that isolate specific effects, such as the distinction between municipalities that have a direct border with another country and those whose municipal headquarters are located outside the Border Strip. This methodological approach will enable the verification of the consistency of the results obtained across different scenarios, thereby reinforcing the validity of the study's conclusions.

4 LITERATURE REVIEW

The objective of this section is to provide a nonexhaustive review of the recent literature on the Regression Discontinuity Design (RDD) and its development for spatial data applications. The emphasis is not exclusively on studies that empirically implement these models; rather, it is on works that describe their methodological aspects, with the objective of contributing to the achievement of the research objectives. To this end, a selection of articles was made, including those that met the characteristics of systematic reviews, as well as other studies that presented the RDD methodology. The articles were then organized in chronological order. In this initial discussion, we examine publications that address fundamental RDD models, emphasizing the assumptions underlying these models. Subsequently, an analysis of the extant literature is conducted pertaining to the extension of this model to spatial data applications.

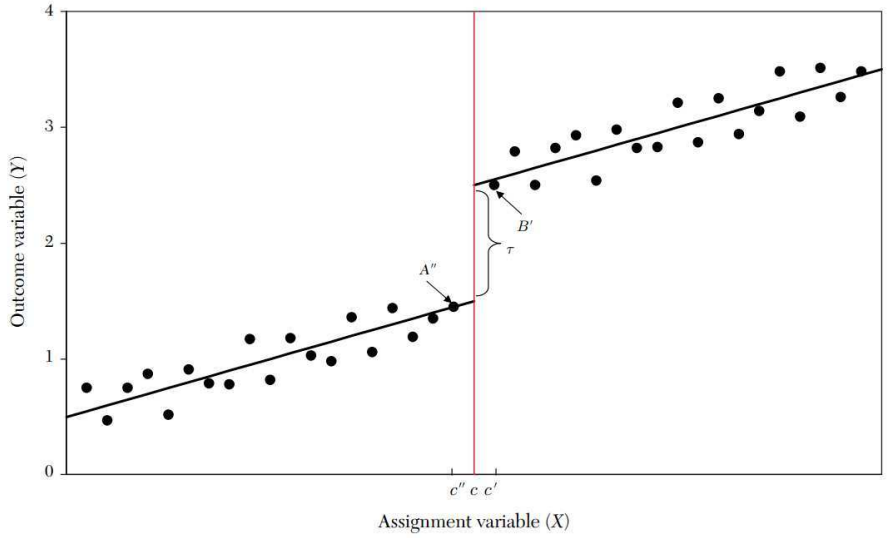
4.1 Regression Discontinuity Design (RDD)

The Regression Discontinuity Design (RDD) is a widely used causal analysis methodology in nonexperimental contexts, wherein the allocation of a treatment or intervention is contingent upon a clearly defined cut-off point in a continuous variable. The work of Thistlethwaite and Campbell (1960) introduced this methodology in the evaluation of the impact of school merit awards on students' academic future (career aspirations, participation in postgraduate courses, etc.). This study exploited the fact that awards were given on the basis of a certain grade: Students whose score X met or exceeded a cut-off value c were awarded, while those with lower scores were not. This mechanism generates a *discontinuity* in the treatment as a function of grade. If reception of treatment is represented by $D \in 0,1$, then we have $D = 1$ if $X \geq c$ and $D = 0$ if $X < c$.

Analyzing this problem, there is no reason why the function that relates the academic future (Y) and grades (X) should be discontinuous at any point. If a discontinuity is observed, the natural conclusion is that it arises from the assignment of the intervention at the cut-off point c. Assuming a linear relationship between Y and X, a simple way of estimating the effect of treatment can be expressed by equation 4.1. As demonstrated in Figure 2, the graphical representation of this relationship offers a visual interpretation of the underlying principles.

$$Y = \alpha + D\tau + X\beta + \varepsilon \tag{4.1}$$

Figure 2 – Basic setup of an RD model



Source: Lee and Lemieux (2010)

Various guides on the application of the model, such as Imbens and Lemieux (2007), underscore the efficacy of RDD for causal inferences. This methodology involves the comparison of units located just above and just below the cut-off point, thereby minimizing the influence of extraneous factors. This approach is particularly useful when direct randomization is not feasible; however, it still makes it possible to assess the effect of an intervention by observing a discontinuity in the outcome as a function of the cut-off variable.

As Lee and Lemieux (2010) demonstrated in their seminal work on RDD models, this approach offers a comprehensive foundation to understand the fundamental principles and practical guidelines that underpin the application of these models. The primary argument of this study is that, under certain conditions, the variation in treatment near the cut-off point is as random as in a randomized experiment. Participation in treatment is exogenous and the cutoff variable cannot be manipulated. This is considered the gold standard for evaluating interventions.

Therefore, as previously stated in Lee and Lemieux (2010), the assumptions underlying the RDD model are comparatively less complex than those of alternative methods applied to nonrandomized data. However, it is imperative to ensure that the assignment to the treatment or control group cannot be determined or influenced by individuals and that there is no discontinuity in the covariates at the cut-off point.

As demonstrated in Calonico *et al.* (2020), the regression is estimated in a subsample of the data that is statistically optimized close to the cutoff point. The underlying reason for the utilization of only a subset of the available data is the inherent trade-off between variance and

bias. In order to mitigate the impact of extraneous variables on the outcomes, it is imperative to restrict the data set to a point as close to the cut-off value at which the units exhibit the greatest similarity to each other. However, this reduction in the number of observations available introduces imprecision in estimators and causal inference, thereby limiting the feasibility of implementing policy suggestions.

Consequently, with respect to the selection of the bandwidth, as described in the study by Calonico *et al.* (2020), the optimal choice is determined by employing a triangular kernel function when describing the functions of the *rdrobust* package.

As indicated in the work of Cattaneo and Titiunik (2022), this line of research could be further developed by expanding the range of RDD applications and offering a more contemporary review of methodological advances. Two primary approaches are presented: the continuous framework, which utilizes local polynomial regression to capture the discontinuity at the cutoff point, and the Local Randomization Framework, which treats the area surrounding the cutoff point as a natural random experiment. The necessity of rigorous validation and falsification methods, including placebo tests and density analysis, is underscored to ensure the validity of the results.

As stated in Huntington-Klein (2022) there are three crucial components to effectively address the discontinuous regression design.

1. Running variable: this is the variable that determines whether the element is part of the treatment group or not. Examples include the case of receiving a government program from a certain income, where income is the cut-off variable, or the allocation of scholarships to students above a certain grade, where the grade is the cut-off variable.

2. Cut-off: is the specific value in the cut-off variable that determines eligibility for treatment. In the above examples, the cut-off points are the income value at which you receive the benefit or the grade value to receive the scholarship.

3. Bandwidth: refers to the interval around the cut-off point that is used to analyze the effect of the treatment. Huntington-Klein (2022) states that it is reasonable to think that individuals immediately next to either side of the cut-off point are basically the same, except for the treatment. The choice of window is crucial as it involves deciding which area around the cut-off point is comparable.

The paper by Wuepper and Finger (2023) is a comprehensive review of the applications of RDD in research focused on agricultural economics. In this work, the formalization

of RDD is described in Equation 4.2. Let the treatment be denoted by $D \in \{0,1\}$, the cut-off variable by X and the cut-off point by c. Therefore, there is a mechanism that $D = 1$ if $X \geq c$ and $D = 0$ if $X < c$. The regression, in its most basic form, would then be as follows:

$$Y = \alpha + \tau D + \beta_1 X^{above} + \beta_2 X^{below} + \varepsilon \tag{4.2}$$

Y is the variable of interest (e.g., number of homicides), α is the constant, β_1 and β_2 control for the distance to the cutoff point above and below (e.g., distance to the cut-off), τ is the estimated discontinuity and ε is an error term.

In the above equation, there are no control variables. According to Huntington-Klein (2022), the central idea of discontinuous regression is that you have an almost random assignment on both sides of the cutoff point. The necessity of incorporating control variables is debatable. However, this is not a prohibition, but rather a matter of caution when adding them. Incorporation of controls has been shown to enhance the precision of the estimator, thus reducing the extent of unexplained variation.

In a recent publication, Moss (2025) offers concrete illustrations of the implementation of RDD in the context of social research. Given the prevalence of eligibility criteria based on cutoff points for continuous variables in numerous services, the present cases offer an optimal context for the application of the proposed methodology.

As demonstrated in Moss (2025), RDD has the potential to be applied in a wide variety of areas, including health, education, and social care. However, it is imperative to determine whether the setting is conducive to a RDD, that the sample size is adequate, and that visual analysis can offer insight into the validity of the approach. The robustness of RDD contributes significantly to high-quality research in the evaluation of social interventions, especially when combined with other traditional methods of analysis. This combination enables the complementation of the strengths and mitigation of the weaknesses of each model.

The Regression Discontinuity Design (RDD) is a particularly suitable methodology for studying the impacts of belonging to the Brazilian Border Strip on public safety. The RDD makes it possible to explore the non-random assignment of treatment based on a clearly defined geographical cut-off point. In this case, the cutoff point corresponds to the distance from the boundary of the municipalities belonging to the border strip, thus allowing a comparison between municipalities immediately inside (treatment group) and outside (control group) this area. By

focusing on the discontinuity around this boundary, the RDD helps to identify the causal effect of the presence of the Armed Forces and other interventions specific to these locations, minimizing biases associated with structural differences between municipalities further away from the border. Furthermore, this approach is robust and effective for evaluating policies and interventions in contexts where randomization is not feasible. It is particularly useful for examining impacts in geographically delimited areas where there are logistic and ethical limitations to conducting a controlled experiment.

4.2 Spatial Regression Discontinuity Design (Spatial RDD)

Despite its extensive utilization to identify causal effects within observational contexts, the implementation of regression discontinuity design (RDD) in the analysis of spatial data poses substantial methodological challenges, particularly in the context of boundary analysis. A body of research has emerged that underscores the challenges associated with the implementation of RDD in geographical contexts. This research, as evidenced by studies such as Keele and Titiunik (2015), Kaza (2018) and Jardim *et al.* (2024), calls for adaptations that improve the efficacy of RDD in such environments.

One of the first studies to examine geographic variations in RDD was Black (1999), which estimated the willingness to pay for enhanced educational opportunities based on residential location within specific neighborhood boundaries.

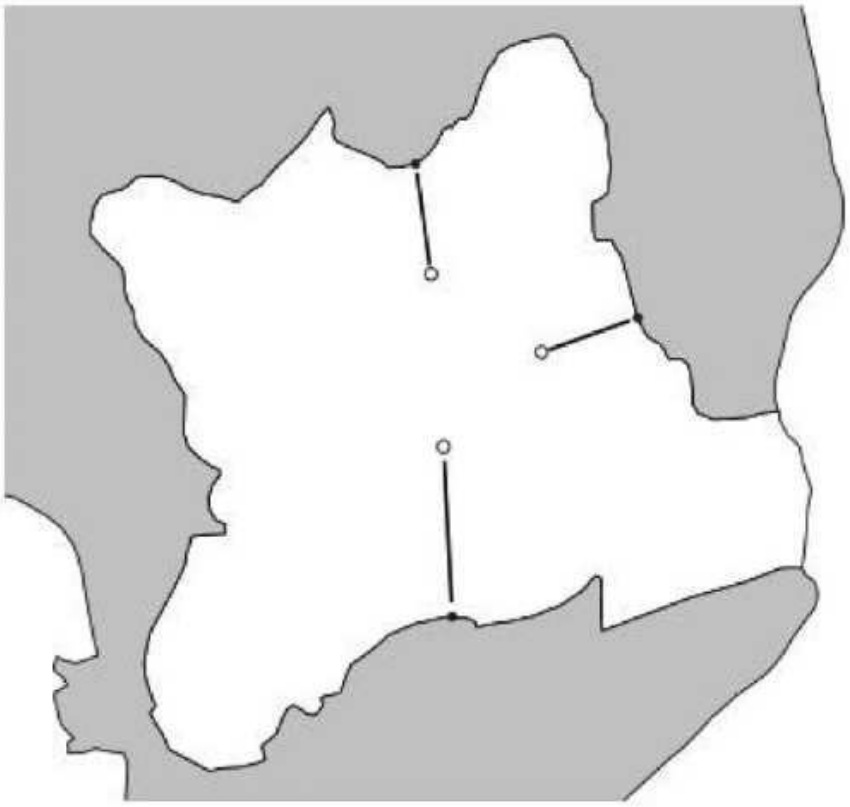
The approach delineated in Keele and Titiunik (2015) is further elaborated on in the subsequent discussion, which explores the potential of geographic variation to function as a natural experiment within the established framework of traditional RDD. This study evaluates the impact of ballot initiatives on voter turnout in Wisconsin and Ohio, based on two fundamental assumptions: Local Geographic Ignorability (LGI) is predicated on the assumption that units in close proximity to the border are commensurable. Geographic Regression Discontinuity (GRD), on the other hand, is predicated on the assumption that the discontinuity in treatment occurs precisely at the border.

However, the geographical application of RDD poses inherent challenges in the nature of the data. The authors emphasize that the validity of the inference is contingent on the manner in which the units are distributed along geographical boundaries. Furthermore, they emphasize that the intersection of multiple institutional boundaries can complicate causal inference, as different treatments may be in effect concurrently.

Another pertinent example is the study by Zimmert and Zorn (2023), which investigates the impact of direct payments in the agricultural sector on family employment on Swiss farms, with a particular focus on the participation of female labor. The study examines how spatial discontinuity in Switzerland's agricultural zones impacts the allocation of labor on farms. To this end, the RDD model is used, although with a certain degree of ambiguity, given that some farms may receive payments despite being located beyond the designated subsidy zone. The estimation process uses two-stage least squares (TSLS) with the geographical designation of agricultural zones serving as an instrumental variable.

In this work, the traditional approach for spatial RDD can be verified, which brings it closer to classical RDD models: the cut-off variable is the shortest distance from the point of interest (in this case, the farms) to the polygon. As illustrated in Figure 3, the variable's calculation process is demonstrated.

Figure 3 – Example of calculating the cut-off variable in Spatial RDD



Source: Zimmert and Zorn (2023)

Jardim *et al.* (2024) examined the spillover effects of municipal minimum wage laws in neighboring regions. To do so, the author used a geographic discontinuity method for causal inference. This study offers an illustration of how spatial RDD can be utilized to analyze

spillover effects, thereby evaluating the influence of local minimum wage laws on wages and hours worked both within and outside the cities that implement the policy.

Various methodologies were used to measure spatial spillovers, including parametric decay models and clustering by commute time. The authors conclude that the presence of spatial spillovers can generate bias in causal estimates obtained by border discontinuity methods. In major metropolitan areas such as Seattle, minimum wage policies have the potential to exert indirect influence on neighboring labor markets. Consequently, when assessing the efficacy of this legislation, it is imperative to take into account the potential indirect effects.

A significant constraint of conventional RDD in spatial data is its reliance on a unidimensional cutoff point. In conventional RDD methodologies, the delineation of the cut-off is accomplished through the utilization of a continuous variable. However, within the paradigm of spatial contexts, the boundary in question is inherently two-dimensional in nature, frequently expressed through the lens of geographical coordinates. This necessitates methodologies capable of addressing the multidimensional character of geographical boundaries, given that the distance from a unit to the cut-off cannot be reduced to a single scalar value.

In this sense, the article by Lehner (2024) offers a critical review of the literature on spatial RDD, emphasizing its key methodological limitations. To illustrate the shortcomings of conventional estimators and to validate his proposals, the author employs Monte Carlo simulations. Furthermore, he proposes a novel methodology for the visualization and estimation of heterogeneous effects along the border, a departure from the conventional approach of collapsing the geographical space into a single distance variable. To achieve this objective, the proposed methodology employs randomization inference within the framework of spatial RDD, thereby generating random counterfactual borders and assessing treatment effects under various spatial configurations.

Boundary randomization has been demonstrated to be a robust approach to causal inference in Spatial RDD, reducing problems of bias and offering an alternative to conventional hypothesis testing. As argued by Lehner (2024), spatial RDD should consider complex spatial patterns, rather than simply applying traditional RDD with a single distance variable.

Consequently, while traditional RDD is a robust instrument for causal analysis, it exhibits notable limitations in spatial contexts. More advanced approaches offer robust methodological solutions to these challenges, broadening the applicability of the method in geographical studies and increasing the credibility of causal inferences in these settings.

5 METHODOLOGY

5.1 Methodological Approach

The present study is characterized as a quasi-experimental, or observational, study with a causal approach. As Kim and Steiner (2016) show, this methodological approach aims to elucidate the relationships between cause and effect. However, it diverges from traditional experimental methods by not incorporating direct manipulation or total randomization of variables. In fact, in the context of quantitative social sciences, the execution of a controlled experiment with a completely randomized sample is often challenging.

Given that the objective of the study is to evaluate the impact of an intervention or a treatment that becomes active if the municipality belongs to the border area, it is not possible to randomly assign municipalities with and without treatment. Consequently, suitable models will be employed to ascertain a causal relationship, that is, Regression Discontinuity Design. Specifically, a spatial discontinuity determines the municipalities that are subject to treatment (border strip) and those that are not.

It is imperative to acknowledge the profound impact of the Armed Forces' presence on Brazil's border strip, which significantly influences a wide array of national realities. Consequently, it would be imprudent and presumptuous to imply that we intend to evaluate or invalidate the actions of the Armed Forces, considering the wide array of operations they undertake. In this regard, a pivotal initial step involves the systematic identification and evaluation of the potential ramifications that may ensue from the operations of the Armed Forces. A suitable conceptual alternative would be to examine the official objectives described in Brazil's National Defense Policy (PND). (Brasil, 2020).

According to the PND, the three objectives of the Armed Forces can be systematized and succinctly defined as follows.

National Defense: A set of state measures and actions, with an emphasis on military expression, for the defense of the territory, sovereignty, and national interests against predominantly external threats, potential, or manifest. This objective can be considered the "classic" aim of any armed force seeking to deter potential or actual threats from other nations.

National Security: The condition that allows for the preservation of sovereignty and territorial integrity, the realization of national interests, despite pressures and threats of any kind, and the guarantee to citizens of the exercise of constitutional rights and duties. In

particular, the Armed Forces have made a decisive contribution to issues related to public security, both in large urban centers and in the border region. In fact, borders demand attention as people, goods, and merchandise pass through them, integrating regions and fostering proximity between nations. Currently, illicit activities of a transnational nature are perpetrated through these frontiers, rendering their permeability a perpetual concern. This underscores the need for constant vigilance, coordinated action between defense and public security agencies, and close cooperation with bordering countries.

Regional and Social Development: The Brazilian army has maintained a presence along the border since the 17th century, as evidenced by Monte and Moreira (2017). This presence intensified following the military regime that lasted from 1964 to 1985. The continuous augmentation of frontier units has exerted a direct influence on the region, giving rise to the emergence of development hubs that have subsequently given rise to various housing centers. In fact, the Brazilian Army's pioneering actions in occupying the border, whether by providing basic services or developing the infrastructure of the region, have facilitated local growth and development.

Consequently, it is hypothesized that the IMPACTS expected from the presence of the Armed Forces on the border strip are the achievement of the three objectives mentioned. From an analytical point of view, it is assumed that the Armed Forces have an impact in three dimensions: 1) guaranteeing National Defense; 2) maintaining National Security; and 3) collaborating with regional and social development (see Chart 1). Given the capacity of each of the three IMPACTS to be decomposed into an array of quantitative and qualitative indicators, it is imperative to maintain concision. In this study, we will restrict our analysis to a quantitative impact assessment exercise for the "National Security" objective, with a more specific focus on reducing homicide rates.

Chart 1 – Expected impacts of the presence of the Armed Forces on the Border Strip

Area	Summary
National Defense	Defense of territory, sovereignty and national interests against threats
National Security	Preservation of sovereignty and guarantee for citizens the exercise of constitutional rights and duties, with special attention to vigilance against illicit activities at the border
Social and Regional Development	Provision of basic services to the population and development of the region's infrastructure

Source: Prepared by the author (2025)

5.2 Treatment: Armed Forces in the Border Strip

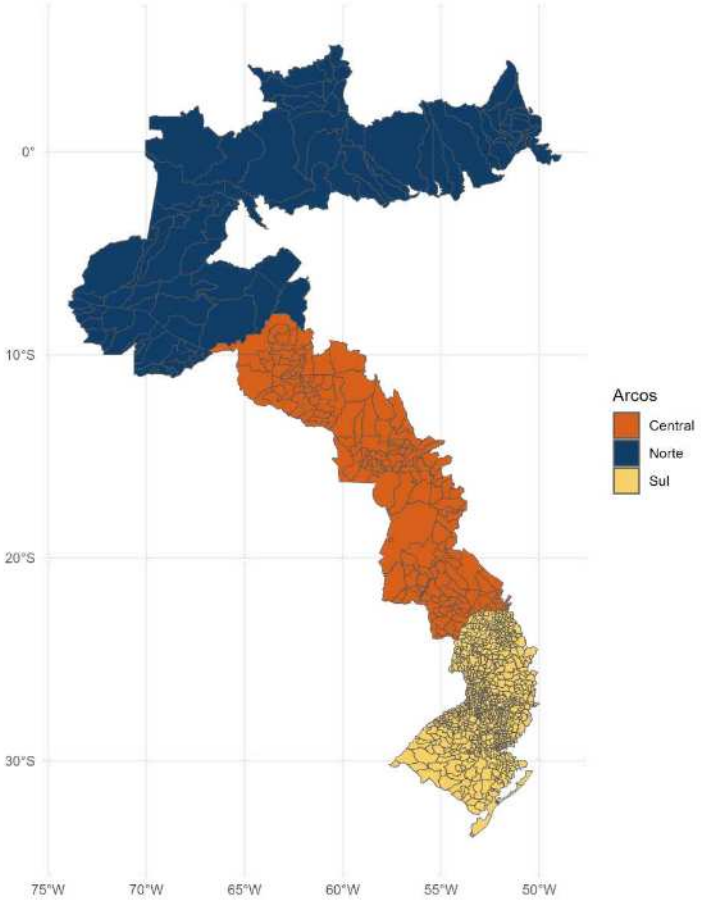
The Border Strip is a region that measures up to 150 kilometers in width along the Brazilian land borders. As delineated in Article 20 of the 1988 Federal Constitution (Brasil, 1988), it is considered a region of particular concern for the Brazilian state from the perspectives of public security and national defense, as well as sustainable development (see Figure 4).

Figure 4 – Border Strip in 2022.

Source: IBGE, Digital municipal grid 2022

The federal government's actions in the Border Strip were planned on a territorial basis, divided into three arcs. These arcs were defined on the basis of the proposal to restructure the Border Strip Development Program (PDFF-2005). The arcs were further defined on the basis of the Ministry of Integration's National Regional Development Policy (Política Nacional de Desenvolvimento Regional, PNDR). The arcs are illustrated in Figure 5.

Figure 5 – Border Strip Arcs



Source: Prepared by the author (2024)

The Brazilian border states exhibit considerable variation in the proportion of their territory that falls within the Border Strip, a factor that can influence the effects estimated in the analysis. As demonstrated in Table 1, while states such as Acre (88.3%) and Roraima (68.9%) have a significant portion of their area encompassed by the strip, others, including Mato Grosso (12.3%) and Pará (7.4%), exhibit a substantially lower degree of integration. These discrepancies can result in heterogeneity in the observed impacts, given that exposure to the Border Strip's regulatory and institutional regime varies considerably between states. Consequently, the magnitude and direction of the effects may be influenced not only by the presence in the strip but also by the territorial extent of this insertion.

Table 1 – Percentage of the states' area integrated into the Border Strip

State	Integrated area
Acre	88.275%
Roraima	68.892%
Rondônia	52.388%
Rio Grande do Sul	52.111%
Amapá	49.334%
Mato Grosso do Sul	40.175%
Paraná	27.897%
Amazonas	23.313%
Santa Catarina	15.290%
Mato Grosso	12.302%
Pará	7.414%

Source: IBGE (2024)

Act No. 601, of 18 September 1850, is regarded as the inaugural regulation concerning a border region, stipulating a width of ten leagues along the border limits, which is equivalent to 66 kilometers. The first instance of the Border Strip being subject to regulation is documented in the Constitution in 1934, in the National Security section, which stipulated a width of 100 kilometers along the land boundaries. Article 166 stipulates that the initiation of land concessions and the establishment of communication routes within the specified area are contingent upon the prior approval of the Higher Council for National Security through a designated hearing process. This regulation is indicative of the legislator's apprehensions regarding population expansion, particularly in the Northern regions. Subsequently, in the 1937 Constitution, the stipulations for the region were essentially reiterated, accompanied by a notable addition: the Border Strip was delineated as 150 kilometers wide, the measurement that persists in its application for the purpose of demarcation.

The 1988 Federal Constitution addresses the Border Strip in three distinct sections. Firstly, in Article 20, which pertains to federal property, the term is defined as a strip with a width of up to 150 kilometers along land borders. This strip is characterized as essential for the defense of national territory, and its occupation and use are subject to legal regulation. According to Article 91, which pertains to the National Defense Council, the aforementioned body is responsible for proposing the criteria and conditions for the utilization of areas deemed essential to the security of the national territory. In addition, the Council is tasked with offering advice on the effective management of these areas, with a particular emphasis on the Border Strip. Finally, Article 176, in its discussion of the conditions for the research and mining of mineral resources and the exploitation of the hydraulic energy potential, states that such activities can only be carried out with the authorization or concession of the Union, with specific conditions when

these activities are carried out on the border strip or on indigenous lands.

The Brazilian government has been engaged in deliberations on the potential expansion of the border strip within the legal region of Amazônia, which encompasses an area of more than 100 km. This initiative is purportedly motivated by the government's strategic intent to fortify security measures and augment state presence in the region. This claim is reported by Cravo (2023) and Governo… (2023). This measure, advocated by the Ministry of Justice and Public Security and the Ministry of Defense, seeks to expand the role of the Armed Forces and security agencies in combating environmental crimes, drug trafficking, and other illicit activities that occur in the most remote areas of the forest. This proposal is situated within a broader context of growing concern about the vulnerability of the Amazon border. The challenges associated with surveillance in this region include dense vegetation, extensive territorial expansion, and the presence of transnational criminal organizations. The extension of the strip, which is currently 150 km long, could facilitate the implementation of public policies aimed at sustainable development and environmental protection. At the same time, this initiative could serve to strengthen control over the national territory.

Although the proposal did not ultimately achieve success, it represented a significant milestone in the broader discourse. In this context, the Amazon Plan: The Security and Sovereignty (Amas Plan) was formally instituted through Decree No. 11,614, issued on July 21, 2023 (Brasil, 2023). The strategic plan calls for the establishment of 34 integrated security bases, which will entail a coordinated effort by the Armed Forces, the Federal Police, and the state police, in addition to the enhancement of the region's monitoring infrastructure. The primary objective of the initiative is to establish a more effective response to environmental crimes, including illegal deforestation and illegal mineral extraction. In addition, it aims to enhance the state's presence to ensure improved security for local communities. The strategic implementation of investments in technological and infrastructural enhancements is a core tenet of the AMAS Plan, with the overarching objective being the consolidation of a territorial governance model that fortifies national sovereignty and the preservation of the Amazon's natural resources.

In order to ensure that the Border Strip receives the attention it deserves under the Constitution, the actions of the Armed Forces in the region have also been described in different laws throughout history. As indicated by Figueredo (2017), four fundamental normative frameworks regulate the actions of the Brazilian Armed Forces in the Border Strip. These frameworks are described in Chart 2

Chart 2 – Normative frameworks for military action in the Border Strip

Document	Summary
Federal Constitution	Establishes the strategic importance of the Border Strip and the role of the Armed Forces in the defense of national territory
National Defense Program	Document guiding the planning of actions for national defense, coordinated by the Ministry of Defense
Integrated Border Protection Prog.	Through Operation Ágata, it promotes cooperation between different government agencies to control borders and combat transnational illegal activities
Complementary Law 97/1999	Assigns the Armed Forces to act on the Border Strip against cross-border and environmental crimes

Source: Figueredo (2017)

The Federal Constitution recognizes the strategic importance of the border strip and delineates the function of the Armed Forces in protecting national territory. Since the establishment of the first Republican Constitution in 1891, the Armed Forces have undergone institutionalization, and their fundamental mission has remained virtually unchanged throughout the various Magna Cartas: to defend the Homeland, guarantee the functioning of constitutional powers, and ensure the maintenance of law and order.

The National Defense Policy (Brasil, 2020) serves as the overarching directive for the formulation of strategies aimed at protecting national interests, a process that is orchestrated by the Ministry of Defense. The document's core priorities encompass border surveillance, environmental preservation, and the sustainable utilization of resources, all of which are indispensable for the advancement and incorporation of the Amazon region.

The Integrated Border Protection Program (Brasil, 2001), employs Operation Ágata as a strategy to promote collaborative efforts between various government agencies with the aim of improving border control and combating transnational illegal activities. Operation gata is an episodic military operation that is carried out by the Brazilian Armed Forces at strategic points along the terrestrial and fluvial Border Strip. The operation was established as part of the Federal Government's policies, with the primary objective being to reduce the incidence of cross-border and environmental crimes, as well as to combat the actions of organized crime. During the operation, military personnel from the Navy, Army and Air Force, with the support of public security agencies, carry out tactical missions to curb a range of criminal activities, including drug trafficking, smuggling, embezzlement, arms and ammunition trafficking, environmental crimes, immigration, and illegal mining. These actions are characterized by their punctuality and

extravagance, which includes a range of activities such as airspace surveillance, patrol operations, and inspection of major waterways and thoroughfares leading to Brazilian territory.

In addition to its focus on crime suppression, Operation Ágata [1] plays a crucial role in enhancing international cooperation and providing assistance to the local population. In each edition, Brazil notifies neighboring countries and invites them to participate in the operation. Participation may take the form of providing troop support in their own territories close to the border or sending military observers to monitor the actions. This approach promotes transparency and avoids diplomatic tensions. In addition to the implementation of enforcement actions, the operation includes social support initiatives, including medical and dental assistance, the distribution of pharmaceuticals, the issuance of documentation, and even services such as haircuts for underprivileged communities in the border region. In this way, the governance of Operation Ágata has pursued a multifaceted approach, which includes both the enforcement of law and order and the undertaking of humanitarian and diplomatic initiatives. This strategy has allowed Agata to consolidate its position as a significant instrument of state presence and regional security.

The fourth normative framework, the Complementary Law No. 97/1999 (Brasil, 1999), establishes the general regulations for the organization, preparation, and employment of the Armed Forces. Art. The 16th article establishes its role as a subsidiary, thus stipulating its mandate to cooperate with national development and civil defense initiatives. According to the provisions outlined in Complementary Law No. 136/2010 (Brasil, 2010), the Brazilian Armed Forces have been entrusted with the responsibility of addressing cross-border and environmental crimes. This mandate covers the implementation of preventive and repressive measures within the Land Border Strip, in maritime domains, and in inland waters. The scope of these operations is not contingent on possession, ownership, purpose, or any existing encumbrance in the affected areas. The execution of these operations must be conducted in a manner that is independent or in collaboration with other entities of the executive branch. The following actions have been identified as potential components of this mandate:

1. patrol;
2. search of persons, land vehicles, vessels and aircraft; and
3. arrests in flagrante delicto.

In consideration of the constitutional interpretation of the role of the Armed Forces in

[1] Appendix A presents a schematic representation of the operational structure and the personnel allocation of Operation Ágata across the designated time frame.

the Guarantee of Law and Order (GLO), as well as the six constitutionally legitimate possibilities for action delineated in the Chart 3, and given the findings of Figueredo (2017), it is concluded that, since Complementary Law No. 97/1999, the Armed Forces were assigned to a seventh public security activity for the Guarantee of Law and Order. This activity, which focused on the border strip, included the implementation of explicit police powers, including patrols, searches of individuals, vehicles, boats, and aircrafts, seizures of criminal objects, and arrest in *flagrante delicto*.

Chart 3 – Use of the Armed Forces in public security activities for Guarantee of Law and Order

	Activity
1.	Federal Intervention
2.	State of Defense
3.	State of Siege
4.	Security at official or public events of national importance
5.	Shock and riot policing, at the request of the state government
6.	Conducting measures determined in a Military Police Inquiry Acting in the Border Strip, with explicit police power,
7.	in patrol actions; searching people, vehicles, boats and aircraft, seizing objects of crime; and arresting in flagrante delicto.

Source: Figueredo (2017)

The Armed Forces' actions on the Border Strip are materialized in the fight against cross-border crime. Ordinance No. 061/2005 of the Brazilian Army considers cross-border crimes to be:

1. Illegal entry (and/or attempted exit) into national territory of weapons, ammunition, explosives and other related products;
2. Illicit trafficking in narcotics and/or substances that cause physical or mental dependence, or raw materials intended for their preparation;
3. Smuggling and tax fraud (Brazilian Penal Code, art. 334);
4. Trafficking in plants and animals, in accordance with the Environmental Crimes Law (Act 9.605/98) and the Fauna Protection Code (Act 5.197/67);
5. The entry (and/or attempted exit) into national territory of vectors that do not comply with epidemiological surveillance standards;
6. The practice of acts harmful to the environment, as defined in the Environmental Crimes Act (Law No. 9.605/98);
7. Predatory or illegal exploitation of natural resources; and
8. Committing acts harmful to the diversity and integrity of the country's genetic heritage, in

accordance with Executive Order No. 2.186-16, of August 23, 2001 (repealed by Act No. 13.123, of May 20, 2015).

As demonstrated in the works of Fagundes (2019) and Figueredo (2017) the police power of the Armed Forces on the Border Strip differs significantly from other GLO operations. Fagundes' observations reveal a notable distinction between the Brazilian Army's operational autonomy and that of GLO operations. The Brazilian army operates with a high degree of autonomy, allowing it to act proactively and repressively against cross-border crimes on the Border Strip without explicit presidential authorization. This autonomy is in contrast to the GLO operations, which require presidential authorization in scenarios where conventional security forces prove inadequate. In a similar vein, Figueiredo emphasizes that in the border strip, the Armed Forces wield continuous and explicit police power, allowing patrols and searches to be conducted in a more comprehensive and less restricted manner compared to the episodic and limited nature of GLO operations, which are aimed at temporarily restoring public order in specific areas. This distinction underscores the role of the Armed Forces as a constant and proactive presence along the border, as opposed to a reactive force that is only mobilized in emergency situations. [2]

5.3 Definition of Treatment and Control Groups

Distinguishing between treatment and control groups in a spatial Regression Discontinuity Design (RDD) presents particular challenges compared to the traditional one-dimensional context. In contrast to a clear cut along an ordered variable, in spatial RDD the cut-off is defined in a two-dimensional space, where municipalities proximate to the border may have different exposures to treatment. Furthermore, the irregular shape of geographical regions complicates the precise delineation of groups, making the identification of causal effects more susceptible to the definition of these groups.

Given these difficulties, the approach adopted in this study combines a main classification, used in the reference analysis, with three alternative classifications to test the robustness of the results. The primary definition of the treatment group considers municipalities with any part of their territory located within the 150 km Border Strip, while the control group is made up

[2] Indeed, the military possesses the capacity to organize operations to combat these crimes along the Border Strip. Recent examples include Operation Ágata and the VIGIA Program, now known as Guardians of the Border. As stated by Figueredo (2017), Operation Ágata is regarded as a significant milestone in the development of public security within the region.

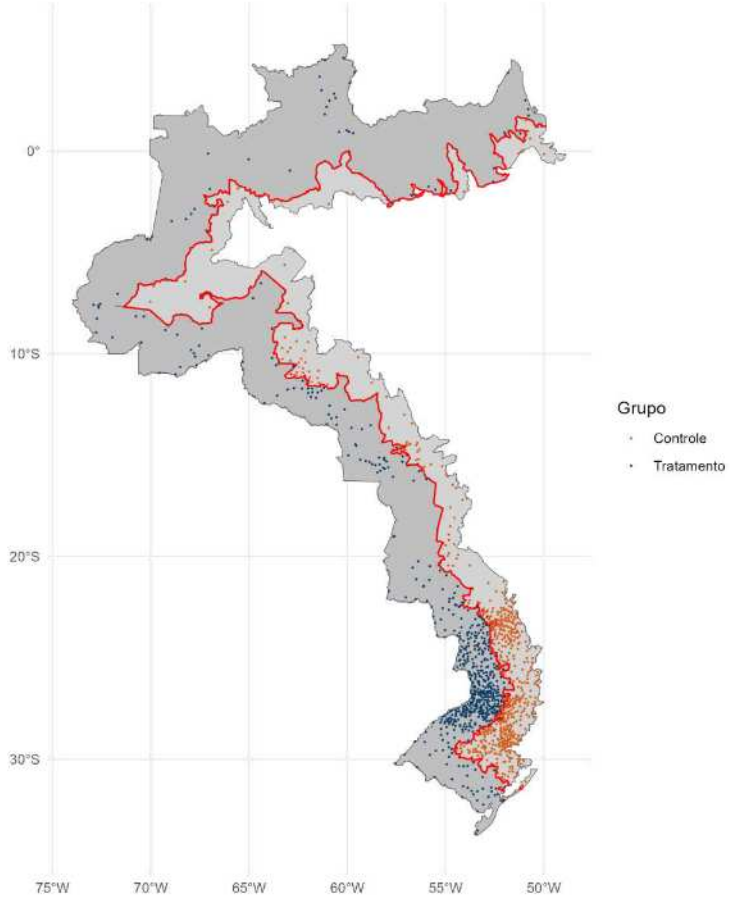
of municipalities immediately outside this limit up to 300 km from the border. This classification is here called Classification 1 and the details of each group are described in Table 2 and are represented on the map in Figure 6. The alternative classifications vary the spatial criteria to consider different levels of exposure to treatment, allowing us to assess whether the results are sensitive to changes in the definition of the groups.

Table 2 – Municipalities in the sample by group (Classification 1)

Grupo	Northern Arc	Central Arc	Southern Arc	TOTAL
Treatment	69 (75.8%)	101 (54.0%)	418 (48.9%)	588 (51.9%)
Control	22 (24.2%)	86 (46.0%)	436 (51.1%)	544 (48.1%)

Source: Prepared by the author (2024).

Figure 6 – Map of municipal seats according to Classification 1



Source: Prepared by the author (2024)

In this study, the delineation between the treatment and control groups is designated as the cut-off. This element plays a pivotal role in the interpretation of results for two primary reasons. Firstly, the discontinuous regression model, as described in Section 4.1, requires a continuous variable with a clearly defined cutoff point. In this case, the cutoff point corresponds

to the distance between the municipal seat and the cut-off. Secondly, the points located on the cutoff have a distance equal to zero in the analysis. The municipalities belonging to the control group, located to the right of the cutoff, have negative distances that decrease as they move away from this dividing line, while the municipalities in the treatment group, located to the left, have positive distances that become progressively greater.

In order to adapt to the demands of spatial discontinuous regression in relation to the definition of control and treatment, we propose alternative criteria for selecting treatment and control groups to assess effects other than Classification 1.

For example, among the municipalities situated along the border strip, some have their administrative seats located at a distance greater than 150 km. As illustrated in 3, the distribution of municipal seats within and outside the strip is depicted for each arc. A notable observation is that, in terms of proportionality, the South arc exhibits a significantly lower proportion of seats outside the belt, while the North arc demonstrates a proportion that exceeds one-third of the sample.

Table 3 – Treatment group seats by position in Border Strip and Arc

Municipal seat	Northern Arc	Central Arc	Southern Arc	TOTAL
Inside	45 (65.2%)	78 (77.2%)	404 (96.7%)	527 (89.6%)
Outside	24 (34.8%)	23 (22.8%)	14 (3.3%)	61 (10.3%)

Source: Prepared by the author (2024).

It is important to note that CLASSIFICATION 1 is not the sole potential allocation between treatment and control municipalities. Three additional classifications were adopted for the municipalities in the Border Strip and the control group, which resulted in different possibilities.

- SEAT EFFECT: Exclusion of municipalities that are in the border strip but have a seat more than 150 km away. It is hypothesized that these municipalities, which are located more than 150 km from the border, would have received less "treatment," thereby affecting the calculation of a possible effect in the sense of reducing it. In essence, this would constitute a classification error in which a unit that was not treated was classified as treated.
- BORDER EFFECT: Treatment and control are handled by the armed forces, but control does not border another country. We hypothesize that the very condition of bordering a country can be conceptualized as a situation of discontinuous spatial regression. In essence, the exercise involves a spatial RDD approach, wherein the delineation (or cutoff)

is defined by the border itself. However, it is crucial to maintain exposure to the "Armed Forces" treatment uniform for both treaties and controls.

- ARMED FORCES EFFECT: Treatment and control do not border another country, but treatment receives armed 'forces' and control does not. We implicitly assume that the border (and not the 'border strip') has particularities that can influence the analysis. Therefore, the aim here is to remove the "border" effect from the original arrangement of CLASSIFICATION 1.

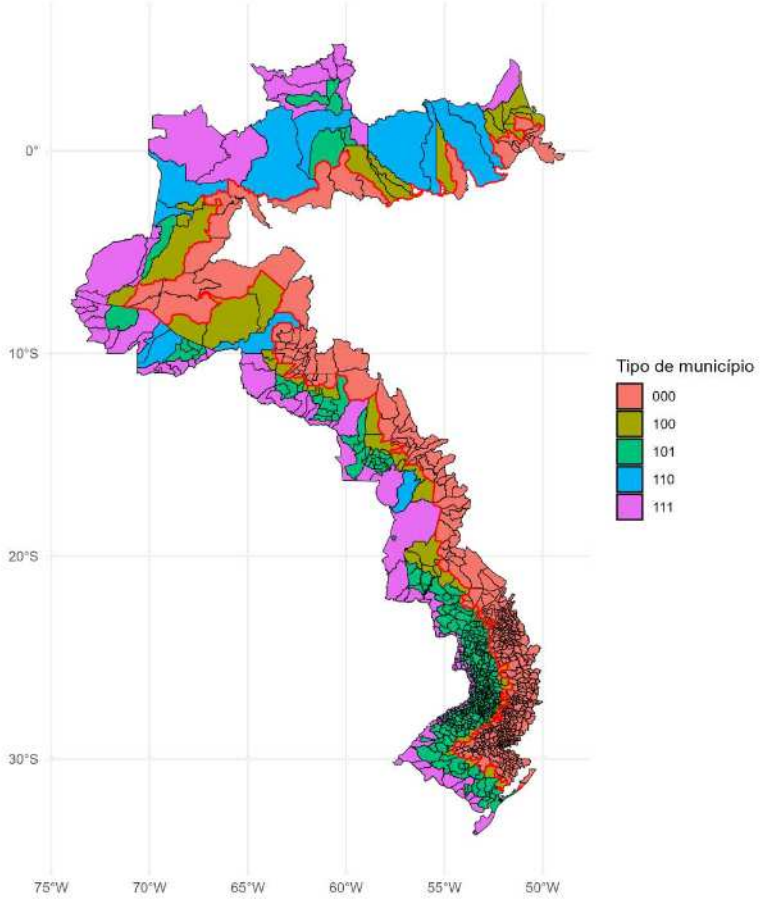
Initially, the variable `m_ff` was created, which takes the value 1 for municipalities located on the Border Strip. The variable `m_fronteira` indicates municipalities bordering other South American countries with a value of 1. In turn, the variable `m_sedeff` identifies whether the municipality's seat is within the border strip. The combination of these three variables generates eight theoretical possibilities, only five of which are empirically observable, as shown in Table 4 and Figure 7.

Table 4 – Possible markers for defining municipalities

m_ff	m_fronteira	m_sedeff	Possible	Marker	Quantity
0	0	0	Yes	M_{000}	544
0	0	1	No	-	
0	1	0	No	-	
0	1	1	No	-	
1	0	0	Yes	M_{100}	72
1	0	1	Yes	M_{101}	390
1	1	0	Yes	M_{110}	12
1	1	1	Yes	M_{111}	114

Source: Prepared by the author (2024).

Figure 7 – Border municipalities according to markers



Source: Prepared by the author (2024).

With the markers assigned to each municipality, we investigated three possible influential effects using classical OLS estimators:

- "Seat effect": Treatment defined by M101 ∪ M111 and control by M000.
- "Border effect": treatment and control are handled by the armed forces, but control does not border another country. Treatment defined by M110 ∪ M111 and control by M100 ∪ M101.
- "Armed Forces Effect": treatment and control do not border another country, but treatment receives the armed 'forces' and control does not. Treatment defined by M100 ∪ M101 and control by M000.

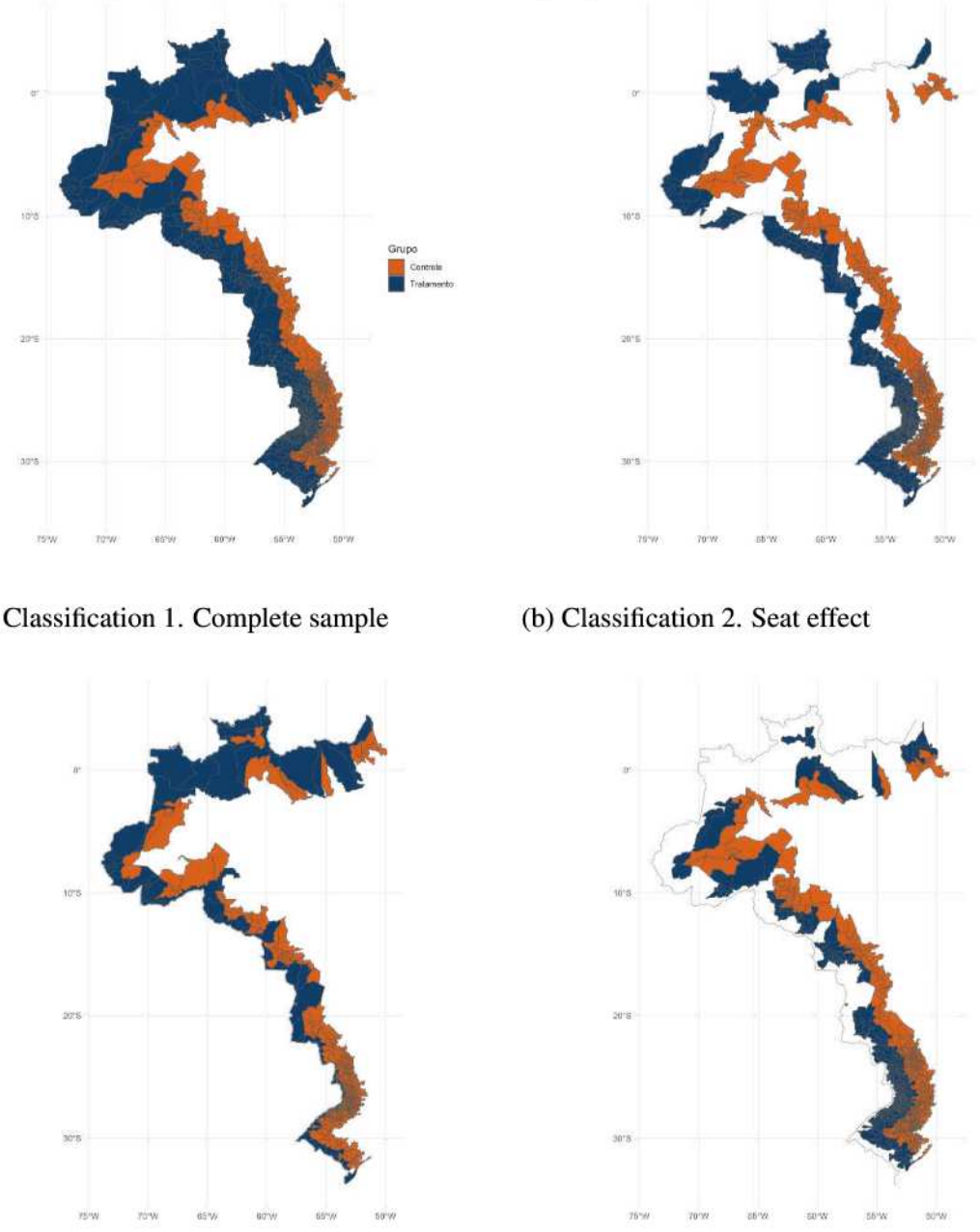
The description of the classifications is summarized in graph 4 and the maps for each attribution of effects are represented in Figure 8.

Chart 4 – Alternative classifications for treatment and control

	Classification	Description
2	Seat effect	Exclusion of municipalities that are part of the Border Strip, but whose headquarters are located more than 150 km away. Treatment defined by M101 ∪ M111 and control by M000.
3	Border effect	Treatment and control are handled by the armed forces, but control does not border another country. Treatment defined by M110 ∪ M111 and control by M100 ∪ M101.
4	Armed Forces effect	Treatment and control do not share a border with another country, but treatment receives armed "forces" and control does not. Treatment is defined by M100 ∪ M101 and control by M000.

Source: Prepared by the author (2024)

Figure 8 – Alternative classifications proposed for treatment and control



(a) Classification 1. Complete sample

(b) Classification 2. Seat effect

(c) Classification 3. Border effect

(d) Classification 4. Armed Forces effect

Source: Prrepared by the author (2024)

5.4 Database

The dependent variable is the rate of homicide per 100,000 inhabitants obtained from the IPEA Atlas of Violence (IPEA, 2023a), at the municipal level and for the period between 2010 and 2019. We also used socioeconomic covariates available at the municipal level related to employment and income. The selected socioeconomic covariates were obtained from IPEAData

(IPEA, 2023b) and are shown in table 5, for Classification 1.

Table 5 – Descriptive statistics for socio-economic variables

	Control		Treatment	
	Mean (SD)	MinMax	Mean (SD)	MinMax
Illiteracy rate	9.17 (5.26)	[1.1, 39.4]	10.48 (6.41)	[1.4, 40.2]
Unemployment rate (16 years)	4.08 (2.66)	[0.1, 19.08]	4.13 (2.96)	[0.16, 27.76]
Gini	0.48 (0.07)	[0.319, 0.7761]	0.51 (0.08)	[0.3278, 0.778]
GDP per capita	16 925.12 (13 508.80)	[3742.82, 220358.29]	15 887.95 (10 266.24)	[3129.35, 150363.03]
Pop. rate with income <1/4 sm	11.55 (11.41)	[0.33, 72.53]	16.26 (14.96)	[0.07, 77.91]
Child labor rate	17.19 (10.61)	[1.16, 62.29]	17.67 (10.88)	[2.55, 72.09]
Rate of young men	12.57 (1.46)	[8.7, 26.72]	12.50 (1.48)	[7.88, 18.12]

Source: IPEAData(2024)

The Atlas of Violence functions as a centralized database, compiling, arranging and disseminating information about violence in Brazil. In addition, it provides access to Ipea publications that address topics related to violence and public safety. The index was developed in 2016 and is currently administered by the Institute for Applied Economic Research (IPEA), in collaboration with the Brazilian Public Security Forum (FBSP). The objective of this initiative is to provide a comprehensive resource for researchers, journalists, and interested individuals seeking information on the world of crime and violence within the nation.

The Atlas of Violence is an analytical tool that utilizes data from the Ministry of Health's Mortality Information System (SIM) and population estimates from the IBGE to calculate the homicide rate per 100,000 inhabitants. The International Classification of Diseases (ICD) codes are used to compile data on homicides. For the period from 1979 to 1995, the ICD-9 codes E960-E978 and E990-E999 are used, while the ICD-10 codes X85-Y09 and Y35 are used for data collected from 1996 onward. The rate is obtained by dividing the number of homicides recorded in the victims' place of residence by the estimated population for that year and then multiplying the result by 100,000 for standardization.

The Ipeadata database is a comprehensive source of social data and indicators. Covers a wide range of topics, including per capita income levels, inequality in the income distribution of individuals and households, educational performance, health and housing conditions, labor

market integration, and the human rights situation. In instances where feasible, historical series are rendered accessible on a monthly, annual, and decennial basis, encompassing the nation, primary geographical regions, states, and metropolitan areas. These series are meticulously segmented according to rural or urban residence of households, demographic age, educational attainment levels, years of schooling, gender, and racial or ethnic characteristics of individuals. The database also includes data on municipalities and their minimum comparable areas (MCA), as well as information related to river basins and sub-basins and administrative regions, available in IPEAdata Regional. In this work, IPEAdata is the source of the list of municipal socio-economic indicators used, providing essential data for the analysis carried out.

5.5 The Spatial RDD Model

Estimation of the causal effect in the context of Spatial Regression Discontinuity Design (RDD) follows the traditional formulation of the RDD model, adapted to the two-dimensional nature of the geographical cut-off point. The model can be represented as follows:

$$Y = \alpha + \tau D + \beta X + Z'\gamma + \varepsilon \tag{5.1}$$

where Y is the homicide rate variable, D is the variable of the treatment indicator, taking the value 1 for municipalities located within the Border Strip and 0 for the others, and X represents the municipality's distance from the cut-off, or inner border, which acts as the cut-off variable of the model.The cutoff point is set at 0, thereby establishing a dichotomy between municipalities with positive values of X, which are designated as the treatment group, and those with negative values of X, which are classified as the control group. The symbol Z denotes other covariates, while the symbol represents the error term. Identification of the causal effect depends on the hypothesis that, in the absence of treatment, the function $\beta X + \gamma Z$ would be continuous at the cut-off point, thus ensuring that observed discontinuities are attributable to the presence of treatment.

This study utilizes the rdrobust package to estimate the model. This package, which was described in Calonico *et al.* (2015), implements advanced methods for RD analysis. These methods include optimized estimators for bandwidth choices and flexible trend function specifications. The package facilitates the calculation of robust estimates for various core and bandwidth options. In addition, it provides tools for assessing the validity of the RD design, including balancing tests and cutoff manipulation. The implementation of robustness ensures

greater precision in the estimation of local treatment effects, thereby minimizing potential biases arising from the arbitrary choice of model parameters.

It is hypothesized that the implementation of linear regression on the three additional classifications (or additional arrangements, see Subsection 5.3) will contribute to the enhancement of the spatial RDD that will be estimated with the spatial arrangement derived from Classification 1. Consequently, the main focus of the analysis will be the model applied to classification 1, with brief remarks provided on the results estimated with empirical evidence from the other classifications. We proceed to analyze the spatial RD applied to classification 1. As illustrated in Figure 9, the number of homicides per 100,000 inhabitants exhibits variation according to proximity to the border.

In all the years analyzed, there is a downward trend in homicides as the distance from the international border increases. Visually, there is a difference in the intercepts at the cut-off point, indicating that the treatment effect can be positive or negative, depending on the year considered.

Table 6 shows the estimates of the regression discontinuity model. Statistically significant results were observed in 2010 and 2019, indicating a decrease of 8.4 and 9.8 deaths per 100,000 inhabitants in the treatment group, respectively. On the other hand, in 2017, the treatment group showed an increase of 11.1 deaths per 100,000 inhabitants. Consequently, when evaluating the Border Strip in its entirety during the specified period, the impact of regional affiliation remains ambiguous.

Table 6 – RDD model: homicides throughout the Border Strip. Classification 1

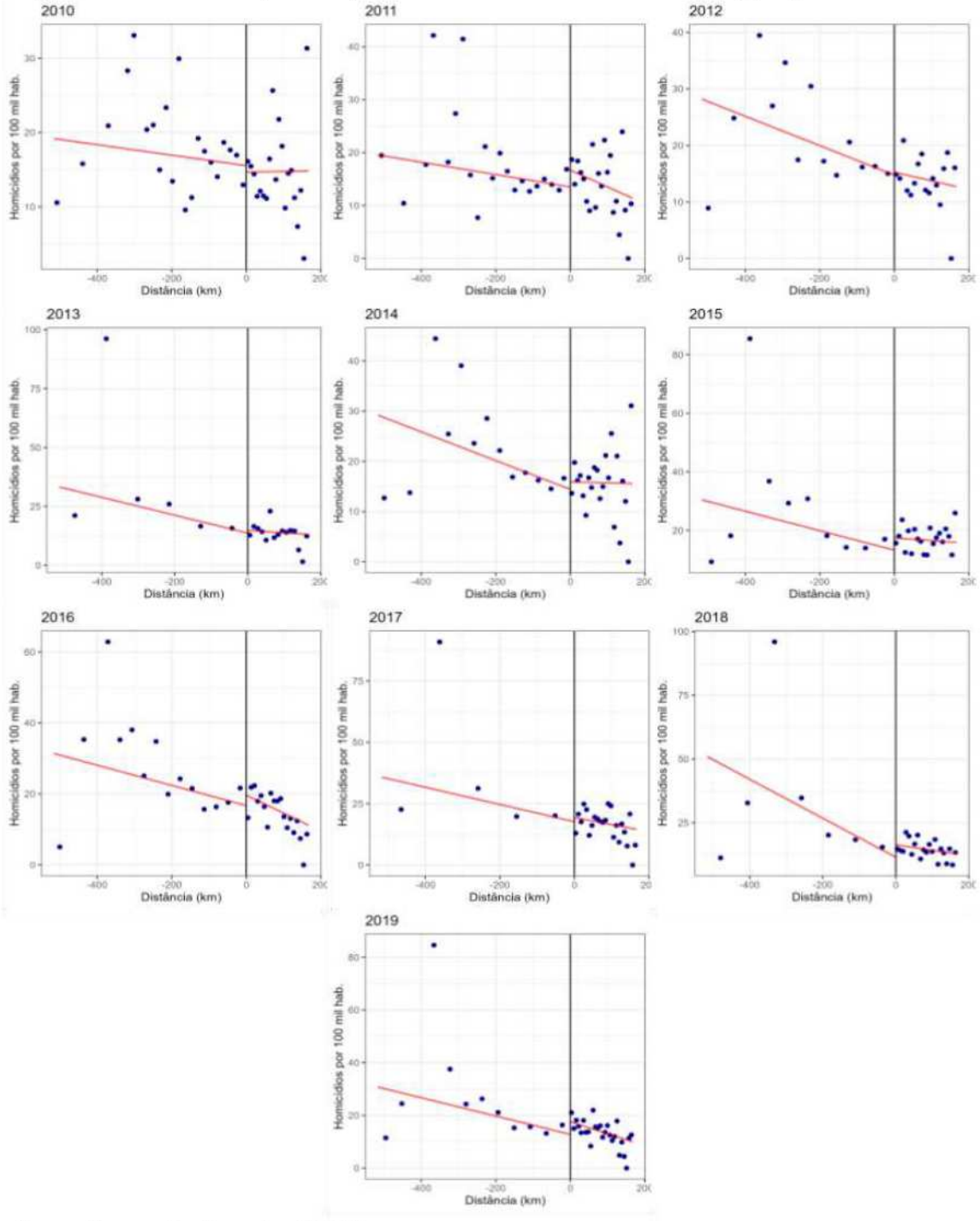
	year 2010	year 2011	year 2012	year 2013	year 2014
distance to inner border	−8.401*	1.783	−0.495	2.690	0.010
	(3.956)	(3.882)	(3.061)	(3.669)	(3.668)
	year 2015	year 2016	year 2017	year 2018	year 2019
distance to inner border	0.292	2.228	11.084*	−0.445	−9.809*
	(4.406)	(4.256)	(5.112)	(3.455)	(4.353)
N_obs_treated	417				
N_obs_control	424				

+ p <0.1, * p <0.05, ** p <0.01, *** p <0.001

Source: Prepared by the author (2024).

In light of the pronounced heterogeneity characteristic of border regions, it was determined that the estimations of the discontinuous regression be conducted for each arc of the

Figure 9 – Homicides per 100,000 inhabitants x distance to cutoff, per year



Source: Prepared by the author (2024)

border in isolation, with the objective of facilitating a more nuanced interpretation of the effects manifesting within the Border Strip. The results are displayed in Table 7

With the exception of years 2011 and 2017, distance from the cut-off demonstrated statistically significant estimators in all years within the Northern Arc of the border. The observed results, ranging from a 19 to a 53 decrease in mortality rates per 100,000 individuals within the treatment group, suggest a correlation between the municipalities belonging to the Border Strip

Table 7 – RDD model: effect of the border on homicides by arc. Classification 1.

NORTHERN ARC					
	year 2010	year 2011	year 2012	year 2013	year 2014
distance to cutoff	−22.910+	−10.000	−23.103**	−30.228*	−39.801***
	(12.400)	(8.847)	(8.223)	(13.927)	(10.569)
	year 2015	year 2016	year 2017	year 2018	year 2019
distance to cutoff	−19.071*	−45.928**	−11.731	−53.409***	−32.803***
	(8.190)	(14.205)	(13.678)	(11.517)	(7.660)
N_obs_treated	56				
N_obs_control	21				
CENTRAL ARC					
	year 2010	year 2011	year 2012	year 2013	year 2014
distance to cutoff	13.208	13.788	15.098	−16.383*	1.836
	(14.451)	(13.730)	(10.403)	(7.260)	(9.087)
	year 2015	year 2016	year 2017	year 2018	year 2019
distance to cutoff	6.534	32.823*	18.567**	13.973**	4.860
	(14.713)	(12.837)	(7.073)	(5.395)	(16.645)
N_obs_treated	65				
N_obs_control	58				
SOUTHERN ARC					
	year 2010	year 2011	year 2012	year 2013	year 2014
distance to cutoff	−5.326	0.746	1.427	4.971	1.733
	(3.599)	(4.244)	(3.962)	(4.388)	(4.558)
	year 2015	year 2016	year 2017	year 2018	year 2019
distance to cutoff	1.487	1.280	12.553+	0.614	−3.744
	(5.318)	(4.007)	(6.470)	(4.141)	(4.635)
N_obs_treated	296				
N_obs_control	336				

+ p <0.1, * p <0.05, ** p <0.01, *** p <0.001

Source: Preprared by the author (2024).

and a decline in violence within the region.

In the Central Arc, the distance to the border was statistically significant only in 2013 and from 2016 to 2018. In 2013, there was a reduction of 16.3 deaths per 100,000 inhabitants; however, increases ranging from 13.9 to 32.8 were estimated in subsequent years. The alteration in the sign of the estimator, in conjunction with the absence of statistical significance in the subsequent years, underscores the necessity for a prudent interpretation of the findings. This is particularly salient when considering the intrinsic limitations inherent in the discontinuous regression methodology.

In the Southern Arc, no statistically significant estimators were identified at the 5% level of significance ($p < 0.05$). In 2017, a statistically significant outcome was observed at the 10% level, with an estimator of 12.5, indicating an increase in the number of deaths in the treatment group. As with the Central Arc, the interpretation of these results should be approached with caution. In both Arco Central and Arco Sul, regressions were performed with modified optimal bandwidth selection, and all estimators were not significant.

A brief commentary on the findings derived from the OLS estimators of alternative classifications, whose regression tables are appended in the appendix, reveals that, in the context of the entire frontier, there is an absence of evidence indicating an effect in Classification 3. In Classifications 2 and 4, a significant effect was identified only in 2012. As was the case in the primary analysis, the model was reapplied separately for each of the arc groups.

In the Classification 2 model, which assesses the seat effect, the Central Arc exhibited statistically significant estimators in the years 2016, 2017, and 2018. This finding suggests an increase in violence in municipalities classified as the treatment group. Classification 3, which evaluates the Border effect, was the only category that did not present any significant estimators in any of the arcs analyzed. This finding suggests that in this specification there is an absence of evidence that indicates the impact of the border on violence indicators.

However, Classification 4, which measures the effect of the presence of the Armed Forces, revealed a pattern similar to that identified in the RD model for Classification 1. Specifically, in the Northern Arc, the significant estimators point to a reduction in homicides, while in the Central Arc the effect is the opposite, suggesting an increase in violence indices.

The results indicate that there are no statistically significant effects for most of the classifications and periods analyzed, except for the northern and central arcs from 2016 onward.

In the case of the Northern Arc, one possible interpretation for the reduction in homicides along the Border Strip is the presence of a robust surveillance apparatus in the region. This interpretation can be rationalized in two ways, which are not necessarily mutually exclusive: i) the existence of a "buffer" effect exerted by the armed forces on the border, which has an impact on transnational crime; or ii) the effect of displacing violent crime practices to the interior of the country, particularly to municipalities located along drug trafficking routes.

In contrast, within the Central Arc, the observed outcomes indicate a contrasting effect, suggesting that the border region exhibits elevated levels of violence compared to the municipalities comprising the control group. One potential explanation for this phenomenon is

the proximity to the state of São Paulo, which, according to the classification criteria, included some municipalities in the control condition. São Paulo's security apparatus is widely recognized for its well-organized structure and its integration with the neighboring states of Mato Grosso and Mato Grosso do Sul. This integration may have strengthened the capacity of these municipalities to curb violent actions, making them relatively safer than the border areas.

In the Southern Arc, the absence of significant estimators can be attributed to the almost total incorporation of the region's states into the Border Strip, resulting in greater homogeneity between the treatment and control groups in terms of combating violent crime.

It is important to note that the findings presented in this study are preliminary and require further study to fully understand their implications. Subsequent studies could investigate alternative specifications of the model and integrate novel data sources to enhance the robustness of the results.

6 FINAL REMARKS

The objective of this study was to analyze the relationship between the actions of the Armed Forces in the Brazilian Border Strip and violence, with a focus on the rates of homicide in municipalities within and outside this territorial delimitation. To achieve this objective, a data consolidation approach was employed, which included all recorded homicides from 2010 to 2019. This methodological framework enabled the establishment of a georeferenced data panel, thus facilitating a comprehensive analysis of the temporal progression of violence across various border segments.

A regression discontinuity design was used to investigate the variation in the homicide rate per 100,000 inhabitants in the various regions of the Border Strip, with the objective of identifying any potential discontinuities generated by this territorial classification. The study findings indicated that within the Northern Arc, the incorporation of municipalities within the Border Strip is associated with a decrease in the rate of homicide. This observation may be attributed to the increased presence of inspection and surveillance activities in the region. Conversely, in the Central Arc, we identified a contrasting effect, with the border strip exhibiting significantly higher homicide rates compared to the municipalities within the control group. In the Southern Arc, no statistically significant effects were identified, which may be attributable to the higher degree of homogeneity among the region's municipalities. This reduced the model's ability to discern substantial variations in violence.

Another salient aspect that was discussed was the influence of the presence of the Armed Forces on the dynamics of violence over time. A comparison of the effects in different periods has indicated that the presence of the Armed Forces can be associated with a reduction in crime in some regions. However, the same presence can also generate displacement of violence in neighboring areas, as suggested in the case of Northern Arc (Dias, 2024). As demonstrated in the existing literature, these effects may be associated with the magnitude and intensity of security operations, such as Operation Ágata (Figueredo, 2017), whose variations over time may have influenced the ability to deter and suppress crime in the Border Strip.

To assess the robustness of the results obtained in the primary analysis, alternative classifications were applied to the treatment and control groups. This was done to isolate different aspects of the relationship between the Border Strip and violence. Classification 2, termed the "Seat Effect," was excluded from the sample municipalities whose headquarters are more than 150 km from the border, under the hypothesis that these localities received less exposure to

treatment. The findings indicated substantial estimators for the Central Arc, thereby suggesting that the presence of the seat within or without the belt may influence the intensity of the observed effects. This finding underscores the necessity of incorporating the geographical context of municipal headquarters in public safety analyses in border regions. The distance from the border area can serve as an important factor in the implementation of security policies within these regions.

The objective of Classification 3, Border Effect, was to isolate the influence of the border condition itself. To this end, municipalities that border another country were compared with those that, despite being in the Border Strip, do not have an international border. In particular, this was the only classification that did not show significant estimators, indicating that proximity to the border alone does not serve as a determining factor for the levels of violence.

In contrast, Classification 4, Armed Forces Effect, which categorizes municipalities based on their receipt of Armed Forces action, exhibited trends analogous to the primary analysis. The findings suggest that the national security apparatus may play a more significant role in the dynamics of violence than the mere geographical proximity to an international border. This observation underscores the necessity of considering state action when assessing the impact of the border strip on crime (Andrade *et al.*, 2019).

Public security constitutes one of the three anticipated consequences of the presence of the Armed Forces in the Border Strip, alongside national defense and regional development. Although the present study concentrated on the effects on violence, it is imperative to acknowledge that military action in the region has broader strategic objectives, such as protecting national sovereignty and fostering territorial integration (Brasil, 2020). In our analysis, the repercussions of increased surveillance and the presence of the state on the local economy, infrastructure, and security of border populations were not addressed. Consequently, the results presented should be interpreted within the specified scope, without asserting a comprehensive coverage of the intricacies inherent to border policies.

The objective of this study is not to provide an exhaustive review of the literature on public security, but rather to contribute to the advancement of knowledge about the impacts of the Border Strip from a quantitative approach. There is an urgent need to expand the research on the Brazilian border in other dimensions, such as socioeconomic development, international trade, and transnational security cooperation. Furthermore, the findings of this study can be refined by improving the econometric model used. Such refinements may include the incorporation of

additional variables, more extensive robustness tests, and the application of more sophisticated spatial inference techniques. These advances will facilitate a more precise understanding of the mechanisms underlying security dynamics in the Border Strip, thereby providing more robust subsidies for the formulation of effective public policies.

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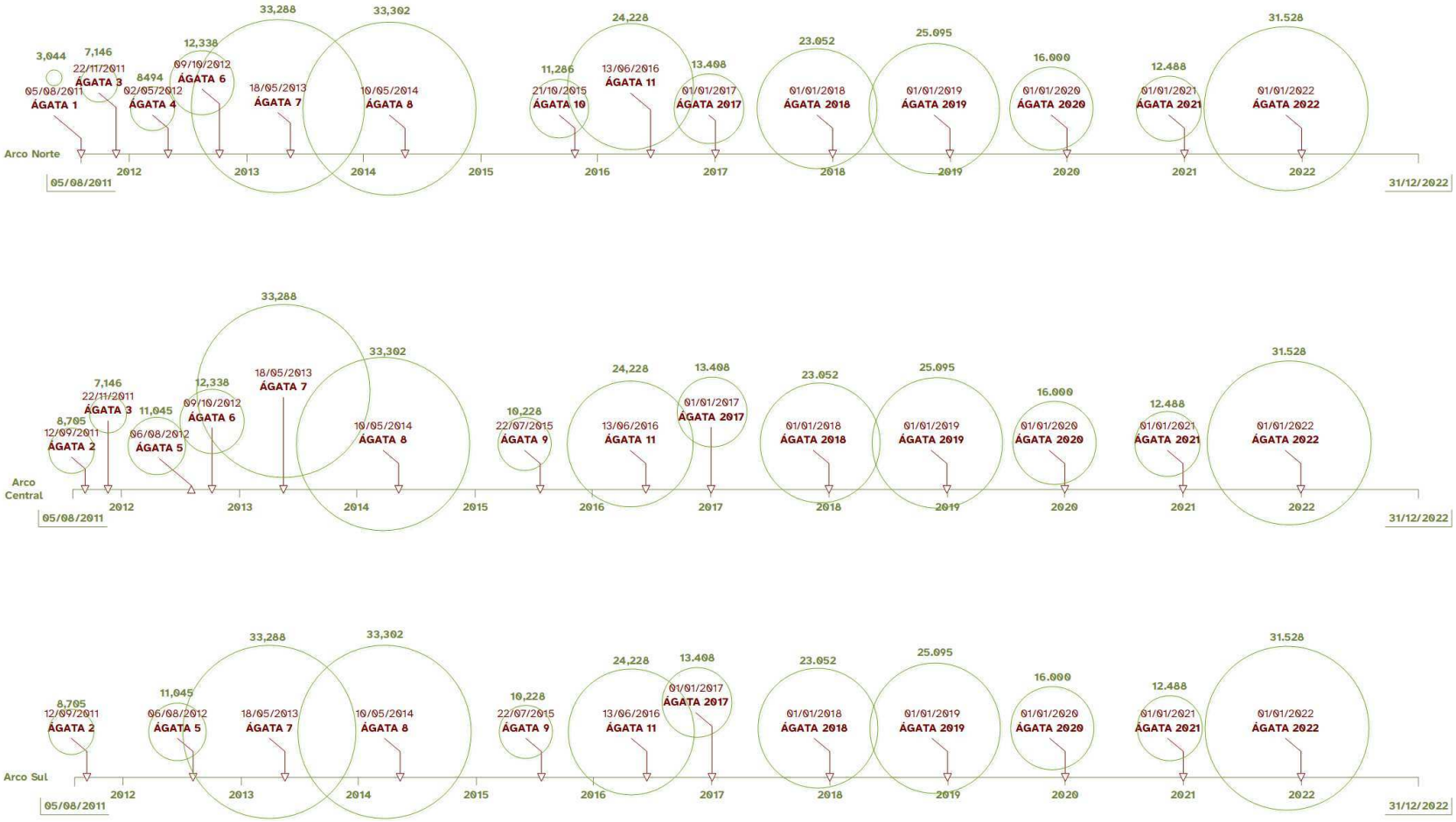
APPENDIX A – OPERATION ÁGATA TIMELINE

Figure 10 – Timeline of Operations Ágata and their respective personnel, by arc



Source: Prepared by the author (2024).

APPENDIX B – REGRESSION RESULTS FOR CLASSIFICATIONS 2, 3 AND 4

Table 8 – Linear model: treatment effects on homicides throughout the Border Strip. Classification 2

	year 2010	year 2011	year 2012	year 2013	year 2014
Treatment	2.491+	−0.043	2.716*	2.695+	1.427
	(1.441)	(1.366)	(1.332)	(1.414)	(1.419)
Num.Obs.	781	781	781	781	781
R2	0.073	0.083	0.098	0.078	0.107
	year 2015	year 2016	year 2017	year 2018	year 2019
Treatment	−0.951	2.092	2.359	3.102*	0.307
	(1.469)	(1.488)	(1.693)	(1.543)	(1.483)
Num.Obs.	781	781	781	781	781
R2	0.084	0.110	0.086	0.130	0.070

+ p <0.1, * p <0.05, ** p <0.01, *** p <0.001

Source: Prepared by the author (2024).

Table 9 – Linear model: treatment effects on homicides throughout the Border Strip. Classification 3

	year 2010	year 2011	year 2012	year 2013	year 2014
Treatment	−2.971	−0.255	−1.778	−0.073	1.144
	(2.377)	(2.148)	(2.351)	(2.497)	(2.558)
Num.Obs.	407	407	407	407	407
R2	0.134	0.139	0.101	0.110	0.082
	year 2015	year 2016	year 2017	year 2018	year 2019
Treatment	3.962	−2.304	0.856	4.260	0.026
	(2.445)	(2.743)	(3.126)	(2.980)	(2.805)
Num.Obs.	407	407	407	407	407
R2	0.125	0.145	0.143	0.151	0.069

+ p <0.1, * p <0.05, ** p <0.01, *** p <0.001

Source: elaborado pelo autor (2024).

Table 10 – Linear model: treatment effects on homicides throughout the Border Strip. Classification 4

	year 2010	year 2011	year 2012	year 2013	year 2014
Treatment	2.449+	0.527	3.321*	2.491+	1.093
	(1.449)	(1.369)	(1.331)	(1.361)	(1.388)
Num.Obs.	743	743	743	743	743
R2	0.074	0.089	0.110	0.078	0.103
	year 2015	year 2016	year 2017	year 2018	year 2019
Treatment	−1.313	2.039	2.673	1.455	−0.284
	(1.445)	(1.462)	(1.630)	(1.366)	(1.418)
Num.Obs.	743	743	743	743	743
R2	0.078	0.119	0.060	0.100	0.060

+ p <0.1, * p <0.05, ** p <0.01, *** p <0.001

Source: Prepared by the author (2024).

Table 11 – Linear model: treatment effect in Classification 2 (seat effect)

NORTHERN ARC					
	year 2010	year 2011	year 2012	year 2013	year 2014
Treatment	1.130	−1.572	7.503	7.598	−1.418
	(5.004)	(5.607)	(6.943)	(10.914)	(9.452)
Num.Obs.	55	55	55	55	55
R2	0.305	0.225	0.206	0.282	0.274
	year 2015	year 2016	year 2017	year 2018	year 2019
Treatment	−4.925	−0.125	14.095	7.104	−14.471
	(8.383)	(8.699)	(13.698)	(14.677)	(9.219)
Num.Obs.	55	55	55	55	55
R2	0.353	0.240	0.254	0.277	0.194
CENTRAL ARC					
	year 2010	year 2011	year 2012	year 2013	year 2014
Treatment	6.048	3.858	2.111	7.597	3.719
	(6.130)	(5.852)	(4.929)	(5.145)	(5.982)
Num.Obs.	119	119	119	119	119
R2	0.149	0.139	0.116	0.090	0.161
	year 2015	year 2016	year 2017	year 2018	year 2019
Treatment	0.996	13.441*	16.112**	16.564**	8.255
	(6.136)	(5.443)	(5.147)	(5.257)	(5.497)
Num.Obs.	119	119	119	119	119
R2	0.134	0.175	0.208	0.195	0.093
SOUTHERN ARC					
	year 2010	year 2011	year 2012	year 2013	year 2014
Treatment	2.744	−2.990	−0.918	0.584	0.191
	(2.190)	(2.036)	(2.044)	(2.090)	(2.077)
Num.Obs.	607	607	607	607	607
R2	0.045	0.079	0.094	0.036	0.036
	year 2015	year 2016	year 2017	year 2018	year 2019
Treatment	−1.961	−0.523	−1.348	−1.308	−0.765
	(2.183)	(2.264)	(2.541)	(2.170)	(2.259)
Num.Obs.	607	607	607	607	607
R2	0.028	0.057	0.023	0.029	0.017

+ p <0.1, * p <0.05, ** p <0.01, *** p <0.001

Source: Prepared by the author (2024).

Table 12 – Linear model: treatment effect in Classification 3 (border effect)

NORTHERN ARC					
	year 2010	year 2011	year 2012	year 2013	year 2014
Treatment	3.712	4.805	5.218	12.063	6.061
	(4.055)	(3.841)	(5.981)	(9.022)	(7.340)
Num.Obs.	48	48	48	48	48
R2	0.300	0.350	0.168	0.353	0.347
	year 2015	year 2016	year 2017	year 2018	year 2019
Treatment	11.761+	4.750	8.581	10.636	4.188
	(6.604)	(7.859)	(10.942)	(12.177)	(7.007)
Num.Obs.	48	48	48	48	48
R2	0.470	0.259	0.373	0.353	0.266
CENTRAL ARC					
	year 2010	year 2011	year 2012	year 2013	year 2014
Treatment	−4.286	2.996	−8.278	−5.081	−0.489
	(7.345)	(6.748)	(6.216)	(5.765)	(7.049)
Num.Obs.	63	63	63	63	63
R2	0.090	0.082	0.150	0.292	0.130
	year 2015	year 2016	year 2017	year 2018	year 2019
Treatment	3.071	−12.870+	4.367	8.138	−6.351
	(6.422)	(7.519)	(7.425)	(6.277)	(6.825)
Num.Obs.	63	63	63	63	63
R2	0.189	0.212	0.175	0.245	0.089
SOUTHERN ARC					
	year 2010	year 2011	year 2012	year 2013	year 2014
Treatment	−6.492+	−1.743	−3.519	−2.086	−0.500
	(3.304)	(2.920)	(3.236)	(3.163)	(3.388)
Num.Obs.	296	296	296	296	296
R2	0.053	0.100	0.070	0.023	0.028
	year 2015	year 2016	year 2017	year 2018	year 2019
Treatment	3.396	0.440	−1.809	1.393	0.897
	(3.267)	(3.664)	(4.110)	(3.669)	(3.946)
Num.Obs.	296	296	296	296	296
R2	0.041	0.049	0.021	0.040	0.018

+ p <0.1, * p <0.05, ** p <0.01, *** p <0.001

Source: Prepared by the author (2024).

Table 13 – Linear model: treatment effect in Classification 4 (armed forces effect)

NORTHERN ARC					
	year 2010	year 2011	year 2012	year 2013	year 2014
Treatment	−5.488	−7.833	1.136	−4.630	−12.126+
	(4.659)	(4.640)	(5.130)	(5.514)	(6.473)
Num.Obs.	45	45	45	45	45
R2	0.361	0.460	0.282	0.315	0.326
	year 2015	year 2016	year 2017	year 2018	year 2019
Treatment	−13.994*	−15.387*	0.118	−3.700	−14.010*
	(5.152)	(6.994)	(8.064)	(8.230)	(6.345)
Num.Obs.	45	45	45	45	45
R2	0.523	0.366	0.270	0.407	0.330
CENTRAL ARC					
	year 2010	year 2011	year 2012	year 2013	year 2014
Treatment	12.319*	5.546	8.004+	10.634*	11.239+
	(6.007)	(5.637)	(4.810)	(4.928)	(5.936)
Num.Obs.	111	111	111	111	111
R2	0.178	0.133	0.185	0.189	0.198
	year 2015	year 2016	year 2017	year 2018	year 2019
Treatment	6.195	18.730***	19.977***	14.869**	11.855*
	(5.934)	(5.299)	(4.874)	(4.671)	(5.375)
Num.Obs.	111	111	111	111	111
R2	0.179	0.261	0.260	0.198	0.116
SOUTHERN ARC					
	year 2010	year 2011	year 2012	year 2013	year 2014
Treatment	1.008	−1.970	−1.864	−0.065	−0.095
	(2.148)	(2.005)	(2.007)	(2.056)	(2.000)
Num.Obs.	587	587	587	587	587
R2	0.036	0.087	0.093	0.040	0.030
	year 2015	year 2016	year 2017	year 2018	year 2019
Treatment	−1.427	−1.015	−0.202	−1.648	−2.133
	(2.121)	(2.165)	(2.503)	(2.013)	(2.109)
Num.Obs.	587	587	587	587	587
R2	0.036	0.060	0.021	0.025	0.021

+ p <0.1, * p <0.05, ** p <0.01, *** p <0.001

Source: Prepared by the author (2024).