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Does a Federal Penitentiary impact crime? Evidence from Catanduvas, Brazil

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ABSTRACT
The investment in prison infrastructure is a policy to fight crime. On the other hand, if it influences in the spatial displacement of crime, the construction of a penitentiary may generate negative localized effects. Dispite this, there are few studies evaluating the potential localized effects arising from the establishment of new maximum-security prisons. We use a 24-year longitudinal data on sinthetic control models to estimate the impacts of the construction of the Catanduvas Maximum-Security Penitentiary on homicide rates in its microregion. Furthermore, we combine the observation of spatial spillover effects with the synthetic control methodology to achieve better fit between the pretreatment control and the synthetic unit. Our findings suggest a transient and isolated increase in local homicidies, which support that the prison did not act as a catalyst for long-term local violence.

KEYWORDS
Synthetic control; Spatial analysis; Penitentiaries

Uma penitenciária federal impacta o crime? Evidências de Catanduvas, Brasil

RESUMO
O investimento em infraestrutura prisional é uma política de combate ao crime. Por outro lado, se ele influenciar o deslocamento espacial da criminalidade, a construção de um estabelecimento penitenciário pode gerar efeitos localizados negativos. Apesar disso, há poucos estudos que avaliem os potenciais efeitos locais decorrentes da instalação de novas prisões de segurança máxima. Utilizamos dados longitudinais de 24 anos e modelos de controle sintético para estimar os impactos da construção da Penitenciária Federal de Segurança Máxima de Catanduvas sobre as taxas de homicídio em sua microrregião. Além disso, combinamos a observação de efeitos de transbordamento espacial com a metodologia de controle sintético, a fim de obter um melhor ajuste entre o grupo de controle no período pré-tratamento e a unidade sintética. Nossos resultados sugerem um aumento transitório e isolado dos homicídios locais, o que sustenta a conclusão de que a prisão não atuou como catalisadora de violência local de longo prazo.

PALAVRAS-CHAVE
Controle sintético, Análise espacial, Penitenciárias

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1. Introduction

The decision to build a prison in a specific locality involves various possible consequences, including increased perceptions of insecurity, crime rates, and uncertain economic benefits (Fonsêca, 2018; King et al., 2004; Netto e Chagas, 2019). Nevertheless, smaller municipalities may view prison construction as attractive due to incentives offered by public authorities (Abrams e Lyons, 1987). Although there is substantial literature on the impacts of incarceration on crime at both the individual and community levels where former inmates return (Spelman, 2020; Clear, 2008; Morenoff e Harding, 2014; Dhondt, 2018; Kirk e Wakefield, 2018), the broader implications of prison construction for local crime rates remain underexplored.

Using the construction of the Catanduvas Maximum Security Penitentiary (PSMC), this paper investigates the impact of building a prison on local crime by accounting for spatial displacement of criminal activity. PSMC was intended to house high-risk offenders- in Catanduvas, a municipality in southern Brazil, in 2006. Although the PSMC follows a standard maximum-security prison model (King et al., 2004; Abrams e Lyons, 1987), its location in a region of Paraná marked by significant challenges in combating organized crime—due to its complex geography, including multiple rivers and its position at the tri-border area of Brazil, Argentina, and Paraguay—warrants an exploration of potential unintended effects. Moreover, although certain terms of an agreement with the federal government -such as the construction of housing for prison staff to encourage their retention and the purchase of the materials used in the construction coming only from the city of Catanduvas- were not met (Santin, 2009).

We conduct a geographic analysis at the micro-region level to assess the PSMC's impact not only on Catanduvas but also on surrounding municipalities. Previous studies show that crime is not randomly distributed across space (Almeida et al., 2005; Santos e Santos Filho, 2011; Santos e Kassouf, 2012). For instance, Almeida et al. (2005) demonstrates that certain areas in Minas Gerais act as focal points for criminal activity, reflecting spatial dependence in crime dynamics. Vulnerable communities with high incarceration flows—typically composed of young, low-educated Black men—are often concentrated in impoverished peripheral neighborhoods (Clear, 2008). Moreover, although studies like Fonsêca (2018) have assessed the relationship between penitentiaries and criminality in Brazil, it largely overlooks spillover effects and analyzes the effect of all penitentiaries collectively, without considering that they may differ in their outcomes due to regional specificities. To the best of our knowledge, only the study of (Da Rocha Filho, 2022) analyzed the effect of the construction of federal prisons in Brazil, by using a t-test for equality of means. The present paper addresses these gaps in the economics of crime literature by using the synthetic control method to produce more robust estimates for causal inference, as well as accounting for spatial spillovers effects.

Overall, it is noted that the topic is underdeveloped in the Brazilian context, with

the empirical exercise developed throughout this article serving not only as an attempt to explain the phenomenon, but also to introduce the debate on the location of prisons in the national literature.

Two key issues guided the choice of the synthetic control methodology: the limited number of treated units and the non-random nature of treatment selection. While both of these challenges could undermine conventional impact evaluations (Angrist e Pischke, 2009), they do not prevent synthetic control model from providing a unbiased evaluation of the hypothesis under analysis (Abadie, 2021). Moreover, conventional econometric analyzes, such as panel data methodologies or a traditional event study, may face difficulties in isolating the effect given the methodological limitations in contexts where the treatment is not random and there is only one treated unit. It is also worth noting that, with the synthetic control method, it is possible to visualize the effect year by year, within a policy context that may generate transitory or long-lasting effects.

The synthetic control method, deemed appropriate for the aforementioned reasons, requires long time series for its efficient implementation (Abadie e Gardeazabal, 2003; Abadie, 2021). Thus, the dependent variable employed had to meet this requirement. Consequently, the study was limited to analyzing crime through the lens of homicides, which offer sufficient temporal coverage through the Mortality Information System (SIM, in Portuguese) SIM (2022). Other variables related to organized crime, such as vehicle thefts and robberies or drug seizures, do not provide sufficient temporal coverage to generate an efficient synthetic control model.

To evaluate the effects of this localized intervention—assigned to a single treated unit—we employ the synthetic control method. Although the PSMC was built in Catanduvas, a small municipality of 10,000 residents, its proximity to larger cities such as Cascavel (population 332,000) presents identification challenges due to potential spatial displacement of crime. Therefore, our analysis assumes minimal spatial barriers to such displacement within the micro-region level.

Our findings indicate a temporary increase in homicides in the Cascavel micro-region following the PSMC's implementation. Robustness checks support the validity of the synthetic control estimates. We also incorporate a spatially lagged variable, following an approach established in the literature (Castro e Almeida, 2023). However, we do not attribute the brief rise in crime directly to the intervention, given the time lag between the prison's construction and the observed temporary increase in violence. This study contributes to the limited Brazilian literature evaluating the effects of prison implementation and offers insights into the broader implications of adopting the U.S.-style maximum-security prison model, informing debates on future policies.

This article is structured as follows. Section 2 presents a review of the literature. The regional context of the intervention is discussed in Section 3. Subsection 4.1 outlines the identification strategy employed, Subsection 4.2 describes the data used

and their sources, and Section 5 details the study findings. Finally, the conclusions are presented in Section 6.

2. Literature

Traditionally, incarceration is seen as a means of reducing crime through three main mechanisms: incapacitation, deterrence, and rehabilitation (Morenoff e Harding, 2014; Dhondt, 2018; Kirk e Wakefield, 2018). Incapacitation prevents offenders from committing further crimes while imprisoned, with its effectiveness increasing when individuals with high criminal propensity are removed from society. However, this effect diminishes as incarceration rates rise (Spelman, 2020). Moreover, the presence of criminal organizations within prisons and substitution effects—especially in drug trafficking—can further weaken the impact of incapacitation on reducing crimes (Morenoff e Harding, 2014; Dhondt, 2018).

Deterrence operates by discouraging potential offenders through the threat of imprisonment, and depends on the sentence length and on the imprisonment conditions, including the distance from home. Bedard e Helland (2004) suggest that increasing the average distance to a women's prison expands the deterrence effect and reduces the female violent crime. Improvement of prison quality of newer, less crowded, and higher service prisons reduced recidivism in (Tobón, 2022).

Rehabilitation, in turn, focuses on reintegrating former inmates and reducing recidivism. Additionally, the removal of "problematic" individuals may, in some cases, foster greater social cohesion and strengthen informal social control within affected communities (Morenoff e Harding, 2014).

Conversely, population turnover driven by prison admissions and releases undermines multiple forms of social control. It weakens private control (exercised through family and close relationships), parochial control (by eroding ties with institutions such as schools, churches, and businesses), and public control (by diminishing a community's capacity to attract external resources and public goods). This erosion is linked to reduced civic and institutional engagement (Clear, 2008; Morenoff e Harding, 2014; Kirk e Wakefield, 2018)[1].

Incarceration also imposes severe burdens on families. It negatively affects children's academic performance, future employment, and increases their likelihood of criminal involvement. It contributes to family dissolution, often resulting in single-mother households. Additionally, a reduced pool of potential partners can lead to early pregnancies or pressure women to remain in unhealthy relationships (Clear, 2008). Economically, incarceration confines former inmates to unstable, low-paying jobs, weakening the economic vitality of communities with high concentrations of ex-offenders. It can also trigger labor market discrimination against residents of these

[1]High incarceration rates can lead communities to perceive law enforcement and the justice system as unjust, decreasing voter turnout and reducing their influence on public policy (Clear, 2008).

areas, regardless of their criminal background (Clear, 2008).

In summary, this cycle of population displacement—termed "coercive mobility" by Rose e Clear (1998, apud (Clear, 2008)) intensifies community vulnerability and increases recidivism among former inmates (Morenoff e Harding, 2014), creating a vicious cycle. Importantly, many do not return to their original communities due to unstable family housing during incarceration, often settling near the site of their imprisonment (Morenoff e Harding, 2014).

The hypothesis that the PSMC may have contributed to rising crime in the Catanduvas region is partly informed by literature on crime in Brazil. Prisons are often used or controlled by criminal organizations, which may exploit their influence within the prison system to expand organized crime in surrounding areas (Netto e Chagas, 2019; Manso e Dias, 2017). Given that the PSMC was built to house high-risk offenders and gang members, its construction could have displaced criminal activity to neighboring municipalities (Fonsêca, 2018).

Drug trafficking and disputes between rival factions are key drivers of Brazil's high homicide rates (Cerqueira, 2014). Understanding the role of organized criminal groups is essential to grasping the dynamics of violence in the country. Historically, factions such as the PCC (Primeiro Comando da Capital in portuguese) have emerged within the prison system as mechanisms for coordinating criminal activities and controlling the drug trade. Combining the insights of Cerqueira Cerqueira (2014) and Manso e Dias (2017), prisons may act as entry points for criminal factions into new regions, where ensuing territorial disputes can intensify local homicide rates.

In Becker (1968), crime is modeled as a function of the offender's expected utility. The offender is viewed as a rational agent who weighs the potential gains from committing a crime against the likelihood of apprehension and the severity of punishment. Crime rates are thus expected to rise with higher anticipated returns and fall with greater expected penalties.

Thus, criminal reasoning could be modeled using Equation 1:

$$(1 - pr) \times U(l_i - c_i - m_i) - pr \times U(pu) > U(w_i) \tag{1}$$

where pr represents the probability of capture and conviction, pu is the monetary value assigned to the punishment, li is the return of crime, ci denotes the costs of planning and executing the criminal act, mi is the moral cost, and wi represents the income from legal work. Thus, the potential criminal considers the probability of punishment (pr) and its cost, which includes lost wages during prison time, as well as potential stigmatization that may reduce their remuneration in the legal labor market (pu). In other words, an increased probability of punishment tends to dissuade criminal behavior (Jorge, 2011).

Akerlof (1991) introduces criminal hysteresis, where past crimes—through threats like blackmail or punishment—trap individuals in ongoing criminal behavior. Exiting may be difficult due to serious offenses or sensitive knowledge. Additionally, criminal involvement can foster a sense of belonging, particularly among youth, who are often driven by a desire to maintain social status. This contributes to their reluctance to leave crime, even when they could be benefited, reinforcing hysteresis in a group already prone to risk-taking and deviance.

Incarceration tends to hinder the individual reintegration into the labor market, often resulting in reduced earnings and more likelihood to unemployment, which in turn lowers both the opportunity costs (w_i) and the deterrent effect of potential sanctions for former prisoners (pu). Thus, the cost of a criminal act for an ex-convict would be lower than the cost faced by an individual without a prior history of the penitentiary system, potentially making recidivism a rational action, creating a vicious cycle (Jorge, 2011).

In Paraná, Borilli e Shikida (2006) examined the motivations of inmates convicted of economic crimes. Interviewees commonly cited low education levels and the inability to achieve financial stability through legal means. Few had committed crimes while holding formal employment, suggesting that job stability may act as a deterrent. Additionally, a lack of confidence in law enforcement's ability to prevent crime, as theorized by Becker (1968). Leite (2016) presents a comparative analysis of violence in Medellín and Cascavel, highlighting the role of youth-focused public policies in reducing violence. In Cascavel, programs promoting education, culture, and sports mirrored Medellín's successful strategies and may explain the decline in homicides during the 2010s.

Santos e Santos Filho (2011) note a pattern of criminal migration driven by opportunity—toward areas with more potential victims (higher income) or weaker policing. As Spelman (2020) suggests, increased incarceration in one region may reduce crime in another by incapacitating mobile offenders. Understanding criminal mobility is therefore essential for studies on localized violence, particularly those using spatially lagged variables.

The decision to build a prison involves complex trade-offs, such as reduced property values, damage to a city's reputation, and the influx of inmates' families (Shichor, 1992; Armstrong, 2014; Martin e Myers, 2005). Prisons are often considered inferior public goods due to the social costs they impose on host communities (Cherry e Kunce, 2001). Less developed municipalities are more likely to be selected for prison construction, as they face limited development alternatives and view prisons as potential sources of economic activity. (Cherry e Kunce, 2001).

However, the benefits of hosting a prison remain uncertain. The literature highlights a lack of connection between government promises and actual outcomes—many prison jobs are filled by workers who commtute from other cities, offering limited eco-

nomic gains for local residents (King et al., 2004). Prisons bring substantial and persistent gains in public employment, but generate little spillover effects on private sector jobs and fail to boost local economic activity (Chirakijja, 2024), especially in rural areas that present low educational attainment rates (Hooks et al., 2010).

Proximity to medium or large urban centers is another key factor influencing prison siting decisions (Eason, 2010). The construction of the PSMC followed this pattern, given its proximity to Cascavel, a regional hub with over 300,000 residents (IPARDES).[2] According to Santin (2009), Cascavel's infrastructure supported the prison's development and housed much of its staff. As a result, some of the outcomes identified by King et al. (2004), such as lower-than-expected local benefits, may also apply to Catanduvas.

Da Rocha Filho (2022) examined the effects of the installation of federal prisons in four Brazilian municipalities, Campo Grande-MS, Catanduvas-PR, Mossoró-RN, and Porto Velho-RO – on three types of crimes: firearm-related homicides, firearm-related deaths, and violent deaths from undetermined causes. He used a Student's t-test for equality of means, comparing the five years before and after the construction of the prisons and found statistically significant differences for firearm-related deaths in Catanduvas (between 2007 and 2011), and homicides and firearm-related deaths in Mossoró (between 2010 and 2014). Despite its pionerism on investigating the influence of a new prision on criminality rates in Brazil, his identification strategy has ommited variable bias, which limits the reliability of his findings.

Ando (2015) used synthetic control methods to evaluate the impact of nuclear plant construction in Japanese municipalities. The findings varied across locations, reflecting the heterogeneity of the municipalities and reinforcing the suitability of this methodology for non-randomly assigned treatments. Similarly, Freire (2018) applied synthetic controls to analyze the decline in crime rates in São Paulo, attributing the reduction to public security initiatives such as increased police presence, community centers, and violence prevention programs. Lastly, Catolico et al. (2021) also employed synthetic controls to assess the impact of a hydroelectric plant on a municipality, highlighting the importance of complementary policies to enhance benefits and address challenges. Lastly, Ceccato et al. (2024) applied synthetic control approach to analyze the impact of a set of safety interventions aimed at reducing crime in a small Swedish municipality. Their findings underscore how heterogeneous environments can produce varied outcomes.

3. The PSMC and the study region

The Catanduvas Federal Penitentiary was inaugurated in June 2006 with a capacity for 208 male convicted inmates. In December 2007, it housed 109 detainees. At the end of 2019, the last year of the period analyzed in this study, the prison held 141

[2] Instituto Paranaense de Desenvolvimento Econômico e Social.

inmates, 74 sentenced and 67 in pretrial detention.

It is a maximum-security prison, designed for individuals with high criminal potential. This is reflected in the length of their sentences: 64 (55% of the inmates for whom information was available) were sentenced to 30 years or more in prison (five over 100 years).

The inmates were charged with 581 different types of crimes, 59 (10.2%) for homicide and 96 (16.5%) for robbery. Those convicted of forming a gang were 26 (4.5%) and for links to drug trafficking, 112 (21.0%), which indicates association with criminal factions that practice this activity (data from the 16th Cycle of Penitentiary Information Survey prepared by the National Secretariat for Penal Policies (SENAPPEN), na agency of to the Brazilian Ministry of Justice and Public Security).

Catanduvas is a municipality in western Paraná with a population of 10,446 (IBGE, 2022). Catanduvas is part of the metropolitan region of Cascavel, located near the Triple Frontier—Brazil's borders with Argentina and Paraguay (see Figure 1).

This study uses microregions as the unit of analysis, rather than municipalities, to avoid potentially misleading results. Small or underdeveloped municipalities may offer limited opportunities for criminal activity, making them unlikely targets for crime displacement (Almeida et al., 2005; Freire, 2018). In contrast, nearby urban centers with greater accessibility may attract such spillovers. Microregional analysis also accounts for Brazil's economic inequality in urban agglomerations, where marginalized populations often reside in satellite cities rather than central ones. In these contexts, the effects of an intervention may be more pronounced in peripheral areas. Furthermore, crimes like homicides are not always recorded at the location where they occurred, as victims' bodies may be relocated to hinder investigations. Using microregions helps to incorporate such complexities into the analysis.

Although Catanduvas is a small municipality, its location—just 192 kilometers from the Paraguayan border—makes it potentially vulnerable to the spatial displacement of criminal groups involved in drug trafficking and smuggling. Additionally, it is situated near larger urban centers: Cascavel, with 348,051 residents (IBGE, 2022), is 57 kilometers away, and Toledo, with 150,470 residents (IBGE, 2022), is 98 kilometers away. This proximity provides physical access to consumer markets, which can facilitate the entrenchment of criminal organizations within the Cascavel metropolitan area—an important corridor connecting the Triple Frontier (including Ciudad del Este and Foz do Iguaçu) to Paraná's major cities, such as Curitiba, Maringá, and Londrina. Figure 1 also highlights key geographic features of the region, including extensive river systems and forested areas, which may hinder law enforcement efforts to combat trafficking and smuggling (Santos e Santos Filho, 2011).

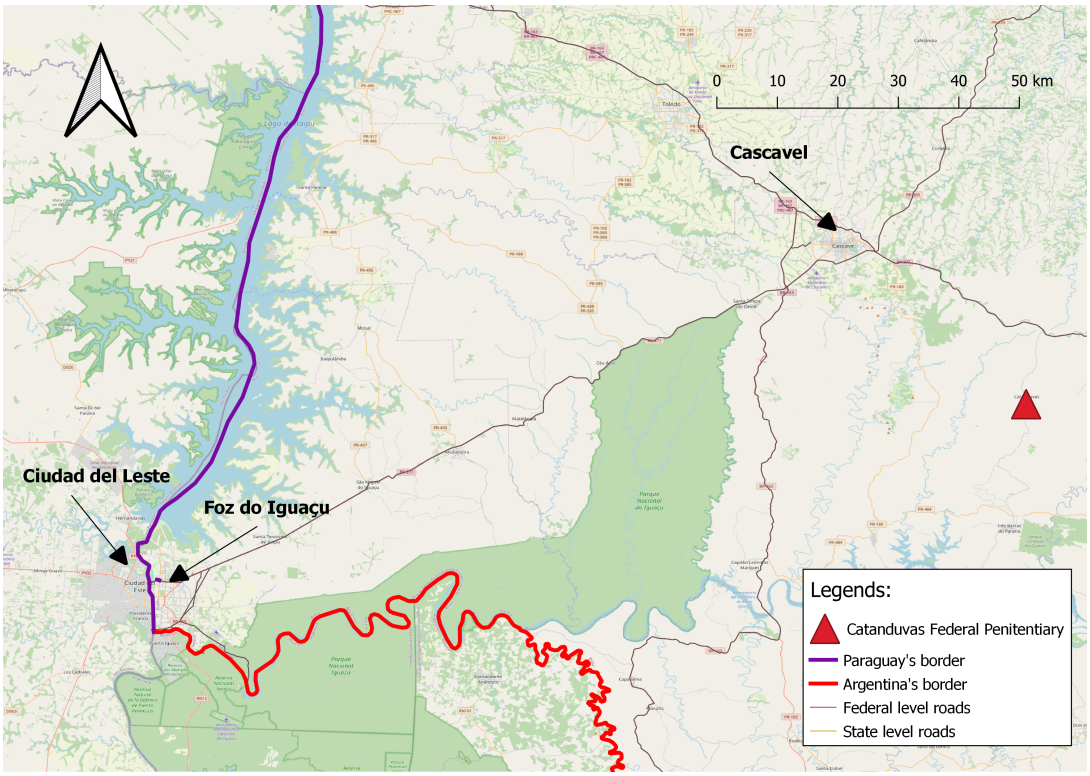
The location of the Cascavel Metropolitan Region played a key role in its urban consolidation, marked by significant migration flows and a population boom beginning in the second half of the 20th century (Mariano, 2022). This rapid growth led to an

urban configuration characterized by stark socioeconomic inequalities. In particular, the peripheral areas of Cascavel experienced limited infrastructure and high poverty rates—factors correlated with rising crime in the region (Ramão e Wadi, 2010).

This regional dimension of violence in Cascavel is also evident in the findings of Santos e Santos Filho (2011) regarding crime and spatial dependence in Brazil. Given this context, the construction of the Catanduvas Federal Penitentiary (PSMC) in such a sensitive area warrants a closer examination of its potential impact on local violence.

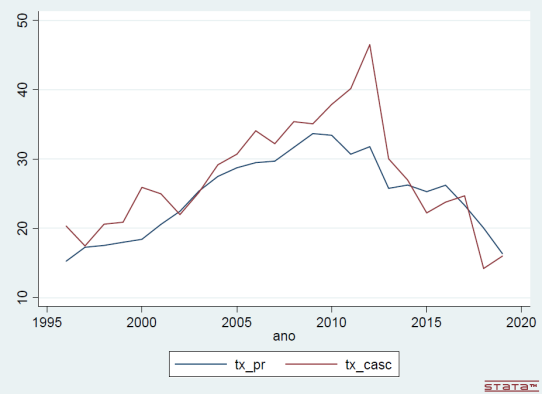
Figure 2a shows that between 1995 and 2010, the homicide rate in the Cascavel microregion remained slightly above or aligned with the state average for Paraná. However, a divergence occurred starting in 2009, with Cascavel's homicide rate peaking at approximately 47 homicides per 100,000 inhabitants in 2013. In contrast, Figure 2b reveals a different pattern for the Foz do Iguaçu microregion, which historically exhibited much higher homicide rates than the state average, reaching a peak of around 79 homicides per 100,000 inhabitants in 2006. Notably, Foz do Iguaçu experienced a sharp decline in homicides after 2006, which may reflect either more effective crime control measures or a spatial displacement of criminal activity. The contrasting trends in homicide rates between Cascavel and Foz do Iguaçu are particularly striking, as the rise in one coincides with the decline in the other. Given the geographic proximity of the two regions, this pattern may be explained by the spatial displacement of crime.

Figure 1. Intervention area

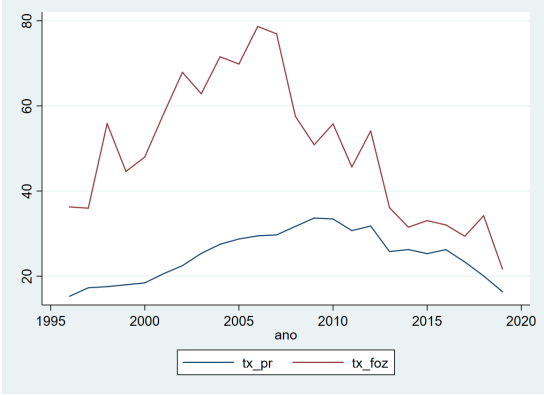


Source: own elaboration, using OpenStreetMap data.

Figure 2. Micro-region homicide rate



(a) Homicide rate per 100.000 inhabitant in Paraná and Cascavel micro-region.



(b) Homicide rate per 100.000 inhabitant in de Foz do Iguaçu micro-region.

Source: Own elaboration, from DATASUS.

As previously noted, the Catanduvas Federal Penitentiary (PSMC) was built in 2006 and began receiving inmates later that same year. This study examines the hypothesis that the prison's construction may have influenced subsequent homicide rates in the region. It is also important to note that the municipality of Cascavel implemented crime reduction initiatives in response to rising violence (Leite, 2016)), further underscoring the need to investigate the sources of this increase. Based on the evidence discussed, this study proposes that proximity to the PSMC may have become strategically advantageous for criminal groups seeking to coordinate, sustain, and expand their activities in the region.

4. Empirical strategy and data

This section outlines the variables used in the analysis and the theoretical rationale behind their selection. It then presents the strategy employed to establish a causal relationship between these variables. Finally, it addresses potential challenges in defining the treated municipalities, particularly in light of possible spatial displacement of crime.

4.1 Empirical strategy

The PSMC stands out as a tailored project compared to other prisons. It was designed to provide the state with a facility to isolate individuals considered highly dangerous. Additionally, authorities chose to house influential gang leaders from other states to prevent them from leveraging their local influence to obtain privileges or exert control. Given the distinct nature of this project and the non-random selection of Catanduvas—chosen for its specific characteristics (Santin, 2009; King et al., 2004), the synthetic control method is particularly appropriate.

The synthetic control method enables impact evaluation in cases with few treated

units. Its core assumption is that a weighted combination of untreated, comparable regions can replicate the trajectory the treated unit would have followed in the absence of the intervention (Abadie e Gardeazabal, 2003). The estimation strategy is described as follows:

$$\alpha_{it} = Y_{it}^{I} - Y_{it}^{N} \tag{2}$$

Where Y_{it}^{I} represents the observed outcome for the treated unit i and year t, Y_{it}^{N} denotes the counterfactual outcome that would have been observed in Y_{it}^{I} in the absence of treatment. In this study, the counterfactual outcome for the treated group is estimated using the reduced-form expression referred to by Abadie et al. (2010) as the *factor model*:

$$Y_{it}^{N} = T_{it} + \delta_t + \beta_{it} X_{it} + \lambda_t \mu_i + \varepsilon_{it} \tag{3}$$

where Y_{it}^{N} represents the homicide rate in microregion i at year t. $T_{i,t}$ is a treatment dummy variable equal to 1 if the region is treated and 0 otherwise. $delta_t$ is an unobserved common factor with constant loadings across units, X_{it} is a vector of covariates for region i at year t, including: the share of youth in the population, the log of total population, the ratio of formal jobs per capita, the number of security personnel per capita, the spatial lag of employment (in log) and the the lagged homicide rate in region i at year $t-1$. Additionally, λ_t is a vector of unobserved common factors, μ_i is a vector of unknown factor loadings, and ε_{it} is the error term.

Abadie (2021) highlights several precautions when applying the synthetic control method. A key step is to exclude from the *donor pool* any municipalities that experienced similar interventions during the analysis period—in this case, the construction of a prison. It may also be necessary to remove municipalities affected by idiosyncratic shocks in the dependent variable. Since this study focuses on a municipality in Paraná, the *donor pool* includes only other municipalities of the same state, following the approach of Abadie et al. (2015), who recommend selecting units from the same "group" to ensure greater comparability and reduce the risk of unobserved shocks[3].

Abadie (2021) also emphasizes the possibility of an anticipation effect, whereby local residents may be affected or alter their behavior prior to the formal implementation date of a given intervention. Accordingly, it is recommended to test for the presence of such effects within the proposed model. This article tested specifications with different intervention years to verify the presence of an anticipation effect. It is reported that no significant effect was observed in any of the cases, with the 2007 intervention year being the only one yielding adjusted and significant models. The results can be made available upon request to the authors.

Moreover, Catanduvas is a small municipality that experienced a structural shock with the construction of the federal prison. Given its limited economic capacity and

[3]The authors construct a synthetic version of Germany based on other OECD member countries, an organization to which Germany also belongs.

increased local policing, it is plausible that criminal activity would not be incentivized to establish itself directly within the municipality. In this context, the effects of the prison may extend beyond its immediate location, potentially impacting nearby municipalities that are more vulnerable to the policy's indirect consequences—particularly Cascavel, due to its pronounced socioeconomic inequalities. To test this hypothesis, a synthetic control was not constructed specifically for the municipality of Catanduvas. Instead, the analysis focuses on the Cascavel microregion, where the prison is located. To capture possible spillover effects, neighboring municipalities were treated as directly affected, and individual synthetic controls were constructed for each. In addition, the analysis was extended to the broader microregion encompassing Catanduvas. This approach allows for the evaluation of whether any increase in violence occurred asymmetrically, shaped by the distinct characteristics of the surrounding municipalities.

Neighboring units to the treated area may be subject to *spillover effects*, potentially biasing the analysis (Abadie et al., 2015). To uphold the non-interference assumption among control units, it may be necessary to exclude potentially contaminated units from the *donor pool*. The use of microregions as the unit of analysis can also help address possible violations of the non-interference assumption. However, defining contamination risk on an *ad hoc* basis is not ideal.

An exploratory analysis suggests spatial autocorrelation in formal employment levels across microregions. A Moran's I test revealed statistically significant positive spatial dependence, with a value of 0.14 for the spatial lag of this variable, using a first-order *queen* contiguity spatial weight matrix. This spatial dependence may reflect the spatial displacement of crime, such as criminal activity occurring in neighboring microregions due to limited labor market opportunities in the treated area.

In light of this, the present study adapts the methodology proposed by Castro e Almeida (2023) to assess the effects of spatial lags in control variables on the predictive accuracy of synthetic control estimations, specifically in terms of minimizing the root mean squared prediction error (RMSPE). It further proposes that spatial spillover effects related to crime displacement be detected through the inclusion of spatially lagged covariates.

4.2 Data

The dependent variable in this study is the number of homicides, as reported by the Mortality Information System (SIM, 2022), based on ICD codes X85–Y09. All deaths resulting from assaults are included, without distinguishing the specific method of aggression. Control variables were sourced from the Brazilian Institute of Geography and Statistics (IBGE) and the Identified Annual Social Information Report (RAIS). From RAIS, two key variables were extracted: the number of formal employees and the number of security personnel in each microregion. Table 1 outlines the variables obtained from each data source. The analysis covers the period from 1995 to 2019.

The selection of variables is theoretically grounded in the rational choice model of crime of Becker (1968). A lack of *deterrence*[4] was cited by inmates interviewed in Borilli e Shikida (2006) as a key motivation for criminal activity, based on the perception that law enforcement in Paraná was ineffective in preventing crime. Furthermore, the absence of formal employment among offenders was identified as another major contributing factor. These findings justify the inclusion of both policing capacity and formal employment as control variables. Not only are they supported by empirical research, but they also align with the theoretical underpinnings of Becker's model, making them essential to understanding criminal behavior in the region.

The importance of controlling for the proportion of young males is well established in the literature, as this demographic is more prone to risk-taking behaviors and has a lower aversion to risk (Borilli e Shikida, 2006; Shikida, 2010; Cerqueira, 2014). To capture this effect, population projections from DATASUS were used to identify the number of individuals aged 15 to 29 in each microregion. Additionally, the logarithm of the total population was included as a control variable to account for population size, a standard practice given its relevance to crime analysis. According to Santos e Kassouf (2012), omitting population controls for groups more susceptible to criminal behavior undermines the quality of the analysis.[5], The inclusion of these variables aims to address this issue and enhance the robustness of the estimated model.

Table 1. Description of variables included in the dataset

Variable	Measure	Source
Dependent variable:		
Homicide rate	Rate of homicides per 100.000 inhabitants in micro-region "i"	SIM - DATASUS
Explanatory variable:		
$T_{i,t}$	*Dummy* with value 0 or 1 to indicate if the micro-region i was treated (hosting a new penitentiary) in year t	
Covariates at micro-region level:		
Lagged homicide rate	homicide rate in the past year ($t-1$)	SIM - DATASUS
Population (in log)	Log of the total number of inhabitant	IBGE
Security personnel rate	The total number of police or security workers by inhabitant	RAIS - MTE
Formal emplyment rate	The ratio between the total number of formal employment and inhabitants	RAIS - MTE
Proportion of young	Percentage of male inhabitant with age between 15 and 29 years	DATASUS
Population density	Total number of inhabitant by km^2	IBGE
per capita GDP	Micro-region GDP divided by the total number of inhabitant	IBGE

Source: own elaboration.

Table 2 presents the descriptive statistics of the dataset used in this study. The dataset covers all 39 microregions of the state of Paraná, spanning the period from 1996 to 2019. Only the variables employed in the models presented in Section 5 are reported.

[4]The concept of deterrence suggests that an increase in the probability of being caught while committing a crime or illicit act should, in theory, discourage individuals from engaging in such behavior. This idea is theoretically grounded in expected utility models, particularly in Becker (1968) rational choice model of crime, where individuals weigh the potential costs and benefits before deciding to commit a criminal act.

[5]For alternative models not presented in this article, per capita GDP was used as a well-established control for the municipality's level of economic development, serving as a partial proxy for the economic conditions of the local population. Population density was also calculated and included in models not reported in the results. The authors chose to exclude this model due to its significantly inferior performance compared to models estimated using the alternative viable proxy, the logarithm of the population.

Table 2. Descriptive statistics of the micro-region level database

Variable	N	Mean	S.D.	Min	Max
Population	936	265,103	474,501	28,885	3,477,344
Homicide rate	936	18.44	10.510	0.000	78.65
Youth_pop	936	12.96	0.87	10.21	16.16
Log of pop density	936	11.96	0.893	10.27	15.06
Pol + sec workers_pop	936	0.003	0.003	0.0001	0.02
Formal emp_pop	936	0.237	0.107	0.051	0.669
Spatial lagged_emp	936	202,316	189,454	30,162	1,300,322

Source: Own elaboration.

5. Results

Following the strategy outlined in this study, the effects of the PSMC's construction on the potentially affected microregion are examined. The results show some association between the prision location and homicide rates in 2011 and 2012, as the model detects a statistically significant and positive treatment effect. However, this effect appears considerably lagged and the causal link to the prison's construction should be interpreted cautiously. Therefore, the results suggest that it is not possible to attribute a significant effect of the prison's construction on local homicide rates.

As shown in Table 3, the model incorporating spatially lagged employment variables exhibits superior predictive power in constructing a synthetic control group compared to the model without spatial lags. This conclusion is supported by the lower RMSPE[6] recorded in Model 1. Additionally, the fit of Model 1 outperforms its counterpart, as evidenced by a visual comparison between Figure 3a and Figure 3b. The figures also illustrate the increase in homicide rates discussed previously, with the rise occurring between 2008 and 2013—although only the years 2011 and 2012 show statistically significant effects.

Table 3. Synthetic Control for Cascavel micro-region

	Model 1		Model 2		
Variable	Treated	Synthetic	Variable	Treated	Synthetic
Homicide rate ($t-1$)	23.16	23.14	Homicide rate ($t-1$)	23.16	23.22
Youth rate	13.81	13.79	Youth rate	13.81	13.85
Population (log)	12.90	12.83	Population (log)	12.90	12.85
Formal employment by inhabitant	0.24	0.23	Formal jobs by inhabitant	0.24	0.24
Pol/sec workers by inhabitant	.0036	.0046	Pol/sec workers by inhabitant	.0036	.0036
Spatial lagged formal emp (log)	11.19	11.18			
RMSPE:	2.1336		RMSPE:	3.0880	

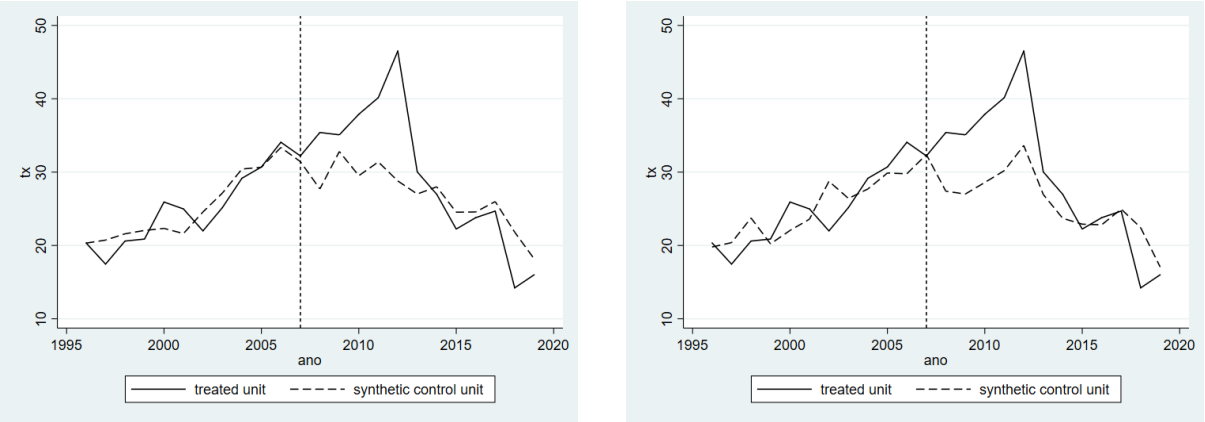
Source: Author's own elaboration.

[6]The RMSPE measures the average differences in the control variables between the treated and synthetic series. The synthetic control literature often uses the minimizing of this error as measure of model's prediction quality.

Given that the inclusion of the spatial lag of employment per capita improved the model's fit, we assume that the distribution of economic opportunities is an important explanatory factor in understanding the dynamics of violence. Formal employment may serve as a proxy for a region's attractiveness to criminal activity. For instance, in areas where jobs are scarce, individuals more prone to crime may be tempted to commit offenses in neighboring, more prosperous regions (Santos e Santos Filho, 2011). Alternatively, more urbanized and affluent areas may attract criminal activity regardless of local labor market conditions.

Building on the approach proposed by Castro e Almeida (2023), this study supports that the use of spatial lags in synthetic control models may offer a valuable contribution to the crime literature, as it enhances the pre-treatment fit of the model, bringing more reliance to the statistical relevance of the estimated effects. Temporal lags of homicide rates were also found to be important for model estimates, as homicides in prior periods are a well-documented explanatory factor in the literature (Santos e Kassouf, 2012). The use of temporal lags is likewise employed in the empirical applications of Abadie e Gardeazabal (2003) and Abadie et al. (2010). To validate these findings, robustness checks and placebo tests are necessary. Table 4 presents the statistical significance of the treatment effect for each year, as well as the overall significance, based on the placebo tests.

Figure 3. Synthetic control models for Cascavel micro-region



(a) Using formal employment spatial lag.

(b) Not using formal employment spatial lag.

Table 4. Treatment effect by year

Year	Effect	p-value	Normalized p-value
2007	0,7771	0,8421	0,7895
2008	7,6966	0,2368	0,1316
2009	2,2778	0,7368	0,5789
2010	8,3763	0,3421	0,1053
2011	8,7637*	0,1316	0,0526
2012	17,7049***	0,0263	0,0000
2013	3,0201	0,5526	0,4211
2014	-1,0276	0,9211	0,8421
2015	-2,3003	0,8947	0,6579
2016	-0,7764	0,9474	0,9474
2017	-1,2968	0,7895	0,6579
2018	-7,5998	0,4211	0,1053
2019	-2,1677	0,6053	0,4211
Number of units:	38		
Normalized p-valor:	0.2105		
Compatibility:	0.8947		

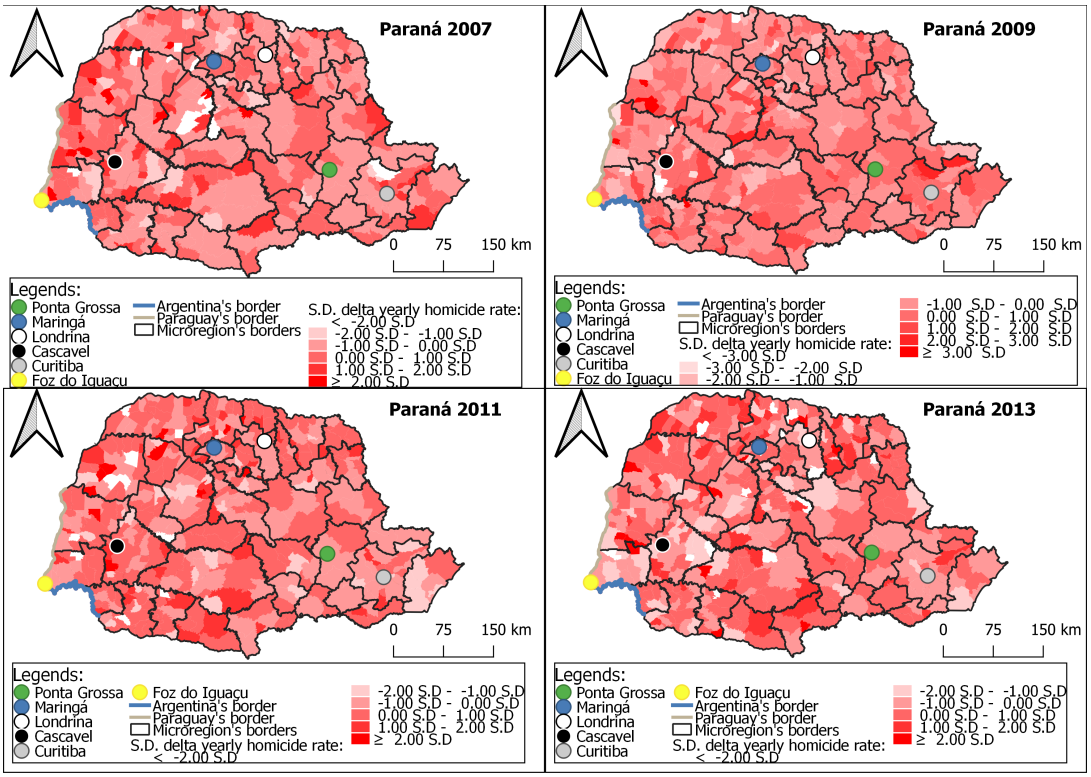
Source: Author's own elaboration.

To conduct an exploratory spatial analysis of homicide rate dynamics, the annual variation in homicide rates was calculated by subtracting the homicide rate in period t from that in period $t-1$. Figure 4 displays the standard deviations of these variations across municipalities within each microregion during the years covered in this study. Notably, the Cascavel microregion exhibited a sharper decline in homicide rates than the state average in 2007 (the year of the intervention) and 2009. However, from 2011 onward, a significant increase in homicide rates is observed—an effect found to be statistically significant in the synthetic control model results.

Based on the findings presented in this section, it is plausible that the prison may have contributed, at least partially, to the rise in crime, consistent with hypotheses derived from the literature. Nonetheless, the data suggest that the prison's impact on local crime rates would likely operate through endogenous, long-term mechanisms. Two primary channels may explain this contagion effect. First, the release of former inmates into the microregion may increase local vulnerability due to impacts on family structures, informal social control, and the labor market (Clear, 2008; Morenoff e Harding, 2014; Dhondt, 2018; Kirk e Wakefield, 2018). Second, the prison may have served as a hub for the consolidation or expansion of organized criminal networks (Manso e Dias, 2017). Relatedly, the analysis of Da Rocha Filho (2022) also found statistically significant differences in the means of firearm-related deaths in Catanduvas between the years of 2007 and 2011.

Therefore, the body of evidence gathered in this study suggests that the prison may have functioned as a catalyst for violence, particularly when combined with other exogenous factors—such as spatial displacement of crime from neighboring microregions, especially those near state borders (see Figure 4). In this case, the mechanism of influence would likely involve coordination efforts by organized crime groups.

Figure 4. Variation in homicide rates in Paraná, 2007, 2009, 2011 and 2013



Source: Author's own elaboration. Notes: Delta yearly homicide rates are t - t-1, where t is the year shown in each map. S.D is standard deviation. Geographic units of homicide rates are at municipality level.

5.1 Robustness analysis

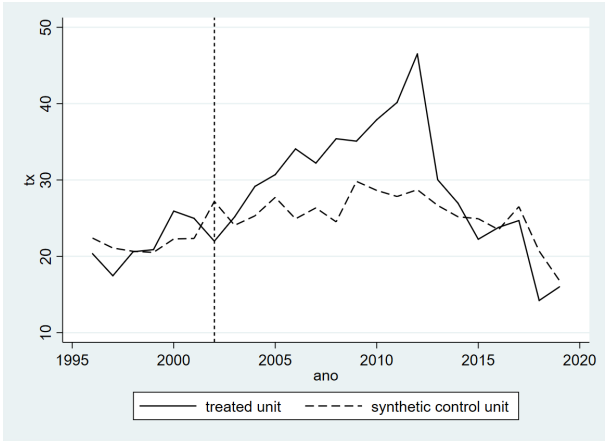
As a robustness check, a temporal placebo test was conducted by assuming that the treatment occurred in 2002. This test aims to rule out the hypothesis that the construction of the Marcelo Pinheiro Industrial Penitentiary in Cascavel influenced local homicide dynamics. The trajectory of homicide rate in the Cascavel microregion was analyzed under this hypothetical intervention year. The robustness analysis does not indicate a significant increase in local crime following the prison's establishment. It is worth noting that this facility is not a maximum-security prison and, in theory, does not house a comparable number of high-risk offenders as the PSMC, which may explain the lack of statistical significance observed. Moreover, due to the reduced number of pretreatment observations, the model exhibited slightly lower accuracy (RMSPE) and weaker inter-group trajectories matching.

Table 5. Synthetic control for Cascavel micror-region, assuming the treatment in 2002

Variable	Treated	Synthetic
Homicide rate ($t-1$)	20.4622	20.4628
Youth rate	13.9773	13.9770
Population (log)	12.8741	12.8755
Formal employment *per capita*	0.20770	0.19850
Police officers per capita	0.00310	0.00401
Lagged employment (log)	11.0387	11.1194
RMSPE:	2.50920	

Source: Author's own elaboration.

Figure 5. Synthetic control with treatment year in 2002



Source: Author's own elaboration.

In addition to this test, a series of placebo tests—detailed in Appendix 6—were conducted. These tests strongly suggest that there was no significant increase or decrease in local homicide rates following the establishment of the PSMC. Placebo in-place tests are particularly important when the treatment effect may not be statistically significant over the analyzed period. In these tests, a hypothetical treatment is applied to each region in the dataset, allowing for a comparison between the observed effects and those produced by placebo assignments. This approach helps validate the robustness of the results.

Further estimations were also carried out using alternative variables, specifically per capita GDP and population density. In the case of per capita GDP, it was used both as a substitute for and in combination with the formal employment per capita variable. Population density, in turn, was tested in place of the logarithm of total population. These alternative models did not produce any significant change in the interpretation or significance of the results. However, they were qualitatively inferior in terms of statistical performance compared to the models reported in this article. Therefore, they are not presented here but are available upon request from the authors.

6. Final remarks

This study investigates whether the construction of the PSMC led to an increase in crime within its microrregion, contributing to the literature of crime economics by addressing a relatively underexplored topic. The findings of this study suggest that, in line with theoretical expectations regarding the potential for increased local crime following the installation of a correctional facility, there is evidence of a temporary effect of the PSMC on violence in Cascavel microregion. The evidence, thus, do not support the hypothesis that the Maximum-security prison serves as a source of persistent violence. On our analysis, the homicide rate in the Cascavel microrregion converges toward that of the synthetic control following the temporary treatment effect. However, the delayed increase in violence observed between 2011 and 2013 can be attributed to the existence of organized crime activity attracted by the presence of the prison.

The methodology employed in this study may also offer valuable contributions to the broader literature on crime, as it proposes applying the synthetic control method not only to the directly treated unit, but also to neighboring municipalities that may have experienced effects equal to or greater than those observed at the intervention's epicenter. This consideration is particularly useful in studies aiming to understand the impact of prisons located in peripheral municipalities. The use of the microrregion as the unit of analysis enables the detection of broader territorial effects, given the high degree of spatial integration typically observed in such areas. Even in larger municipalities, this level of aggregation can help identify whether metropolitan areas experienced differential impacts from the intervention.

From a policy perspective, the findings suggest that the construction of the PSMC — based on the principle of locating prisons in smaller municipalities near more relevant urban centers—does not appear to contribute significantly to a permanent increase in violence. The study does have certain limitations, particularly those stemming from the challenges of constructing a longitudinal database spanning from 1996 to 2019. Nevertheless, the potential inclusion of additional variables could enhance our understanding of the dynamics captured by the estimated models. Future research should consider whether similar temporary effects are observed in the context of economic crimes, such as vehicle theft or robbery rates, in the region where the prison was established. Another fruitful path for research would be to analyze how the construction of a prison might influence the local real estate market or property taxes in that municipality.

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Appendix:

Composition of the synthetic units

Table 1 shows that the composition of the synthetic control group for the main model (Model 1, with spatial lag) differs considerably from that of Model 2 (without the lag). It is observed that fewer units are required to construct the synthetic control group, with only 5 out of the 38 microrregions being used. Moreover, the microrregions of Foz do Iguaçu and Toledo are not included in the construction of the synthetic control, making it unnecessary to remove them from the *donor pool* due to potential contamination.

A.1. *Donor pool* composition of synthetic controls

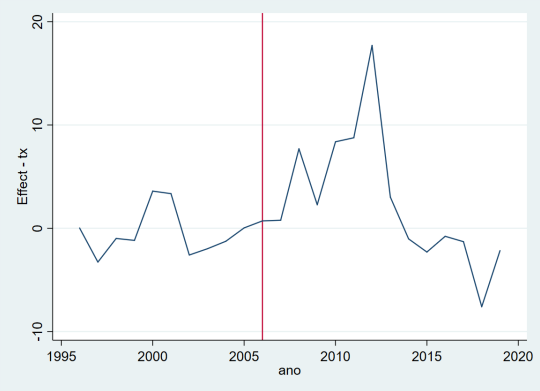
Micro-region name	Model 1 Unit_Weight	Model 2 Unit_Weight	Robustness Unit_Weight
Paranavaí	0	.002	0
Umuarama	0	.002	0
Cianorte	0	.001	0
Goioerê	0	.001	0
Campo Mourão	0	.001	0
Astorga	0	.001	0
Porecatu	0	.001	0
Floraí	0	0	0
Maringá	0	.348	0
Apucarana	0	.007	0
Londrina	0	.005	0
Faxinal	0	.001	0
Ivaiporã	0	.001	0
Assaí	0	.001	0
Cornélio Procópio	0	.001	0
Jacarezinho	.019	.001	0
Ibaiti	0	.001	0
Wenceslau Braz	.213	.001	.158
Telêmaco Borba	0	.002	0
Jaguariaíva	0	.002	0
Ponta Grossa	0	.002	0
Toledo	0	.003	0
Foz do Iguaçu	0	.169	0
Capanema	0	.001	0
Francisco Beltrão	0	.001	0
Pato Branco	0	.001	0
Pitanga	0	.002	0
Guarapuava	.28	.262	.42
Palmas	.183	.003	0
Prudentópolis	0	.006	.171
Irati	0	.001	0
União da Vitória	0	.003	.004
São Mateus do Sul	0	.001	0
Cerro Azul	0	.001	0
Lapa	0	.002	0
Curitiba	.304	.058	.247
Paranaguá	0	.001	0
Rio Negro	0	.106	0

Source: Author's own elaboration.

Placebo analysis

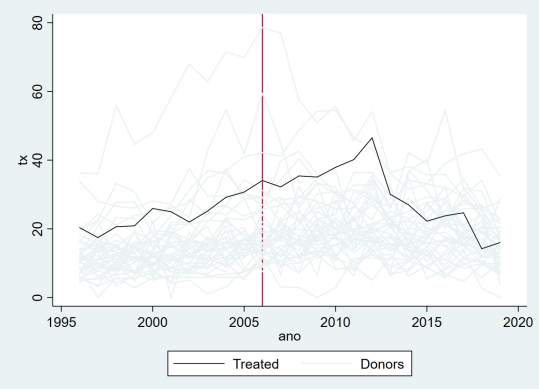
The robustness check using placebo tests—where each microrregion in the donor pool is treated as if it were the treated unit—yields some noteworthy results. First, the treatment effect can be visualized by year in Figure 6. In this case, a statistically significant effect different from zero is observed only for the lagged periods previously analyzed. In Figures 7a and 7b, it becomes evident that, for most periods, the treatment effect is not significant. This conclusion stems from the observation that in only a few periods does the treatment effect stand out as statistically significant when compared to the distribution of placebo effects.

A.6. Treatment effect



Source: Author's own elaboration.

A.7. Placebo tests



(a) Comparison of results.

(b) Comparison of effects.

Source: Author's own elaboration.