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Armed police and violence: Evidence from a quasi-natural experiment in Brazil

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ABSTRACT

While governments discuss arming their police, or retaining their armed status, the literature shows no evidence of the effect on violent crimes when the police are armed. Unlike this literature, our work shows that the effect of arming the police is a reduction in violent crimes (homicides and acts of aggression). With data taken from Brazilian municipalities for the period between 2002 and 2012, we estimate the effect that armed police have on violent crime using a quasi-natural experiment: a change in the law that regulates the use of firearms by the municipal police force based on population size. The mechanism that explains the reduction in violent crimes is police effort (incapacitation). We also observe that violent crimes do not increase in municipalities that are neighbors of municipalities in which the police are armed (a deterrence effect).

1. Introduction

Various countries worldwide are having difficulties in addressing the issue of gun ownership because they are experiencing new forms of violence provoked by terrorist attacks, or by attacks against people on university or school premises. The discourse of the authorities recommends prudence with regard to this decision, since a new direction in legislation might not solve the problem and could even aggravate it.[1]

Most of the public debate about policies for curbing violence rely on evidence about the presence of the police, their militarization (the use of military equipment), or the right of private individuals to carry firearms. To the best of our knowledge, there is no evidence that shows that there is an effect on violent crimes when the police carry firearms.[2] Our work, however, shows that when the police carry firearms there is a reduction in violent crime, such as homicides and acts of aggression.

The empirical literature on the effects of the presence of the police for deterring offenders who are involved in criminal activity is vast (e.g., Evans and Owens, 2007; Lin, 2008; Marvell and Moody, 1996, Levitt, 1997, and Chalfin and McCrary, 2012, on police manpower; Braga, 2001; Sherman and Weisburd, 1995 and Blair and Weintraub, 2021 on "hot spots"; Braga et al., 2001 on "problem-oriented policing"; Bove and Gavrilova, 2017; Harris et al., 2017; Olugbenga, 2017; Lowande, 2020 on the militarization of the police). Almost all of these works present a strategy of identification to correct bias given the possibility of reverse causality, or the omission of variables when establishing a causality relationship between the variables.

We observe three strategies being used for dealing with this problem: instrumental variable, exogenous change (shock), and difference-in-difference. Levitt (1997, 2002), for example, uses the timing of mayoral and gubernatorial elections as an instrumental variable for identifying the causal effect of the police on crime in the 59 biggest US municipalities between 1970 and 1992. McCrary (2002, 2002a) replied to this result by correcting computational problems with the data, showing that the magnitude of the result in the second-stage was half

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[1] Following the protests against Dilma Roussef's government in Brazil (2015), a group of senators proposed (Constitutional Amendment Number 51) that the state military police be disarmed given the confrontation between the police and organized groups of civil society, including violent confrontations with the self-proclaimed "Black Block" group, for example.

[2] Jawadi et al. (2021) distinguish violent and non-violent crimes through the existence of monetary benefit. Violent crimes do not have monetary benefits and non-violent crimes have a direct monetary benefit (property crimes like larceny and burglary).

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what was published and statistically indistinguishable from zero. In exogenous change (shock), Di Tella and Schargrodsky (2004) used the moment of the terrorist attack (July 1994) on the main Jewish center in Buenos Aires (Argentina) as a change that led to unusual police protection. Draca et al. (2011) also use the terrorist attack (a shock) in Central London as causing an unusual change in the police (police activity in Central London increased by over 30 percent in the six weeks following the July 7, 2005 bombings as part of a police deployment policy stylishly entitled "Operation Theseus" by the authorities). The last two hot-spot studies find evidence that a police force reduces crime. Interestingly, the police used firearms as usual/standard equipment in one of the situations (Argentina), while in the other situation they did not (England). Finally, in literature on the (de)militarization of the police, Lowande (2020), for instance, uses a difference-in-difference approach. Basically, the empirical strategy was sustained by revoking Executive Order 13,668 in January 2015. The results show that demilitarization does not lead to any change in violent crimes or an increase in officer deaths (comparing demilitarized municipalities with municipalities that were not affected by the program).

We leverage a quasi-natural experiment in Brazil, which creates the appropriate environment for investigating this issue. The Brazilian central government approved new federal legislation in 2003 (the Statute of Disarmament No.10,826) that increased the requirements for individuals who wish to purchase a gun, and banned civilians from carrying guns (a homogenous change; for all individuals in any municipality). It allowed non-metropolitan municipalities, however, to decide whether their municipal police should carry firearms (this was a heterogeneous change for some municipalities). Only non-metropolitan municipalities with 50,000 inhabitants or more are allowed to have an armed municipal police force. We produce our evidence using panel data for the 2002 to 2012 period for non-metropolitan municipalities with a municipal police force, and the population discontinuity rule (more than or fewer than 50,000 inhabitants) as an exogenous source of variation that explains the choice of police (armed or unarmed). This is basically a parametric regression discontinuity design (RDD) in two-stages.

Following Becker's model (1968), in fact, the general idea is that police intervention affects the calculation of individual decisions about criminal activity and, as a consequence, has an aggregate result on homicides and acts of aggression. Assuming that this intervention has incapacitation and deterrence effects (see also Rehman et al., 2017), one of the main challenges of empirical literature is to correctly identify each mechanism in the aggregate results (Chalfin and McCrary, 2017). We try, therefore, to disentangle these two channels using two procedures; first, we treat police intervention as a general deterrent that changes the behavior of offenders (see the studies by Levitt and Miles, 2006; Nagin, 2013; Chalfin and McCrary, 2017); and second, we treat police efforts as "incapacitation" (see the studies by Levitt, 1998; Owens, 2013; Bove and Gavrilova, 2017; Harris et al., 2017).

With a sample that is restricted to the State of São Paulo, for which we have access to police data, we explore the incapacitation mechanism. We find evidence suggesting that the reduction in crime is at least partially due to greater police efforts. Armed police make a greater number of inquiries, the number of individuals over 18 years old arrested for flagrant criminal behavior increases, as do the seizure of narcotics, the number of vehicles recovered, and the number of arrests. These results suggest that incapacitation might be one of the channels that explain the reduction in crime.

Although we have no data on offenders who carry weapons that would allow us to directly investigate offenders' reactions, in shedding light on deterrence mechanisms we find evidence of a reduction in the number of firearm seizures in those municipalities where the police are armed. We also investigate the spillover effects on neighboring municipalities (municipalities in which the police do not carry firearms, but where the police in adjacent municipalities do). The 15% of municipalities that have a municipal police force (the average between 2002 and 2012) and their distribution in Brazil allows us to introduce this type of strategy: to verify whether potential offenders migrate from municipalities in which the local police start carrying firearms to nearby municipalities in which the local police do not use firearms. If crime is migrating (crime in neighboring municipalities is increasing), then incapacitation might not be so important, but if it is not migrating, then incapacitation becomes important. We find that, given these conditions, violent crime decreases in neighboring municipalities. In doing this same exercise in São Paul State in isolation, we observe no change in the rate of violent crimes. We interpret the effect of incapacitation, therefore, as the dominant factor for explaining the reduction in violent crimes in Brazil.

Finally, we extended our identification strategy of the main results to include: a different functional form in the parametric RDD estimate (quadratic) in the first-stage (the main result is linear); Poisson results with control function in the second-stage; and controlling for heterogeneous police manpower in the results (Levitt, 1997; Chalfin and McCrary, 2017). The main results remain robust.

Although recent studies involving the (de)militarization of the police show no evidence of an effect on violent crime (Bove and Gavrilova, 2017; Harris et al., 2017; Olugbenga, 2017; Lowande, 2020), Chalfin and McCrary (2017), our more conservative result for Brazil (with the Poisson control function in the second stage) shows a reduction in homicides of between 0.5% and 1.9%, and in acts of aggression of between 0.6% and 2.3% per 100,000 inhabitants in municipalities that have armed police compared to municipalities in which the police are unarmed.

This paper makes important and novel contributions to the literature. First, we compare the difference between having armed police and unarmed police (no heterogenous military equipment, like in some cases in the US 1033 Program), and the consequent results on violent crime. Second, we obtain evidence in the main channel that might suggest an explanation for our findings (Chalfin and McCrary, 2017): incapacitation. We also investigate the expansion of violent crimes in municipalities that are the neighbors of municipalities in which the police are armed, and we observe no deterrence effect.

Unlike other experiments that are based on main cities and their metropolitan areas (Di Tella and Schargrodsky, 2004; Draca et al., 2011; Adda et al., 2014), our natural experiment, which employs many small and medium-sized cities outside metropolitan areas, contributes to the applied literature on crime in general terms. To the best of our knowledge, this dimension is rarely covered in crime experiments.

This paper is organized in eight sections, including this introduction. Section 2 describes a simple model showing the influence of armed police on individual decisions about violent crimes. Section 3 describes the institutional background. Section 4 describes the source of the data and of our sample. Section 5 presents the empirical strategy. Section 6 presents the results. Section 7 discusses possible mechanisms that might explain the results. Section 8 presents an additional robustness check: police manpower as control; while Section 9 presents our conclusions.

2. Individual decisions about violent crime and the influence of armed police

Since rational choice is considered to be an aspect of the general theory of crime (Loughran et al., 2016), following the seminal idea from Becker (1968) in partial equilibrium (see Adda et al., 2014 in general equilibrium), a rational individual (offender) will decide to commit a violent crime by observing the net income from committing a physical offense by way of its benefit and costs:

$$NET\_INC(x) = y(x) - p(x,\ AP)^{*}f(x,\ AP) \tag{1}$$

where $NET\_INC(x)$ is the net income received from an offense (this income is available to the offender in an illegal activity; see also Jawadi et al., 2021, about the possible association between types of crime and types of income) associated with (i.e., x variable) either the number of violent crimes committed or the severity of the violent crime (homicides or aggression); $y(x)$ is the benefit from this violent crime (the gross

income derived from an offense), which also depends on the x variable: $y'(x) > 0$, $y''(x) < 0$; $p(x, AP)$ is the probability that the offender will be caught committing a violent crime, which also depends on the x variable: $p'(x) > 0$, $p''(x) < 0$; $f(x, AP)$ is the effective punishment for the violent crime (prison); f is transformed into the equivalent income received from a violent crime (income from an offense committed), which also depends on the x variable; AP is the "status acquired" by the police because of their work instrument: a firearm. The armed police have an influence on the net income received by the offender in two ways: 1) incapacitation (f): armed police are more efficient at fulfilling their role in terms of justice. The justice system determines compliance with and enforcement of the law. Efficient police are fundamental in terms of law enforcement. The literature has already established the influence of police manpower on their efficiency (see Chalfin and McCrary, 2017); given that the level of f depends on a combination of compliance and enforcement, we can find heterogeneity at the f level. Thus, armed police (AP) increase the effective punishment: $f'(AP) > 0$; $f''(AP) < 0$; 2); 2) deterrence (p): armed police also affect the probability that the offender will be caught committing some type of violent crime, because the police are better prepared for action (see Levitt and Miles, 2006; Nagin, 2013; Chalfin and McCrary, 2017). Since other factors of the police can influence the probability that the offender will be caught committing a violent crime (see Nagin, 2013), we assume that armed police (AP) increase the probability of the offender being caught: $p'(AP) > 0$; $p''(AP) < 0$.

Under these conditions, the optimal level of net income from an offense that guides the offender with regard to the number of violent crimes they commit (or their severity) is:

$$y(\acute{x}) - p'(x)f(x, AP) + p(x, AP)f'(x) = 0 \quad (2)$$

We observe in equation (2) that this optimal level of net income is the point at which the marginal benefit of violent crime ($y(\acute{x})$) is equal to its marginal cost ($p'(x)f(x, AP) + p(x, AP)f'(x)$). In this condition, the offender is indifferent to additional violent crime. If the marginal benefit of violent crime, however, is superior to the marginal cost, the offender increases the number or severity of the violent crimes committed. On the other hand, if the marginal benefit of violent crime is inferior to the marginal cost, the offender reduces the number and severity amount of the violent crimes they commit. Armed police increase the marginal cost for the offender through f and p (the marginal benefit is less than the marginal cost). Armed police, therefore, result in fewer individual violent crimes being committed, and in aggregate, with the number of violent crimes observed in each municipality following this trend. The dominant effect of armed police on the increase in marginal cost (deterrence or incapacitation) on the aggregate number of violent crimes, however, depends on empirical investigation.

3. Institutional background

3.1. The Brazilian municipal police

The municipal police were created in 1988 by the Federal Constitution to protect municipal public properties, services and facilities. Over time, the duties of the municipal police have diversified into performing several public safety functions. Among their urban activities municipal police are responsible for: (i) school and street patrols; (ii) assistance with traffic control; (iii) assisting the state civil police and the military police; (iv) promoting educational activities; and (v) controlling and combatting illegal or informal (clandestine) municipal businesses (MUNIC-IBGE, 2012).

The municipal police come under the local authority (Executive and Legislative Branches), while the state civil and military police forces fall under state authorities, and the federal police come under the federal authority. In any given municipality, therefore, three police forces (federal, state, and municipal) may work on solving crimes depending on the criminal occurrence. According to the Planning Coordinator & Analyst of the Department of Public Safety of the São Paulo State government, the municipal police, the largest police contingent in non-metropolitan municipalities, are responsible for ostensible policing. The state military police coordinate policing, and act in criminal events when either the municipal police or the population calls on them to intervene. The state civil police are responsible for investigating criminal events. We interviewed civil police chiefs in the State of São Paulo who reported on the importance of the municipal police in everyday life. According to them, the police on the streets in big cities in the state, like Piracicaba, Campinas, Ribeirão Preto, and Sorocaba are municipal police.

3.2. Armed municipal police legislation

The increase in tasks over time has generated a demand for the use of similar technologies for combatting crime, including the use of firearms. Recognizing the possibility of a generalized and indiscriminate use of this instrument, the Federal Legislature decided to regulate the use of firearms by individuals and police forces by enacting Law No. 10,826 on December 22, 2003, called the Statute of Disarmament. This law increased the requirements for individuals who wish to purchase a gun and banned civilians from carrying them.[3] Chapter III, Article 6 also establishes the criteria under which municipal police can carry firearms. These criteria are as follows: (i) all municipalities in metropolitan areas are allowed to have municipal police that carry firearms, and members of the local police force can carry them at any time[4]; (ii) for all municipalities in non-metropolitan areas, permission to carry firearms depends upon the size of the municipality. In municipalities with fewer than 50,000 inhabitants, local police officers cannot carry firearms. In municipalities with 50,000 inhabitants or more, municipal police officers can bear firearms.[5] Members of the local police force in municipalities with a population between 50,000 and 500,000 can only use firearms as instruments for security purposes during working hours. Municipal police officers in municipalities with over 500,000 inhabitants, however, can also carry firearms outside of their working hours.

As explained in more detail below, we explore the population eligibility criterion established by federal law (2003) as a source of exogenous variation in the probability that a municipality has local police carrying firearms, since this can solve the existing bias in the investigation into the effect of armed police on violent crime.

[3] See the importance of the *Statute of Disarmament* in Hartung (2009) and Dos Santos (2012).

[4] Metropolitan and non-metropolitan municipalities are established by law. The metropolitan areas include Manaus, Belém, Macapá, São Luis, Sudoeste Maranhense, Cariri, Fortaleza, Natal, João Pessoa, Campina Grande, Recife, Maceió, Agreste, Aracaju, Salvador, Belo Horizonte, Vale do Aço, Vitoria, Rio de Janeiro, São Paulo, Baixada Santista, Campinas, Curitiba, Londrina, Maringá, Florianópolis, Itajaí, Nordeste Catarinense, Rio Itajaí, Carbonífera, Tubarão, Lages, Chapecó, Porto Alegre, Cuiabá, Goiânia, Nordeste – Rio Grande do Sul, Urbana Sul – Rio Grande do Sul, Integrada de Desenvolvimento, do Distrito Federal e Entorno, Integrada de Desenvolvimento da Grande Teresina e Integrada de Desenvolvimento do Polo Petrolina e Juazeiro.

[5] When this law was established, the number of 50,000 inhabitants was challenged by municipalities. Reading the arguments on the bill proposed by federal deputy Carlos Sampaio (bill number 3854/2004) to change this cutoff, we clearly observe dissatisfaction: "*Thus, the legal field established an unreasonable discrimination based on random numerical data – municipal population – which has no relationship with the level of risk that the municipal police are subjected to. It is possible that the level of insecurity of a municipality with forty-five thousand inhabitants is much higher than the level of uncertainty of a municipality with fifty-one thousand inhabitants. However, in the second case, the municipal police have the right to bear arms in service and, at first, they did not.*"

4. Data and sample selection

4.1. Data sources

We compiled different sources of data for this work. First, we collected information about municipal police and whether they are armed or not from the *MUNIC* survey *(Pesquisa de Informações Básicas Municipais*), which has been produced by the Brazilian Census Bureau, *IBGE* (*Fundação Instituto Brasileiro de Geografia e Estatística)* every two or three years since 2001. *MUNIC* is a census of all Brazilian municipalities and carries information about the structure and functioning of municipal public institutions. The questionnaire is completed by the administrative branch of the municipality. Particularly relevant to our study is the information available for selected years about the existence of municipal police forces and the possession of firearms. Information about the municipal police is available for the following years: 2002, 2004, 2006, 2009, and 2012. These are the years we used in our analysis.

MUNIC information about the possession of firearms is only available for the following years: 2004, 2006, 2009, and 2012. Since the law changed in 2003, we also want to obtain information on the use of firearms for 2002. We collected these data ourselves retrospectively. First, we collected retrospective information about the use of firearms by the local police for 2002 for a group of municipalities that was used in our national sample. A total of 818 municipalities declared in the 2002 *MUNIC* (*IBGE*) survey that they had a municipal police force during that year. We contacted these municipalities directly and obtained 221 accurate answers; the municipal public agent knew the municipal police situation in 2002. Of these municipalities, 44 declared that their municipal police used firearms in 2002, 177 of them declared that their municipal police did not use firearms in 2002, and the remainder either did not know, or did not reply to our questions. We assume that in those municipalities for which we did not receive a precise answer, the local police did not use firearms.[6] To check the sensitivity of the imputation procedure of our main samples, we performed a second procedure in which we excluded from our exercise those municipalities for which we received no precise answer as to whether the local police use firearms. The results from this alternative sample are consistent with the main results for Brazil discussed in the results section (see Table A1 in the online appendix without the result with Poisson with control function).[7]

We present our main results for Brazil as a whole, but we use information from the State of São Paulo for investigating the police (police effort; for example, the total number of inquiries, the number of individuals arrested for flagrant behavior, the seizure of narcotics, the number of recovered vehicles, the number of arrests, and the seizure of firearms). This information is important when investigating mechanisms. The information is aggregated at the municipal level on a yearly basis. The data were collected from the Department of Public Safety of the São Paulo State government (*INFOCRIM*).

National information about crime outcomes (homicides and acts of aggression) was obtained from the National Public Hospital Reports of the Ministry of Health (*SIM/DATASUS*). Physicians register events (homicides or acts of aggression). They can occur on the street or in households. The Ministry of Health compiles, organizes and makes publicly available a series of indicators that are constructed from different data sources. The *SIM/DATASUS* system collects information from hospital reports that is provided by victims; this information is of particular interest. The information is aggregated at the municipality level and by year, and has been made publicly available to all municipalities since 1996. We use this information to construct our crime outcomes (crimes against the person – homicide and acts of aggression rates – following the World Health Organization, ICD-10, Chapter XX). We created homicide and aggression indicators for all municipalities and merged them with the *MUNIC* dataset for 2002, 2004, 2006, 2009 and 2012. Our reference for this source was "The Brazilian National Hospital Report".

We also constructed municipality control variables that are derived from additional data sources. We used demographic and economic control variables at the municipality level. The demographic controls (municipal population and the percentage of the total municipal population between 15 and 29 years old (see the importance of juvenile crime in India; Dutta et al., 2020); Chalfin and McCrary, 2012; Levitt, 1998) were extracted from the *DATASUS* database. The education variable (the percentage of individuals in the municipality with a graduate college education) was extracted from two censuses (2000 and 2010; see Lochner and Moretti, 2004; Machin et al., 2011). The nominal municipal GDP (see Dutta et al., 2020) was extracted from the *IBGE*.[8] The real municipal GDP was calculated using the *IGP-DI* price index from the *IBGE*. Finally, we controlled for the unconditional transfer values from the federal government to the municipalities.[9] This fiscal variable (Unconditional Federal Transfer – *FPM*) was obtained from the National Treasury and deflated by the same *IBGE IGP-DI* price index.

4.2. Sample selection

Table 1 shows the information about the municipal police forces that either carry or do not carry firearms in non-metropolitan areas. It presents the total result, with separate results for municipalities that have fewer than, and more than 50,000 inhabitants.

Brazil had approximately 5700 municipalities in 2012, 4882 of which were in non-metropolitan areas. On average, non-metropolitan municipalities represent approximately 88% of all municipalities in Brazil. Of all the Brazilian municipalities in non-metropolitan areas, approximately 15% (average across the years) have a municipal police force. The number and distribution of municipalities nationwide is vital to our investigation into deterrence. We need a great number of neighboring municipalities without armed police that are close to those with armed police. Of these municipalities, approximately 10% have police who carry firearms. Interestingly, the process by which municipalities adopted the new law (after 2003) appears to have been captured by our data. Of the 656 Brazilian non-metropolitan municipalities with a municipal police force and fewer than 50,000 inhabitants in 2002, 22 had police who bore firearms, corresponding to 3.3% of them. Of all the 162 Brazilian municipalities with municipal police and a population equal to or greater than 50,000 inhabitants in 2002, 22 of them had a police force whose officers carried firearms, corresponding to 13.7% of them. Over the period covering the change in the law, these shares increased for both groups of municipalities. They increased more, however, in municipalities with more than 50,000 inhabitants. Indeed, in 2012 these shares were 5.8% (34/585) and 24.29% (45/186) for municipalities with fewer than and more than 50,000 inhabitants, respectively.

Fig. A1 in the online appendix shows maps of the distribution of municipal police forces across municipalities in Brazil in 2002 and 2012, respectively. Although the municipalities with municipal police are scattered across the regions, those municipalities with police who carry

[6] We established two procedures to obtain and check the 2002 municipal information on firearms. First, we hired a specialized firm to obtain the information from the municipalities (Destaque Pesquisa de Marketing LTDA – CNPJ 001699598/0001–68). The firm contacted by phone all municipalities in Brazil with municipal police in 2002 from a list provided by us. Second, to check the information obtained for municipalities in São Paulo state, we hired two research assistants. They contacted by phone all municipalities in São Paulo with municipal police in 2002.

[7] We establish three other procedures imputing the probabilities of a municipality having fire-armed local police. The results are similar and can be requested from the authors.

[8] We do not have data of the municipal *GDP* for 2012. Thus, we use the *GDP* from 2011 to impute the 2012 *GDP*.

[9] Unconditional transfers are the most important source of revenue of municipalities. See Arvate, Mattos and Rocha (2015).

Table 1
Municipal Police with or without firearms in non-metropolitan areas (Brazil).

Years	Total Municipalities in non-metropolitan areas (approximately 88% of the total in Brazil)	Municipal Police (Total)				Municipal Police with firearms*				Municipal Police without firearms*			
		Total	Freq of Total	Less than 50,000 inhabitants	More than or equal to 50,000 inhabitants	Total	Freq of Total Municipal Police	Less than 50,000 Inhabitants	More than or equal to 50,000 inhabitants	Total	Freq of Total Municipal Police	Less than 50,000 inhabitants	More than or equal to 50,000 inhabitants
						Brazilian National Data							
2002	4867	818	16.81%	657	161	44	5.38%	22	22	774	94.62%	634	140
2004	4867	779	16.01%	610	169	79	10.14%	30	49	700	89.86%	580	120
2006	4869	611	12.55%	451	160	69	11.29%	21	48	532	88.71%	430	112
2009	4869	683	14.03%	518	165	78	11.42%	33	45	605	88.58%	485	120
2012	4882	771	15.79%	585	186	79	10.25%	34	45	692	89.75%	551	141

Note: Brazil data are from MUNIC's search (IBGE). Although the IBGE is an institution of the government, a small number of municipalities refuse to give information about their municipal police. * The IBGE did not produce information regarding whether the municipal police had firearms in 2002. Thus, we investigated whether the municipalities with municipal police did or did not have firearms in 2002 by calling them. In some cases, it was impossible to obtain the information.

firearms are concentrated more in the southeast and northeast regions.[10]

Our identification strategy relies on changes in the probability that municipalities have police who carry firearms among the eligible (equal to or greater than 50,000 inhabitants) and ineligible (fewer than 50,000 inhabitants) municipalities according to the law. The number of municipalities with a municipal police force changes over time. To illustrate the nature of the variation in the data explored in our empirical exercise, Table 2 presents the transitions between having and not having an armed police force before and after the law was passed for all Brazilian municipalities with municipal police in 2002.

Table 3 shows the descriptive statistics for the main variables used in our exercises. The variables are shown for all municipalities with a police force, and are separated by municipality with and without an armed police force.

The first column of Table 3 shows that the overall means of crime in the national sample (all municipalities in the country) are 21.23 homicides (S.D.:15.70) per 100,000 inhabitants, on average, for 2002, 2004, 2006, 2009, and 2012, and 21.23 acts of aggression (S.D:16.62) per 100,000 inhabitants for the same period. The second and third columns present the results for non-metropolitan municipalities that have a police force (armed and unarmed).

Fig. A2.A and A.2.B in the online appendix show maps of the distribution of homicides and acts of aggression per 100,000 inhabitants for Brazilian municipalities in 2002 and 2012. The distribution of crime rates across municipalities is highly skewed. There is a high number of municipalities with zero homicides and acts of aggression per 100,000 inhabitants, which reduces the sample average. Fig. A3 in the online appendix presents histograms of homicide and aggression rates for the national sample.

Violent crime rates are lower in municipalities where the local police are armed than in those where the local police are not armed. In fact, an average of 19.97 (S.D. = 19.60) homicides (acts of aggression: 21.24; S.D. = 19.68) per 100,000 inhabitants is found in municipalities where the police do not carry arms, whereas these figures are 17.33 (S.D. = 22.71) (acts of aggression: 18.86; S.D.:22.93), respectively, in municipalities with armed police. Moreover, the municipalities with armed police are more populous, richer, and receive more transfers from the federal government.

4.3. *Visual discontinuity*

We also show how the discontinuity that the population threshold rule imposed by legislation (50,000 habitants) affected the transition of fire armed police, homicides, and acts of aggression. Results for Brazil and São Paulo are shown together because we use data from the São Paulo State police to investigate mechanisms. There is a lack of observations in the São Paulo figures for municipalities close to but lower than the eligible population (50,000 inhabitants), because these municipalities do not have municipal police forces. This is not the same for other states in the country. We restricted the samples to non-metropolitan municipalities with population sizes of between 30,000 and 70,000 inhabitants in 2000. In each figure, we present the non-parametric estimates for each side of the cut-off value. The *x-axis* is the size of the municipal population in 2000. The first two figures at the top show the difference between eligible and non-eligible non-metropolitan municipalities. The *y-axis* corresponds to the difference between the situation of police that were armed or unarmed in 2002 and the situation of the same police after 2002. The transition is constructed by comparing two indicator variables of the armed status. The initial indicator variable assumes the value equals one if a municipality had an armed local police force in 2002. The final indicator variable assumes the value equals one if the municipality had a local armed police force in at least one of the years

[10] See Ferreira, Mattos, and Terra (2016) on the importance of municipal police in criminology.

Table 2
Transition Matrix of Firearm use by Non-Metropolitan Municipalities with Municipal Police in 2002 (Brazil).

		Before the law (2002)	After the law (2004, 2006, 2009, and 2012)		
		With Municipal Police	With Municipal Police		Without Municipal Police all years
Eligible	With firearms	22	8	At least one year without firearms	0
			14	All years with firearms	
	Without firearms	140	37	At least once with firearms	8
			95	All years without firearms	
Non-Eligible	With firearms	22	9	At least one year without firearms	0
			13	All years with firearms	
	Without firearms	634	31	At least one year with firearms	147
			456	All years without firearms	
Total of Municipalities		818	663		155

Note: Eligible municipalities have more than 50,000 inhabitants (the 2000 population) and zero otherwise. "After the law" considers only the municipalities for which we have information for at least one year (i.e., municipalities with municipal police for at the least one year after 2002).

Table 3
Descriptive statistics (non-metropolitan areas).

	All municipalities (2002, 2004, 2006, 2009, and 2012)				Non-metropolitan municipalities							
					With Firearmed Police in at least one year (2002, 2004, 2006, 2009, and 2012)				Without Firearmed Police in all years (2002, 2004, 2006, 2009, and 2012)			
	Av.	Sd.	Min.	Max.	Av.	Sd.	Min.	Max.	Av.	Sd.	Min.	Max.
The Brazilian National Hospital Report												
Homicides per 100,000 inhabitants	21.23	15.70	0	351.06	17.33	22.71	0	273.87	19.97	19.60	0	194.18
Acts of aggression per 100,000 inhabitants	21.23	16.62	0	351.06	18.86	22.93	0	273.87	21.24	19.68	0	194.18
Municipal Controls												
Percentage of individuals with graduate college education in the total population	0.03	0.03	0	0.33	0.03	0.02	0	0.34	0.03	0.03	0	0.33
Percentage of population between 15 and 29 years old in the total current municipal population	0.26	0.01	0.19	0.31	0.27	0.01	0.19	0.34	0.27	0.01	0.21	0.35
The current municipal population	130,574.4	153,669.30	1922	619,746	108,939.5	124,879	1922	643,603	43,171.42	52,944.42	2415	472,300
Municipal per capita GDP	14.14	14.82	3.87	116.54	9.42	9.32	0.88	643,603	5,07	7.75	0.62	111.90
Unconditional federal transfer (FPM)	1.11e+07	6,326,113	1,803,010	2.50e+07	1.20e+07	1.15e+07	0	1.17e+08	6,874,472	8,545,429	0	1.86e+08

between 2004 and 2012. The transition variable is obtained from the difference between these two final and initial indicator variables of armed status. The next two sets of figures show the differences between eligible and non-eligible non-metropolitan municipalities for homicides and acts of aggression, respectively. The *y-axis* of each figure corresponds to the difference between homicides (acts of aggression) before implementation of the law (2002) and the average of these same variables after implementation of the law (2004–2012).

Fig. 1 shows the existence of a discontinuity near 50,000 inhabitants. There was an increase in the proportion of armed police in municipalities with just over 50,000 inhabitants compared with municipalities with just under 50,000 inhabitants (Brazil and São Paulo State). Likewise, there was a decrease in violence (homicides and acts of aggression) in municipalities with just over 50,000 inhabitants compared with municipalities with just under 50,000 inhabitants (Brazil and São Paulo State).

5. Empirical strategy

The challenge in estimating the causal effects on crime outcomes of the police carrying firearms is, as mentioned, solving the potential endogeneity of firearms and crime: omitted bias and reverse causality. The main challenge of this exercise, therefore, is to credibly find an exogenous variation in firearm possession by the police. The Brazilian natural experiment in the 2000s provides this opportunity. We explore the change in the federal law at the end of 2003 that regulated the carrying of firearms by the local police as a source of exogenous variation. We use a fuzzy RD design to address these problems.

5.1. Fuzzy regression discontinuity design (RDD)

Population size in the year 2000 was used as a running variable with a threshold value of 50,000 inhabitants (as defined by legislation). We use the population eligibility criterion as an excluded instrument and apply

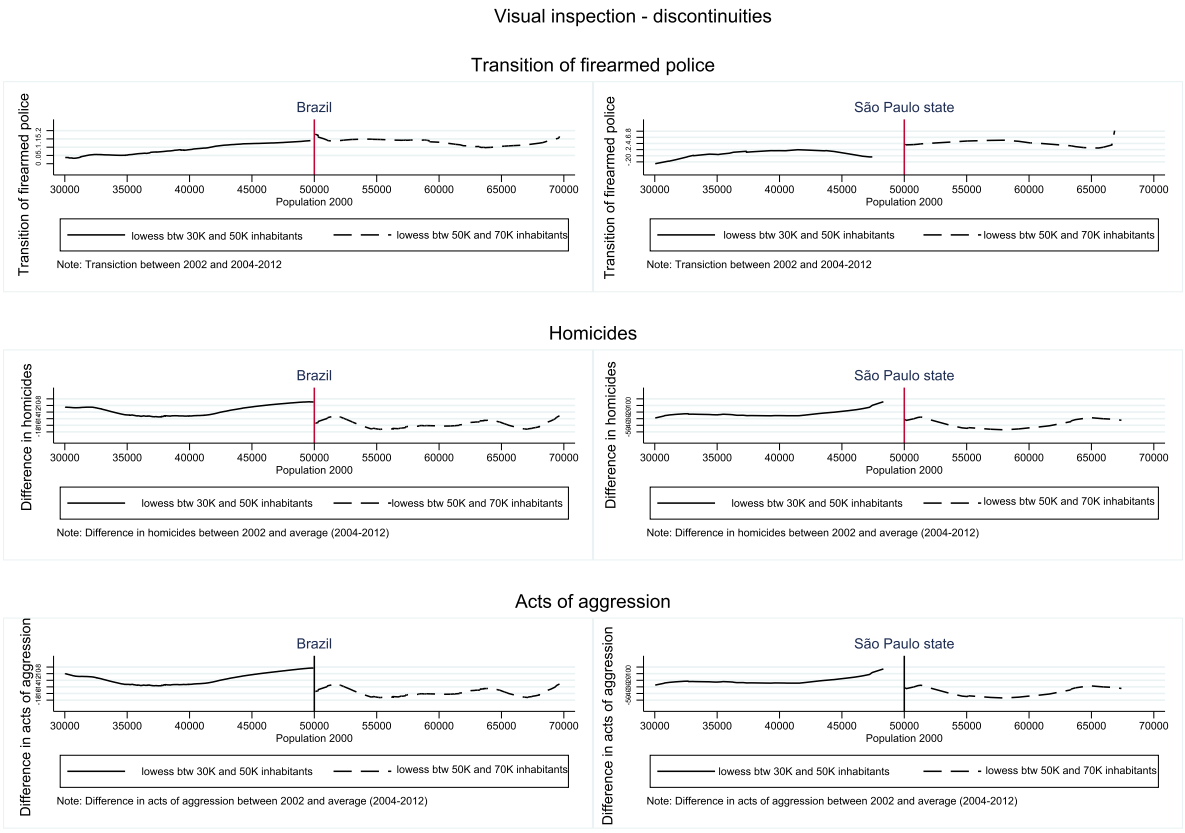

Fig. 1. Visual inspection - discontinuities.

the instrumental variable approach to estimate the effect of the use of firearms by the police on crime outcomes.

We formally estimate the following system of equations. The first-stage regression is as follows:

$$G_{mt} = \alpha_0 + \alpha_1 1(pop_{m2000} \geq 50)_m * 1(post\ law)_t + \sum_t \lambda_t T_t + g(pop_{m2000}; T_t) + \sum_b \gamma_b P^b_{mt} + \varphi' \boldsymbol{X}_{mt} + \rho_m + \epsilon_{mt} \quad (3)$$

where G_{mt} is an indicator variable that assumes that the value equals one if the local police in municipality m used firearms in year t (and zero, otherwise), $1(pop_{m2000} \geq 50)_m$ is an indicator variable that assumes that the value equals one if municipality m has equal to or more than 50,000 inhabitants in the year 2000 (and zero otherwise)[11]; $1(post\ law)_t$ is an indicator variable that assumes that the value equals one if the period is after 2002, i.e., the post-legislation period (and zero otherwise); T_t is the year t dummy variable (the increase in the requirement for individuals who wish to purchase a gun and banned civilians from carrying guns by a change in the law is controlled with dummy time variables: they capture the homogenous effect which affects all municipalities); $g(pop_{m2000}; T_t)$ is a function of the running variable and the year dummies; P^b_{mt} is an indicator variable that assumes that the value equals one if municipality m has a population size within the range of bracket b in year t. The brackets are defined by the cut-off values used for federal transfers to the municipalities; $\boldsymbol{X}_{mt}$ is a set of time-varying municipality controls. These controls are as follows: the values of unconditional federal transfers to municipality m in year t; the current population in year t; the percentage of individuals with a graduate college education in the total population of municipality m in year t; the percentage of 15 to 29-year-old individuals in the total population of municipality m in year t; the municipal per capita GDP; ρ_m is the municipality fixed effect (it may capture non-observable differences in the application of the federal law on crimes in municipalities, differences in work coordination between the different police forces – federal, state, and municipal - present in municipalities, and non-observable characteristics of the local judiciary); and ε_{mt} is the error term.

Different states can have different rules and practices concerning assigning state police to the municipalities. We do not have full information about the distribution of the state police across municipalities. We know that the State of São Paulo, the richest and most populous in the country, has clear rules on the distribution of military police across localities (dispatch 004/322/2003 from the general commander of the Military Police). The rules are essentially based on population distribution. We have no information about the distribution of the federal police.

The specifications of the function $g(.)$ allows for different functional forms. Specifically, we use two different specifications as follows:

$$g() = \begin{cases} \sum_t \tau_t\ pop_{m2000} * T_t\ (4.a) \\ \sum_t \tau_t\ pop_{m2000} * T_t\ + \sum_t \theta_t\ (pop_{m2000})^2 * T_t\ (4.b) \end{cases} \quad (4)$$

The first eq. (4.a) is the linear specification and the second eq. (4.b) is the quadratic specification.

The second-stage regression is as follows:

$$VC_{mt} = \beta_0 + \beta_1 G_{mt} + \sum_t \rho_t T_t + g(pop_{m2000}; T_t) + \sum_b \vartheta_b P^b_{mt} + \varphi' \boldsymbol{X}_{mt} + \mu_m + \omega_{mt} \quad (5)$$

VC_{mt} are violent crimes in municipality m in year t; μ_m is the municipality fixed effect and ω_{mt} is the error term.

[11] The law establishes the year 2000 as the reference year for the immediate effect of the law. The year 2000 was a population census year.

The parameter of interest is β_1. The parameters of equations (3) and (5) with the different functional forms of (4) are estimated using a two-stage, least squares estimation in which the (potentially endogenous) firearm use variable G_{mt} is instrumented by the instrumental variable $1(pop_{m2000} \geq 50)_m * 1(post\ law)_t$. The instrumental variable captures the eligibility criterion of the law that allows all non-metropolitan municipalities with a population equal to or greater than 50,000 inhabitants (measured by the 2000 population census) to have municipal police who carry firearms after 2003. Note that because we control for the municipality fixed effect and because of the interactions of the 2000 municipal population and year dummies, our strategy can be interpreted as changes in crime rates near the cut-off population value of 50,000 inhabitants. Our identification assumption is that (since we control for other variables) the eligibility criterion directly affects the probability that a municipality has a change in status with regard to having local police who carry firearms and does not directly affect changes in local crime outcomes. The correlation between the population eligibility criterion and crimes involving the use of firearms is for local police only (armed or not).

We believe this assumption is plausible given the additional controls we use. We control for year fixed effects and municipality fixed effects that are entirely collinear with population levels in year 2000. We control for the interactions of population levels in 2000 and the year fixed effects, current municipal population levels and current proportions of young adults in municipal populations. We also control with dummy variables the population brackets that the federal government uses to regulate the values of the yearly unconditional federal transfers to municipalities. The discontinuity of the value transfers associated with population size can potentially be confounded by the discontinuity that is driven by the law that we use as an instrument.[12] We also control for the values of the unconditional federal transfers. Thus, the effect of the population eligibility criterion on the probability of a change in firearm use by the local police is an effect over and above the direct effects of the population in the year 2000 and the current population on current crime outcomes. This effect is likely to have been driven by the change in the law. The effect can be interpreted as a local average treatment effect (near the cut-off value of 50,000 inhabitants), in which the effect of firearm use is estimated for those municipalities that began to arm their local police force because of the law.[13]

Since there is a large number of municipalities with zero homicides and acts of aggression (see Fig. A3 in the online appendix), we also decided to show the second-stage results using Poisson (a nonlinear estimate) following the methodology established by Lin and Wooldridge (2019): Poisson with a control function.

6. Results

We present our main estimated results in this section. We highlight the results of three different samples of non-metropolitan municipalities by population bandwidths in 2000: between 40,000 and 60,000 inhabitants; between 10,000 and 200,000 inhabitants; and the full sample. Because there is a trade-off between small bandwidths (lower power and higher RD validity) and large bandwidths (higher power and lower RD validity), we performed the exercises for all these different samples to verify the overall robustness of the findings.

Table 4 shows the results for Brazil using the parametric RD strategy as specified in equations (3)–(5). All the main empirical results are shown with the functional form of eq. (4.a). The result with the functional forms (4.b) is shown as robustness in Table A5 in the online appendix; the results are very similar. We present two types of second-stage parametric result: linear results (columns 1–6) and nonlinear results (columns 7–12; Poisson with a control function).

The first-stage regression (linear) results show that the point estimates are in the expected direction in all samples. Being eligible to have a municipal police force bearing firearms increases the probability that a municipality's local police will carry firearms by between 12 (0.122) and 16 (0.159) percentage points. The eligibility results for different sample sizes are robust.

The second-stage point estimate results reveal the positive effect (negative signal) of armed police (compared to unarmed police) on homicides and acts of aggression in Brazil. In fact, in the linear results, having an armed municipal police force, can reduce the homicide rate between 83.57 and 123.75 per 100,000 inhabitants (acts of aggression between 122.69 and 158.34).

Altogether, these results point to the strongly negative effect that police carrying firearms has on the number of homicides and acts of aggression. The homicide rate distribution across municipalities with municipal police in non-metropolitan areas in 2002 ranges from 0 to 195.8 homicides per 100,000 inhabitants (the second result is average for the 99th percentile), as shown in Fig. A4 in the online appendix. Reducing this rate by approximately 84 per 100,000 inhabitants roughly corresponds to moving a municipality from the top percentile (99th) to the 95th-99thpercentile: 117 homicides. The same exercise with a reduction of approximately 124 homicides per 100,000 inhabitants moves the municipality to another percentile (90th-95th: 77.6). Likewise, a reduction of 122 acts of aggression per 100,000 inhabitants corresponds to moving a municipality from the top percentile (99th) to the 90th-95thpercentile: 78 acts of aggression.

On the other hand, the nonlinear results are lower (the coefficient represents the incident rate ratio). Municipalities having armed police have between 0.005 and 0.019 fewer homicides per 100,000 inhabitants than those in which the municipal police do not carry arms (acts of aggression between 0.006 and 0.023 fewer). This represents between 0.5% and 1.9% fewer homicides if the municipal police are armed. We worked with this more conservative estimate.

We re-estimated this same exercise using different cut-off values as a robustness test to check whether any other discontinuities are correlated with the transition to a locally armed police force (Table A2 in the online appendix). We performed two exercises. In the first, we used two cut-off values: 20,000 and 30,000 inhabitants, and a restricted sample of non-metropolitan municipalities with fewer than 50,000 inhabitants. In the second, we used two cut-off values: 200,000 and 300,000 inhabitants, and a restricted sample of non-metropolitan municipalities with more than 50,000 inhabitants. It is possible to observe that the discontinuity does not exist at these four (fake) cut-offs levels. These results show that there is no other confounding discontinuity and that the discontinuity observed at the 50,000 threshold captures the effect of the law.

7. Mechanisms

At least two potential non-excluding mechanisms exist - incapacitation and deterrence – that can explain the difference in violent crimes between municipalities in which the police either carry or do not carry firearms. We try to track both.

[12] The *Complementary Law no. 91/1997* and the *Supplementary Law no. 106/2001* establish the rules for the unconditional federal transfers to the municipalities. The amount of the transfers is a function of the municipalities' population size. The population brackets established in the law are as follows: up to 10,188; 10,189–13,584; 13,585–16,980; 16,981–23,772; 23,773–30,564; 30,565–37,356; 37,357–44,148; 44,149–50,940; 50,941–61,128; 61,129–71,316; 71,317–81,504; 81,505–91,692; 91,693–101,880; 101.881–115,464; 115,465–129,048; 120,049–142,632; 142,633–156,216; and above 156,216. Eggers et al. (2017) develop arguments about the need to consider population rules.

[13] We performed McCrary tests on the discontinuity of the density functions at the cut-off value of 50,000 inhabitants for each year of the sample (Eggers et al., 2017). They are presented in fig. A5 in the online appendix. We do not find any discontinuity of the densities at this cut-off level. The results suggest that there is no population manipulation related to the change in the law.

Table 4
Brazil – Non-metropolitan municipalities with police – Regression Discontinuity.

	The Brazilian National Hospital Report											
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	Homicides	Aggression	Homicides	Aggression	Homicides	Aggression	Homicides	Aggression	Homicides	Aggression	Homicides	Aggression
	Different population brackets						Different population brackets					
	BTW 40,000 and 60,000		*BTW 10,000 and 200,000*		*Full Sample*		*BTW 40,000 and 60,000*		*BTW 10,000 and 200,000*		*Full Sample*	
	Brazil						*Brazil*					
	SECOND-STAGE						*SECOND-STAGE*					
	IV-FE						*POISSON with control function*					
							The coefficient represents the incident rate ratio [(1)]					
Is there a municipal police force with firearms? (vs. without firearms)	−83.573*	−158.342*	−119.496***	−122.692***	−123.755***	−128.772***	0.005***	0.006***	0.019***	0.023***	0.019***	0.022***
	(69.438)	(83.638)	(27.698)	(28.258)	(28.846)	(29.179)	(0.005)	(0.006)	(0.007)	(0.007)	(0.006)	(0.007)
Control Function Wald statistic							20.82***	21.36***	89.10***	109.99***	99.53***	118.78***
	FIRST-STAGE for The MUNICIPAL POLICE with FIREARMS						*FIRST-STAGE for The MUNICIPAL POLICE with FIREARMS*					
Municipality has more than 50,000 inhabitants?$_{2000}$*After 2004 (2004/2006/2009/2012)	0.122**		0.159***		0.159***		0.122**		0.158***		0.159***	
	(0.063)		(0.034)		(0.033)		(0.048)		(0.022)		(0.020)	
Year Fixed Effects?	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Municipal Fixed Effects?	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Municipal controls?	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
F-statistic (First-Stage)	F (1,79)	3.70*	F (1,677)	20.83***	F (1,848)	22.26***						
Observations	316		2536		3079		316		2536		3079	
Number of municipalities	80		678		849		80		678		849	

Note: Standard errors are presented in parentheses and are clustered at the municipal level; t-statistic: *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. **Municipal controls:** Percentage of population between 15 and 29 years old in the total current municipal population; Percentage of individuals with graduate college education in the total population; the current municipal population; Municipal per capita GDP; and Unconditional Federal Transfer (FPM), the 2000 municipal population*Year Fixed Effects; and Dummies for each bracket of population (established by the FPM law). (1) We follow the procedures for control function established in Lin and Wooldridge (2019); We included the residual from the first-stage for the municipal police with firearms in the Poisson estimation; We reported standard errors corrected; z-statistic.

Table 5
Police Efforts and Deterrence - São Paulo - Non-metropolitan municipalities with police – Regression Discontinuity – Parametric Results.

	The São Paulo Police State Report					
	(1)	(2)	(3)	(4)	(5)	(6)
	Full Sample					
	Police Efforts					Deterrence
	Total number of inquiries	Number of individuals over 18 years arrested in flagrant criminal behavior	Seizure of narcotics	Vehicles recovered	Number of arrests	Seizure of firearms
	REGRESSION DISCONTINUITY – PARAMETRIC RESULTS					
	SECOND-STAGE					
	IV-FE					
Is there a municipal police force with firearms? (vs. without firearms)	1297.419*** (401.152)	379.626*** (124.699)	36.125** (18.271)	338.739** (139.980)	562.300*** (188.302)	−108.577** (43.936)
	FIRST-STAGE for The MUNICIPAL POLICE with FIREARMS					
Municipality has more than 50,000 inhabitants?$_{2000}$*After 2004 (2004/2006/2009/2012)		0.261*** (0.056)				0.261*** (0.056)
Year Fixed Effects?	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Municipal Fixed Effects?	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
Municipal controls?	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*	*Yes*
F-statistic (First-Stage)		21.21***				21.21***
Observations		733				733
Number of municipalities		171				171

Note: Standard robust are presented in parentheses and are clustered at the municipal level, t-statistic test; *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. **Municipal controls:** Percentage of population between 15 and 29 years old in the total current municipal population; Percentage of individuals with graduate college education in the total population; the current municipal population; Municipal per capita GDP; and Unconditional Federal Transfer (FPM), the 2000 municipal population*Year Fixed Effects; and Dummies for each bracket of population (established by the FPM law).

7.1. Incapacitation: police efforts

We constructed the police effort indicators for each municipality in the State of São Paulo that we used in our sample for the years 2002, 2004, 2006, 2009 and 2012. All indicators are measured per 100,000 inhabitants. The indicators are as follows: the total number of inquiries, the number of individuals over 18 years old arrested for flagrant criminal behavior, the seizure of narcotics, the number of vehicles recovered and the number of arrests (flagrant or judge-ordered). We used these indicators as dependent variables (columns 1 to 5) in the parametric RD strategy. Table 5 presents the results.

The first-stage regression (bottom of the table) is a little higher than those for Brazil: 0.261 in Table 4. Conversely, the second-stage regression results are all positive (linear results). Municipalities that arm their police (compared with municipalities that do not arm them) exhibit an increase in the number of: inquiries (1297.42); adults arrested because of flagrant behavior (379.62); seizures of narcotics (36.125); vehicles recovered (338.74) and; arrests (562.30) per 100,000 inhabitants. Thus, the São Paulo State police achieve better results when they use new equipment (firearms).

7.2. Deterrence effects: the use of firearms by potential offenders

As mentioned in the institutional background section, the Statute of Disarmament also increased the penalty for civilians illegally carrying firearms to between one- and six-years imprisonment (Articles 12, 14, and 16 of the Statute of Disarmament, Law No.10,826). Because the same statute allowed municipalities with 50,000 or more inhabitants to have a local police force carrying firearms, the probability of an individual being arrested for carrying a firearm increased. Although we know that the penalty for civilians caught carrying a firearm affects all municipalities (it is homogeneous for municipalities that have either armed police, or unarmed police, and for those that have no police), in principle a potential criminal might react differently. On the one hand, potential offenders might reduce their use of firearms in order to reduce their expected punishment (Becker, 1968; Loughran et al., 2016; Bove and Gavrilova, 2017; Harris et al., 2017), while on the other, potential offenders might increase their use of firearms in order to confront a better-equipped police force.

We have no data on offenders carrying weapons to enable us undertake a direct investigation.[14] We do, however, have municipal data on the total number of firearms seized by the police in the State of São Paulo. We investigated the effect on the seizure of firearms, again using the parametric RD strategy. The results are presented in the same Table 5 (column 6). The linear result shows that there are fewer firearm seizures in 'treated' municipalities compared with 'non-treated' municipalities (108.57 per 100,000 inhabitants). We can interpret this result as the net effect of the change in behavior of both the police and offenders. This result, together with the previous result of more effort being exerted by the police, suggests that potential criminals might have reduced their use of firearms.

7.3. Deterrence effects: Investigating spillovers[15]

To estimate the spillover effect, we constructed new samples for Brazil to include neighboring municipalities. The first sample, the (new) treated municipalities, is the non-metropolitan municipalities that did

[14] There is evidence of an increased relative scarcity of firearms. In total, 1,885,910 firearms were removed from circulation and destroyed by the Army between 1997 and 2008. Additionally, gun sales reduced by 90% (from 2000 to 2008). The practical effect of the reduction in the supply of weapons was their increased cost on the illegal market. Before the statute, the cost of a 9 mm pistol in São Paulo was at least R$ 800 (the Real is the Brazilian currency), and in 2008, the cost was R$1300; in Rio de Janeiro, an automatic shotgun was sold for US$6,000, and in 2008, the cost was between US$ 30,000–40,000 (information mentioned in Implementing Brazil's "Disarmament Statute": Putting Law into Practice, 2010).

[15] Spillover effects are used in "hot spot" and problem-oriented policing studies (see Chalfin and McCrary, 2012).

Table 6
Deterrence – Difference of spillovers between neighbors – Regression Discontinuity – Parametric Results.

	The Brazilian National Hospital Report			
	Full Sample			
	Neighbors of municipality with firearmed police			
	Non-coincidence of years (2002–2012)		Coincidence of years (2002–2012)	
	The situation described below may not occur in the same year		The situation described below occurs in the same year	
	Treatment: municipality can or not have police but never armed			
	Control: municipality has police ever non-armed			
	(1)	(2)	(3)	(4)
	Homicides	Aggression	Homicides	Aggression
	REGRESSION DISCONTINUITY – PARAMETRIC RESULTS			
	SECOND-STAGE			
	IV-FE			
Is there a neighboring municipal may or not have police (never armed)?	−37.226***	−36.254***	−28.614***	−27.691***
	(7.721)	(7.727)	(8.590)	(8.585)
FIRST-STAGE for The MUNICIPAL POLICE with FIREARMS				
Municipality has more than 50,000 inhabitants?$_{2000}$*After 2004 (2004/2006/2009/2012)	0.422***		0.448***	
	(0.054)		(0.077)	
Year Fixed Effects?	*Yes*	*Yes*	*Yes*	*Yes*
Municipal Fixed Effects?	*Yes*	*Yes*	*Yes*	*Yes*
Municipal controls?	*Yes*	*Yes*	*Yes*	*Yes*
F-statistic (First-Stage)	60.13***		33.84***	
Number of municipalities	48		35	
Observations of municipalities that can have firearms at any time	804		569	

Note: Standard errors are presented in parentheses and are clustered at the municipal level, t-statistic test; *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. **Municipal controls:** Percentage of population between 15 and 29 years old in the total current municipal population; Percentage of individuals with graduate college education in the total population; the current municipal population; the Municipal Current Population; Municipal per capita GDP; and Unconditional Federal Transfer (FPM), the 2000 municipal population*Year Fixed Effects; and Dummies for each bracket of population (established by the FPM law).

not have an armed police force between 2002 and 2012, but were neighbors of a municipality whose local police force was armed in at least one of the years between 2002 and 2012. The comparison group is composed of municipalities that are a neighbor of a municipality with armed police and that had a municipal police force in at least one of the years between 2002 and 2012 that was not armed. We chose this comparison group so that we could directly compare the spillover results with the main results. Note that our treatment and comparison groups are formed by municipalities that have never had an armed local police force. We restricted the second sample to municipalities that have never armed their local police, but that are neighbors of a municipality whose police force was armed in at least one of the study years. The treated municipality in a given year is a municipality that is a neighbor of a municipality whose police were armed in the same year. The control in a given year is the municipality that is a neighbor of a municipality whose police were armed in that same year. Because the status of having armed police changes over time, being treated or control changes with time. Table 6 shows the results for Brazil using our main empirical strategy (the parametric RD strategy).

Columns 1 and 2 are the results using the first sample, while columns 3 and 4 show the results using the second sample. The first-stage regression of the RD strategy refers to the indicator variable, which equals one if the municipality has a neighboring municipality with an armed local police force in year *t*, and zero otherwise. The instrumental variables and additional controls refer to the neighboring municipality with an armed police force in the case of the treatment group. As expected, the first-stage result is positive with a *p-value* < 0.01. Eligible municipalities are more likely to have an armed local police force.

In the first sample, the second-stage linear regression results show a decrease in the rates of homicide and acts of aggression. The results have a *p-value* < 0.01. In a municipality that may or may not have a police force (always unarmed) there is a decrease in its homicide (aggression) rate by 37.22 homicides (36.25; acts of aggression) per 100,000 inhabitants because its neighbor has an armed police force due to the change in the law. The results of the second sample are qualitatively the same, but the impact is lower.

We did the same exercise with the sample for São Paulo State (see Table A4 in the online appendix). For the first sample design, the result is qualitatively the same, except for its non-significance (homicides have a *p-value* < 0.10). The second sample design is for neighbors, but since there are few municipalities (a lack of power in the results), it is impossible to draw any conclusion from the results.

These results suggest that there is no positive spillover effect; in fact, we find negative spillover effects for Brazil (and one result of two for São Paulo state). These results reinforce the plausibility of incapacitation being the main mechanism for explaining the decrease in violent crime rates due to the police force's use of firearms.

8. Additional robustness check: heterogenous police manpower

Our exercises use the indicator variable for armed local police as a dichotomous variable that assumes a value equal to one if the local police bear firearms in year *t*, and zero otherwise. However, it is possible that the local police's choice to use firearms, and the number of police officers are jointly determined. We can imagine that once a municipality is eligible to have an armed local police force, it might change the number of local police officers (police manpower). Established evidence shows that a greater presence of police officers reduces the incidence of crime. Not controlling for the number of police officers, therefore, might introduce bias into our results. To check this possibility, we performed

Table 7
Heterogeneous Police Manpower – Non-metropolitan municipalities with police – Regression Discontinuity – Parametric Results.

	The Brazilian National Hospital Report	
	Full Sample	
	(1)	(2)
	Homicides	Aggression
	REGRESSION DISCONTINUITY – PARAMETRIC RESULTS	
	IV-FE	
	SECOND-STAGE	
Is there a municipal police force with firearms?	−118.793***	−123.553***
	(18.031)	(18.455)
Police manpower	−0.023	−0.027
	(0.022)	(0.022)
	FIRST-STAGE for The MUNICIPAL POLICE with FIREARMS	
Municipality has more than 50,000 inhabitants?$_{2000}$*After 2004 (2004/2006/2009/2012)	0.165***	
	(0.020)	
Year Fixed Effects?	*Yes*	*Yes*
Municipal Fixed Effects?	*Yes*	*Yes*
Municipal controls?	*Yes*	*Yes*
F-statistic (First-Stage)	62.55***	
Observations	3004	
Number of municipalities	839	

Note: Standard errors are presented in parentheses and are clustered at the municipal level, t-statistic test; *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. **Municipal controls:** Percentage of population between 15 and 29 years old in the total current municipal population; Percentage of individuals with graduate college education in the total population; the current municipal population; Municipal per capita GDP; and Unconditional Federal Transfer (FPM), the 2000 municipal population*Year Fixed Effects; and Dummies for each bracket of population (established by the FPM law).

the same exercises for our main sample, adding the number of municipal police officers reported by the municipalities as a control. Table 7 presents the results.

The linear results of Table 7 are similar to our main results. After the presence of municipal police manpower was controlled, we found similar magnitudes for the effect of armed police on a reduction in violent crime.

9. Conclusions

We estimated the effect of armed police on violent crime using a quasi-natural experiment in Brazil. In 2003, Brazilian legislators approved a law that regulated the use of firearms by municipal police. The law established that non-metropolitan municipalities with 50,000 or more inhabitants are allowed to have a local police force that carries firearms. We used the discontinuity of the population eligibility criterion as a source of exogenous variation of firearm possession to determine the treatment status. We used a parametric RD methodology and found that non-metropolitan municipalities with a local police force that is armed show a significant reduction in violent crime (homicides and acts of aggression).

There are at least two reasons why these findings contribute to the literature. First, the study adds to findings on the effect on crime of the use of equipment by the police. The introduction of new police strategies, such as "hot spots" and "problem-oriented policing", has recently been investigated (see Chalfin and McCrary, 2017). These strategies have been found to reduce criminality. No investigation has ever been carried out and documented in literature, however, comparing the effect on violent crimes of having armed police: whether homicides and/or acts of aggression reduce as a consequence. If we consider the arms that are common to any police force in the world, and the equivalent in military equipment, we found robust evidence of the effects of the police carrying arms that was not found in the literature dealing with (de)militarization (Bove and Gavrilova, 2017; Harris et al., 2017; Olugbenga, 2017; Lowande, 2020). Authorities in several countries in the world question whether their police should carry firearms or not. Our investigation is a positive answer to attempts by the police to introduce new equipment as the solution for violent crimes: there is a reduction in homicides and acts of aggression. Second, we obtain evidence in the main channel that might suggest an explanation for our findings (Chalfin and McCrary, 2017): incapacitation. We also investigate the expansion of violent crimes in municipalities that are neighbors of municipalities in which the police are armed, and we observe no deterrence effect.

Most of the quasi-experimental exercises are in a specific locality or city and therefore have less external validity (e.g., Di Tella and Schargrodsky, 2004; Draca et al., 2011; Adda et al., 2014). Our quasi-natural experiment is for a group of small and medium-sized cities outside metropolitan areas, which provides it with greater external validity that can help in the application of a generalized policy design.

Some caveats are worth mentioning. First, our exercises compare municipalities with an armed municipal police force with municipalities with an unarmed municipal police force. The results, therefore, are conditional upon municipalities having a municipal police force. There are two choices. First, the municipality chooses whether to have (or not have) a municipal police force. Second, the municipality has the (restricted) choice of having (or not having) an armed municipal police force. We can address the potential endogeneity problem of the second choice, but we do not address the first choice. Our results should be interpreted as the effect of armed police in those municipalities that choose to have a municipal police force.

Second, we use the population eligibility criterion in the parametric RD strategy as an instrumental variable for the possession of firearms. Thus, the results are the local average treatment effects in those municipalities that introduced an armed local police force due to the change in the law and that have population sizes near the cut-off value of 50,000 inhabitants (small and mid-sized non-metropolitan municipalities).

Third, like previous studies on police presence, our study tries to disentangle the effects of incapacitation or deterrence on reductions in crime. Correct identification of these mechanisms is one of main challenges of criminology literature (Chalfin and McCrary, 2017). We find negative spillover effects in neighboring municipalities. Municipalities that are neighbors of municipalities that started to arm their local police show a greater reduction in crime rates than unarmed municipalities, all of whose neighbors have armed local police forces in Brazil. Without fully ruling out other deterrence mechanisms, the results suggest that the incapacitation mechanism plays a role in reducing crime.

Declaration of competing interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.econmod.2022.105825.

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