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Law enforcement and illegal markets

Evidence from the regulation of junkyards in Brazil

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Abstract: I describe how monitoring and harsher law enforcement reduce the expected economic benefits of crime. I investigate the effect of shifts in legal authorities' surveillance by focusing on junkyards, firms often associated with illegal markets and auto theft. Starting in 2014, many municipalities in Brazil increased the monitoring of spare parts sold by junkyards through new regulations at the state level. I show that levels of auto theft dropped significantly after introduction of the new law, and this decrease is more extensive in neighbourhoods containing junkyards. Municipalities that implemented the new regulation presented, on average, a 6.4 per cent drop in auto thefts by year compared to non-target ones. Other crimes do not show a similar decrease, and there is no evidence of a previous downward trend in vehicles stolen. My results shed some light on the effect of harsher supervision over a market that criminals may exploit to convert stolen vehicles into cash.

Key words: law enforcement, state-level regulations, illegal markets, economic benefits of crime

JEL classification: K40, K42, D04, C23

Note: As the research is part of the author's PhD thesis, he will hold copyright to facilitate its publication.

1   Introduction

Despite the anecdotal evidence regarding markets for stolen goods and criminal gangs, there are few studies focused on the interplay between these firms and crime. Criminals exploit difficulties in distinguishing between legal and illegal products as an opportunity to convert stolen goods into cash. In a context in which consumers demand these items, and there is no punishment for sellers and buyers of products obtained illegally, some firms may choose illegal suppliers to reach the maximum profits possible. Therefore, it is possible that increasing barriers to illegal products may affect the expected returns of criminals (Becker 1968). More precisely, harsher law enforcement and supervision of these markets would lower the rents from illegal activities, reducing the incentives to commit some crimes such as robbery and theft, given the increased difficulty converting stolen items into money. In this paper, I investigate the causal effect of new regulations on junkyards. More specifically, I focus on the harsher supervision of these firms following the introduction of state and federal laws that imposed strict rules on sale of recovered spare parts from crashed and apprehended vehicles. Improvements in the regulation and monitoring of junkyards imposed a higher cost on collusive agreements between criminals and junkyards. In this context, harsher law enforcement on junkyards may have reduced the expected returns of criminals by increasing the cost of operating in the illegal market for spare parts. I collect auto-theft data from different states in Brazil from 2011 to 2019 and exploit differences in the timing of approval of new regulations on junkyards across municipalities as a quasi-experiment to assess the causal effect of law enforcement on auto theft. The federal government allowed each state to decide how and when to implement the traceability of items sold by junkyards. Even after implementing the regulation, the monitoring of junkyards differed significantly across states. The state of São Paulo created a sophisticated system demanding the use of QR codes in each spare part negotiated by a junkyard. In contrast, the state of Rio Grande do Sul focused primarily on registering which junkyards could acquire vehicles in public auctions, without creating proper supervision of items sold by these firms. Last, some states, such as Rio de Janeiro, still do not implement the requirements imposed by the federal law. I exploit these differences in compliance with the law to shed more light on the mechanisms driving the effect of monitoring junkyards on auto theft.

I find evidence that municipalities that adopted harsher supervision of junkyards saw 6.4 per cent fewer vehicles stolen per year than those that did not implement the law.[1] The auto-theft reduction is heterogeneous across states, and the effect is twice as significant in São Paulo municipalities than in Rio Grande do Sul. Further, event-study estimates show that the effect of law enforcement increases over time, and the drop in robberies is more significant 2–3 years after the junkyard regulations are implemented. The more significant decrease in auto theft in São Paulo seems directly related to the system created to track spare parts sold by junkyards. Moreover, these findings show that it takes some time for the law to promote a persistent reduction in vehicles robbed, which indicates that criminals do not respond immediately to the new regulation. My results are consistent with the hypothesis that monitoring capabilities are a relevant instrument in the effectiveness of the law. When legal authorities start enforcing the regulation through inspections and punishment of non-complier junkyards, criminals gradually face more restrictions in the performance of illegal transactions using stolen vehicles and probably move on to other activities or states.

Next, I test if the junkyard location is relevant to the drop in auto theft after the introduction of the law. I geolocate junkyards and occurrences of vehicles robbed in the municipality of São Paulo to estimate which areas show a more significant decrease in auto theft after increasing the supervision of dismantling firms. Driving a stolen car for long distances increases the risk of encountering a police officer. Therefore, to reduce the probability of apprehension, criminals who steal cars and sell them to

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[1] In the remainder of the paper *robbery* of vehicles refers to cars taken using violence and *theft* of vehicles to cars taken without the use of violence.

junkyards may prefer to stay closer to the firms where they deliver the stolen vehicle. In this approach, counterfactual districts are those far from junkyards that should not show significant changes in vehicles robbed, given the long distance to the closest junkyards. Despite the significant decrease in vehicles robbed in all districts of São Paulo, I find evidence that the drop in auto theft is still more significant in neighbourhoods with a junkyard within 200 metres. These results highlight a high incidence of vehicles robbed closer to junkyards. However, this finding must be interpreted cautiously because I only obtained data about junkyards formally registered in the Federal Taxes Authority database, and some firms that acquire stolen vehicles from criminals may not be formal companies. In this case, I would only capture part of all possible junkyards of São Paulo.

To enhance the validity of my results, I run several robustness checks. First, event-study estimates show no previous downward trend in vehicles robbed in municipalities that increased the supervision of junkyards. My estimates capture a specific reduction in vehicles robbed instead of a general decrease in violence in municipalities that approved the regulation. Second, I show that the decrease in auto theft is more significant in municipalities that contain at least one junkyard, reinforcing the relevance of these firms to my identification strategy. Third, I present falsification tests using homicides and other robberies as dependent variables. I find no evidence of a contemporaneous decrease in violent crimes following the new regulation on junkyards. Therefore, I present compelling evidence that other crimes did not change significantly following harsher supervision of junkyards, and there was no displacement of offences to other robberies, which suggests the law's effectiveness in reducing criminality.

Last, I present two robustness tests of the relevance of junkyards' location on the dynamic of vehicles robbed. First, I exploit the effect of the new regulation near junkyards closed after the introduction of the law. Firms that face difficulties complying with the new legal requirements and monitoring are arguably better candidates to estimate the effect of harsher law enforcement. My results show that auto theft decreased 70 per cent more in districts near junkyards closed after the introduction of the law compared to the results considering all firms. Although I cannot rule out that these junkyards decided to close or move to other states because of factors other than harsher supervision, this result shows significant heterogeneity of the decrease in robberies at the census tract level. I also run a falsification test using distances to police stations and areas that present relevant deterrence effects to criminals. I find no significant change in auto theft at any distance to a police station after increasing the supervision of junkyards. Thus, shifts in auto theft closer to junkyards differ from other locations within a municipality after the introduction of the law.

Latin American and other developing countries have persistent high crime rates (Soares and Naritomi 2010). The literature shows that several factors may affect criminality and individuals' decisions to engage in illegal activities, especially if they obtain more significant returns in the illegal market compared to jobs in the legal market (Chalfin and McCrary 2017; Draca and Machin 2015). However, there has been little empirical research regarding harsher law enforcement on crime outcomes in developing countries. Most studies about criminal deterrence have focused on the effect of policing on crime (Evans and Owens 2007; Levitt 2002) and shifts in sentencing and incarceration (Drago et al. 2009; Johnson and Raphael 2012). Hence, there is a significant gap in the literature regarding causal evidence of changes in regulation of firms deterring violent crimes. Chimeli and Soares (2017) show that the lack of law enforcement can increase violent crimes.

My finding that harsher law enforcement significantly reduces criminality contributes to a broader literature on the economic returns to crime. Several papers focus on the effect of private investments in security that increase the fixed cost of stealing, lowering the expected returns to criminals (Ayres and Levitt 1998; Gonzalez-Navarro 2013; Vollaard and Van Ours 2011). My paper adds to this literature by showing compelling evidence that a regulation change that provides harsher supervision also affects criminal returns by increasing the cost of operating in the illegal market. This paper also contributes to the literature on the effect of stolen goods markets on crime (d'Este 2020) and changing returns to crime

(Draca et al. 2019). These studies find that legal firms associated with illicit trade may affect crime outcomes by reducing theft-related costs and lowering burglars' probability of arrest. Furthermore, they also show that crimes are highly responsive to market conditions following significant changes in the expected benefit of illegal activities. I contribute to this literature by estimating the effect of harsher monitoring from legal authorities over a market that criminals use to convert stolen vehicles into cash. My findings represent rigorous empirical evidence supporting policy initiatives to reduce crime outcomes by improving law enforcement.

Following Chimeli and Soares (2017), I use an institutional change as a natural experiment to assess the effect of law enforcement on violent crime. These authors show that new regulations may increase violence when enforcement is absent. I differ from Chimeli and Soares (2017) by showing how differences in the timing of approval and law enforcement affect crime outcomes. Furthermore, my paper also uses more granular data that allows exploiting the interplay of junkyard locations and auto thefts after increasing monitoring. My findings also contribute to the literature about the relationship between illegal markets and violent crimes (Adda et al. 2014; Owens 2014). However, my paper tackles these questions by changing the monitoring of legal businesses associated with illegal markets rather than changes in the criminal status of consumers. From a policy perspective, providing evidence about the effect of harsher monitoring and enforcement is essential to understanding the effectiveness of legal changes in reducing criminality.

The remainder of the paper is structured as follows. Section 2 provides the background of the market for vehicle spare parts and the regulation of junkyards in Brazil. Section 3 presents the data used in the paper and the empirical strategy. Section 4 presents the results of increasing supervision of junkyards at the municipality level, while Section 5 shows the effect of junkyard locations on auto thefts after the regulation. Finally, Section 6 concludes the paper.

2   Institutional setting

In this section, I describe the spare parts market and junkyard regulations that started in São Paulo before coming into effect nationwide.

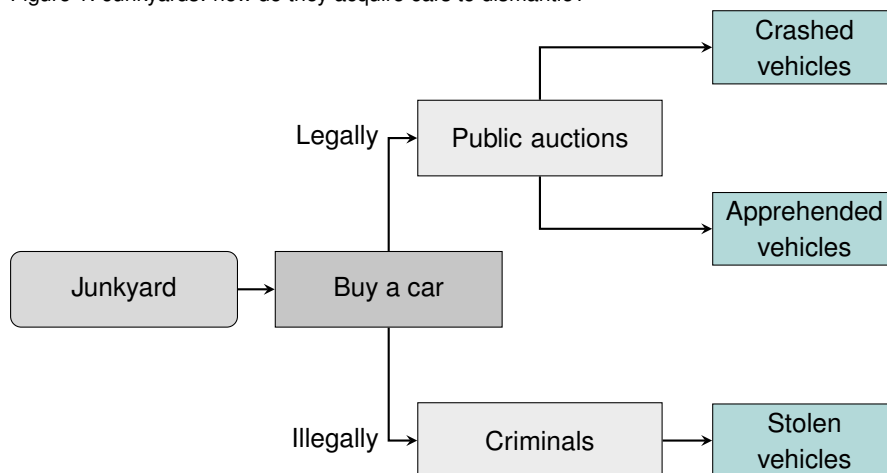### 2.1   Junkyards and the market for vehicle spare parts

Junkyards specializing in vehicles are suppliers of spare parts. Brazil has more than 46 million registered vehicles, including cars, trucks, buses, and motorcycles, with an average of one vehicle to five people in 2020.[2] The industry estimates an average life cycle of ten years for Brazilian cars (CNN Brasil 2021), which demand spare parts for regular maintenance and also to replace items damaged in traffic accidents. Therefore, the market for vehicle spare parts is vast and accounted for about R$150 billion in revenues in 2020. Automobile manufacturers also provide spare parts, and the difference between these and junkyards is straightforward; the former sells brand new items, whereas the latter focus on the recovery of used vehicle parts. There are also significant differences between the new and used spare parts markets. While vehicle assemblers and large auto-service companies mainly buy from manufacturers, end users and small mechanical workshops buy spare parts from junkyards due to the price difference. The Brazilian Automotive Recycling Association (ABCAR) estimates that junkyards' annual revenues represent about 1.5 per cent of the market for vehicle spare parts, which would be R$2.25 billion according to the figures for 2020.

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[2] According to data provided by the industry association Sindipeças (2021).

Anecdotal evidence points to a possible interplay between junkyards and auto thefts. Items sold by junkyards come from apprehended or crashed vehicles that are impossible to repair. Without proper regulation and control of the dismantling activity, it is hard to ensure that a used spare part comes from a vehicle acquired through a legal public auction or from the illegal market (stolen/robbed cars). Thus, weak supervision over junkyards can create conditions for collusive agreements with criminals specializing in auto theft. If this context, harsher law enforcement and strict rules to open and keep a firm in this market can impose a barrier to spare parts being acquired illegally, and thus affect criminals' behaviours.

Junkyard supervision may have a selection effect on business owners. Without monitoring and proper regulation of these firms, junkyards that acquire vehicles from the illegal market have lower costs than competitors that only buy cars through public legal auctions. Figure 1 shows the problem junkyards face when acquiring vehicles. Arguably there are three types of junkyards: (1) the ones that only operate in the legal market, (2) the ones that only operate in the illegal market, and (3) the ones that combine purchases from the legal and illegal markets. Given the risks of keeping stolen products, criminals generally sell them at prices much lower than similar items in the legal market. Adequate supervision over the acquisition and dismantling of vehicles may increase formality in this sector, forcing junkyards to operate legally and reducing the number of competitors that dismantle stolen cars.

Figure 1: Junkyards: how do they acquire cars to dismantle?

Note: junkyards acquire cars to dismantle in the legal or illegal market. Changes in supervision and law enforcement may make it more difficult to access the illegal market, decreasing the demand for stolen cars.
Source: author's compilation.

Last, since consumers hardly distinguish between legal and illegal products in this market, the traceability of used spare parts is fundamental to deterring criminals from selling illegal goods. The idea is that criminals have lower incentives to sell stolen products when potential buyers can easily identify the illegal origin of these items. Assuming that even junkyards established as formal companies can dismantle vehicles acquired illegally, it is essential to provide tools that allow verifying the authenticity of products to reduce the demand for illegal goods. Hence, regulation changes may allow consumers to exert complementary supervision of legal authorities, which decreases monitoring costs.

2.2 State Law 15.276 ('Junkyard Law')

Auto theft is a prevalent crime in metropolitan areas and large municipalities. There was a huge increase in the number of these events in the state of São Paulo over the 2000s, reaching more than 165,000 vehicles stolen in 2014. Furthermore, the recovery rate is less than 50 per cent according to the association of insurance companies. Public concern regarding the increase in auto theft and the possible interplay with junkyards was the motivation for intense debates in legislative houses about improvements to the

supervision of dismantling firms. The State Legislative House of São Paulo considered the role of junkyards as a possible destination of stolen vehicles. The first policy recommendation in 2012 suggested complete prohibition of junkyards and sales of used vehicle parts.[3] In 2013, the state security secretary sent a formal proposal to the State Legislative House to banish junkyards from public auctions of crashed and apprehended vehicles.

These proposals faced strong opposition from junkyard owners that claimed there were alternatives to tackle the illegal market of stolen cars without closing all dismantling business units. The junkyards, through ABCAR, argued to the State Department of Traffic and Vehicles (DETRAN-SP) that the market for used spare parts had economic and environmental value since these firms recover items that otherwise would become garbage. Moreover, ABCAR mentioned that these firms fill a gap in the spare parts market, especially for long-age or imported cars. In this sense, junkyards would be complementary to manufacturers supplying vehicle parts. After several debates, the state government, the State Legislative House, ABCAR, and DETRAN-SP agreed to regulate junkyards by approving Law 15.276 ('Junkyard Law') in January 2014, with legal effect starting in July.

The Junkyard Law has increased the legal requirements to open and run a dismantling firm and sell vehicle spare parts. More precisely, to acquire crashed and apprehended vehicles in state public auctions, junkyards need a permit issued by DETRAN-SP. This permit must be renewed every year and is a mandatory document to dismantle cars and motorcycles, such as for selling vehicle spare parts. Moreover, junkyards must comply with a series of legal requirements and present (1) their registered by-law document (a business registration document), (2) any criminal records of owners and employees, (3) a municipality business licence, (4) a technical capacity certificate, (5) a tax-compliance certificate, (6) an environmental certificate,[4] (7) electronic records of all vehicles acquired and spare parts recovered that allow tracking any sale and acquisition, and (8) periodically an updated list of employees (regular and temporary staff).

As described above, traceability of items sold is a crucial requirement to ensure the history of products in this market. Each junkyard must present detailed information to DETRAN-SP regarding its inventory and revenues. After acquiring a vehicle, the firm must present to the legal authority a complete list of spare parts recovered, and it must register these items as inventory in the DETRAN-SP system. Junkyards must also fill out a technical report signed by a certified employee regarding the dismantled vehicle and provide a complete list of items that will be discarded. Moreover, the law also imposes the obligation to provide consumers with an identification number in their payment receipt to track the item on the DETRAN-SP website and to check the legal origin of that item. In October 2015, the state government improved this control by requiring a QR code tag for all spare parts recovered and sold by junkyards. Figure 2 shows photos highlighting the QR identifier of an engine recovered by a junkyard.

Therefore, the new regulation reduced supervision costs since legal authorities, such as police officers and taxes auditors, can quickly check every item dismantled and sold by a junkyard. Furthermore, the QR code allows consumers to act as auditors, verifying the authenticity of spare parts. This last feature is critical because the new legislation established punishments for anyone buying or selling illegal vehicle spare parts. Junkyards, mechanical stores, and consumers must pay a fine of up to R$50,000 (about US$10,000) if spare parts do not show the QR code or they cannot prove the legal origin of these products in the legal authority's inspections.

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[3] State law project number 4.330: https://www.camara.leg.br/propostas-legislativas/553717.

[4] Junkyards must have a building suitable to deal with potential pollutants like oil and batteries and guarantee that there will be no risks of soil contamination.

Although other confounding factors may have affected criminality in São Paulo, the Junkyard Law seems to be a relevant mechanism driving an impressive 40 per cent drop in auto theft from 2014 to 2019, which suggests that harsher supervision of dismantling firms had a massive effect on crime. One year after implementing the law, inspections commanded by a task force involving DETRAN-SP, state police, and the State Taxes Authority closed about 700 non-complier firms in São Paulo (G1 2015).

Figure 2: Field evidence: items sold by junkyards

(a)

(b)

(c)

Note: following the introduction of the law, any vehicle spare part in stock must present an identifier QR code proving the legal origin of the product. Consumers can verify the authenticity of the QR code with the DETRAN-SP by scanning it using a smartphone.

Source: photos taken in Salvador Luchesi's Junkyard in São Paulo.

Inspired by these preliminary results reported in São Paulo, the federal government decided to extend the same regulation on junkyards to the whole country through Federal Law 12.997 in May 2014. However, each state governor would have the autonomy to decide the timing of implementation, such as creating specific regulations to monitor dismantling firms in municipalities. Surprisingly, many states in Brazil still have not created these local regulations on junkyards. Even states that created specific rules differ from São Paulo, since some have not implemented all requirements described in Federal Law 12.997. The state of Rio Grande do Sul approved a local regulation in December 2015 without imposing the electronic control of items sold by junkyards. In 2017, the Traffic State Authority of Goias and Minas Gerais joined the group of states that started implementing the law. In 2020 Paraná and Santa Catarina announced harsher regulations on junkyards.
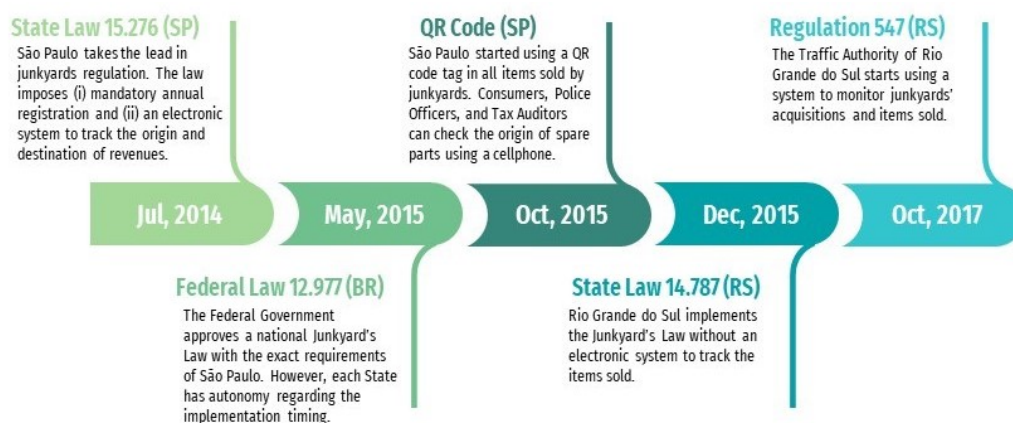
3 Data and empirical strategy

3.1 Data

I use monthly data on auto theft from 2011 to 2019 at the municipality level. This panel data comprises 645 municipalities of São Paulo, 92 in Rio de Janeiro, and 497 in the Rio Grande do Sul. Detailed crime data is very scarce in Brazil, and there are huge differences regarding publicly available data provided by each state secretary. Some provide only state-level data for short periods, making it challenging to compose a detailed panel data set comprising more granular information regarding municipalities from all 27 Brazilian states. The selection of these three states is mainly driven by the availability of detailed crime data before and after the introduction of the Junkyard Law. I also use data regarding violent deaths and other robberies in the same period and information provided by the Brazilian Bureau of Statistics (IBGE) regarding socioeconomic and demographic characteristics, especially population and gross domestic product per capita at the municipality level from the national census.

Differences in the time of approval by each state are a unique opportunity to test the effect of law enforcement on crime outcomes. Figure 3 shows the timing of events related to the regulation of junkyards in São Paulo and Rio Grande do Sul. The state of Rio de Janeiro has not approved a regulation for dismantling firms in the period of analysis. São Paulo imposed the traceability of cars acquired and items sold by junkyards since the law was approved, and the state government improved this system in 2015 by requiring a QR code tag on all items. In São Paulo, consumers and legal authorities can use a smartphone to verify if a spare part came from a legally acquired vehicle. On the other hand, Rio Grande do Sul created a system to track junkyards' purchases and revenues two years after approving a state regulation. I exploit the differences regarding timing and compliance with the law by comparing auto theft across municipalities, where cities in Rio de Janeiro are the *pure control group* which were not affected by changes in law enforcement on junkyards.

Figure 3: Timeline of events

Note: the state of Rio de Janeiro did not create a state regulation for the federal law in the period analysed (2011–19).

Source: author's compilation using information provided by state security secretaries and traffic authorities.

Table 1 presents summary statistics on criminality and GDP per capita for São Paulo, Rio de Janeiro, and Rio Grande do Sul before and after the Junkyard Law came into effect in 2014. Figures 4–7 show the distribution of robbery and theft of vehicles across municipalities before and after the introduction of the law. The monthly average of vehicles robbed decreased by about 23 per cent in São Paulo. In contrast, Rio de Janeiro and Rio Grande do Sul presented a 46 and 28 per cent increase, respectively. Moreover, Rio de Janeiro presents a more significant level of homicides and other robberies. São Paulo shows an impressive decrease in violent deaths comparing these two periods (–48.4 per cent) and a significant increase in the GDP per capita (+71 per cent). Last, I use Taxes and Labor National Authority data to

identify the number of junkyards in each municipality of São Paulo. To compile even more granular data, I use the coordinates of each junkyard to geolocate its position at street level. This data allows exploiting auto-theft dynamics by the distance from junkyards.
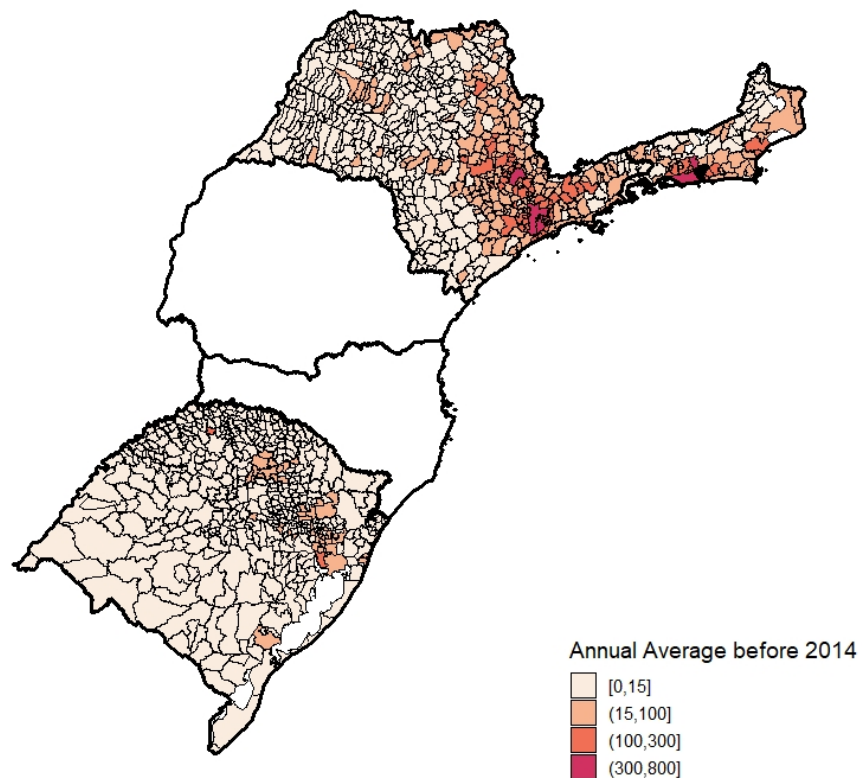
Table 1: Descriptive statistics

	São Paulo		Rio de Janeiro		Rio Grande do Sul	
	2002–14	2015–19	2002–14	2015–19	2002–14	2015–19
	(1)	(2)	(3)	(4)	(5)	(6)
Auto theft (annual avg. per 100K inhab.)	377.87	313.43	254.12	300.29	218.08	243.55
Robbery—other (annual avg. per 100K inhab.)	482.45	537.43	513.30	800.17	391.55	583.28
Homicides (annual avg. per 100K inhab.)	11.69	6.03	29.57	23.61	15.32	17.26
GDP per capita (annual average in R$)	27,532.80	47,230.77	25,669.57	41,628.88	28,272.05	38,066.19

Note: the sample comprises 645 municipalities in São Paulo ('*treated group*'), 497 in Rio Grande do Sul, and 92 in Rio de Janeiro (*1pure control group*'). Columns 1, 3, and 5 show descriptive statistics before the Junkyard Law (2002–14), whereas columns 2, 4, and 6 show the period afterwards (2015–19). Auto theft, other robberies, and homicides are presented as annual averages by municipality over 100,000 inhabitants. The GDP per capita is the average of the annual GDP by person for each state in Brazilian reais.

Source: author's compilation.

Figure 4: Robbery: vehicles (monthly average by municipality 2000–14)

Source: author's compilation based on data provided by state security secretaries of São Paulo, Rio Grande do Sul, and Rio de Janeiro.

Figure 5: Robbery: vehicles (monthly average by municipality 2015–19)

Source: author's compilation based on data provided by state security secretaries of São Paulo, Rio Grande do Sul, and Rio de Janeiro.
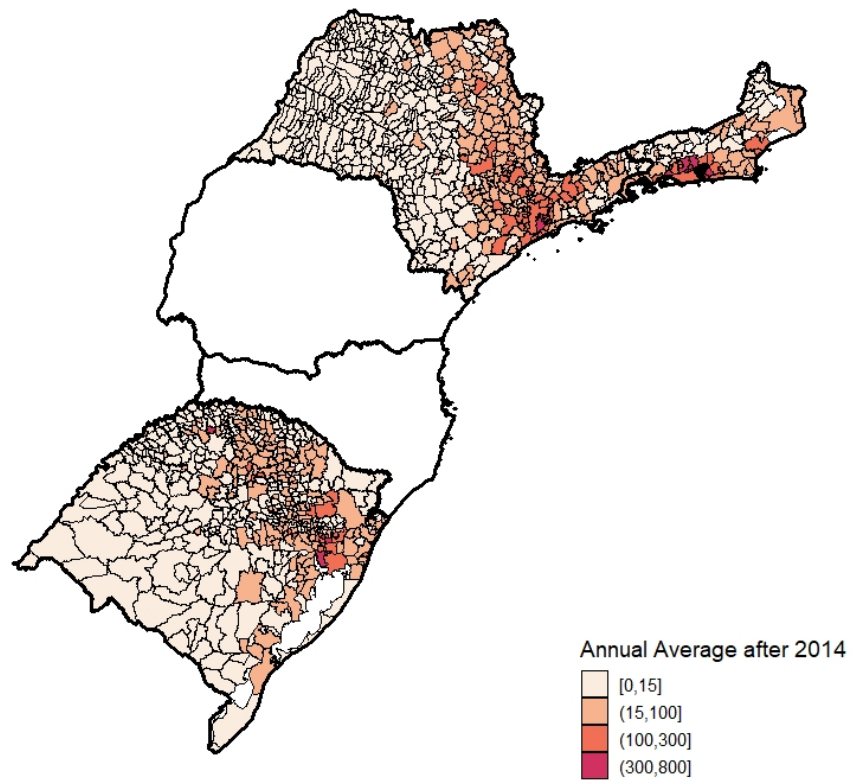
Figure 6: Theft: vehicles (monthly average by municipality 2000–14)

Source: author's compilation based on data provided by state security secretaries of São Paulo, Rio Grande do Sul, and Rio de Janeiro.

Figure 7: Theft: vehicles (monthly average by municipality 2015–19)

Annual Average after 2014
- [0,15]
- (15,100]
- (100,300]
- (300,800]
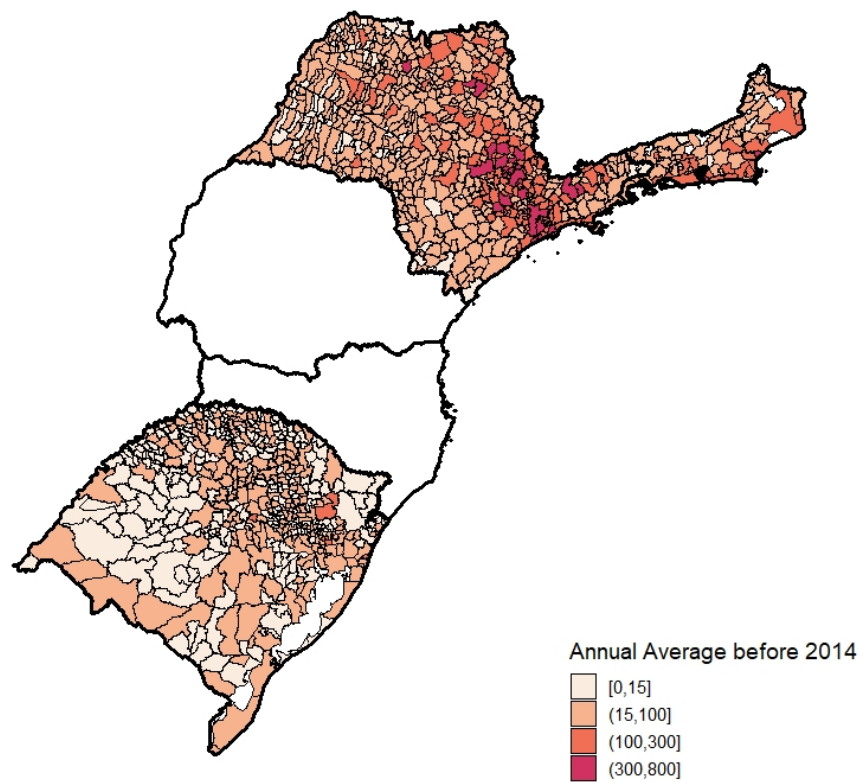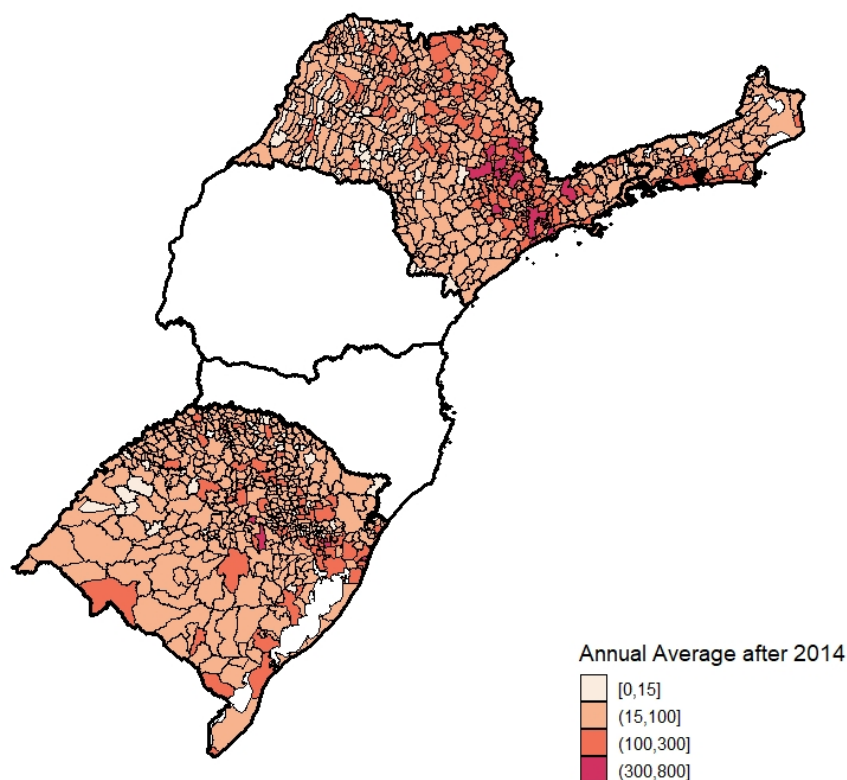
Source: author's compilation based on data provided by state security secretaries of São Paulo, Rio Grande do Sul, and Rio de Janeiro.

3.2   Empirical strategy

The staggered approval of the Junkyard Law

To identify the causal effect of the Junkyard Law, I exploit that São Paulo approved and implemented the new regulation, whereas other states did not. I define the municipalities of São Paulo as a *'treated group'* in this setting, and the municipalities of Rio de Janeiro and Rio Grande do Sul as the control group. Rio de Janeiro has not implemented the requirements imposed by Federal Law 12.997 in the entire period of my sample, so it is a pure control state that must not present any contamination by the treatment. Between July 2014 and December 2015, municipalities in Rio Grande do Sul are also part of the control group, which alleviates a possible selection bias of using only Rio de Janeiro municipalities to evaluate the effect of the Junkyard Law. Rio Grande do Sul approved a regulation for junkyards only 16 months after São Paulo. However, the state did not create an electronic system to track and monitor junkyard purchases and revenues. Hence, the case of Rio Grande do Sul provides the perfect conditions to test differences in approval timing and compliance with the law.

Given the panel data structure, it is possible to control non-observable time and location fixed effects, which can be correlated with the evolution of crime outcomes, eliminating a possible source of endogeneity. I estimate a differences-in-differences model to assess the causal effect of the Junkyard Law. The identification comes from the variation in stolen vehicles: (a) across treated and control municipalities; and (b) before and after the introduction of the law. I include time fixed effects to absorb all common shocks in the number of stolen vehicles across municipalities. I also include municipality fixed effects to control for unobservable crime determinants that are invariant at the local level. I obtain the differences-in-differences estimator of the Junkyard Law effect on stolen vehicles using the following

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model:

$$y_{it} = \alpha_i + \beta_1 \times Law_{it} + X_{it} + \varphi_t + \mu_{it} \qquad (1)$$

where the subscripts i and t respectively denote municipality and date; Law_{it} is a dummy equal to 1 after the Junkyard Law's approval in municipalities i, X is a vector of control variables including GDP and population, φ is a set of time fixed effects that include year and month dummies, and α is municipality fixed effects. The dependent variable y indicates crime outcomes in a municipality in one month. State secretaries of São Paulo, Rio de Janeiro, and Rio Grande do Sul provide information on different types of crimes, which allows testing for different specifications of the dependent variable in the equation 1. I use vehicles robbed as a dependent variable in my main specification. However, I also test the theft of vehicles, homicides, and other robberies to investigate how the law affects other offences. The validity of my results comes from two key assumptions. The first is that the treated and control group present parallel trends to the number of vehicles stolen before the beginning of the Junkyard Law in July 2014. The second crucial hypothesis is that the decrease in the number of vehicles stolen is exclusively due to the harsher enforcement and supervision over dismantling businesses following the Junkyard Law and not due to other confounding factors. Under these assumptions, the coefficient β_1 represents the relative change in crime comparing treated and control municipalities following the introduction of the Junkyard Law.

The effect of junkyard locations

Do criminals respond to harsher supervision of junkyards by reducing thefts in the neighbourhood of these locations? Driving a stolen car for long distances increases the probability of being caught by police officers. Therefore, criminals who keep collusive agreements with junkyards arguably prefer to drive short distances to minimize the risk of apprehension. It is hard to believe that criminals would drive a car for hours within a municipality if they had a closer place to hide and sell the vehicle.

Identifying which junkyards keep such collusive agreements with criminals is a challenging task. First, I only have access to firms registered in the Federal Tax Authority database, and some junkyards may operate as informal companies without tax identification. If only informal junkyards receive and dismantle stolen and robbed cars, legal firms' locations will not provide accurate estimates of proximity of junkyards to vehicles robbed. On the other hand, legal requirements and supervision were significantly weaker before the Junkyard Law. It is possible that some firms formally constituted previously operated in the legal and illegal markets. However, it is still hard to identify those with collusive agreements with criminals. Despite the inherent difficulties in assigning which junkyards acquired vehicles illegally, I assume the location of junkyards identified by the Federal Tax Authority as a proxy variable to assess the effect of distances to junkyards on vehicle robbery.

I evaluate the effect of the law within the city of São Paulo, the largest municipality in the state with the most significant presence of junkyards. As described before, it is reasonable to assume that a criminal would not drive a stolen car for long distances and hours because of the probability of being followed by police officers. Furthermore, some vehicles may have electronic trackers, which increase the risk of keeping a stolen car for an extended period. In the research made for this paper, police officers and junkyard owners mentioned that gangs specialized in auto theft usually keep hidden garages where they check whether the vehicle taken has an electronic tracker. Even when criminals do not find a tracker, these gangs usually wait for some days to move the car to junkyards in the neighbourhood late at night, a process called *'cold the car'*. Hence, stealing a car in districts closer to a junkyard would be arguably less risky to successful collusive agreements between criminals and junkyard owners. Evaluating the heterogeneous effect of the law by distances to junkyards also allows testing whether there was a displacement of criminal activity—that is, whether gangs moved to districts far from junkyards to respond to the harsher supervision on these firms after the introduction of the law.

The spatial analysis of the law's effectiveness presents two significant challenges. First, junkyard locations in São Paulo maybe are not randomly assigned. If junkyards are near streets with a significant incidence of auto theft, this will characterize a selection bias. Second, even if junkyard locations were randomly assigned, it is difficult to define a counterfactual for their absence due to contamination concerns. Places far from junkyards prior to the new law can be affected if junkyards decide to reallocate within the city, and the treatment ('Law') would contaminate districts of the control group. To overcome these issues, I present two robustness tests. First, I use the location of junkyards that left the market as an instrumental variable. As described above, the Junkyard Law closed many dismantling firms. Some junkyards may have decided to move to other states or businesses, given the increased supervision by legal authorities. Hence, using the location of closed junkyards as an instrument would capture the change in auto theft near firms that arguably had more difficulty complying with the legal requirements demanded by the Junkyard Law. Second, I perform a falsification test using distances to police stations as the dependent variable in the baseline regression. This approach allows checking whether the deterrence effect of police increased after the Junkyard Law, affecting the number of vehicles robbed in police station neighbourhoods. Thus, I can verify whether the decrease in robberies near junkyards was more intense than in locations with a strong police presence.

I combine data regarding junkyard location and auto-theft registers at the street level to assess the effect of the law by distance to each junkyard and evaluate whether the decrease in vehicles robbed were more significant in junkyard neighbourhoods. I estimate a differences-in-differences model with time fixed effects to absorb all common shocks in auto theft across districts. I also include district-fixed effects to control for unobservable crime determinants that are invariant at the local level. I obtain the differences-in-differences estimator using the following model:

$$y_{it} = \alpha_i + \beta_1 Law_t + \sum_d \beta_2^d T_i^d Law_t + \varphi_t + \mu_{it} \qquad (2)$$

where the subscripts i and t denote census tract[5] and date; T_{it}^d is 1 if the census tract i lies at distance d from a junkyard; d defines six categories of distance: up to 0.2 km, 0.2–0.4 km, 0.4–0.6 km, 0.6–0.8 km, 0.8–1.0 km, and 1.0–1.2 km. The measure of 1.2 km is the median distance between census tracts and the closest junkyard. Therefore, areas in São Paulo with a junkyard at 1.2 km are the treated group, while neighbourhoods with the closest junkyards at longer distances are the control group. The dependent variable y indicates robbery and theft of vehicles in a census tract i in time t. The identification comes from two main assumptions. The first is that census tracts more than 1.2 km from junkyards were less affected by the law (non-contamination of the control group). The second is that groups present parallel trends of robbed vehicles before the law. The variable Law_t controls the Junkyard Law's approval effect in all census tracts within São Paulo. Hence, the coefficient β_2 shows the specific effect of the proximity to junkyards on thefts after approval of the law.

4   The effect of the Junkyard Law

4.1   Results at the municipality level

Table 2 reports the results from the estimation of Equation 1 using as a dependent variable the logarithm of auto theft in the sample from 2003–19 with municipalities of Rio de Janeiro as the control group. In this first approach, I use only these two states to assess the effect of the Junkyard Law in a setting without a possible concern regarding staggered adoption of the treatment.[6] I show the differences-in-

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[5] A geographic region defined for the purpose of taking a census.

[6] As main results I show the estimates controlling by the staggered adoption of the treatment in São Paulo and Rio Grande do Sul.

differences point estimates to the Junkyard Law in São Paulo with and without controlling for GDP and population. As shown in columns 3 and 4, I find a large and significant effect of the Junkyard Law on vehicles robbed; the estimates are equivalent to an average 4.8 per cent decrease by year in robberies compared to Rio de Janeiro municipalities that were not affected by the law. By contrast, as shown in columns 5 and 6, I find no effect on the theft of vehicles.

Table 2: Results: TWFE (two-way fixed effects) baseline specification

	Auto theft (1)	Auto theft (2)	Robbery (3)	Robbery (4)	Theft (5)	Theft (6)
Junkyard Law	−0.133***	−0.137***	−0.352***	−0.357***	0.007	0.003
	(0.009)	(0.009)	(0.012)	(0.012)	(0.009)	(0.009)
GDP		0.102***		0.0934***		0.0905***
		(0.009)		(0.013)		(0.010)
Population		−0.068**		0.244***		−0.139***
		(0.033)		(0.048)		(0.038)
Observations	76,051	75,870	44,394	44,272	70,232	70,094
R^2	0.913	0.913	0.902	0.903	0.889	0.889
Municipality fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Note: this table shows my baseline results in a framework without concerns about the staggered adoption of the treatment. The sample comprises 645 municipalities in São Paulo (*'treated group'*) and 92 in Rio de Janeiro (*'control group'*), and the sample period is 2003–19. The treatment in my differences-in-differences design is given by the variable *'Junkyard Law'* that assumes value 1 from July 2014 only in municipalities in São Paulo. Columns 1 and 2 show the results to auto theft as the dependent variable. The dependent variable in columns 3 and 4 is the log(number of vehicles robbed), and in columns 5 and 6 the log(number of thefts of cars). Robust standard errors are shown in parentheses. *$p <0.1$, **$p <0.05$, ***$p <0.01$.

Source: author's calculations.

Differences in compliance with the law provide a unique opportunity to evaluate the causal effect of the Junkyard Law. I exploit a reduced sample from 2011 to 2019, including Rio Grande do Sul municipalities, which approved the Junkyard Law only in December 2015, 18 months after São Paulo. This setting allows testing differences in the timing of the treatment. Rio Grande do Sul municipalities were in the control group until December 2015. Moreover, unlike São Paulo, Rio Grande do Sul only imposed in October 2017 the electronic traceability of items acquired and sold by junkyards. Table 3 show the results from the estimation of Equation 1 to vehicles robbed with varying specifications of the control group in the sample from 2011 to 2019. Column 1 shows the results using municipalities of all three states and assuming differences in the treatment time (i.e. July 2014 in São Paulo and December 2015 in Rio Grande do Sul). Column 2 uses only municipalities of Rio de Janeiro as the control group, following the same approach presented in Table 2. Column 3 shows the effect of the Junkyard Law in São Paulo using Rio Grande do Sul as the control group before the regulation on junkyards in January 2016. Last, column 4 presents the results without São Paulo to assess the effect of the law in Rio Grande do Sul compared to municipalities of Rio de Janeiro. I found significant results to all specifications of the treated and control groups. Furthermore, I show that even using municipalities in Rio Grande do Sul as the control group, São Paulo still shows a significant decrease in vehicles robbed (–1.6 per cent per year), although smaller than Rio de Janeiro municipalities as the control group (–2.7 per cent per year). Regarding differences in compliance with the Junkyard Law, a comparison between the coefficients of columns 2 and 4 shows a 25 per cent larger effect of the law in São Paulo relative to Rio Grande do Sul using the same control group as a reference.

These results shed some light on the mechanisms driving the causal effect of the law. The most significant decrease in auto theft in São Paulo compared to Rio Grande do Sul seems to be related to the traceability of spare parts required by the Junkyard Law. Whereas São Paulo implemented an electronic system to track items acquired and sold by junkyards when implementing the law, Rio Grande do Sul only created this system two years after approving the regulation. Moreover, São Paulo improved this control by requiring a QR code tag on all items sold by junkyards in October 2015, providing more efficient tools to consumers and legal authorities monitoring junkyards.

Table 3: Results of auto theft: TWFE different specifications of control group

	All	SP x RJ	SP x RS	RS x RJ
	(1)	(2)	(3)	(4)
Junkyard Law	−0.087***	−0.173***	−0.096***	−0.157***
	(0.008)	(0.010)	(0.011)	(0.014)
Observations	60,978	42,212	29,744	25,635
R^2	0.913	0.920	0.915	0.906
Controls	Yes	Yes	Yes	Yes
Municipality fixed effects	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes

Note: this table shows results from regressions of varying samples and the control group. Across all regressions, the dependent variable is the log(auto theft) monthly and the treatment in my differences-in-differences design is the variable *'Junkyard Law'* that assumes value 1 from July 2014 in municipalities in São Paulo and from January 2016 in municipalities of Rio Grande do Sul, and the sample period is 2011–19. All regressions include municipality, state, and time fixed effects. Column 1 shows the baseline regression using municipalities of SP, RJ, and RS. Column 2 presents the effect of the Junkyard Law in SP using only municipalities of RJ as the control group. Column 3 uses municipalities of RS before the treatment in January 2016 as a control group. Column 4 presents the effect of the Junkyard Law in RS using municipalities of RJ as a control group. Robust standard errors are shown in parentheses. *p <0.1, **p <0.05, ***p <0.01.

Source: author's calculations.

4.2 Robustness

Alternative specifications

My findings show that auto theft dropped significantly more in municipalities that have increased monitoring and supervision of junkyards. To enhance the validity of my results, I present an alternative specification that compares municipalities with and without the presence of junkyards. A more significant decrease in auto theft after the introduction of the law in cities with junkyards compared to those without these firms would reinforce the interplay between harsher law enforcement on the dismantling business and stolen/robbed vehicles. However, if there is no difference when comparing municipalities with and without junkyards, confounding factors other than the new regulation may have driven the reduction in auto theft. I rewrite the Equation 1 to account for the different effects of regulation given the presence of junkyards by a municipality. In this setup, the differences-in-differences estimator is:

$$y_{it} = \alpha_i + \beta_1 \times Law_{it} + \beta_2 \times Law_{it} \times D_i^j + X_{it} + \varphi_t + \mu_{it} \tag{3}$$

where D_i^j is a dummy variable equal to 1 when there is at least one junkyard in municipality *i*. Hence, the coefficient β_2 shows the differential of the Junkyard Law across cities with and without junkyards after controlling for location and time fixed effects. Table 4 reports the results from Equation 3 using as the dependent variable the logarithm of auto thefts in municipalities of São Paulo from 2003 to 2019. In this approach, 192 municipalities that contain at least one junkyard are the *treatment group*, and the remaining 453 are the *control group*. I show the differences-in-differences point estimates to the Junkyard Law in São Paulo with and without controlling for GDP and population. My results show an effect about two times more significant for auto theft in cities with junkyards. Regarding theft of vehicles, the results in columns 5 and 6 show that the Junkyard Law was only effective for the treatment group. These findings are supportive evidence about junkyards' role in the law's effectiveness. It alleviates concerns about confounding factors unrelated to these firms driving the reduction in auto theft.

Last, a possible inference concern is that the treatment *'Junkyard Law'* occurs at the state level, whereas the unit of analysis in my estimates is municipalities. Suppose auto theft is serially correlated over time within municipalities. In that case, the mismatch between the measurement level of the dependent variable and the treatment can underestimate the standard errors of the *'Junkyard Law'*. The standard solution to this mismatch is clustering standard errors to the state level to account for the potential serial correlation in auto theft. However, I only have three states in my specification, and there is robust evidence that the standard asymptotic method cannot be applied when the number of groups is small

(Conley and Taber 2011; Donald and Lang 2007). In these cases, differences-in-differences estimation is inconsistent and reports misleading standard errors. I perform the following exercise to alleviate concerns regarding the small number of states to estimate cluster-robust standard errors. First, I increase the number of states in the pure control group by including the municipalities of Paraná and Mato Grosso do Sul. Second, I compute the Junkyard Law effect and standard errors such as proposed by Donald and Lang (2007). Using this procedure, I show the estimates of the effect of the law on auto theft in Figure 8. The results are significant and confirm my previous findings that the harsher supervision of junkyards reduced auto theft.
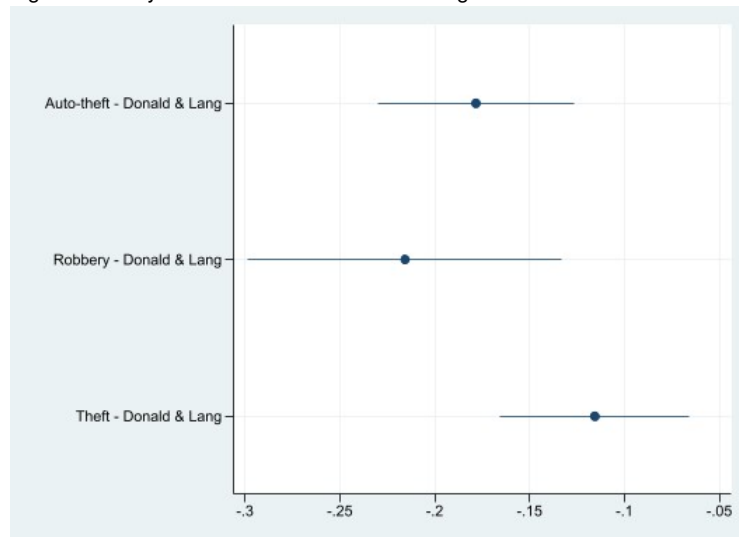
Table 4: Results: TWFE alternative specification

	Auto theft	Auto theft	Robbery	Robbery	Theft	Theft
	(1)	(2)	(3)	(4)	(5)	(6)
Junkyard Law	−0.0339**	−0.0340**	−0.0557**	−0.0570**	−0.0183	−0.0175
	(0.0169)	(0.0170)	(0.0231)	(0.0231)	(0.0181)	(0.0181)
Junkyard Law × presence of junkyard	−0.0568***	−0.0565***	−0.0931***	−0.0930***	−0.0353***	−0.0355***
	(0.0107)	(0.0107)	(0.0150)	(0.0150)	(0.0114)	(0.0115)
GDP		0.0153		0.0403		0.0246
		(0.0190)		(0.0294)		(0.0202)
Population		0.0152		−0.613***		0.339**
		(0.145)		(0.215)		(0.159)
Observations	35,343	35,343	19,263	19,263	32,935	32,935
R^2	0.918	0.918	0.913	0.913	0.898	0.898
Municipality fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Time fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

Note: this table shows my results to an alternative specification. The sample comprises 645 municipalities in São Paulo (*'treated group'*) in the period is 2003-2019. The treatment in my differences-in-differences design is given by the variable *'Junkyard Law × Presence of Junkyard'* that assumes value one from July, 2014 only to municipalities in São Paulo that have at least one junkyard. Columns 1 and 2 show the results to log(auto-theft) as dependent variable. The dependent variable in columns 3 and 4 is the log(number of vehicles robbed) and in cols 3 and 4 the log(number of thefts of cars). Robust standard errors are shown in parentheses. *p<0.1,**p<0.05,***p<0.01

Source: author's calculations.

Figure 8: Junkyard Law effect: Donald and Lang estimates

Note: the effect of the Junkyard Law on auto theft using the aggregation method proposed by Donald and Lang (2007). Blue lines provide point estimates and uniform 95 per cent confidence bands for the treatment effect of the law, allowing clustering at the state level. The sample comprises 645 municipalities in São Paulo (*'treatment group'*), 79 in Mato Grosso do Sul, 23 in Paraná, 497 in Rio Grande do Sul, and 92 in Rio de Janeiro (*'control group'*) from 2012 to 2019. The treatment in my differences-in-differences design is given by the variable *'Junkyard Law'* that assumes value 1 from July 2014 only in municipalities in São Paulo. The dependent variables are log(auto theft) in the top row, log(vehicles robbed) in the middle row, and log(theft of vehicles) in the bottom row.

Source: author's calculations.

Event study and group-specific effects

São Paulo and Rio Grande do Sul municipalities had significantly decreased numbers of auto thefts after implementing harsher supervision of junkyards. However, it is not clear that the reduction in vehicles robbed was driven only by the Junkyard Law. Other factors can affect the decision of criminals to steal a car, such as the choice of junkyard owners to acquire and dismantle stolen vehicles. If the cities of São Paulo and Rio Grande do Sul had a previous trend in criminality, auto theft will fall regardless of the enforcement of the Junkyard Law. Moreover, the crime reduction can be short-lived if the supervision and punishment of non-complier junkyard owners are weak. To enhance the validity of my results, I present an event-study model exploiting the variation across municipalities that did and did not implement the Junkyard Law and the timing of the law's approval to check the trend and the effect on vehicles robbed over time.

Each state government has significant autonomy to decide how and when to implement the legal requirements imposed by the federal government in May 2015. Figure 3 shows the timeline of events related to the regulation of junkyards from 2011 to 2019. São Paulo was the first state to impose harsher supervision on junkyards in July 2014. Afterward, Rio Grande do Sul approved a state regulation in December 2015. Although both states have approved and implemented thelaw, there were significant differences when comparing the monitoring systems in São Paulo and Rio Grande do Sul. Whereas the former provided consumers and legal authorities with tools to track the origin of items sold in junkyards, the latter required this traceability only two years after approving the law. Last, Rio de Janeiro did not implement a state regulation on junkyards from 2011 to 2019, even after the law became national in May 2015.

To identify the dynamic treatment effect of the Junkyard Law, I use the method proposed by Callaway and Sant'Anna (2021). The authors present a framework applied to differences-in-difference models with staggered adoption. In my setting, there is variation in the treatment timing across states. Once units receive the treatment, they remain treated for the following periods. In this setup, the average treatment effect is:

$$ATT(g,t) = \mathbb{E}\left[\left(\frac{G_g}{\mathbb{E}[G_g]} - \frac{\frac{p_g(X)C}{1-p_g(X)}}{\mathbb{E}\left[\frac{p_g(X)C}{1-p_g(X)C}\right]}\right)(Y_t - Y_{g-1})\right] \tag{4}$$
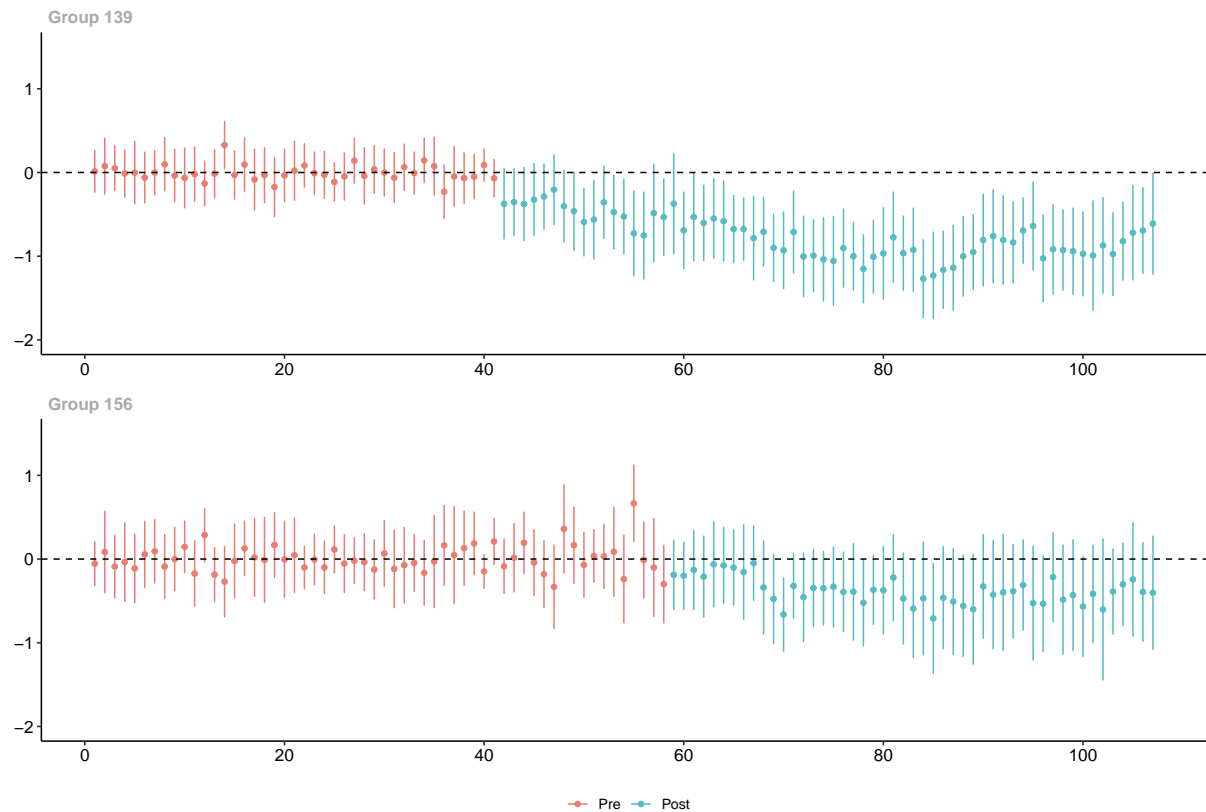
where G is a binary variable that indicates the time when a state approves the Junkyard Law, and C is a binary variable equal to 1 if the state does not approve the law in any period. The variable p_g is the generalized propensity score that indicates the probability of approving the law at time g, conditional on pre-treatment variables, and Y is the potential outcome variable. For states that did not implement the law at any time, observed outcomes are untreated in all periods. In this setup, these 'never treated' states are fixed comparison groups for all states that, in some period, approved the Junkyard Law. Last, the results presented in Table 2 suggest that covariates do not significantly affect the results. If pre-treatment variables do not play a significant role in the identification, the expression 4 collapses to:

$$ATT(g,t) = \mathbb{E}[Y_t - Y_{g-1}|G_g = 1] - \mathbb{E}[Y_t - Y_{g-1}|C = 1] \tag{5}$$

Equation 5 shows that the average effect of approving the Junkyard Law in time g is identified by taking changes in vehicles robbed compared to the most recent period before the law's approval and adjusting by the changes in auto theft experienced by the 'never treated' group. Under the parallel trends assumption, the latter path of outcomes is the counterfactual scenario to states of the 'treatment group' if they had not approved the Junkyard Law. Figure 9 shows the group–time average treatment effects, a uniform 95 per cent confidence band, and the standard errors clustered at the municipality level. The plot presents pre-treatment estimates to verify the parallel trends assumption and treatment effect estimates after the Junkyard Law approval in each state. The group–time average treatment effect estimates show that the harsher monitoring of junkyards led to a decrease in vehicles robbed. However, this effect is

much more evident in municipalities of São Paulo (top row of Figure 9) compared to municipalities of Rio Grande do Sul (bottom row of Figure 9). Moreover, increasing law enforcement also appears to be a dynamic effect. For municipalities in São Paulo, the decrease in robberies is larger two years following the approval (24 months) and remains significant for the rest of the period.

Figure 9: Junkyard Law group–time average treatment effects

Note: the effect of the Junkyard Law on vehicles robbed estimated under the unconditional parallel trends assumption. Red lines give point estimates and uniform 95 per cent confidence bands for pre-treatment periods, allowing for clustering at the municipality level. Under the null hypothesis of the parallel trends assumption holding in all periods, these should be equal to zero. Blue lines provide point estimates and uniform 95 per cent confidence bands for the treatment effect of the law, allowing clustering at the municipality level. The top row includes municipalities in São Paulo that approved the law in July 2014, and the bottom row includes municipalities in Rio Grande do Sul that approved the law in December 2015.

Source: author's calculations.

Table 5 presents aggregated treatment effect measures described by Callaway and Sant'Anna (2021). The results show the effect of the Junkyard Law at the time of approval. Harsher law enforcement on junkyards led to a significant decrease in vehicles robbed, and this effect increases in magnitude over time. The decrease in robberies 12 months after the law's approval is three times lower than after 24 months and almost five times lower than after 36 months. Moreover, both estimates for group-specific effects and length of exposure are larger than TWFE estimates. The decrease in robberies in São Paulo is 27 per cent greater than in Rio Grande do Sul municipalities.

My results show that the harsher monitoring of junkyards reduced auto theft compared to what it would have been without the Junkyard Law. Regarding the dynamic effect of the treatment, the event study suggests that it has taken some time for the Junkyard Law to become effective in reducing auto theft, which potentially reflects improvements in the monitoring over time, with the QR code implementation in São Paulo (15 months after the law's approval) and harsher supervision of legal authorities through inspections of junkyards and punishment of non-complier firms. Last, the significant difference in the group-specific estimates of São Paulo compared to Rio Grande do Sul suggests a crucial role in imposing traceability in junkyard items.

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Table 5: Results: vehicles robbed—aggregated treatment effect estimates

	Partially aggregated				Single parameters
TWFE					−0.226
					(0.011)
Group-specific effects	g = SP	g = RS			
	−0.535	−0.421			−0.510
	(0.121)	(0.104)			(0.095)
Event study	e = 0	e = 12	e = 24	e = 36	
	−0.067	−0.195	−0.563	−0.875	−0.523
	(0.060)	(0.091)	(0.094)	(0.129)	(0.098)

Note: the table reports aggregated treatment effect parameters under the conditional parallel trends assumptions. The row 'TWFE' reports the coefficient on the Junkyard Law dummy from a TWFE regression. The row 'Group-specific effects' summarizes average treatment effects by the timing of the Junkyard Law's approval in each state; here, g indexes the state in the sample that received the treatment. The row 'Event study' reports average treatment effects by the length of exposure to the Junkyard Law; here, e indexes the length of exposure to the treatment in months. The column 'Single parameters' represents a further aggregation of each type of parameter.

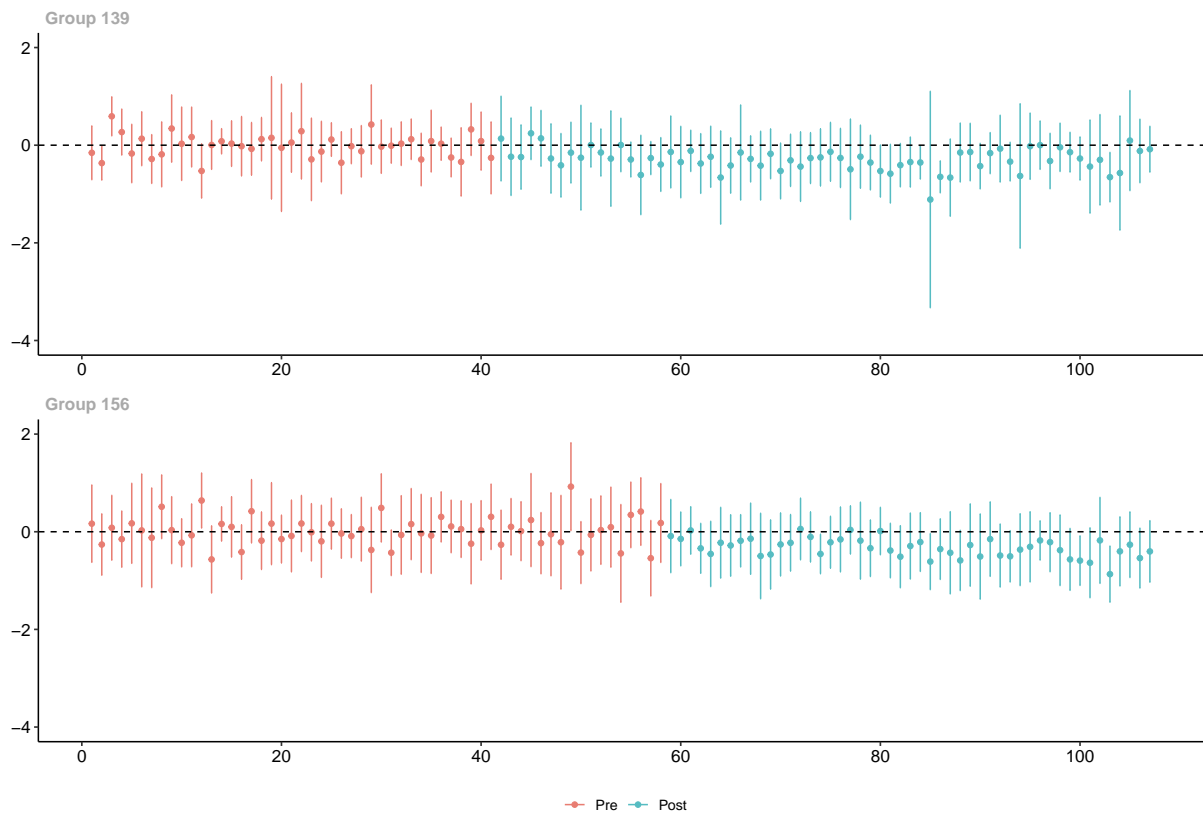Source: author's calculations.

Falsification tests

After approving the Junkyard Law, auto theft in treated municipalities decreased compared to the control group. To enhance the credibility of my results, I ran a falsification test to verify whether other crimes also decreased following the law's approval. If crimes such as homicide also decreased, my estimates would reflect a general downward trend in criminality instead of the effect of harsher law enforcement on junkyards. This would be the case for states that imposed harsher supervision on these firms, but also increased efforts in police surveillance. In this case, my estimates would capture the deterrence effect of police in crime instead of the specific effect of law enforcement on junkyards. Figure 10 shows the results of a falsification test using homicides as dependent variables in the group-specific effects approach of Callaway and Sant'Anna (2021). Violent deaths in São Paulo and Rio Grande do Sul did not decrease after the approval of the Junkyard Law in these states, ruling out a general downward trend in criminality contemporaneous to the law.

Moreover, after increased supervision of junkyards, some criminals may have chosen to commit crimes other than auto theft. If there is an increase in other robberies following the introduction of the Junkyard Law, the side effects of the displacement in criminal activity can outweigh the benefits of the harsher law enforcement over junkyards. I address this question by a second falsification test using other robberies as the dependent variable in the baseline specification. Figure 11 show that other robberies did not increase significantly in the post-treatment period in municipalities of São Paulo (top row of Figure 11) and Rio Grande do Sul (bottom row of Figure 11).

These results show that violent deaths and other robberies did not fall significantly after approving the Junkyard Law. Therefore, it seems that the law specifically affected auto theft and a broad downward trend in criminality does not drive this effect. Moreover, the decrease in vehicles robbed does not appear to be related to increased police patrols and an overall deterrence effect of police on crime. Last, the fact that there was no displacement of offences to other robberies is a critical indicator of the effectiveness of the law in reducing criminality.
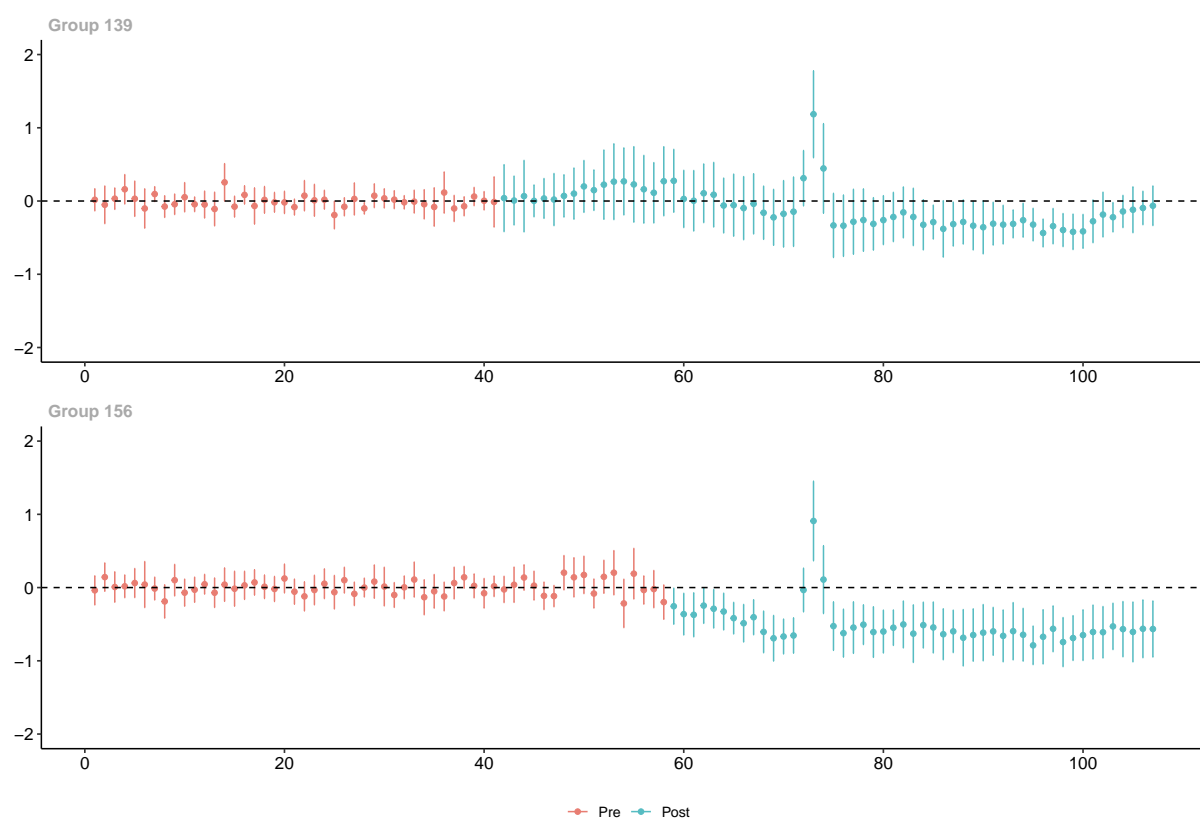
Figure 10: Falsification test: homicides

Note: the effect of the Junkyard Law on homicides estimated under the unconditional parallel trends assumption. Red lines give point estimates and uniform 95 per cent confidence bands for pre-treatment periods, allowing for clustering at the municipality level. Under the null hypothesis of the parallel trends assumption holding in all periods, these should be equal to zero. Blue lines provide point estimates and uniform 95 per cent confidence bands for the treatment effect of the law, allowing clustering at the municipality level. The top row includes municipalities in São Paulo that approved the law in July 2014, and the bottom row includes municipalities in Rio Grande do Sul that approved the law in December 2015.

Source: author's calculations.

Figure 11: Falsification test: other robberies

Note: the effect of the Junkyard Law on other robberies estimated under the unconditional parallel trends assumption. Red lines give point estimates and uniform 95 per cent confidence bands for pre-treatment periods, allowing for clustering at the municipality level. Under the null hypothesis of the parallel trends assumption holding in all periods, these should be equal to zero. Blue lines provide point estimates and uniform 95 per cent confidence bands for the treatment effect of the law, allowing clustering at the municipality level. The top row includes municipalities in São Paulo that approved the law in July 2014, and the bottom row includes municipalities in Rio Grande do Sul that approved the law in December 2015.

Source: author's calculations.

5   The effect of junkyards' location on vehicles robbed

5.1   Results at the district level

Table 6 present the results of Equation 2. I show the effect of the Junkyard Law by the distance of junkyards to vehicles stolen through robbery in column 1 and theft in column 2. Vehicles robbed decreased more in census tracts with at least one junkyard within 200 metres, and the law has no additional effect for census tracts where the closest junkyard is far more than this distance. I find no effect on the stolen vehicles using the same specification of distances to junkyards. Figure 12 shows the estimates and uniform 95 per cent confidence bands. These results show that the Junkyard Law effect on vehicles robbed was more significant in districts closer to junkyards. The Junkyard Law in São Paulo changed the dynamic of auto theft closer to junkyards. Despite the significant decrease in robberies in all census tracts, represented by the variable *Junkyard Law* in Table 6, neighbourhoods with junkyards up to 200 metres away had an additional decrease in robberies by the same magnitude compared to census tracts where the closest junkyard is at least 1.2 km away. Location and time fixed effects do not explain the decrease in vehicles robbed in these neighbourhoods.
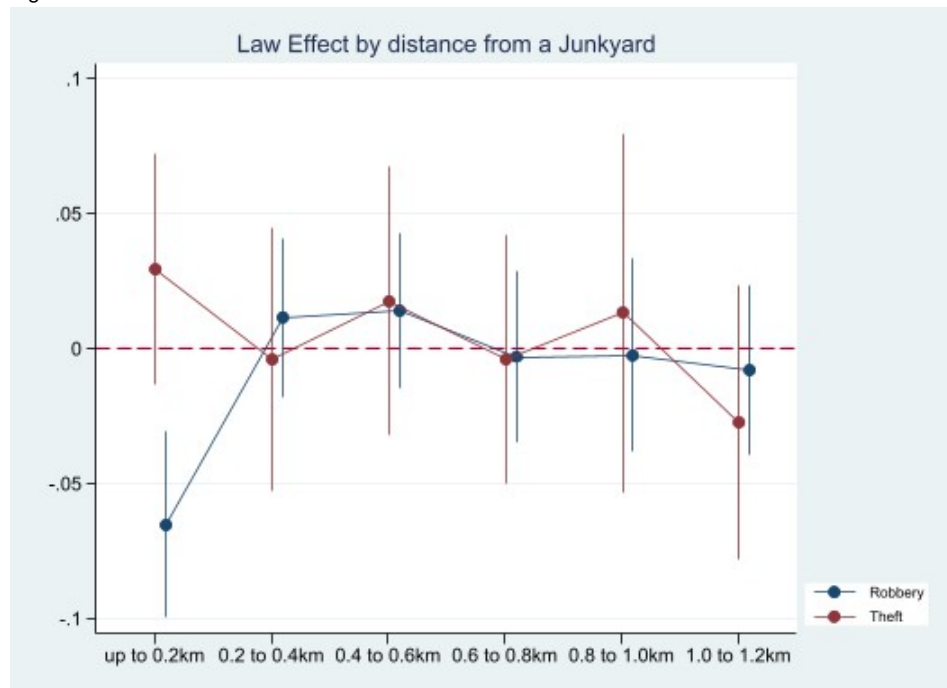
Table 6: Results: robbery and theft—distance to junkyards and police stations

	Distance to junkyards		Distance to police stations		Distance to junkyards	
	Robbery	Theft	Robbery	Theft	Robbery IV	Theft IV
	(1)	(2)	(3)	(4)	(5)	(6)
Junkyard Law	−0.067***	0.023	−0.070***	0.029*	−0.071***	0.028*
	(0.011)	(0.019)	(0.010)	(0.017)	(0.009)	(0.015)
Up to 0.2 km	−0.065***	0.029	−0.028	0.038	−0.118***	0.070
	(0.017)	(0.021)	(0.023)	(0.031)	(0.042)	(0.056)
0.2–0.4 km	0.011	−0.00	−0.008	0.044*	−0.012	−0.062
	(0.015)	(0.024)	(0.016)	(0.024)	(0.045)	(0.066)
0.4–0.6 km	0.014	0.017	0.008	0.000	−0.001	0.026
	(0.014)	(0.025)	(0.018)	(0.026)	(0.031)	(0.043)
0.6–0.8 km	−0.002	−0.003	−0.009	−0.035	−0.020	−0.013
	(0.016)	(0.023)	(0.016)	(0.023)	(0.026)	(0.041)
0.8–1.0 km	−0.002	0.013	0.000	0.018	−0.008	−0.038
	(0.018)	(0.033)	(0.019)	(0.038)	(0.034)	(0.037)
1.0–1.2 km	−0.007	−0.027	−0.009	−0.032	0.003	−0.007
	(0.016)	(0.025)	(0.016)	(0.023)	(0.020)	(0.034)
Observations	249,836	61,269	249,836	61,269	249,836	61,269
R^2	0.163	0.323	0.163	0.323	0.163	0.323
Census tract FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes

Note: the table reports estimated coefficients and standard errors clustered at the census tract level in parentheses. The dependent variable in columns 1 and 3 is log(number of robberies) and in columns 2 and 4 is log(number of thefts). Columns 1 and 2 show the results of Equation 2 using junkyards as reference points to measure the distance d to each census tract of São Paulo. Columns 3 and 4 report a falsification test using police stations as reference points to measure the distance d to each census tract of São Paulo. Columns 5 and 6 present results using junkyards closed after the new regulation as reference points to measure the distance d to each census tract of São Paulo. *$p < 0.1$,**$p < 0.05$,***$p < 0.01$.

Source: author's calculations.

Figure 12: District level: baseline results

Note: this graph plots estimated coefficients to the distance of the closest junkyard or police station for equation 2. The sample includes 14,479 census tracts in São Paulo. Covariates include census tract, year and month fixed effects. Errors are clustered at the census tract level. Dots represent point estimates and bar represents 95% confidence interval.

Source: author's own calculations.

5.2 Robustness

Instrumental variable: junkyards closed after the law

The causal effect of harsher supervision of junkyards on robberies comes from imposing higher costs on criminals converting stolen vehicles into cash. If junkyards stop acquiring robbed and stolen vehicles, this arguably decreases the expected return of criminals to steal a car. Additionally, for junkyards that before the law only operated in the legal market, shifts in law enforcement would hardly force a transition to the illegal market. Thus, junkyards may differ in collusive agreements with criminals, even when comparing firms in the same neighbourhood. The auto-theft dynamic closer to junkyards that negotiate only in the legal market probably differs from that closer to firms that previously bought stolen vehicles. Assuming the same probability of all junkyards acquiring vehicles from criminals may bias my results and underestimate the effect of harsher law enforcement.

To address this issue, I propose using the location of junkyards closed after the new regulation as an instrumental variable in Equation 2. The identification assumption is that these firms had more difficulty complying with the Junkyard Law requirements. Additional costs to implement the traceability demanded by legal authorities and provide detailed information regularly arguably affected the profitability of junkyards. In this context, firms that relied on acquiring stolen vehicles faced more difficulties adapting to the new regulation. The harsher supervision forces junkyards to acquire vehicles primarily through public auctions, where they must outbid other junkyards. Because of such competition, it is reasonable to say that the price of vehicles acquired through public auctions is more significant than that obtained in the illegal market. Criminals typically want to reduce time with a stolen good in their possession. They usually sell vehicles robbed at reduced prices to get rid of the illegal goods and decrease the probability of being followed and arrested by the police. Thus, the more dependent a junkyard was on the illegal market, the higher the probability it would close after the introduction of the law.

Columns 5 and 6 of Table 6 show the results of Equation 2 for vehicles stolen through robbery and theft using the distance to junkyards closed after the introduction of the law as an instrumental variable. The interpretation of this robustness check comes when comparing baseline estimates in column 1 to the IV estimates in column 5. Vehicles robbed fell more in census tracts up to 200 metres from junkyards closed after the law, and this drop is 70 per cent greater than the overall effect estimated considering all junkyards. Figure 13 compares baseline and IV estimates. Although I cannot completely rule out that factors other than the dependence on stolen vehicles made these junkyards close, my results suggest significant heterogeneity within junkyards. Therefore, the Junkyard Law's effect on vehicles robbed presents different magnitudes depending on the group of junkyards evaluated.
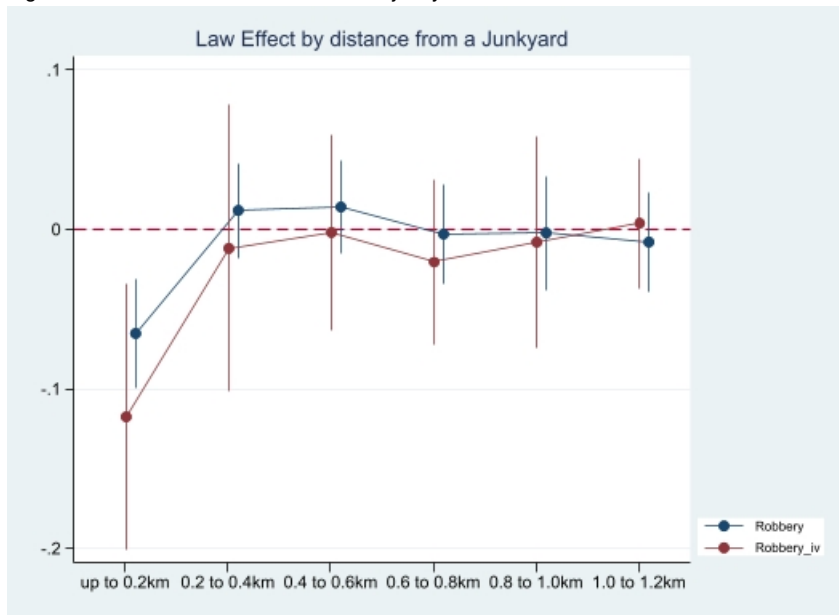
Falsification test: distance to police stations

The more significant decrease in auto theft near junkyards is compelling evidence of a shift in the robbery of vehicles after the Junkyard Law came into effect in these areas. Specific characteristics of the neighbourhoods do not explain this shift in auto theft since Equation 2 controls for location and time fixed effects. I argue that this decrease occurs because of a change in criminals' behaviours, as they responded to the increase in junkyard supervision by reducing robberies closer to these firms.

However, other confounding factors may drive the drop in auto theft in census tracts of São Paulo. Suppose that police capability increased contemporaneously to the Junkyard Law. In that case, my results may capture the deterrence effect of police instead of the causal effect of harsher monitoring of items sold by junkyards. To shed some light on the mechanism driving the reduction in auto theft by census tract, I show the effect of the distance to police stations on vehicles robbed after the introduction of the Junkyard Law. The proximity of a police station represents a significant risk to criminals, and an overall increase in police capabilities probably would affect robbery outcomes closer to these buildings.

Figure 14 shows the estimates and uniform 95 per cent confidence bands of Equation 2 using distances to police stations as the explanatory variable. I do not find any significant change in vehicles robbed in census tracts closer to police stations after the Junkyard Law.
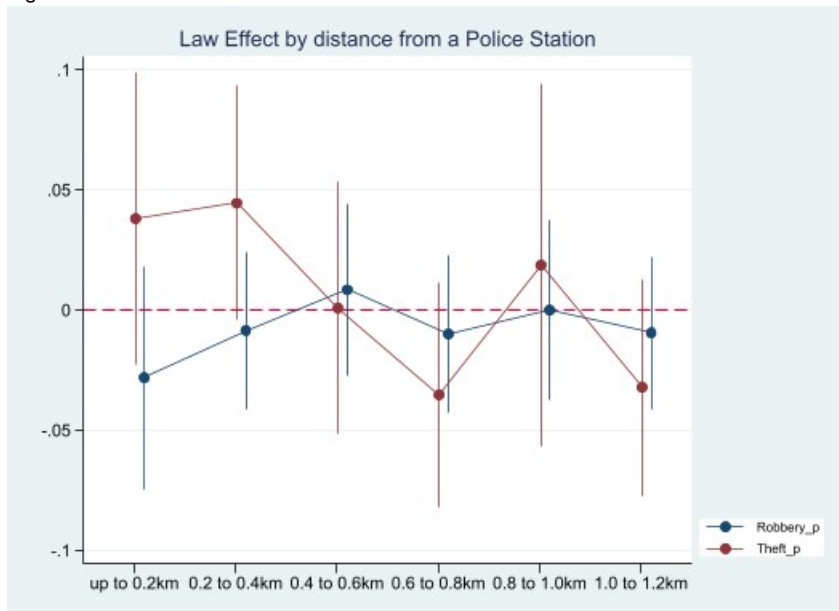
Figure 13: Instrumental variable: closed junkyards

Note: this graph plots estimated coefficients to the distance of the closest junkyard or police station for Equation 2. The sample includes 14,479 census tracts in São Paulo. Covariates include census tract, year, and month fixed effects. Errors are clustered at the census tract level. Dots represent point estimates and bars represent the 95 per cent confidence interval.

Source: author's calculations.

Figure 14: District level: falsification test

Note: this graph plots estimated coefficients to the distance of the closest junkyard or police station for Equation 2. The sample includes 14,479 census tracts in São Paulo. Covariates include census tract, year, and month fixed effects. Errors are clustered at the census tract level. Dots represent point estimates and bars represent 95 per cent confidence intervals.

Source: author's calculations.

These results show that proximity to junkyards is more relevant than the distance to police stations in explaining the decrease in auto theft after the approval of harsher regulations on junkyards. However, it is not possible to rule out that the decrease in robberies closer to junkyards can be related to the deployment of police officers to these areas. In that case, I argue that it would also be a consequence of

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the Junkyard Law that has increased police inspections of these firms to verify their compliance with the law, such as more extensive surveillance and police patrols in junkyard neighbourhoods.

6   Concluding remarks

Despite the anecdotal evidence regarding the association of a market for stolen goods and violent crime, there is very little causal evidence exploiting the interplay between illegal markets and criminals. The traceability of items sold in these firms is crucial to leverage the effectiveness of regulations on junkyards by increasing the difficulty of converting stolen vehicles into cash. This paper presents evidence of the reduction in the number of vehicles robbed in Brazilian municipalities following the harsher supervision of junkyards. I show compelling evidence of a 6.4 per cent annual decrease in stolen vehicles after implementing strict rules to monitor junkyards' activities. The decrease in robberies is not related to an overall downward trend in violent crimes, socioeconomic conditions, or intrinsic characteristics of municipalities that have increased the supervision of junkyards. I also show a more significant decrease in robberies in districts closer to junkyards, and this effect is more intense in neighbourhoods of junkyards closed after the new regulation. Last, there is no displacement of offences to other types of robberies following the introduction of the Junkyard Law.

Differences in compliance with an institutional change are directly associated with the results of harsher law enforcement. Although Brazil had created a regulation on junkyards at the country level, the autonomy of each state about when and how to implement the new legal requirements made it difficult to enforce the monitoring of items sold in junkyards homogeneously across states. For example, criminals may have decided to move to states with lower monitoring of junkyards to exploit legal authorities' lack of commitment to the new regulation. With these caveats in mind, this paper exemplifies how harsher monitoring capabilities and law enforcement affect the relationship between a potential market for stolen goods and crime outcomes.

From a policy perspective, my results provide significant evidence about the potential of institutional changes to reduce criminal outcomes. Increasing enforcement capabilities through reduced monitoring costs is essential to ensure that new regulations can successfully affect criminal behaviour and thus reduce violent crime, especially in countries where violence is a prevalent issue.

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