# Law Enforcement and Illegal Markets: Evidence from the regulation of junkyards in Brazil.

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**Abstract**

I describe how institutional changes affect criminal behavior by reducing the expected benefit of crime through harsher law enforcement. I investigate the effect of legal authorities' supervision on violent crime by focusing on junkyards, firms often associated with auto theft. Starting in 2014, many states in Brazil created new regulations and increased monitoring of spare parts sold by junkyards. I show that the robbery of vehicles dropped significantly after this institutional change, and this decrease is more extensive in locations near junkyards closed after the new regulation. Municipalities that approved the new regulation of junkyards presented, on average, a 6.4% drop in auto theft by year compared to non-target ones. Previous trends or increases in police surveillance do not explain the decrease in stolen vehicles. My results shed some light on the effect on crime of harsher supervision over a market that criminals may exploit to convert stolen vehicles into cash.

*Keywords:* Economics of Crime, Law Economics, Illegal Markets
*JEL*: K40, K42, D04, C23

## 1. Introduction

Violent crimes such as homicides and robberies are prevalent in developing countries, especially in large municipalities and metropolitan areas. Many works show that crime is affected by several factors (Chalfin and McCrary, 2017, Draca and Machin, 2015). Unemployment, inequality, poverty, and public goods provision largely affect individuals' decisions to engage in criminal activities. Although economic growth provides more opportunities in the legal market, many individuals may obtain more significant returns in the illegal market. Therefore, public policies that deter and punish illegal activities are crucial in reducing criminality. Shifts in the expected return of committing a crime by harsher supervision and punishment affect

individuals' decisions to engage in illegal activities, and combining economic development with law enforcement improvements is fundamental to reducing criminality.

Despite the relevance of deterring and punishing criminals, there has been little empirical research regarding harsher law enforcement on crime outcomes, especially in developing countries. Most studies about criminal deterrence have focused on the effect of police on crime (Levitt, 2002, Evans and Owens, 2007) and shifts in sentencing and incarceration (Johnson and Raphael, 2012, Drago et al., 2009). Hence, there is a significant gap in the literature regarding causal evidence of changes in regulation deterring violent crimes. Chimeli and Soares (2017) show that the lack of law enforcement can increase violent crimes. From a policy perspective, providing evidence about the effect of harsher monitoring and enforcement is essential to understanding the effectiveness of regulation changes in reducing criminality.

In this paper, I investigate the impacts of a new regulation on junkyards. More specifically, I focus on the harsher supervision of these firms following state and federal laws that imposed strict rules to dismantle crashed and apprehended vehicles to sell the spare parts recovered. Improvements in the regulation and monitoring of junkyards impose a barrier to collusive agreements between criminals and junkyards to negotiate spare parts from stolen vehicles. Thus, harsher law enforcement on junkyards reduces the expected return of criminals by increasing the cost of operating in the illegal market of vehicle spare parts (Becker, 1968).

To examine this question, I collect auto-theft data in three different states in Brazil from 2011 to 2019. I exploit differences in the timing of the junkyard's regulation approval across these states as a quasi-experiment to assess the causal effect of law enforcement on robbery and theft. Furthermore, the federal government allowed each state to decide how to implement the traceability of items sold by junkyards. Hence, even after the federal government regulation, the monitoring of vehicles dismantled in 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 to dismantle in public auctions without 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 the level of compliance with the Federal Law to disentangle the mechanisms driving the effectiveness of harsher junkyard monitoring on vehicles robbed.

Controlling by group-specific effects, I find evidence that municipalities that implemented harsher supervision on junkyards presented 6.4% fewer vehicles robbed by year than those that did not implement the Federal Law. This decrease is heteroge-

neous across states, and the effect is two times more significant in municipalities of São Paulo compared to municipalities of Rio Grande do Sul. Further, event-study estimates show that the effect of the law enforcement increases over time, and the drop in robberies is much more significant between two and three years after implementing harsher supervision on junkyards. These results suggest that the monitoring of junkyards in São Paulo was more effective, which seems directly related to the traceability of spare parts sold by these firms in the state. Moreover, it takes time for the Law promoting a persistent decrease in robberies, which indicates that criminals do not respond immediately to the new regulation. My results are consistent with the idea that the monitoring capabilities are crucial to the success of regulation. When criminals gradually notice harsher supervision on illegal markets, they move to other activities or states.

Next, I test if proximity to junkyards is relevant to explain the drop in vehicles robbed after the change in the regulation. I geolocate robberies registers and junkyards within the municipality of São Paulo to estimate which areas show a more significant decrease in vehicles robbed after increasing the supervision of dismantling firms. Driving a stolen car for long distances increases the risk of facing a police officer. Therefore, to reduce the probability of apprehension, criminals who steal cars to negotiate with junkyards may prefer to rob a vehicle in neighborhoods closer to the firm where they deliver cars and motorcycles. In this approach, counterfactual districts are those far from junkyards that should not present significant changes in this kind of robbery, given the long distance to the closest junkyards. Despite the significant decrease in robberies in all districts of São Paulo, I find evidence that the drop in vehicles stolen is still more significant in neighborhoods with a junkyard up to 200 meters close. These results highlight a high incidence of vehicles robbed closer to junkyards. However, they must be interpreted cautiously because I only obtained data about junkyards formally registered in the Federal Taxes Authority database. 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 present at least one junkyard, which reinforces the relevance of these firms' presence to the Law's effectiveness. Third, I present falsification tests using homicides and other robberies as dependent variables. I find no evidence of a contemporaneous decrease in homicides following the

new regulation on junkyards. Therefore, I present compelling evidence that other violent crimes did not change significantly following harsher supervision of junkyards, and there was no displacement of offenses to other robberies, which indicates the effectiveness of the Law in reducing criminality.

Last, I show two robustness tests to 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 Junkyard's Law. Firms that face difficulties complying with the new legal requirements and monitoring are arguably better candidates to estimate the effect of the harsher law enforcement. My results show that the robberies decreased 70% more in districts near junkyards closed after the Law compared to the results considering all firms. Although I can not rule out that these junkyards decided to close or move to other states because of other factors than the harsher supervision, this result shows a significant heterogeneity of the decrease in robberies at the district level. I also run a falsification test using distances to police stations, areas that present relevant deterrence effects to criminals. I find no significant change in robberies at any distance to a police station after increasing the supervision of junkyards. Thus, robberies' dynamic closer to junkyards differs from other locations within a municipality.

My findings that harsher law enforcement significantly affects crime outcomes contribute 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 return 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 papers find that legal business 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 could exploit to convert stolen vehicles into cash. My findings represent rigorous empirical evidence supporting policy initiatives to reduce crime outcomes by improving law enforcement.

As Chimeli and Soares (2017) I use an institutional change as a natural experiment to assess the effect of law enforcement on violent crime. They show that new

regulations may increase violence when enforcement is absent. I differ from Chimeli and Soares (2017) by showing how different enforcement levels of an institutional change affect crime outcomes. Furthermore, my paper also uses more granular data that allows exploiting the interplay of the location of junkyards and the robbery dynamic after the increase in monitoring. Last, 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.

The remainder of the paper is structured as follows. Section 2 provides a 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, whereas Section 5 shows the effect of junkyards location on auto-theft after the regulation. Finally, Section 6 concludes the paper.

## 2. Institutional Setting

In this section, I present the context that motivated the regulation change that increased the supervision of junkyards. More specifically, I describe the market of vehicle spare parts and the main details of the regulation that started in the state of São Paulo and became national after one year.

### *2.1. Junkyards and the market of vehicle's spare parts*

Junkyards are relevant suppliers of vehicle's 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[1]. In 2019, the revenues of vehicles reached three million in Brazil. The industry estimates an average life cycle of 10 years for Brazilian cars[2]. Over the years vehicles demand spare parts to regular maintenance and also to replace damaged parts in traffic accidents. Therefore, the market for vehicle spare parts is vast and accounts for about R$ 150 billion in revenues in 2020.

Two leading providers for vehicle spare parts are manufacturers and recycling companies ("junkyards"). The difference between them is straightforward, the former sells brand new items, whereas the last focus on the recovery of used vehicle parts. Moreover, there are also significant differences between the new and used spare parts

[1]According to data provided by the Industry Association "Sindipeças(link)

[2]Source: "Sindipeças" (link)

market. While vehicle assemblers and large auto-service companies mainly buy from manufacturers, some final customers and small mechanical workshops prefer to buy spare parts from junkyards depending on the price difference. The Brazilian Automotive Recycling Association (ABCAR) estimates that junkyard's annual revenues represent about 1.5% of the market for vehicle spare parts, R$ 2.25 billion assuming the numbers of 2020.

Anecdotal evidence points out a possible interplay between junkyards and stolen vehicles. Items sold by junkyards come from apprehended or crashed vehicles that are impossible to repair. Without proper regulation and control of the dismantling activity, there is no way to assure that a used spare part comes from a vehicle acquired in legal public auctioning or the illegal market. Thus, weak supervision over junkyards can create conditions for collusive agreements with criminals specializing in stealing vehicles. If this is true, harsher law enforcement and strict rules to open and keep a firm in this market can impose a barrier to spare parts acquired illegally and thus affect criminals' behavior.

Furthermore, increasing junkyards' supervision has also a selection effect on business owners. Without strict enforcement of a regulation on these firms, a junkyard that acquires vehicles from the illegal market has lower costs than a competitor that only buys cars through public legal auctioning. Figure A.2 displays the problem junkyards face when acquiring vehicles. Arguably there are three types of junkyards: (i) the ones that only operate in the legal market, (ii) the ones that only operate only in the illegal market, and (iii) the ones that combine purchases from the legal and illegal market. Given the risks of keeping robbed products, criminals generally sell them at prices much lower than similar items in the legal market. Without adequate supervision in acquiring and dismantling vehicles, junkyard owners who operate legally face unfair competition in the used spare parts markets compared to competitors that access the illegal market.

Last, proper control and regulation of selling used spare parts is fundamental because consumers hardly distinguish between legal and illegal products. Even junkyards established as formal companies can dismantle vehicles acquired in the illegal market. Hence, providing customers with tools to verify the product's origin is crucial to reducing the demand for illegal products. A regulation that allows consumers to exert complementary supervision to legal authorities decreases monitoring costs. In this context, criminals have lower incentives to sell stolen products because potential buyers easily identify the illegal origin of these items.

The public concern regarding the increase in auto-theft and the possible interplay with junkyards motivated legislators to debate how to improve the control of dismantling firms. After an initial proposal determining the prohibition of all junk-

yards, politicians have agreed with junkyard associations, traffic authorities, and the police department to improve the control and supervision of the sector. The main argument was the relevance of junkyards to fill the gap for some spare parts that manufacturers hardly supply, especially items for long age or imported cars. Moreover, junkyards also argue that these firms reduce environmental damages since recovering spare parts decreases the number of items discarded as garbage. It also alleviates resources employed by the vehicle industry by reducing the number of items produced.

### *2.2. The State Law 15.276 ("Junkyard's Law")*

The increase in auto theft motivated a public debate at the state legislative house of São Paulo about the role of junkyards as a possible destination of stolen vehicles. The first policy recommendation made in 2012 has suggested a 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.

Auto theft is a prevalent crime in metropolitan areas and large municipalities. In the state of São Paulo, these events had a huge increase over the 2000s, reaching an amount of more than 165 thousand vehicles stolen in 2014. Furthermore, the recovery rate is less than 50% according to the insurance companies association ("CNSEG" [4]).

These proposals faced strong opposition from junkyard owners that claimed 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. In this sense, junkyards are complementary to manufacturers supplying vehicle spare parts. After several debates, the State Government, the State Legislative House, ABCAR, and DETRAN-SP reached an agreement to regulate junkyards by approving the Law 15.276 ("Junkyard's Law") in January 2014, with legal effects starting in July.

The Junkyard's Law has increased the legal requirements to open and run a dismantling firm and sell vehicles spare parts. With the new regulation, all junkyards need a permit provided by DETRAN-SP to acquire crashed and apprehended vehicles in State public auctioning. Every year, junkyards must renew this permit, which is

[3]State law project number 4.330 (link)

[4]Source: *Época Negócios* Magazine. (link)

mandatory to dismantle cars and motorcycles, such as selling vehicle spare parts. Moreover, with the new regulation, junkyards must comply with a series of legal requirements and present (i) registered by-law, (ii) criminal records of owners and employees, (iii) municipality business license, (iv) technical capacity certificate, (v) taxes compliance certificate, (vi) environmental certificate[5], (vii) electronic records of all vehicles acquired and spare parts recovered that allow tracking any sale and acquisition and (viii) keep an updated list of employees (regular and temporaries).

Last, the Junkyard's Law also focused on items' traceability. Each junkyard must present detailed information to DETRAN-SP regarding its inventory and revenues. After acquiring a vehicle, the junkyard informs the authority about all spare parts recovered, and it must register the car acquired and all items as inventory in DETRAN-SP system. Junkyards must also fill a technical report signed by a certified employee regarding the dismantled vehicle and provide a complete list of spare parts recovered and items discarded. Moreover, consumers receive an identification number in the fiscal receipt to track at the DETRAN-SP website, which dismantled vehicle provided that spare part. 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 A.8 shows photos highlighting the QR identifier of an engine recovered by a Junkyard.

The new regulation reduced the 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 also 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 up to R$ 50 thousand (about USD 10 thousand) if spare parts do not present the QR Code or they cannot prove the legal origin of the items in legal authority's inspections.

Although other confounding factors must have affected criminality in São Paulo, the Junkyard's Law seems to be an essential feature driving an impressive 40% drop in vehicles stolen in the state from 2014 to 2019. The harsher legal requirements and supervision of dismantling firms had a massive effect on junkyards. One year after the Junkyard's Law approval, about 700 non-compliers firms were closed[6] in São Paulo state after inspections commanded by a task-force evolving DETRAN-SP, State Police and the State Taxes Authority. These changes made it much more

[5]Junkyards must have a building suitable to deal with potential pollutants like oil and batteries and guarantee that there will not be risks of soil contamination.

[6]Source: G1 Magazine. (link)

difficult for junkyards to negotiate spare parts acquired from the illegal market.

The Federal Government exploited the legislation change in São Paulo as a model to create the Federal Law 12.997 in May of 2014. Although the Federal Law applies to the whole country, each State Government is responsible for creating specific regulations to monitor dismantling firms in municipalities. Thus, even after the approval of a Federal Law, many states in Brazil still have not created local regulations on junkyards. Moreover, even states that created specific rules and norms to comply with the federal legislation are not directly comparable to São Paulo since some have not implemented all requirements described in the Federal Law. The State of Rio Grande do Sul approved a junkyard regulation in December of 2015 without imposing the electronic control of items sold by junkyards. Afterward, only in 2017 did the Traffic State Authority of Goias and Minas Gerais join the group of states that started to comply with the Federal Law. In 2020, Parana, Santa Catarina, and Rio de Janeiro announced harsher regulations over junkyards following the national legislation.

## 3. Data and Empirical Strategy

### *3.1. Data*

This paper exploits the Junkyard's Law to assess the effect of harsher supervision of dismantling firms on stolen cars. I use monthly robbery and theft data 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. The Security Secretary of each state provides robbery and theft statistics, and there are huge differences regarding data availability and details publicly available. Some secretaries provide only state-level data for short periods at the municipality level, making it difficult to access a detailed panel data set comprising each municipality from all 27 Brazilian states over time. I selected these three states because of the availability of crime data before and after the Junkyard's Law at the municipality level. I also use data regarding homicides and other robberies provided by state secretaries 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 and the requirements implemented by each state are a unique opportunity to test the effect of Law enforcement on crime outcomes. Figure A.1 shows the timing and main events related to the regulation of junkyards in São Paulo and Rio Grande do Sul. Even after the Law became national, Rio de Janeiro has not approved a state regulation from 2011 to 2019. Since its approval in 2014, São Paulo imposed the traceability of cars acquired and items sold

by junkyards, and the State Government improved this system in 2015 by requiring a QR code tag on all items. Thus, in São Paulo, consumers and legal authorities can use a cellphone to verify if a spare part came from a legally acquired vehicle.

On the other hand, Rio Grande do Sul only created a system to track junkyards' purchases and revenues two years after approving a state regulation. Hence, I exploit differences in timing and compliance with the Law by comparing vehicles robbed across municipalities in São Paulo, and Rio Grande do Sul. Rio de Janeiro municipalities are the *pure control group* which were not affected by changes in law enforcement on junkyards.

Table A.1 presents summary statistics on crime registers and GDP per capita for São Paulo, Rio de Janeiro, and the Rio Grande do Sul pre and post the Junkyard's Law in 2014. Figures A.3 to A.6 display the spatial distribution of robbery and theft of vehicles before and after the Junkyard's Law. The average monthly number of vehicles robbed by the municipality in São Paulo decreased by about 23%. In contrast, Rio de Janeiro and the Rio Grande do Sul presented a 46% and 28% increase. Moreover, Rio de Janeiro presents a more significant level of homicides and other kinds of robbery than the other states before the Law. São Paulo presented an impressive decrease in homicides comparing these two periods (-48.4%) and a significant increase in the GDP per capita (+71%).

Last, I use the Taxes and Labor National Authority data to identify the number of junkyards in each municipality of São Paulo. To assess even more granular data, I use the coordinates of each junkyard to geolocate its position at street level. Over time, this information allows exploiting the number of vehicles stolen in areas by the distance of junkyards.

### *3.2. Empirical Strategy*

#### *3.2.1. Municipality Level - Staggered Approval of The Junkyard's Law*

I exploit auto-theft changes before and after the Junkyard's Law approval. If the Law has not affected criminal behavior, one would expect no significant changes in the number of vehicles stolen compared to municipalities not affected by the Law. On the other hand, if the trend of stolen vehicles shifts after the Junkyard's Law, it can result from harsher law enforcement and supervision of dismantling businesses.

To identify the causal effect of the Junkyard's Law, I exploit that São Paulo 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. Moreover, the Security Secretary of Rio de Janeiro provides detailed data regarding crime at the district level.

Between July 2014 and December 2015, municipalities in Rio Grande do Sul are 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's Law. Moreover, Rio Grande do Sul approved a regulation for junkyards only 16 months after São Paulo, without requiring an electronic system to track and monitor junkyard purchases and revenues. Hence the case of Rio Grande do Sul provides the perfect condition to test differences in timing and intensity of the treatment and disentangle the mechanisms driving the Law's effectiveness.

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's Law. The identification comes from the variation in stolen vehicles: (a) across treated and control municipalities and (b) before and after the Junkyard's Law approval. 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 difference-in-differences estimator of the Junkyard's Law effect on stolen vehicles using the following model:

$$y_{it} = \alpha_i + \beta_1 * Law_{it} + X_{it} + \phi_t + \mu_{it} \tag{1}$$

Where the subscripts $i$ and $t$ respectively denote municipality and date; $Law_{it}$ is a dummy equal to one after the Junkyard's Law approval to the municipalities $i$, $X$ is a vector of control variables including GDP and Population, $\phi$ is a set of time-fixed effects that include year and month dummies, and $\alpha$ are municipality-fixed effects.

The dependent variable $y$ indicates criminal registers in a municipality in a month. Security Secretaries of São Paulo, Rio de Janeiro, and the Rio Grande do Sul provide information on different types of crimes, allowing 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 the Law's effect on other offenses. 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 Junkyard's Law in July 2014. The coefficient $\beta_1$ represents the change in crime outcomes between treated and control municipalities after the Junkyard's Law. 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 after the

Junkyard's Law and not due to other confounding factors.

*3.2.2. District Level - Distance to Junkyards*

Do criminals respond to harsher supervision of junkyards by reducing robberies in the neighborhood of these places? Driving a robbed car for long distances increases the probability of getting caught by police officers. Therefore, criminals who keep collusive agreements with junkyards arguably prefer driving for short distances to minimize the risk of apprehension. For example, 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 junkyards registered in the Federal Tax Authority database, whereas some junkyards may operate as informal companies without tax identification. If only informal junkyards receive stolen cars to dismantle, legal firms' location will not provide accurate estimates of proximity to junkyards on vehicles robbed. On the other hand, legal requirements and supervision were significantly lower before the Junkyard's Law. It is possible that some junkyards formally constituted operate in the legal and illegal market, i.e., before the Law, they acquired vehicles to dismantle in Public Auctions and also from Criminals. However, even assuming that junkyards could operate in legal and illegal markets, it is still tricky to identify how many had collusive agreements to receive and dismantle robbed cars. Despite the inherent difficulties in assigning which junkyards acquired vehicles from the illegal market, 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 vehicles robbery.

I evaluate the effect of the Junkyard's Law within the city of São Paulo, the largest municipality in the state where most junkyards are. As described above, it is reasonable assuming that a criminal would not drive a robbed car for long distances and hours because of the probability of being followed by police officers. Furthermore, some vehicles have electronic trackers, which increases the risk of driving a monitored car. In the research made for this paper, police officers and junkyard owners mentioned that gangs specialized in car robbery usually keep hidden garages where they check if the vehicle robbed has some 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 neighborhood to dismantle it, a process called *cold the car*. Therefore, if criminals keep collusive agreements to rob vehicles for junkyards, stealing a car in districts closer to these places is arguably less risky. Assessing the heterogeneous effect of the Law by distances to junkyards also allows testing if there was a

displacement of criminal activity, i.e., if gangs increased robberies in districts without junkyards to respond to the harsher supervision after 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 large numbers of robberies, this can 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 Law can be affected if junkyards decide to reallocate within the city, making the treatment ("Law") contaminate districts far from junkyards in this scenario.

To overcome these issues, I present two robustness tests. First, I use the location of junkyards that left the market as an instrumental variable after the new regulation. As described above, the Junkyard's Law closed many dismantling firms. Moreover, some junkyards may have decided to move to other states or businesses, given the increased supervision of legal authorities. Hence, using the location of closed junkyards as an instrumental variable captures the change in the dynamic of robberies near firms that arguably had more difficulty complying with the legal requirements demanded by the Junkyard's Law. Second, I perform a falsification test using distances to police stations as the dependent variable in the baseline regression. This approach allows checking if the deterrence effect of police increased after the Junkyard's Law, affecting the number of vehicles robbed in police station neighborhoods. Hence, I am able to verify if the decrease in robberies near junkyards was more intense than in locations with intense police presence.

I combine data regarding junkyard location and registers of robbery and theft at the street level to assess the effect of the Law by distances to each junkyard and evaluate if the decrease in robberies were more significant in junkyards neighborhoods. I estimate a differences-in-differences model with time-fixed effects to absorb all common shocks in the number of stolen vehicles across districts. I also include district-fixed effects to control for unobservable crime determinants that are invariant at the local level. I obtain the difference-in-differences estimator using the following model:

$$y_{it} = \alpha_i + \beta_1 Law_t + \sum_d \beta_2^d T_i^d Law_t + \phi_t + \mu_{it} \tag{2}$$

Where the subscripts $i$ and $t$ denote census tract[7] 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

[7]Geographic region defined for the purpose of taking a census.

0.2km, 0.2 to 0.4km, 0.4 to 0.6km, 0.6 to 0.8km, 0.8 to 1.0km and 1.0km to 1.2km. The measure of 1.2km is the median distance between census tracts and the closest junkyard. Therefore, areas in São Paulo with a junkyard at 1.2km are the treated group, while neighborhoods 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. First is that census tracts more than 1.2km far from junkyards were less affected by the Law (non-contamination of the control group). Second, groups present parallel trends of robbed vehicles before the Law. Last, the variable $Law_t$ controls the Junkyard's Law approval effect in all census tracts within São Paulo. Hence, the coefficient $\beta_2$ shows the specific effect of the proximity to junkyards on robberies after approving the Law.

## 4. The Effect of the Junkyard's Law on Vehicles Robbed

### *4.1. Results at the Municipality Level*

Table A.2 reports the results from the estimation of Equation 1 using as dependent variable the logarithm of Auto-Theft of vehicles in the sample from 2003-2019 with municipalities of Rio de Janeiro as Control Group. In this first approach, I use only these two states to assess the effect of the Junkyard's Law in a setting without a possible concern regarding staggered adoption of the treatment[8]. I show the differences-in-differences point estimates to the Junkyard's Law in São Paulo with and without controlling GDP and Population. As shown in columns 3 and 4, I find a large and significant effect of the Junkyard's Law on robbery; the estimates are equivalent to an average 4.8% 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 theft outcomes.

Differences in compliance with the Law provide a unique opportunity to evaluate changes in outcomes by comparing both states after implementing Junkyard's Law. I exploit a sample from 2011 to 2019, including Rio Grande do Sul municipalities, which approved the Junkyard's Law only in December 2015, 18 months after São Paulo. This setting allows testing differences in the timing of the treatment. Municipalities of Rio Grande do Sul were in the control group until December 2015, and to this period, there is no expected effect of the Junkyard's Law. Moreover, unlike São

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

Paulo, Rio Grande do Sul only imposed the electronic traceability of items acquired and sold by junkyards in October 2017.

Table A.3 show results from the estimation of Equation 1 to robbery 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 A.2. Column 3 shows the effect of the Junkyard's Law in São Paulo using Rio Grande do Sul as the control group before the state approved the regulation on junkyards in January 2016. Last, column 4 presents the results excluding municipalities of São Paulo to assess the effect of the Law in Rio Grande do Sul from January 2016 compared to municipalities of Rio de Janeiro. I found significant results to all specifications of the treated and control group. Furthermore, I show that even using municipalities in Rio Grande do Sul as the control group, São Paulo still shows a significant decrease in the robbery of vehicles (-1.6% by year), however smaller than Rio de Janeiro municipalities as the control group (-2.7% by year). Regarding differences in compliance with the Junkyard's Law requirements, a comparison between the coefficients of columns 2 and 4 shows a 25% larger effect of the Law in São Paulo relative to Rio Grande do Sul using the same control group as reference.

These results shed some light on the mechanisms driving the Law's effectiveness on robbery. A most significant decrease in cars robbed in São Paulo compared to Rio Grande do Sul seems to be related to differences in compliance with the Junkyard's Law. Whereas São Paulo implemented an electronic system to track items acquired and sold by junkyards after the approval of the Law, Rio Grande do Sul only created this system two years after approving the new regulation. Moreover, São Paulo improved this control by requiring a QR code tag in all items sold by junkyards in October 2015, which provided more efficient tools to consumers and legal authorities monitoring junkyards.

### *4.2. Robustness*

#### *4.2.1. Alternative Specifications*

My findings show that auto theft dropped significantly in municipalities that have increased monitoring and supervision of junkyards. To enhance the validity of the mechanisms driving the results, I present an alternative specification that compares municipalities with and without the presence of junkyards.

Suppose the fall of stolen vehicles after the new regulation is more significant in cities with junkyards than those without these firms. In that case, this reinforces

the link between law enforcement and the decrease in auto theft. However, if there is no difference comparing municipalities with and without junkyards, the reduction in vehicles robbed could have been caused by confounding factors other than the Junkyards' Law. 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 difference-in-differences estimator is:

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

Where $D_i^j$ is a dummy variable equal to one when there is at least one junkyard in the municipality $i$. Hence, the coefficient $\beta_2$ show the differential of the Junkyard's Law across cities with and without junkyards after controlling for location and time fixed effects.

Table A.6 reports the results from the estimation of Equation 3 using as dependent variable the logarithm of Auto-Theft of vehicles in the sample from 2003-2019 with municipalities of São Paulo. In this approach, 192 municipalities present at least one junkyard are the *treatment group*, and the remainder of 453 is the *control group*. I show the differences-in-differences point estimates to the Junkyard's Law in São Paulo with and without controlling GDP and Population. My results show an effect about two times more significant to auto-theft in cities with junkyards. Regarding theft outcomes, the results in columns 5 and 6 show that the Junkyard's Law was only effective for the treatment group. These findings are supportive evidence about the role of junkyards in the effectiveness of the Law, and it reduces the probability that confounding factors non-related to junkyards are driving the reduction in auto theft.

A final issue to address is that although the unit of analysis is municipality auto-theft outcomes, the treatment *"Junkyard's Law"* occurs at the state level. Suppose vehicles robbed are serially correlated over time within municipalities. In that case, the mismatch between the measurement level of the dependent variable and the treatment can understate the standard errors of the estimate of *"Junkyard's Law"*. The standard solution to this mismatch is clustering standard errors to the state level to account for possible serial correlation in auto-theft outcomes. However, in my main specification, I only have three states, and there is robust evidence that standard asymptotic method cannot be applied when the number of groups is small (Conley and Taber, 2011, Donald and Lang, 2007). In these cases, difference-in-differences estimation is inconsistent and results in 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 effect and standard errors such as proposed by Donald and Lang (2007). Using this procedure, I show the estimates of the Junkyard's Law on auto-theft outcomes in Figure A.9. The results are significant and confirm that the harsher supervision of junkyards decreased auto theft.

*4.2.2. Event study and Group-Specific Effects*

Auto-theft in São Paulo and Rio Grande do Sul dropped after the harsher supervision of junkyards. However, it is not clear that the decrease in robberies is only because of the enforcement of the Junkyard's Law. Other factors can affect the decision of criminals to rob a car, such as the choice of junkyard owners to purchase stolen vehicles to dismantle. Maybe, São Paulo and Rio Grande do Sul presented a previous trend in criminal outcomes, and in this case, robberies would fall no matter the Junkyard's Law enforcement. Moreover, if the supervision and punishment of non-compliers junkyard owners are weak, the drop in robberies can be only temporary. If this is true, the illegal market can return to its previous levels over time. 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's Law and the timing of the Law 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 A.1 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. Rio Grande do Sul only approved a State regulation in December 2015. Although both states implemented the Junkyard's Law, there are significant differences when comparing the monitoring system in São Paulo, and Rio Grande do Sul. While the first provided consumers and legal authorities with tools to track the origin of items sold in junkyards, the last only imposed this traceability requirement 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's Law, I use the method proposed by Callaway and Sant'Anna (2021). The authors present a framework applied to difference-in-difference models with staggered adoption. Once units receive the treatment, they remain treated in the following periods, which happened in my setting since there is variation in the treatment timing across states. However, once they approve the Law, the new regulation remains enforced afterward. 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 Junkard's Law, and $C$ is a binary variable equal to one 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's Law. Last, the results presented in Table A.2 suggest that covariates do not affect significantly the results. If pre-treatment variables do not play a significant role in the identification, the expression 4 collapses to:

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

The expression 5 shows that the average effect of approving the Junkyard's Law in time $g$ is identified by taking changes in robberies compared to the most recent period before the Law approval and adjusting by the changes in robberies 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 Junyard's Law.

Figure A.10 shows the group-time average treatment effects, a uniform 95% 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's 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 A.10) compared to municipalities of Rio Grande do Sul (bottom row of Figure A.10). Moreover, there also appears to be a dynamic effect of increasing law enforcement. For municipalities in São Paulo, the decrease in robberies is larger after two years of the approval (24 months) and remains significant for the rest of the period.

Table A.5 presents aggregated treatment effect measures described by Callaway and Sant'Anna (2021). The results show the effect of the Junkyard's 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 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 two-way fixed effect estimates. The decrease in robberies in São Paulo is 27% larger than in Rio Grande do Sul municipalities.

My results show that the harsher monitoring of junkyards decreased vehicles robbed compared to what it would have been without the Junkyard's Law, even after considering the dynamic effect of the treatment. Moreover, the Event-Study aggregation suggests that it has taken some time for the Junkyard's Law to become effective in decreasing robberies, which in part reflects improvements in the monitoring over time as the QR Code implementation in São Paulo, 15 months after the Law approval. Last, the remarkable difference in the Group-Specific estimates of São Paulo compared to Rio Grande do Sul shows the crucial role of imposing traceability in items negotiated by junkyards. The state of Rio Grande do Sul started implementing a system to monitor junkyard revenues only two years after approving the Junkyard's Law.

*4.2.3. Falsification Tests*

After approving the Junkyard's 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 if other violent crimes also decreased after the Junkyard's Law approval. If crimes as homicides decreased following the Law, my estimates would reflect a general downward trend in violent crimes instead of the effect of harsher law enforcement on junkyards business. Maybe states that implemented harsher supervision rules over junkyards also increased efforts in surveillance and police patrols. 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 A.11 shows the results of a falsification test using homicides as dependent variables in the group-specific effects approach of Callaway and Sant'Anna (2021). Homicides in São Paulo and Rio Grande do Sul did not decrease after the approval of the Junkyard's Law in these states, ruling out a general downward trend in violent crimes contemporaneous to the Law implementation.

Moreover, after the increase in the supervision of junkyards, some criminals may have moved to other crimes. Therefore, if there is an increase in other robberies following the Junkyard's 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 A.12 show that other robberies did not

increase significantly in the period post-treatment in municipalities of São Paulo (top row in Figure A.12) and Rio Grande do Sul (bottom row in Figure A.12).

These results show that other violent crimes did not decrease significantly following the Junkyard's Law approval. Therefore, it seems that the Law specifically affected vehicles' robbery, and a broad downward trend in criminality does not drive this effect. Thus, the decrease in vehicles robbed does not appear to be a consequence of increasing police patrols and an overall deterrence effect over different types of robberies and violent crimes. Last, the fact that there was no displacement of offenses to other robberies is a critical indicator of the effectiveness of the Law in reducing criminality.

The traceability of spare parts and increased legal requirements to operate a junkyard seem relevant mechanisms to interpret the significant drop in vehicles robbed after approving the Law. The Government of São Paulo closed more than 700 non-compliers junkyards in the state after approving the Junkyard's Law, which supports the hypothesis that enforcing strict rules on junkyards acquiring vehicles from the illegal market had a significant and long-lasting effect on vehicles robbed.

## 5. The Effect of Junkyards Location on Vehicles Robbed

### *5.1. Results at the District Level*

Table A.7 present the results of equation 2. I show the results of the Law by the distance of junkyards to robberies in column 1 and theft in column 2. Robberies of vehicles decreased more in census tracts with at least one junkyard in 200 meters. The Junkyard's Law has no additional effect for census tracts where the closest junkyard is far more than this distance. I find no effect to the theft of vehicles using the same specification of distances to junkyards. Figure A.13 show the estimates and uniform 95% confidence bands. These results show that the Junkyard's Law effect on vehicles robbed was more significant in districts closer to junkyards.

The approval of the Junkyard's Law in São Paulo has changed the dynamic of robberies closer to junkyards. Despite the significant decrease in robberies in all census tracts, represented by the variable *Junkyard's Law* in Table A.7, neighborhoods with junkyards up to 200 meters had an additional decrease in robberies by the same magnitude compared to census tracts where the closest junkyard is at least 1.2 km far. Census tracts and time-fixed effects do not explain the decrease in robberies in these neighborhoods.

### *5.2. Robustness*

#### *5.2.1. Instrumental Variable - Junkyards closed after the Law*

The causal effect of harsher supervision of junkyards on robberies comes from imposing higher costs to criminals converting stolen vehicles into cash. If junkyards stop acquiring robbed vehicles, it arguably decreases the expected return of criminals to steal a car. However, many junkyards may have chosen to acquire vehicles only in the legal market before the Law. Thus, junkyards may differ in collusive agreements with criminals, even when comparing firms in the same neighborhood. The dynamic in robberies closer to junkyards that operated only in the legal market probably differs from that closer to junkyards that previously bought vehicles from criminals. Assuming the same probability to all junkyards acquiring vehicles in the illegal market 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's Law requirements. Additional costs to implement the traceability demanded by legal authorities and provide detailed information of all items probably affected the profitability of junkyards. In such context, firms that relied on acquiring stolen vehicles arguably faced more difficulties adapting to the new regulation. The harsher supervision forces junkyards to acquire vehicles only through a public auction, where they must outbid other junkyards. Because of such competition, it is reasonable to affirm that the price of vehicles acquired through public auctions is greater than that obtained in the illegal market. Criminals typically want to reduce time with a stolen vehicle in possession. In such cases, they sell stolen vehicles at reduced prices to 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 Law.

Columns 5 and 6 in Table A.7 show the results of equation 2 to robbery and theft using the distance to junkyards closed after the Law as an instrumental variable. This robustness check's main interpretation comes from comparing baseline estimates to vehicles robbed in Column 1 to the IV estimates in Column 5. Robberies of vehicles decreased more in census tracts up to 200 meters to junkyards closed after the Law. The drop in robberies is 70% larger than the overall effect estimated considering all junkyards. Figure A.15 compares baseline and IV estimates. Although I can not completely rule out that factors other than the dependence on stolen vehicles made these junkyards close, my results show significant heterogeneity within junkyards. Therefore, the Junkyard's Law's effect on robbery outcomes presents different

magnitudes depending on the group of junkyards evaluated.

*5.2.2. Falsification Test - Distance to Police Stations*

The more significant decrease in robberies in census tracts closer to junkyards is compelling evidence of a shift in the stolen vehicles trend after the Junkyard's Law in these areas. Specific characteristics of these neighborhoods do not explain this decrease that equation 2 controls with location and time fixed effects. I argue that this decrease occurs because of a change in criminal behavior that responded to the increase in junkyards supervision by a reduction in robberies closer to these firms.

However, other confounding factors may drive the drop in robberies in census tracts closer to junkyards. Suppose that police capabilities increased contemporaneously to the Junkyard's 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 nature of the robberies reduction in census tracts closer to junkyards, I show the effect of the distance to police stations on vehicles robbed after the Junkyard's 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 A.14 show the estimates and uniform 95% confidence bands of equation 2 using distances to police stations as covariates. I do not find any significant change in vehicles robbed to census tracts closer to police stations after the Junkyard's Law.

These results show that proximity to junkyards is more relevant than the distance to police stations to explain the drop in vehicles robbed 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 the Junkyard's Law that has increased police inspections on these firms to verify their compliance with the Law, such as more extensive surveillance and police patrols in junkyard neighborhoods.

## 6. Concluding Remarks

Despite the anecdotal evidence regarding the association of a market to stolen goods and violent crime, there is very little causal evidence exploiting the interplay between illegal markets and criminals. This paper presents evidence of the decrease of vehicles robbed in Brazilian municipalities following the harsher supervision of junkyards. I show compelling evidence of a 6.4% annual decrease in stolen vehicles after implementing strict rules to monitor junkyards activities. The traceability of

items sold is crucial to leverage the effectiveness of regulation on junkyards by imposing increasing difficulties to convert stolen vehicles into cash. 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 neighborhoods of junkyards closed after the new regulation. Last, there is no displacement of offenses to other robberies following the Junkyard's 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 discretion 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 at the national level. 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 assure that new regulations can successfully affect criminal behavior and thus reduce violent crime, especially in countries where violence is a prevalent issue.

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## Appendix A. Figures and Tables

Table A.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 '000 hab.) | 377.87 | 313.43 | 254.12 | 300.29 | 218.08 | 243.55 |
| Robbery - Others (annual avg. per '000 hab.) | 482.45 | 537.43 | 513.30 | 800.17 | 391.55 | 583.28 |
| Homicides (annual avg. per '000 hab.) | 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 (*"pure control group"*). Columns 1, 3 and 5 show descriptive statistics before to the Junkyard's Law (from 2002 to 2014) whereas columns 2, 4 and 6 the period afterwards (from 2015 to 2019). Auto-theft, Other Robberies and Homicides are presented as annual averages by municipality over one hundred thousand inhabitants. The GDP per capita is the average of the annual Gross Domestic Product by person for each state in Brazilian Reais.

Table A.2: Results - TWFE Baseline Specification

| | Auto-theft | Auto-theft | Robbery | Robbery | Theft | Theft |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Junkyard's 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-squared | 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 2003-2019. The treatment in my differences-in-differences design is given by the variable *"Junkyard's Law"* that assumes value one from July, 2014 only to municipalities in São Paulo. Columns 1 and 2 show the results to 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

Table A.3: Results Auto Theft - TWFE Different Specifications of Control Group

| | All | SP x RJ | SP x RS | RS x RJ |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Junkyard's 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 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's Law"* that assumes value one from July, 2014 to municipalities in São Paulo and from January, 2016 to municipalities of Rio Grande do Sul, and the sample period is 2011-2019. All regressions include municipality, state and time fixed effects. Columnn 1 shows the baseline regression using municipalities of SP, RJ e RS. Column 2 presents the effect of the Junkyard's Law in SP using only municipalities of RJ as control group. Column 3 uses municipalities of RS before the treatment in January, 2016 as control group. Column 4 presents the effect of the Junkyard's Law in RS using municipalities of RJ as control group. Robust standard errors are shown in parentheses.
*p<0.1,**p<0.05,***p<0.01

Table A.4: Results Auto Theft - TWFE Different Specifications of Timing

| | Full Sample | 12 months | 24 months | 36 months |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Junkyard's Law | -0.087*** | -0.095*** | -0.056*** | -0.067*** |
| | (0.008) | (0.012) | (0.009) | (0.008) |
| Observations | 60,978 | 20,577 | 34,456 | 47,943 |
| $R^2$ | 0.913 | 0.921 | 0.917 | 0.914 |
| Controls | Yes | Yes | Yes | Yes |
| Location Fixed Effects | Yes | Yes | Yes | Yes |
| Time Fixed Effects | Yes | Yes | Yes | Yes |

Note: The sample comprises 645 municipalities in São Paulo , 497 in Rio Grande do Sul and 92 in Rio de Janeiro. The treatment in my differences-in-differences design is given by the variable *"Junkyard's Law"* that assumes value one from July, 2014 to municipalities in São Paulo and from January, 2016 to municipalities in Rio Grande do Sul. The dependent variable in all columns is the log(auto-theft). In column 1 I show the results from 2011 to 2019 and in the remainder columns I display results to different periods pre and post the law approval in São Paulo. Robust standard errors are shown in parentheses.
*p<0.1,**p<0.05,***p<0.01

Table A.5: Results Robbery - 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's Law dummy from a two-way fixed effects regression. The row "Group-Specific Effects" summarizes average treatment effects by the timing of Junkyard's Law 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's 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.

Table A.6: Results - TWFE Alternative Specification

| | Auto-theft | Auto-theft | Robbery | Robbery | Theft | Theft |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Junkyard's 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) |
| Junkyards's Law × Presence of Jukyard | -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-squared | 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 |

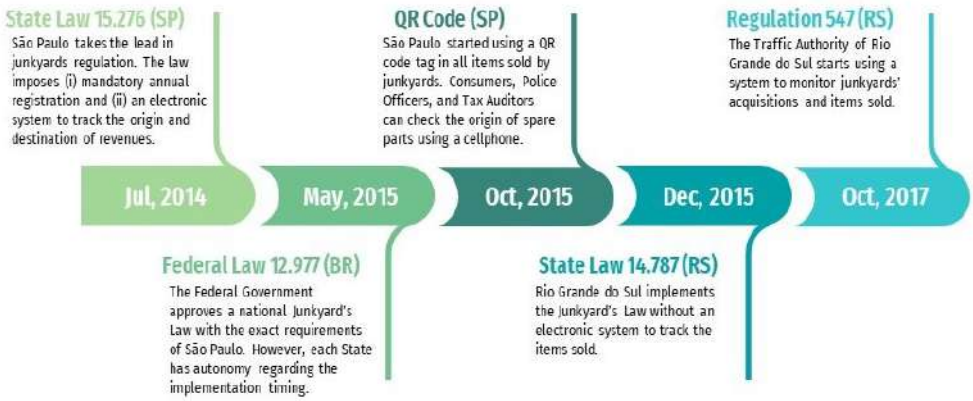
Note: This table shows my results to an alternative specification. The sample comprises 645 municipalities in São Paulo (*"treated group"*) in the period is 2003-2019. The treatment in my differences-in-differences design is given by the variable *"Junkyard's Law × Presence of Junkyard"* that assumes 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

Table A.7: 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's 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 0.2km | -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 to 0.4km | 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 to 0.6km | 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 to 0.8km | -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 to 1.0km | -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 to 1.2km | -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 |

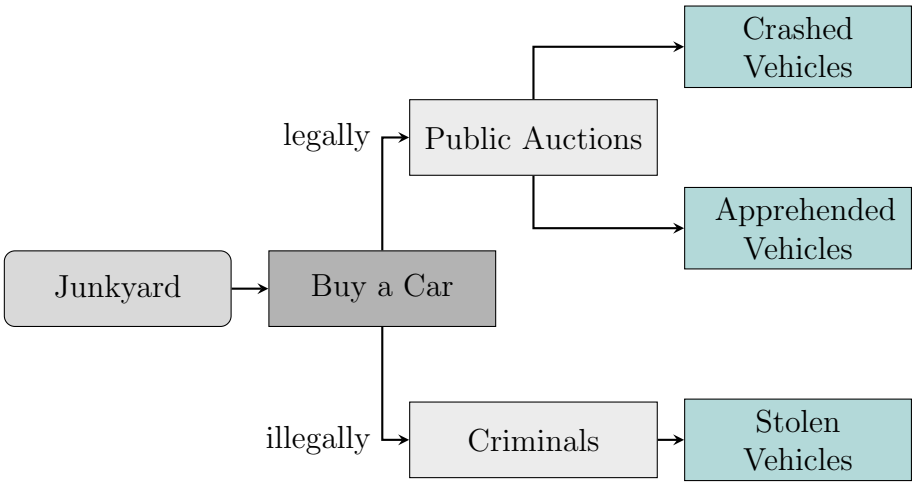
Note: The table reports estimated coefficients and standard errors clustered at the census tract level in parentheses. The dependent variable in columns 1 and 3 is log(number of robberies) and in columns 2 and 4 is log(number of theft). Columns 1 and 2 show results of equation 2 using junkyards as reference 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

Figure A.1: Timeline of Events



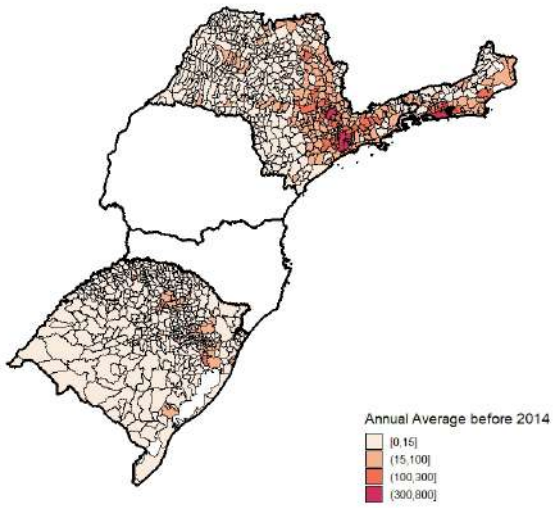

*Notes:* According to information provided by State Security Secretaries and Traffic Authorities. The state o Rio de Janeiro did not create a State Regulation to the Federal Law in the period analyzed (2011-19).

Figure A.2: Junkyards: how do they acquire cars to dismantle?



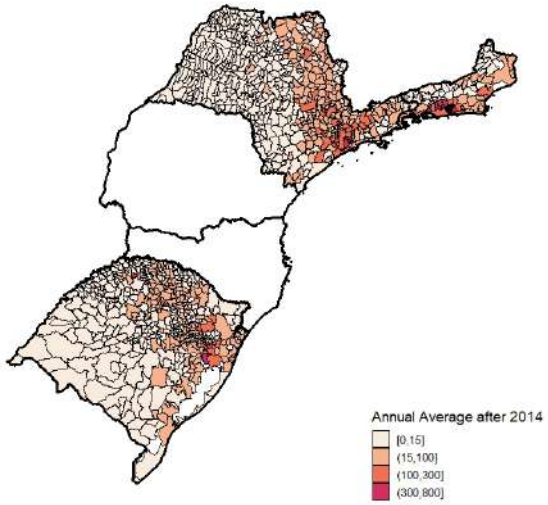

*Notes:* Junkyards acquire cars to dismantle in the legal or illegal market. Changes in supervision and law enforcement may difficult accessing the illegal market decreasing the demand by stolen cars.

Figure A.3: Robbery - Vehicles (Monthly Average by Municipality 2000-2014)



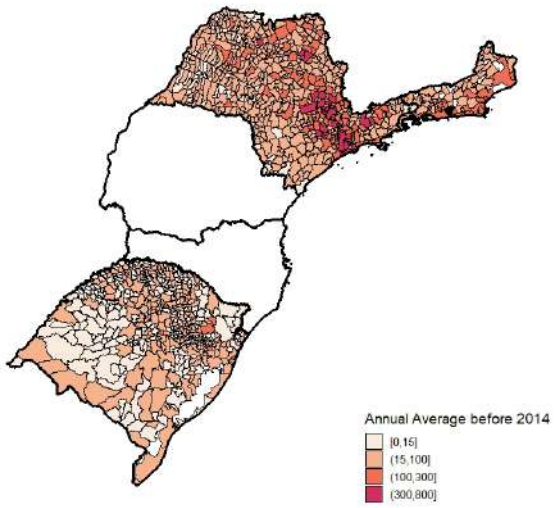

*Notes:* Data provided by States Security Secretaries of São Paulo, Rio Grande do Sul and Rio de Janeiro.

Figure A.4: Robbery - Vehicles (Monthly Average by Municipality 2015-2019)



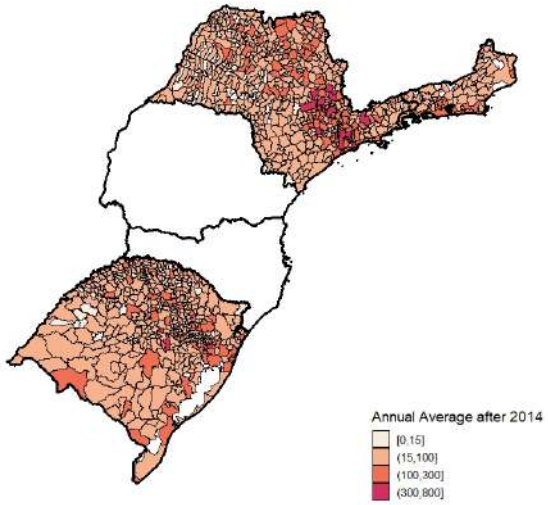

*Notes:* Data provided by States Security Secretaries of São Paulo, Rio Grande do Sul and Rio de Janeiro.

Figure A.5: Theft - Vehicles (Monthly Average by Municipality 2000-2014)



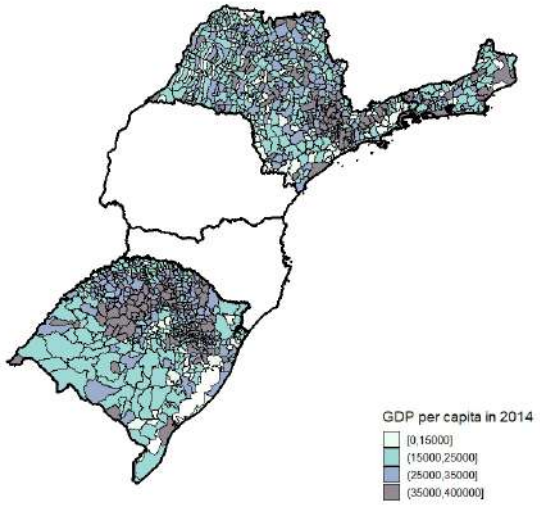

*Notes:* Data provided by States Security Secretaries of São Paulo, Rio Grande do Sul and Rio de Janeiro.

Figure A.6: Theft - Vehicles (Monthly Average by Municipality 2015-2019)




*Notes:* Data provided by States Security Secretaries of São Paulo, Rio Grande do Sul and Rio de Janeiro.

Figure A.7: GDP per capita by Municipality (2014)




*Notes:* Data provided by the National Bureau of Statistics (IBGE).

Figure A.8: Field Evidence - Items sold by Junkyards

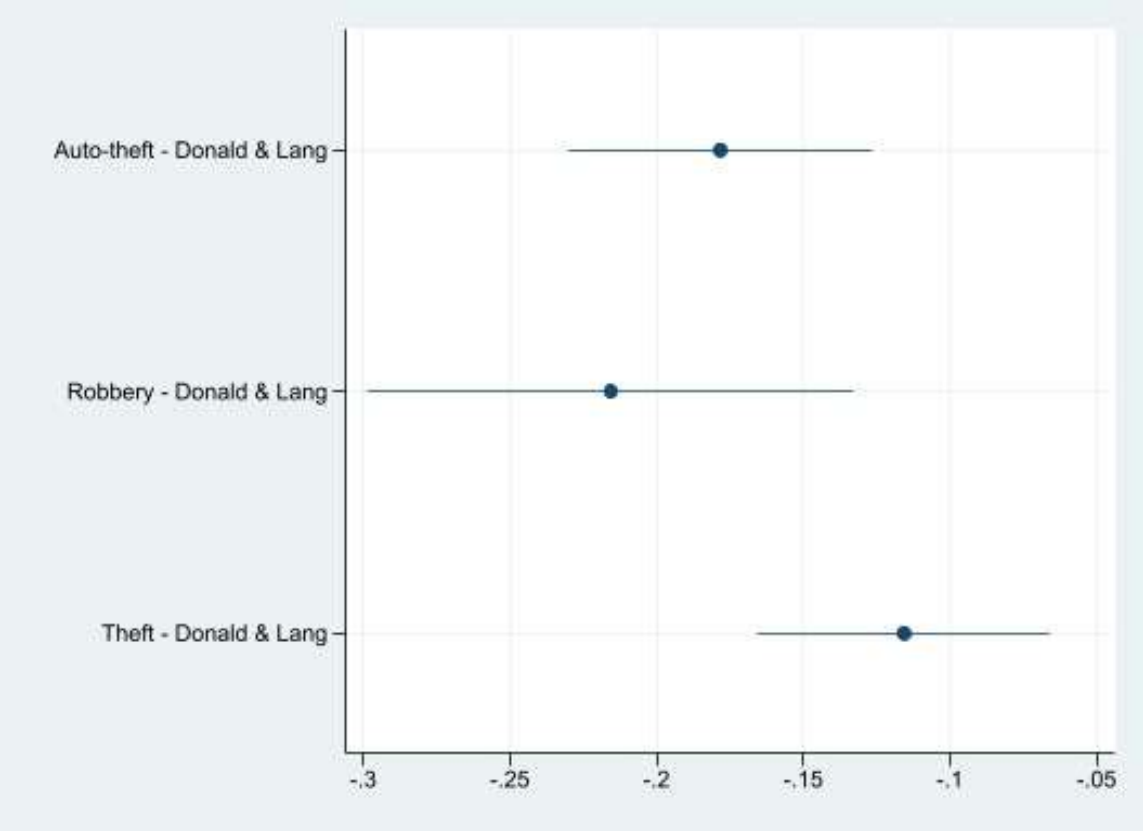
(a) Figure 1

(b) Figure 2

(c) Figure 3

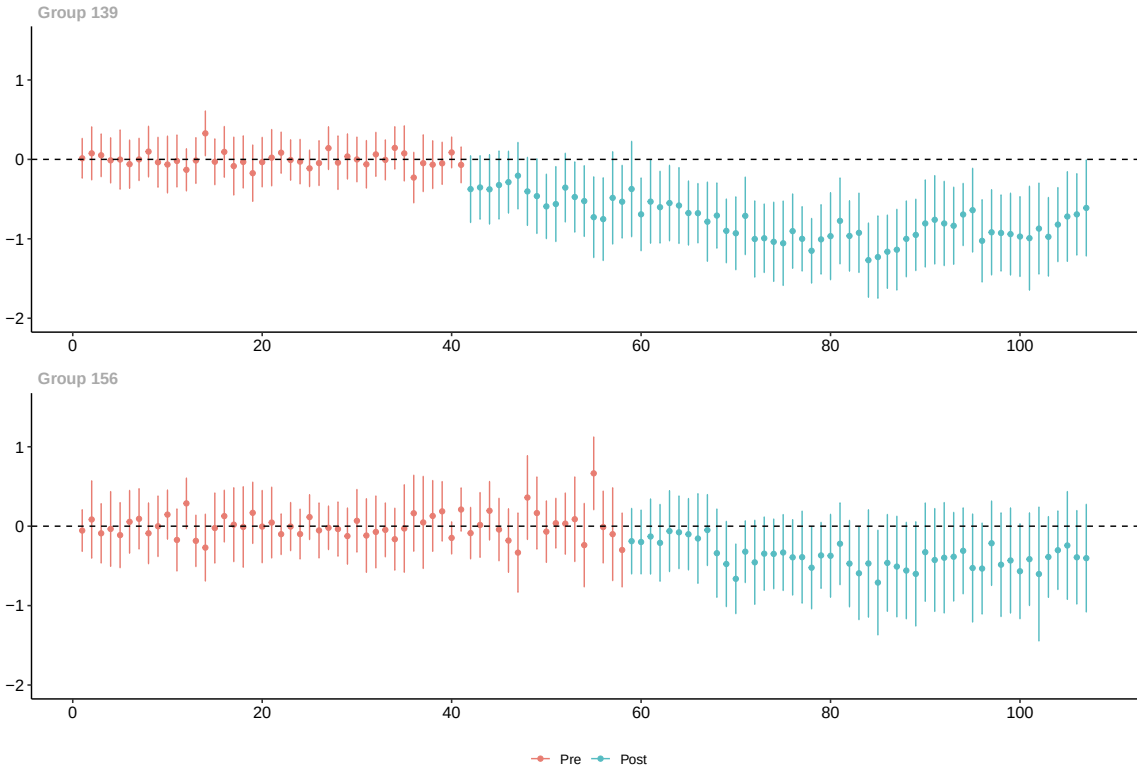
*Notes:* Photos taken in Salvador Luchesi's Junkyard in São Paulo. After the law, any vehicle spare part in stock must present an identifier QR Code proving the legal origin of the product. Consumer can verify the authenticity of the QR code in the State Traffic Authority ("DETRAN-SP") by scanning it using a smartphone.

Figure A.9: Junkyard's Law Effect - Donald & Lang estimates



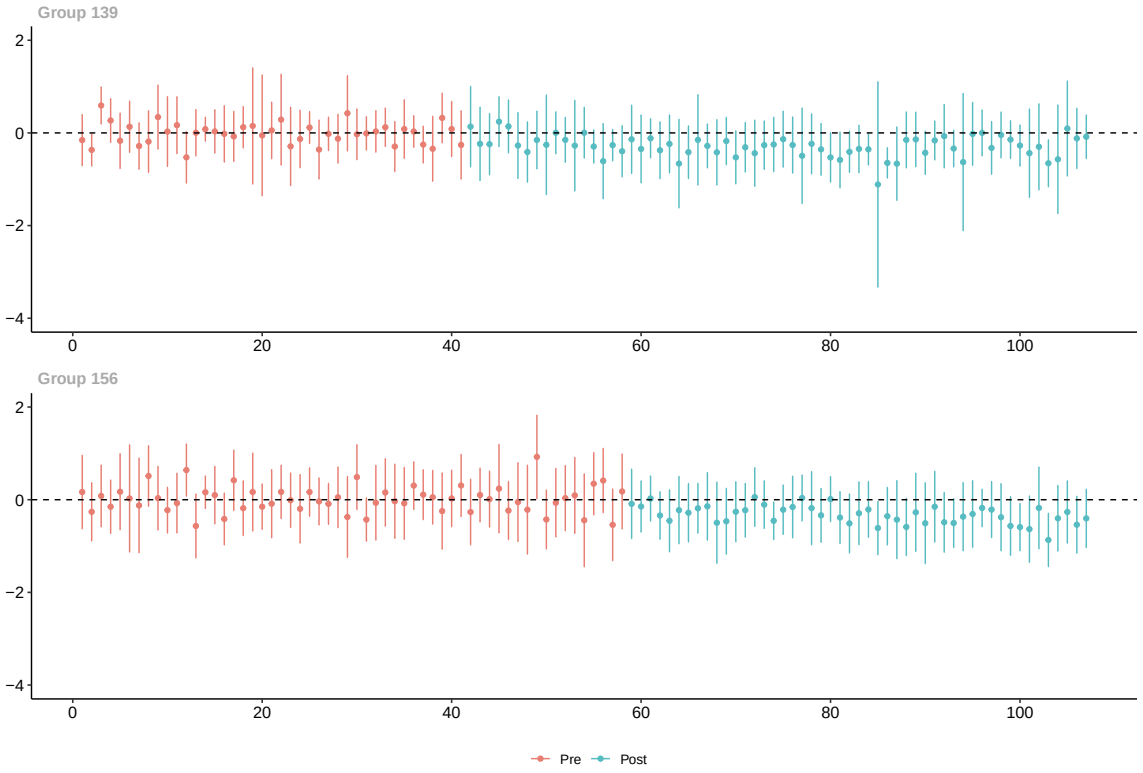

*Notes:* The effect of the Junkyard's Law on auto-theft using use the aggregation method proposed by Donald and Lang (2007). Blue lines provide point estimates and uniform 95% confidence bands for the treatment effect of the Law allowing clustering at the state level. The sample comprises 645 municipalities 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's Law"* that assumes value one from July, 2014 only to 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.

Figure A.10: Junkyard's Law Group-Time Average Treatment Effects



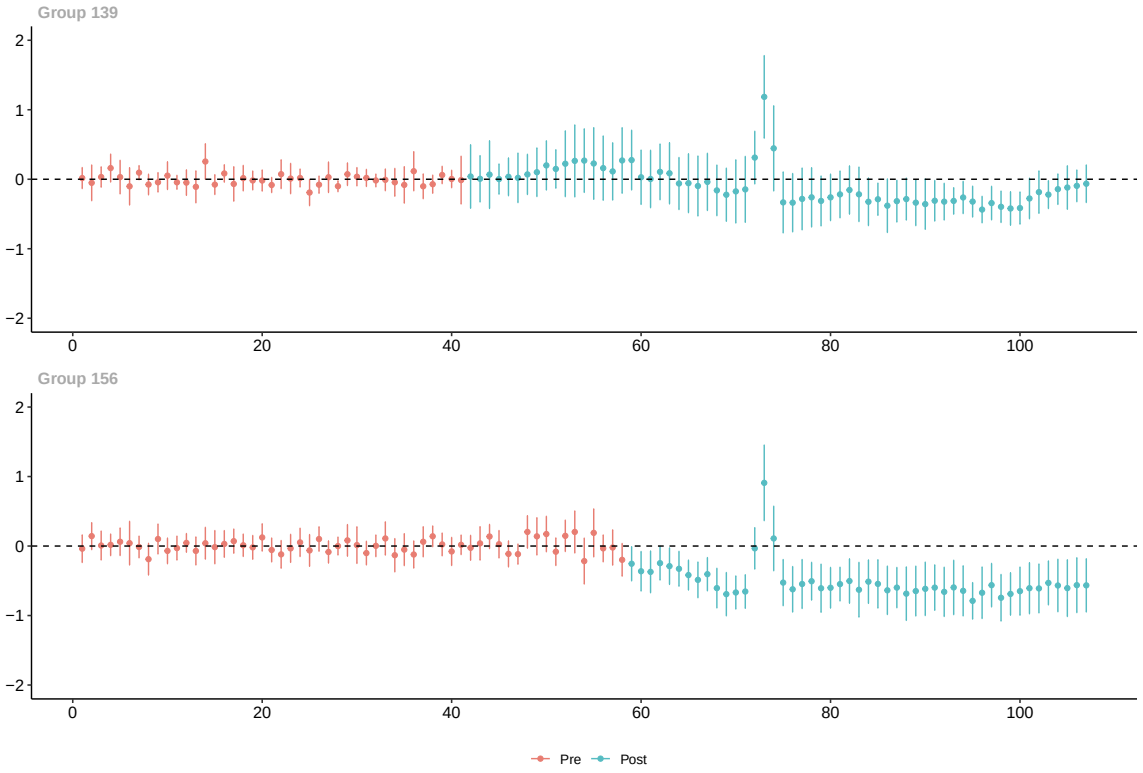

*Notes:* The effect of the Junkyard's Law on vehicles robbed estimated under the unconditional parallel trends assumption. Red lines give point estimates and uniform 95% confidence bands for pre-treatment periods allowing for clustering at the municipality level. Under the null hypothesis of the parallel trends assumption holding in all periods, these should be equal to zero. Blue lines provide point estimates and uniform 95% 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.

Figure A.11: Falsification Test - Homicides




*Notes:* The effect of the Junkyard's Law on homicides estimated under the unconditional parallel trends assumption. Red lines give point estimates and uniform 95% 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% 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.

Figure A.12: Falsification Test - Other Robberies




*Notes:* The effect of the Junkyard's Law on other robberies estimated under the unconditional parallel trends assumption. Red lines give point estimates and uniform 95% 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% 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.

Figure A.13: District Level - Baseline Results

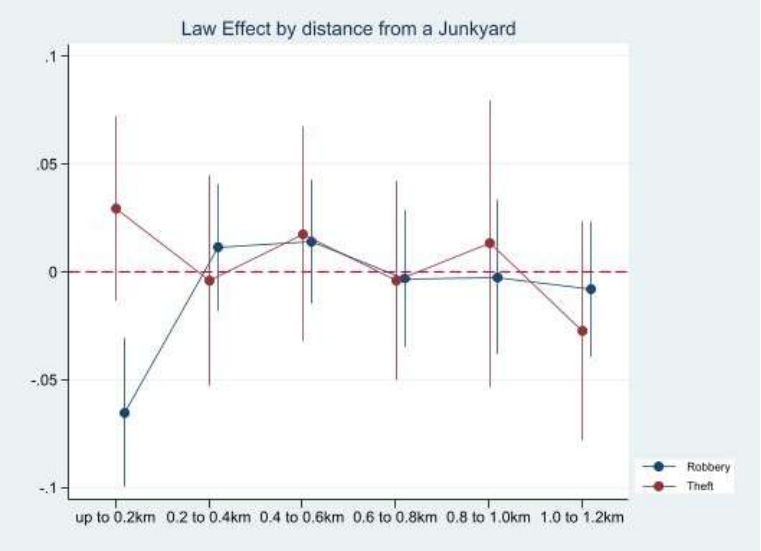
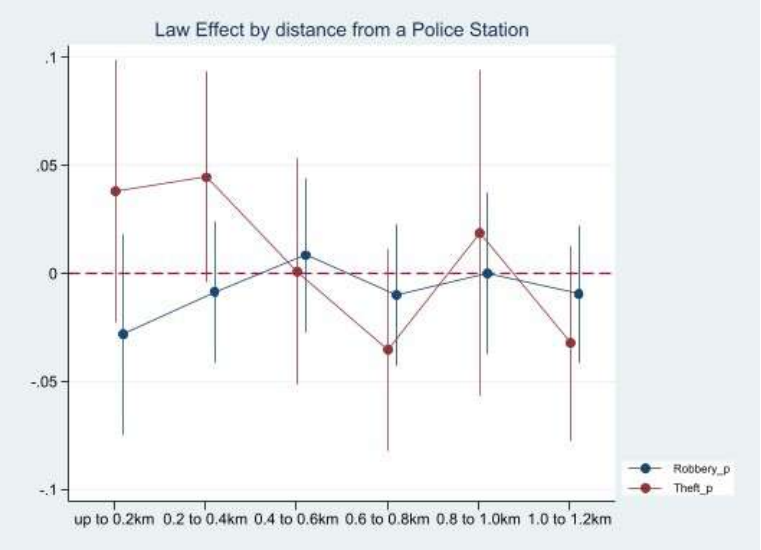
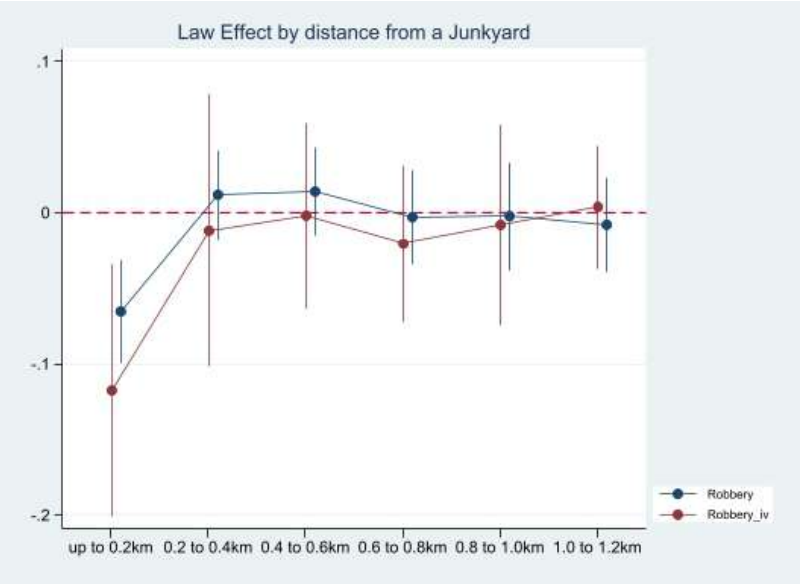



Figure A.14: District Level - Falsification Test




*Notes:* These graphs plot 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.

Figure A.15: Instrumental Variable - Closed Junkyards




*Notes:* These graphs plot 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.