Dismantling a Market for Stolen Goods: evidence from the regulation of junkyards in Brazil.*

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Abstract

This paper investigates the impact of firm monitoring on the illicit market for stolen goods, with a specific focus on the association of junkyards and auto theft. I exploit the effects of state-level regulations implemented in Brazil in 2014, which enhanced supervision of the market for vehicle spare parts. I show a substantial decrease in auto theft, and the most significant reduction occurs in neighborhoods with a prominent presence of junkyards. Overall, municipalities with at least one junkyard specialized in vehicle spare parts show a 4.35% decline in auto theft compared to the control group. I also provide evidence of a 7.09% decrease in vehicle insurance prices, which suggests an improvement in citizens' welfare in the context of lower crime rates. These findings offer crucial insights regarding the role of market regulation in deterring criminal activities related to the trade of stolen goods and emphasize its complementary to traditional public security policies.

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

1. Introduction

The relationship between market regulation, firm supervision, and crime has received limited attention in the literature, despite the prevalence of illicit markets. Criminal organizations exploit the blurred lines between legal and illegal products to convert stolen goods into cash. Consequently, if there is no punishment for buying or

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selling illegal products, some firms choose to obtain their supplies from illegal sources to maximize profits. Therefore, increasing barriers to the trade of illegal goods may impact criminal incentives (Becker, 1968).

This paper investigates the effect of market regulation on the reduction of auto theft. Specifically, I focus on the increased supervision of junkyards resulting from state and federal laws that imposed strict rules on the sale of recovered spare parts from crashed and impounded vehicles. In this setting, legislative changes and enhanced monitoring of junkyards reduce criminal incentives by raising the costs associated with operating in the illicit market for spare parts.

To assess the causal effect of these policy changes on stolen vehicles, I evaluate the impact of the new legislation using panel data on auto theft and other crimes in São Paulo from 2011 to 2019. I exploit the exogenous variation caused by the regulatory approval for junkyards as a quasi-experiment. The federal government granted each state the autonomy to determine the timing of implementing traceability measures for items sold by junkyards, resulting in significant variability in the extent of monitoring across different states. For instance, the state of São Paulo developed a comprehensive system that mandated the use of QR codes to track spare parts, while other states have yet to fully implement the federal law requirements for dismantling firms.

I present empirical evidence that market regulation and increased supervision of junkyards led to an average reduction of 4.35% in the number of stolen vehicles[1], which supports the hypothesis that monitoring capabilities play a crucial role in reducing crime. Additionally, an analysis of junkyard locations and stolen vehicles in São Paulo suggests that the decline in auto theft is concentrated in junkyards' neighborhoods, highlighting the large incidence of auto theft in these areas. These findings have important implications for policymakers, indicating the need to invest in effective monitoring and target areas with high property crime rates.

To ensure the validity of my results, I conduct a series of robustness checks. Firstly, event-study analyses reveal no pre-existing downward trend in stolen vehicles. Secondly, I demonstrate that the impact of the regulation is larger in neighborhoods with a larger incidence of junkyards, providing further evidence for the relevance of these firms in my identification strategy. Last, I perform falsification tests using other violent and property crimes as dependent variables. The results show a specific reduction in auto theft, ruling out the possibility of a general decrease in crime rates

[1]In the remainder of the paper *robbery* of vehicles refers to cars taken using violence, *theft* of vehicles to cars taken without the use of violence, and *auto theft* or *stolen vehicles* as the sum of robberies and thefts.

following the new regulation on junkyards. Thus, I provide compelling evidence that other crimes did not significantly change, and there was no displacement of offenses to other forms of robbery, highlighting the effectiveness of the regulation in reducing crime.

Additionally, I conduct robustness tests on the effect of junkyard locations and the dynamics of auto theft. I leverage the effect of the new regulation on junkyards that were forced to close, assessing the relevance of the locations of firms that faced more difficulties in staying in the market. The findings indicate that auto theft decreased by an additional 30% in districts near junkyards that were closed following the regulation, compared to the results considering all dismantling firms. While it cannot be entirely ruled out that these junkyards chose to close or relocate for reasons unrelated to the regulation, this result suggests significant heterogeneity in the decrease in stolen vehicles at the census tract level.

Finally, I test the effect of the institutional change on vehicle insurance prices to assess the effects on local citizens' welfare. Insurance prices reflect the willingness to pay to protect an asset from risks such as robbery and theft. I find that the regulation on junkyards reduced vehicle insurance prices by 7.09% given the 4.35% reduction in auto theft. These results suggest that enhanced supervision on the market for vehicle spare parts increased social welfare both reducing crime and insurance prices. The implied elasticity of 1.63 suggests that insurance prices are very sensitive to auto theft.

My findings contribute to the broader literature on the economic returns to crime and the effect of institutional changes on crime (d'Este, 2020, Draca et al., 2019, Chimeli and Soares, 2017, Pereira and Pucci, 2022, Ayres and Levitt, 1998, Gonzalez-Navarro, 2013, Vollaard and Van Ours, 2011). These studies have shown that criminals are highly responsive to market conditions and how illicit trade affects crime rates and the demand for illegal goods. In this paper, I extend this literature by providing compelling evidence of how legislative changes that enhance the supervision of firms can affect crime by increasing the costs associated with converting stolen goods into cash. My research focuses on a market that can be exploited for the sale of illegal spare parts and highlights how criminals assess legal markets to obtain liquidity when the monitoring by law enforcement agencies is weak. Therefore, I provide rigorous empirical evidence supporting public policies aimed at reducing the financial gains of criminal gangs through changes in market regulation.

While some evidence exists on legislative changes and unintended increase in violent crimes (Chimeli and Soares, 2017, Pereira and Pucci, 2022), to the best of my knowledge, this paper is the first to document the effects of increasing supervision in legal firms on crime. Similar to these studies, I use a new regulation as a nat-

ural experiment to evaluate the impact of legislative changes on crime. However, I differ from them by showing evidence in the opposite direction, how the increase in monitoring capabilities can reduce illicit trade and subsequently affect crime. Furthermore, my paper uses more granular data that allows for exploiting the interplay between firm locations and crime following enhanced supervision. My findings also contribute to the literature on the association between illegal markets and crime (Adda et al., 2014, Owens, 2014), albeit through the lens of changing the monitoring of legal businesses associated with illegal markets rather than altering the criminal status of consumers.

From a policy perspective, this paper provides valuable insights into the role of legislative changes in reducing crime rates in developing countries, particularly in Latin America, where crime is a pervasive problem (Soares and Naritomi, 2010). Existing literature suggests that the opportunity cost of illegal activities and the potential returns in illegal markets affect individuals' decisions to engage in crime (Chalfin and McCrary, 2017, Draca and Machin, 2015). Despite the significant body of research on criminal deterrence (Levitt, 2002, Evans and Owens, 2007, Johnson and Raphael, 2012, Drago et al., 2009), there has been limited empirical evidence on the role of market regulation in curbing crime. This paper fills this gap by providing compelling results that demonstrate how legislative changes can lead to a substantial and persistent reduction in crime rates. My findings highlight the complementarity of legislative reforms with traditional crime reduction strategies, such as law enforcement and incarceration policies. Furthermore, the case of regulating junkyards illustrates that the costs of implementing monitoring mechanisms were relatively low compared to the long-term benefits of reducing crime, as the firms themselves bore most of the compliance costs, including reporting sales and acquisitions to the state traffic authority.

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 theft after the regulation. Finally, Section 6 discusses policy implications and concludes the paper.

2. Institutional Setting

In this section, I describe the market for spare parts and the regulation approved in São Paulo before other Brazilian states.

2.1. Junkyards and the market for vehicle spare parts

Junkyards in this setting are suppliers of spare parts. Brazil has more than 46 million registered vehicles, an average of one per five people in 2020 (Sindipeças, 2021). The industry estimates an average life cycle of ten years for cars (CNN Brasil, 2021), which demand spare parts for regular maintenance and to replace items damaged in traffic accidents. 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 parts. Moreover, while vehicle assemblers and large auto-service companies mainly buy from manufacturers, end users and small mechanical workshops usually buy spare parts from junkyards due to the lower price. The Brazilian Automotive Recycling Association (ABCAR) estimates that junkyards' annual revenues represent about 10 percent of the market for spare parts, which would be US$450 million according to data for 2020.

Anecdotal evidence points to a possible interplay between junkyards and auto theft. Without proper regulation and monitoring of the dismantling activity, it is hard to distinguish if spare parts sold by these firms come from vehicles acquired through public auctions or from the illegal market (stolen cars). Thus, weak supervision on junkyards creates conditions for collusive agreements with criminals specializing in auto theft. In this context, monitoring and strict rules to open and keep a dismantling firm may impose a barrier to acquiring spare parts illegally, thus affecting auto theft.

Furthermore, junkyards that acquire vehicles from the illegal market have lower costs than competitors that only buy cars through legal auctions. Given the risks of keeping stolen products, criminals sell them at prices much lower than similar items in the legal market. Figure B.4 shows the problem junkyards face when acquiring vehicles. Arguably junkyards may choose to operate (1) only in the legal market, (2) only in the illegal market, or (3) combine purchases from the legal and illegal markets[2].

Last, since consumers hardly distinguish between legal and illegal products in this market, the traceability of spare parts is fundamental to deterring criminals from selling illegal goods. The intuition is that criminals have lower incentives to sell stolen products when potential buyers can quickly identify the illegal origin of these items. Assuming that even junkyards established as formal companies can dismantle

[2]I present in the Appendix A a model that shows how increased supervision of the spare parts market affect prices and quantities of the illegal items sold by junkyards. The increased risk of being punished reduces the supply of illegal goods through changes in the incentives of criminals, junkyards, and the final consumer.

vehicles acquired illegally, it is essential to provide tools to ensure the authenticity of products to reduce the demand for illegal goods. Hence, mechanisms to verify the authenticity of items sold by junkyards 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 these events in São Paulo over the 2000s, reaching more than 165,000 stolen vehicles in 2014. The possible interplay between auto theft gangs and junkyards motivated public debates to increase the supervision of dismantling firms. The first policy recommendation in 2012 suggested a complete prohibition of junkyards in the state.[3] In 2013, the State Security Secretary sent a proposal to the Legislative House to banish junkyards from public auctions of crashed and apprehended vehicles.

However, junkyard owners claimed alternatives to tackle the illegal market of stolen cars without closing all dismantling firms. The ABCAR argued to the State Department of Traffic and Vehicles (DETRAN-SP) that junkyards 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 market by providing spare parts for old and/or imported cars. Hence, both sides agreed to an intermediate solution through a more strict market regulation. Thus, the state government and DETRAN-SP proposed law 15.276 ('Junkyard Law') in January 2014, for which junkyards had six months (up to July 2014) to adapt their operation.

The Junkyard Law increased the legal requirements for dismantling firms. To acquire vehicles in public auctions, junkyards need a permit issued by DETRAN-SP. This permit must be renewed annually and is mandatory to dismantle cars, such as for selling spare parts. Furthermore, junkyards must present (1) a registered by-law, (2) any criminal records of owners and employees, (3) a municipality business license, (4) a technical capacity certificate, (5) a tax-compliance certificate, (6) an environmental certificate, (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).

The regulation also focused on the traceability of items sold by junkyards. After acquiring a vehicle, these firms must report all spare parts recovered as inventory in the DETRAN-SP system. Junkyards must also present a technical report signed by

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

a certified employee regarding the dismantled vehicle and provide a complete list of items that will be discarded. Last, the regulation imposed the obligation to provide an identification number to final consumers in their receipts. This number is an authenticity code to track the item on the DETRAN-SP website. 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 B.5 shows photos highlighting the QR identifier of an engine recovered by a junkyard. Junkyards, mechanical stores, and consumers must pay a fine of up to US$10,000 if spare parts do not show the QR code or if they cannot prove the legal origin of these products facing legal authority inspections.

The institutional change seems to be a relevant driver in the impressive 40 percent drop in auto theft from 2014 to 2019. One year after the Law, inspections commanded by a task force involving DETRAN-SP, state police, and the State Tax Authority closed about 700 non-complier junkyards[4] in São Paulo (G1, 2015).

3. Data and empirical strategy

3.1. Data

I use monthly data on auto theft and other crimes from 2011 to 2019 at the municipality and district levels. This panel data comprises 645 municipalities of São Paulo. Detailed crime data is very scarce in Brazil, there are huge differences regarding data reported by each state secretary, and some provide only state-level data for short periods. Therefore, composing a detailed panel data set comprising granular information regarding municipalities from all 27 Brazilian states is a challenging task. By focusing on São Paulo, I overcame this issue since the state provides high-frequency and geolocated crime data before and after approving the Junkyard Law. I also use data regarding violent deaths and other offenses in the same period and information from the national census provided by the Brazilian Bureau of Statistics (IBGE), especially population and gross domestic product per capita at the municipality level.

Last, I use Tax and Labor National Authority data to identify the number of junkyards in each municipality of São Paulo. To identify junkyards, I rely on a

[4]Table 1 shows some descriptive statistics collected from the Ministry of Labor's RAIS dataset about junkyards legally registered. Junkyards in São Paulo have, on average, 4 employees and about 40% percent of these firms did not report any labor information in 2017, three years after the new regulation. These pieces of evidence reinforce significant changes in the market for spare parts after the Junkyard Law.

specific code called the "Classificação Nacional de Atividade Econômica" (CNAE), which classifies the activity of negotiating used and recovered spare parts. By using this code, I can identify all legally registered junkyards in the Labor Authority dataset (RAIS) and access additional information such as the firms' identification code (CNPJ) and the number of employees registered in each junkyard. To gather more detailed information, I cross-reference each CNPJ identified through the specific CNAE code with the Tax Authority's records to retrieve the addresses of the junkyards. I leverage these addresses to find the precise coordinates of each junkyard, allowing for the geolocation of their positions at the street level. This unique dataset provides the opportunity to analyze the dynamics of auto theft given the distance from junkyards, enabling a more in-depth exploration of the spatial relationship between these establishments and criminal activity.

Table 1: Descriptive Statistics - Junkyards

	2014	2015	2016	2017
Junkyards (total)	959	907	863	887
Junkyards established before 2014 (percentage)	100%	78.3%	65.6%	59.9%
Employees (mean)	4.5	4.4	4.4	4.4
Nominal Salary (median)	1,224.8	1,388.2	1,293.8	1,433.2

Note: This table shows information regarding junkyards of São Paulo state collected from the Ministry of Labor's RAIS dataset (RAIS - MTE).

3.2. Empirical strategy

3.2.1. The Junkyard Law

The distribution of junkyards in each municipality at the time of the institutional change is a unique opportunity to test the effect of regulating junkyards on auto theft. Since the focus of the regulation is to monitor the illicit trade of auto parts in São Paulo, municipalities with a larger incidence of junkyards will arguably be the most affected by the enhanced supervision. Law enforcement inspections started using the system implemented to register cars acquired by junkyards to check the authenticity of spare parts. The monitoring system was further improved by mandating the use of QR code tags on all items. As a result, consumers and legal authorities got a very efficient tool to verify the authenticity of auto parts using a smartphone. Consequently, following the legislative change, junkyards faced a higher probability of punishment if they engaged in the trade of illicit spare parts, which likely led to a reduction in the demand for goods from illegal suppliers.

To identify the effect of the Junkyard Law on auto theft, I focus on the exogenous variation caused by the Junkyard Law within São Paulo. I exploit how market regulation affects auto theft by comparing municipalities with and without the presence of junkyards. After the Law, a larger decrease in auto theft in cities with junkyards compared to those without these firms is evidence of the interplay between strict monitoring of the dismantling business and stolen 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 decrease in auto theft. I use Equation 1 to estimate the effect of the Junkyard Law given the presence of dismantling firms. In this setup, the differences-in-differences estimator is:

$$y_{it} = \phi_i + \phi_t + \beta_1 * Law_t + \beta_2 * Law_t \times D_i + X_{it} + \mu_{it} \quad (1)$$

Where D_i is a dummy variable equal to one when there is at least one junkyard in the municipality i. Hence, the coefficient β_2 shows the effect of the Junkyard Law across cities with and without junkyards after controlling for location and time fixed effects. To account for the difference in the size of each municipality, I use the rate of auto theft as the dependent variable, i.e., the number of stolen vehicles per 100 thousand inhabitants. I also test other violent and property crimes to investigate if the regulation affected other offenses.

Table 2 presents descriptive statistics for both the treated and control groups prior to the approval of the Junkyard Law. The treated group consists of municipalities that have at least one junkyard, while the control group comprises municipalities without dismantling firms. Municipalities in the treated group exhibit higher levels of violent crimes, including total homicides and deaths resulting from robberies, as well as auto theft and other robberies. On the other hand, the control group shows a greater incidence of bank robberies and cases of bodily injuries. Additionally, Figure 1 depicts the trajectory of auto theft for both the treated and control groups from 2011 to 2019.

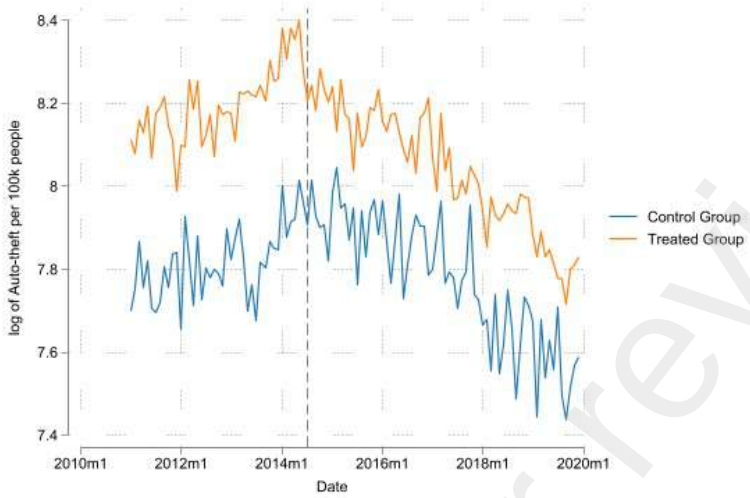
The validity of my findings relies on two crucial assumptions. Firstly, auto theft rates in the treated and control municipalities followed similar trends prior to the implementation of the Junkyard Law in July 2014, and the decrease in stolen vehicles is observed only after the legislation change. Secondly, the decrease in stolen vehicles is exclusively due to the new regulation and increased supervision over dismantling firms, rather than being driven by other confounding factors. Therefore, the regulation may not affect other of crimes, as this could suggest a general decline in overall criminal activity instead of stricter supervision of dismantling firms. Under these assumptions, the coefficient β_2 represents the relative change in auto theft following the Junkyard Law.

Table 2: Descriptive Statistics at the Baseline - Treated and Control Group

	All Municipalities	Treated Group	Control Group
Homicides	7.12	8.20	6.66
	(0.19)	(0.21)	(0.25)
Deaths in Robberies	0.49	0.58	0.46
	(0.04)	(0.05)	(0.05)
Body Injuries	473.33	448.67	483.80
	(4.59)	(7.95)	(5.59)
Auto-theft	100.61	200.53	58.19
	(2.73)	(7.01)	(1.71)
Robbery (others)	123.95	243.21	73.31
	(3.41)	(8.34)	(2.50)
Theft (others)	774.99	934.79	707.14
	(9.84)	(16.77)	(11.71)
Bank Robbery	0.60	0.24	0.75
	(0.07)	(0.05)	(0.10)
Cargo Theft	4.16	5.01	3.80
	(0.40)	(0.33)	(0.55)
GDP per capita	24,296.23	30,796.68	21.536.16
	(412.43)	(807.07)	(462.06)
n	645	192	453

Note: This table shows descriptive statistics prior to the Junkyard Law (2011m1 to 2014m7) for all municipalities of São Paulo and also for the treated and control group. Homicides, Deaths in Robberies, Body Injuries, Auto-theft, Robbery (others), Theft (others), Bank Robbery, and Cargo theft are presented as monthly average rates by municipalities (cases by one hundred thousand inhabitants). The GDP per capita is the average annual Gross Domestic Product per capita in Brazilian Reais. Standard-errors in parenthesis.

Figure 1: Auto-theft - Treated x Control Group



Notes: This graph shows the evolution of auto-theft in treated and control municipalities from January 2011 to December 2019.

3.2.2. The effect of junkyard location

Driving a stolen car for long distances increases the probability of being caught by police officers. Hence, 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.

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 auto theft. The supervision of dismantling firms was significantly weaker before the Junkyard Law. Therefore, it is possible that some of these firms operated in both legal and illegal markets. Figure B.6 shows in orange the location of all active junkyards in São Paulo for 2014. I use the Ward-like hierarchical clustering algorithm presented by Chavent M. et al. (2018) to define 15 clusters of junkyards in São Paulo (Figure B.6). Given the relatively large number of junkyards in these areas, I define these clusters as a baseline to measure the effect of junkyard location on auto theft after implementing the new regulation.

I evaluate the effect of the Law within São Paulo, the largest municipality in the state with the highest number of junkyards in Brazil. 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. Hence, stealing a car in districts closer to one of these 15 clusters would be arguably less risky for criminals who sell stolen vehicles to junkyards. 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 these areas following the strict monitoring of these firms.

The spatial analysis of a new regulation for junkyards presents two significant challenges. First, junkyard locations in São Paulo maybe are not randomly assigned. If junkyards are near streets with a larger 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 before the regulation can be affected if junkyards' owners decide to reallocate within the city, and the treatment ('Junkyard Law') would contaminate districts of the control group. To overcome these issues, I define a second specification using only junkyards that left the market after the new regulation. As described before, law enforcement agencies closed many dismantling firms following the Junkyard Law. Some probably moved to other states or businesses, given the increased supervision and larger costs to adapt to the new regulation. Hence, the location of closed junkyards captures the change in auto theft near firms that arguably had more difficulty complying with the regulation. 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 institutional change, affecting the number of vehicles robbed in police station neighborhoods. Thus, I can verify whether the decrease in robberies near junkyards was larger than in locations with a strong police presence.

I combine data regarding junkyard locations and registers of auto theft at the street level to evaluate whether the decrease in stolen vehicles is larger near to junkyards. 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:

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

where the subscripts i, j, and t denote census tract, district and date; T_i^d is 1 if the census tract i lies at a distance d from a junkyard; d defines six categories of distance: up to 0.5 km, 0.5–1.0 km, 1.0–1.5 km, 1.5–2.0 km, 2.0–2.5 km, and

2.5–3.0 km. The mark of 3.0 km is the median distance between census tracts and the closest junkyard cluster. Therefore, areas in São Paulo with a junkyard cluster at 3.0 km are the *'treated group'*, while neighborhoods 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. I control for census tract, month, and year fixed effects. Besides, I allow each district to have different linear trends. These variables capture heterogeneous dynamics led by different district policies, such as changes in policing strategy. The error term μ_{it} is clustered at the district level.

The identification comes from two main assumptions. The first is that census tracts more than 3.0 km from junkyards were not affected by the regulation of dismantling firms (non-contamination of the control group). Second, the reduction in stolen vehicles is driven by the presence of junkyards instead of other confounding factors. Therefore, the distance from other firms or buildings would not cause a decrease in auto theft contemporaneous with the regulatory change. The variable Law_t assumes the value of one after the market regulation approval in São Paulo. Hence, the coefficient β_1 shows the specific effect of the proximity to junkyards on auto theft after the legislation change.

4. The effect of the Junkyard Law

4.1. Results at the municipality level

Table 3 reports the results from Equation 1 using as the dependent variable the number of stolen vehicles per 100 thousand inhabitants in municipalities of São Paulo from 2011-2019. In this approach, 192 municipalities that 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 Law in São Paulo with and without controlling by GDP. My results show a significant decrease in the number of stolen vehicles in cities with junkyards. The drop in auto theft is equivalent to 4.35% fewer stolen vehicles per month compared to the control group. These findings highlight the interplay between dismantling firms and the increased supervision following the legislation change. Moreover, these results also alleviate concerns about confounding factors non-related to junkyards driving the reduction in auto theft.

To test the parallel trends assumption, I run an event study of Equation 1 to assess the dynamic effect of the legislation change. Figure 2 shows pre and post-coefficients of the Junkyard Law. There is no evidence of a previous trend in auto theft, and the effect of the new regulation increases over time. These findings validate the parallel trends assumption to the differences-in-differences model and are supportive evidence of the causal effect of the regulation reducing auto theft.

Thus, my results show that market regulation reduced auto theft through increased supervision of dismantling firms. The event study suggests that it has taken some time for the Junkyard Law to become effective in reducing auto theft, which reflects improvements in the monitoring over time, as the QR code implementation in São Paulo (15 months after approving the Law) and legal authorities' support through inspections of junkyards and punishment of non-complier firms.

Table 3: Results - Baseline Specification

	Auto-theft (1)	Auto-theft (2)	Robbery (3)	Robbery (4)	Theft (5)	Theft (6)
Junkyard Law × Presence of Junkyards	-2.534***	-2.532***	-1.225***	-1.224***	-1.309***	-1.308***
	(0.143)	(0.142)	(0.0701)	(0.0701)	(0.116)	(0.116)
log(GDP)		0.391		0.169		0.222
		(0.257)		(0.103)		(0.229)
Observations	69,204	69,204	69,204	69,204	69,204	69,204
R-squared	0.628	0.628	0.648	0.648	0.455	0.455
Municipality Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

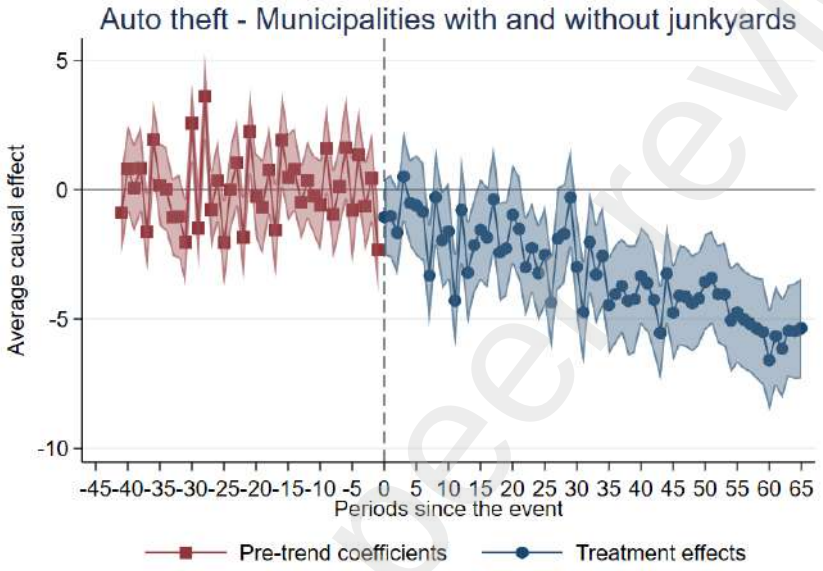
Note: This table shows the results of my baseline specification. The sample comprises 645 municipalities in São Paulo in the period 2003-2019. The treatment in my differences-in-differences design is given by the variable *"Junkyard Law × Presence of Junkyard"* that assumes value one from July 2014 only to municipalities in São Paulo that have at least one junkyard. Columns 1 and 2 show the results of auto-theft per 100 thousand inhabitants as the dependent variable. The dependent variable in columns 3 and 4 is vehicles robbed per 100 thousand inhabitants, and in cols 5 and 6, the number of thefts of cars per 100 thousand inhabitants. Robust standard errors are shown in parentheses.
*p<0.1,**p<0.05,***p<0.01

4.2. Robustness and Potential Mechanisms

A general decrease for all crimes. It is important to test whether the decrease in auto theft following the approval of the Junkyard Law is a result of a general downward trend in criminality or the specific effect of monitoring dismantling firms. To address this concern, I conducted a falsification test to examine if other crimes also decreased after the legislation change. Figure 3 presents the event study estimates for different types of violent and property crimes, and the results provide no evidence of an overall decrease in other crimes. Other crimes remained unchanged for an extended period after the legislation change, indicating a specific effect of the regulation on auto theft.

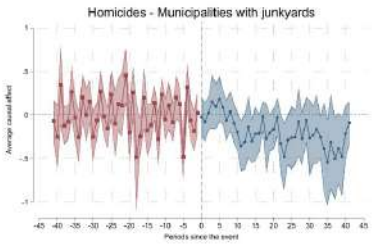
Criminals moving to other crimes. It is possible that the strict supervision of junkyards led some criminals to move from auto theft to other property crimes in order to obtain liquidity. To investigate this possibility, I used other robberies, other theft, bank robberies, and cargo robberies as dependent variables in the Falsification Test. Panels (c) to (f) in Figure 3 demonstrate that there is no evidence of displacement to these crimes. Therefore, there was no increase in other property crimes in municipalities with at least one junkyard following the legislation change.

Figure 2: Event Study - Baseline Specification

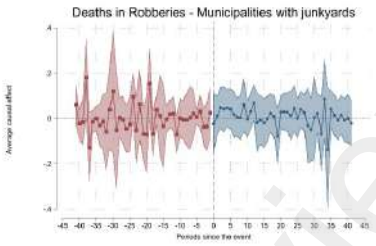


Notes: The effect of the Junkyard Law on auto theft is estimated under the unconditional parallel trends assumption. Red lines give point estimates and uniform 95% confidence bands for pre-treatment periods allowing for clustering at the municipality level. Under the null hypothesis of the parallel trends 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 treatment in my differences-in-differences design is given by the variable *"Junkyard Law* $\times$ *Presence of Junkyard"* that assumes value one from July 2014 only to municipalities in São Paulo that have at least one junkyard.

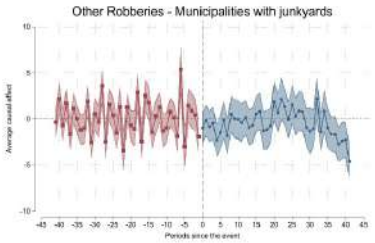
Figure 3: Event Study - Other Crimes



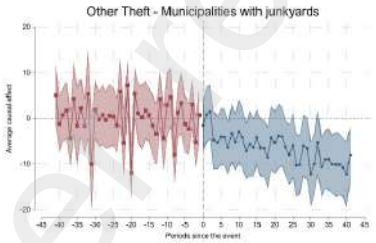
(a) Homicides



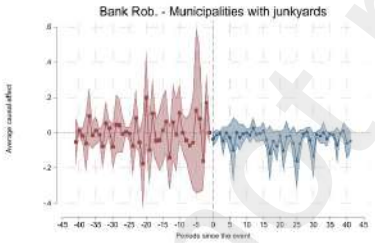
(b) Deaths in Robberies



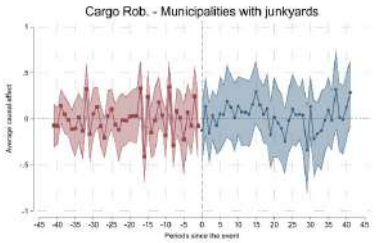
(c) Other Robberies



(d) Other Thefts



(e) Bank Robbery



(f) Cargo Robbery

Notes: The effect of the Junkyard Law on auto theft is 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 treatment in my differences-in-differences design is given by the variable *"Junkyard Law* $\times$ *Presence of Junkyard"* that assumes value one from July 2014 only to municipalities in São Paulo that have at least one junkyard.

Displacement. My findings indicate that a general decline in crime rates does not drive a decrease in auto theft. Therefore, the decrease in stolen vehicles cannot be attributed to an increased deterrence effect of the police on crime. However, it is still possible that criminals shifted their activities to municipalities without junkyards, where law enforcement efforts on the illegal market for spare parts were lower. To address this concern, I compared the trends in auto theft between treated and control groups. Figure 1 demonstrates that auto theft decreased in both treated and control groups following the legislation change, providing evidence that the presence of junkyards in a municipality leads to a larger decrease in auto theft following stricter regulations for dismantling firms. In summary, my findings are not driven by an increase in stolen vehicles in municipalities of the control group, which would support the hypothesis of displacement to other cities.

5. The effect of junkyards' location on stolen vehicles

5.1. Results at the district level

Table 4 presents the results of Equation 2. I show the effect of the law by the distance of junkyards to vehicles stolen through robbery in column 1 and theft in column 2. The number of robbed vehicles decreased more in census tracts between 500 and 1.000 meters to one of the 15 junkyard clusters than in non-affected areas (census tracts located more than 3.0 km from a junkyard cluster). Figure B.7 shows the estimates and uniform 95 percent confidence bands. My findings show that the Junkyard Law in São Paulo changed the dynamic of auto theft closer to junkyards. Census tract and district-specific time fixed effects do not explain the decrease in vehicles robbed in these neighborhoods.

These findings provide further support for the relevance of dismantling firms' location as a relevant proxy variable for measuring the impact of the new regulation on auto theft. Additionally, my findings strengthen the credibility of the argument that criminals specializing in stolen vehicles are unlikely to travel long distances, making regions with a higher concentration of junkyards probable destinations for their activities. Therefore, the district-level approach contributes to a deeper understanding of the increased supervision of junkyards and complements the aggregate results observed at the municipality level.

5.2. Robustness

Junkyards closed after the law. The causal effect of market regulation on auto theft comes from imposing higher costs on criminals converting stolen vehicles into cash. For junkyards that before the regulation only operated in the legal market,

Table 4: Results Robbery and Theft - Distance to Junkyards and Police Stations

	Junkyard Clusters		Distance to Police Stations		Closed Junkyards	
	Robbery	Theft	Robbery	Theft	Robbery	Theft
	(1)	(2)	(3)	(4)	(5)	(6)
up to 0.5km	0.077	0.181	-0.095	0.060	-0.330***	-0.092***
	(0.120)	(0.245)	(0.094)	(0.039)	(0.074)	(0.033)
0.5 to 1.0km	-0.252**	0.108	-0.165*	-0.009	-0.149***	-0.037
	(0.123)	(0.103)	(0.087)	(0.028)	(0.056)	(0.024)
1.0 to 1.5km	-0.181*	0.015	-0.138	-0.024	0.005	-0.022
	(0.103)	(0.127)	(0.098)	(0.026)	(0.046)	(0.018)
1.5 to 2.0km	-0.143	0.129	-0.080	-0.026	-0.095**	-0.037**
	(0.130)	(0.093)	(0.084)	(0.025)	(0.046)	(0.017)
2.0 to 2.5km	-0.130	0.036	-0.118	0.020	-0.105**	0.004
	(0.082)	(0.111)	(0.102)	(0.027)	(0.047)	(0.018)
2.5 to 3.0km	0.114	0.165*	-0.082	-0.016	-0.050	-0.000
	(0.071)	(0.090)	(0.099)	(0.036)	(0.047)	(0.019)
Observations	249,836	61,269	249,836	61,269	249,836	61,269
R-squared	0.177	0.307	0.174	0.332	0.174	0.332
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 the log(number of robberies), and columns 2 and 4 are the log(number of theft). Columns 1 and 2 show the results of equation 2 using the centroid of junkyards clusters presented in Figure B.6 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

shifts in monitoring would hardly force a transition to the illegal market. Assuming the same probability for all junkyards acquiring vehicles from criminals may bias my results and underestimate the effect of the regulation on junkyards.

To address this issue, I propose using only the location of junkyards closed after the law in Equation 2. The identification assumption is that these firms had more difficulty complying with the new regulation. 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. Thus, the more dependent a junkyard was on the illegal market, the higher the probability it would close after the legislation change.

Columns 5 and 6 of Table 4 show the results of Equation 2 for vehicles stolen through robbery and theft using only junkyards closed after the Junkyard Law. The interpretation of this robustness check comes when comparing baseline estimates in column 1 to the estimates in column 5. The number of vehicles robbed decreased more in census tracts up to 500 meters from junkyards closed after the law. This drop is 31 percent greater than the overall effect estimated considering all junkyards. Figure B.8 compares both estimates. Although I cannot completely rule out that

factors other than the dependence on stolen vehicles made these junkyards leave the market, my results suggest significant heterogeneity within junkyards.

Falsification test (distance to police stations). The larger decrease in auto theft near junkyards is compelling evidence of the causal effect of the Junkyard Law through increased monitoring of dismantling firms. However, suppose that police capability increased contemporaneously with market regulation. In that case, my results may capture the deterrence effect of police instead of the causal effect of junkyards' location. 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 legislation change. The proximity of a police station represents a substantial risk for criminals, and an overall increase in police capabilities would likely reduce auto theft rates in areas closer to these buildings. Furthermore, by conducting this falsification test, I can evaluate the influence of the legislation change using a different location (police stations) to verify if the presence of junkyards exerts a stronger influence on auto theft compared to other locations. Columns 3 and 4 in Table 4 show the estimates of Equation 2 using distances to police stations as the explanatory variable. I do not find a similar decrease in stolen vehicles closer to police stations after the institutional change.

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 Junkyard Law. Last, even if the decrease in auto theft closer to junkyards can be related to the deployment of police officers to these areas, I argue that it would also be a consequence of the new regulation that increased police inspections on junkyards, such as more extensive surveillance and police patrols in the neighborhoods of these firms.

6. Discussion and Conclusion

6.1. Local Welfare

Extensive research in the literature has shown a negative correlation between crime rates and property values (Gibbons, 2004, Besley and Mueller, 2012). This evidence suggests that individuals are willing to pay a premium to protect their assets and avoid exposure to high-crime environments (Thaler, 1978, Linden and Rockoff, 2008). In light of the substantial and persistent reduction in auto theft observed in this paper, it is reasonable to hypothesize that there was an impact on the risk perception of local citizens, potentially influencing their willingness to pay for vehicle insurance.

To investigate the effect of market regulation on local welfare, I examine the average vehicle insurance prices in municipalities with and without junkyards. The

intuition is that the drop in auto theft resulting from the institutional change will likely lead citizens to reassess their need for vehicle insurance, given the reduced risk of car theft. Consequently, I expect to observe a larger drop in insurance prices in municipalities that show larger reductions in auto theft.

I use data on insurance vehicle transactions in São Paulo between 2011 and 2019, provided by the *"Superintendência de Seguros Privados"* (SUSEP) on a semester basis. These records provide detailed information on each insurance contract, including vehicle type and fabrication year. By constructing a panel dataset at the municipality level, I estimate Equation 1 with the mean insurance price by car model as the dependent variable. Thus, I assess the impact of the new regulation on insurance prices in municipalities with at least one junkyard specializing in vehicle parts, as these areas experienced more substantial reductions in auto theft.

Figure B.9 shows the event study estimates on insurance prices. There is a large and sustained drop in the average insurance price following the new regulation. This decrease corresponds to a 7.09% reduction in insurance prices in municipalities with at least one junkyard, compared to the mean of the control group. Considering the combined effect of the 4.53% reduction in auto theft and the 7.09% decrease in insurance prices, I estimate an insurance price elasticity of 1.63 with respect to auto theft. These findings suggest that the reduction in auto theft not only contributes to improved local welfare by lowering crime rates but also brings tangible economic benefits to vehicle owners through reduced insurance costs.

6.2. Policy Implications

From a policy perspective, my results provide robust evidence regarding the effectiveness of market regulation in reducing criminal outcomes. Specifically, by improving monitoring capabilities at a lower cost, the regulation reduced junkyards' purchases from illegal sources. As a result, there was a reduction in the demand for stolen goods, which in turn reduced the incentives for auto theft gangs, leading to a decrease in the number of stolen vehicles following the new regulation. This finding highlights the relevance of monitoring markets that are associated with illicit trade to deter criminal activities. Therefore, it is crucial to implement strong market regulation to prevent criminals from exploiting the low monitoring and converting illicit goods into cash.

We learn from the Junkyard Law that changes in legislation exert a complementary role to investments in public security to deter criminals. São Paulo spent US$ 5 billion on Police Forces and US$ 1 billion on Penitentiaries in 2020, which account for 10% of the state budget. Despite the public investment in developing a system to supervise junkyards, the amount spent seems very small compared to the benefits

of a significant reduction in auto theft following the new regulation. As a reference, DETRAN-SP had a budget of US$ 150 million in 2020 to perform all tasks related to traffic and vehicle legislation. Furthermore, junkyard owners paid most of the cost of the regulation when adapting their firms to the new legal requirements.

One of the most relevant findings is the persistence of the drop in stolen vehicles after the legislation change. The effect of the regulation on auto theft is large and increases over time when comparing municipalities with and without junkyards in São Paulo. Moreover, the larger decrease in auto theft seems directly associated with more strict monitoring of junkyards' revenues and acquisitions, especially the system managed by DETRAN-SP to track all spare parts recovered and sold by these firms. This result sheds some light on the crucial role of supervising firms to reach a larger reduction in property crime when approving more strict market regulations. As a guide for future public policies and other states, monitoring mechanisms are essential when approving new legislation to tackle a market for stolen goods.

Last, regarding potential spillovers, there are arguably effects on the formalization of firms and tax revenues. Given the reduced demand for stolen vehicles and increased supervision of dismantling firms, the regulation forced junkyards to report their sales to legal authorities, increasing tax revenues collected from spare parts.

6.3. Concluding Remarks

Despite the anecdotal evidence regarding the association of a market for stolen goods and crime, there is little evidence of the interplay between firms and criminals. This paper presents compelling evidence of the reduction in auto theft following increased supervision of dismantling firms. The decrease in auto theft is not related to an overall downward trend in crime, socioeconomic conditions, or intrinsic characteristics of municipalities. Following the new regulation, I show evidence of a larger decrease in the number of stolen vehicles for districts closer to junkyards. Last, there is no displacement to other robberies following the new regulation.

The traceability of items sold by junkyards seems crucial to leverage the effectiveness of market regulation by increasing the difficulty of converting stolen items into cash. 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 supervision of junkyards homogeneously across states. Criminals may have decided to move to states with lower monitoring to exploit legal authorities' lack of commitment to the new regulation. With these caveats in mind, this paper illustrates how market regulation and supervision of firms affect a potential market for stolen goods and complements public security policies to reduce crime.

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Appendix A. Theoretical Model

The conceptual setting

Let the price for spare parts be p_C for criminals selling to junkyards, p_J^I for junkyards selling stolen goods to the final consumer, and p_J^L for junkyards selling legal goods to the final consumer. Furthermore, let the expected punishing for being in the illegal market as μ_C for criminals, μ_J for junkyards, and μ_F for the final consumer.

Criminals. Let's assume that there is a cost of c to steal a car, increasing and convex. Furthermore, suppose that there is a continuum of identical criminals in $[0, 1]$. The problem of the criminal $x \in [0, 1]$ is to decide how many vehicles she steals. She maximizes in q

$$p_C q - [c(q) + \mu_C q],$$

and the optimum interior solution q_x is given by

$$q_x = c'^{-1}(p_C - \mu_C).$$

Integrating both sides in the number of agents we have

$$Q^I := \int_0^1 q_x dx = \int_0^1 c'^{-1}(p_C - \mu_C)dx = c'^{-1}(p_C - \mu_C),$$

where Q^I is the aggregate quantity of illegal spare parts.

Junkyards. Basically, the junkyards only act by buying vehicles (legally or illegally) and selling recovered spare parts. The quantity Q^L of spare parts from public auctioning is inelastically offered to them. Assuming free entry and a competitive market, quantities demanded and supplied by junkyards must be equal, profits are zero, and the problem of a junkyard y is

$$p_J^L q_y^L + p_J^I q_y^I - [p_J^L q_y^L + p_C q_y^I + \mu_J q_y^I] = 0.$$

Note that $p_J^L q_y^L$ cancels. Dividing the role expression by q_y^I we find

$$p_J^I - p_C - \mu_J = 0$$

for all junkyards.

Final Consumers. Finally, the consumer (also a continuum in 0 to 1) has a utility

u for the total amount of spare parts acquired, and u is increasing and concave. The consumer z maximizes choosing q^L and q^I,

$$u(q^L + q^I) - [p_J^L q^L + p_J^I q^I + \mu_F q^I].$$

The existence of interior solutions q_z^L and q_z^I may respect

$$u'(q_z^L + q_z^I) = p_J^L = p_J^I + \mu_F.$$

Integrating analogously to the case of criminals, we have

$$u'(Q^L + Q^I) = p_J^L = p_J^I + \mu_F.$$

Solving the system, we find Q^I from

$$u'(Q^L + Q^I) = c'(Q^I) + \mu_C + \mu_J + \mu_F.$$

And the prices are given by

$$p_J^L = c'(Q^I) + \mu_C + \mu_J + \mu_F, \quad p_J^I = c'(Q^I) + \mu_C + \mu_J, \quad p_C = c'(Q^I) + \mu_C.$$

The result is quite intuitive, the expected marginal value of punishment is added to the price in each stage. The final step is to calculate the derivatives. To simplify the notation let's call $u''(Q^L + Q^I)$ as u'' and $c''(Q^I)$ as c''. Using the implicit derivative theorem, we find the effect on prices and quantities with respect to the expected punishments:

- illegal market supply

$$\frac{\partial Q^I}{\partial \mu_C} = \frac{\partial Q^I}{\partial \mu_J} = \frac{\partial Q^I}{\partial \mu_F} = \frac{1}{u'' - c''} < 0.$$

- price for criminals selling to junkyards

$$\frac{\partial p_C}{\partial \mu_J} = \frac{\partial p_C}{\partial \mu_F} = \frac{c''}{u'' - c''} < 0, \quad \frac{\partial p_C}{\partial \mu_C} = \frac{u''}{u'' - c''} > 0.$$

- price for junkyards selling legal spare parts

$$\frac{\partial p_J^I}{\partial \mu_C} = \frac{\partial p_J^I}{\partial \mu_J} = \frac{u''}{u'' - c''} > 0, \quad \frac{\partial p_J^I}{\partial \mu_F} = \frac{c''}{u'' - c''} < 0.$$

- price for junkyards selling illegal spare parts

$$\frac{\partial p_J^L}{\partial \mu_C} = \frac{\partial p_J^L}{\partial \mu_J} = \frac{\partial p_J^L}{\partial \mu_F} = \frac{u''}{u'' - c''} > 0.$$

Interpreting the Mechanisms

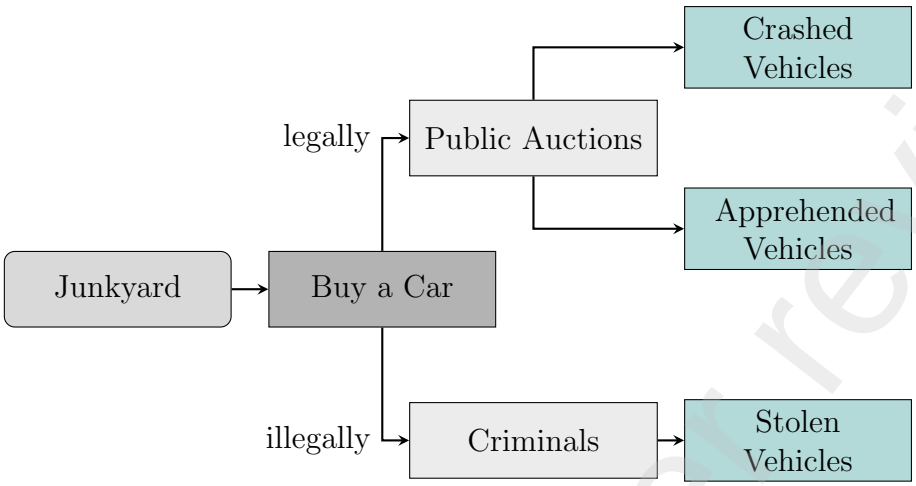
The parameters μ's show how the agents perceive the increased risk of punishment after the regulation of the spare parts market. Ideally, if we have a detailed dataset with the price and quantities of items sold by junkyards before and after the regulation, it would be possible to test these mechanisms. Even if we obtain data about the prices of original items, this proxy variable may not be accurate since manufacturers usually sell these items for a price not directly comparable to recovered spare parts sold in junkyards.

As a theoretical exercise, if we could access the prices of legal and illegal items sold by junkyards, it would be possible to decompose all effects in prices given the increased supervision after the institutional change:

$$\begin{cases} \Delta\mu_F &= \Delta(p_J^L - p_J^I) \\ \Delta\mu_J &= \Delta(p_J^I - p_C) \\ \Delta\mu_C &= \Delta(p_C - c'(Q^I)) \end{cases}$$

Appendix B. Figures and Tables

Figure B.4: Junkyards: how do they acquire cars to dismantle?



Notes: Junkyards can use the legal or illegal market to acquire cars to dismantle. Changes in supervision and punishment may make it difficult to access the illegal market, decreasing the demand for stolen vehicles.

Figure B.5: Field Evidence - Items sold by Junkyards

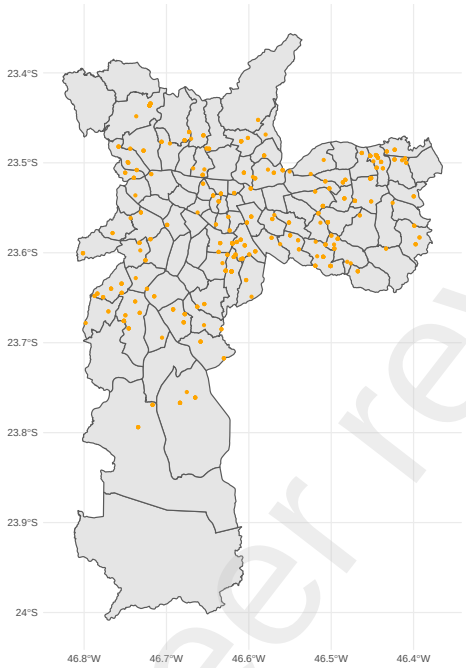
(a)

(b)

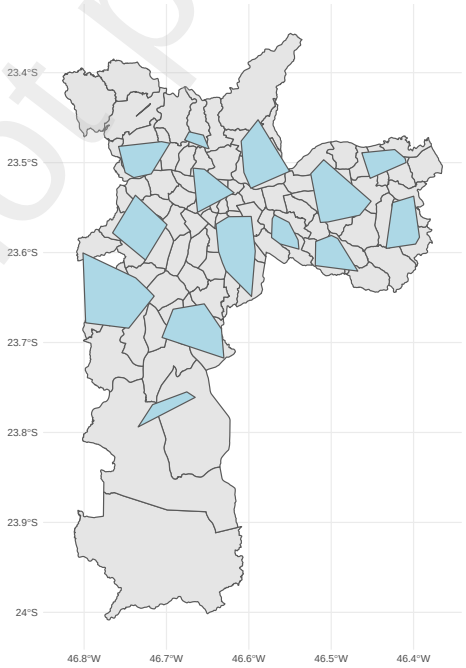
(c)

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. The consumer can verify the authenticity of the QR code in the State Traffic Authority ("DETRAN-SP") by scanning it using a smartphone.

Figure B.6: Clustering Analysis



Junkyards coordinates.



Junkyards clusters.

Figure B.7: District Level - Baseline Results

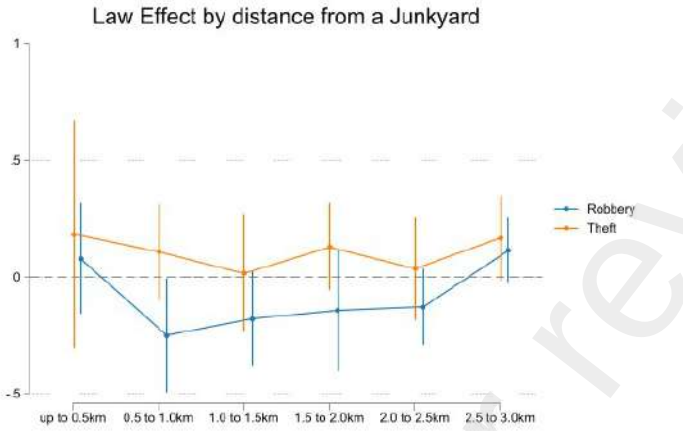
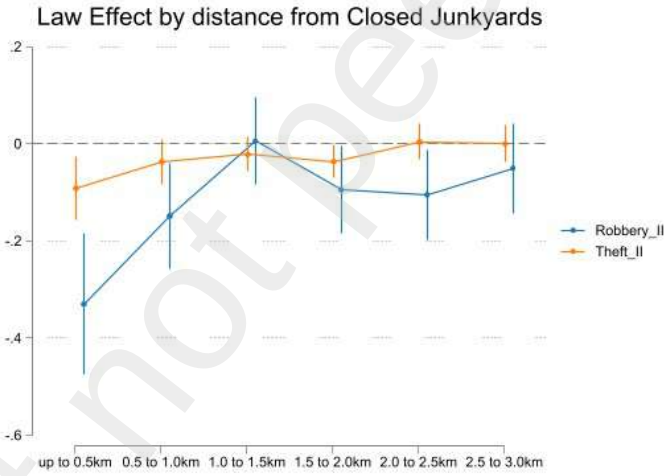
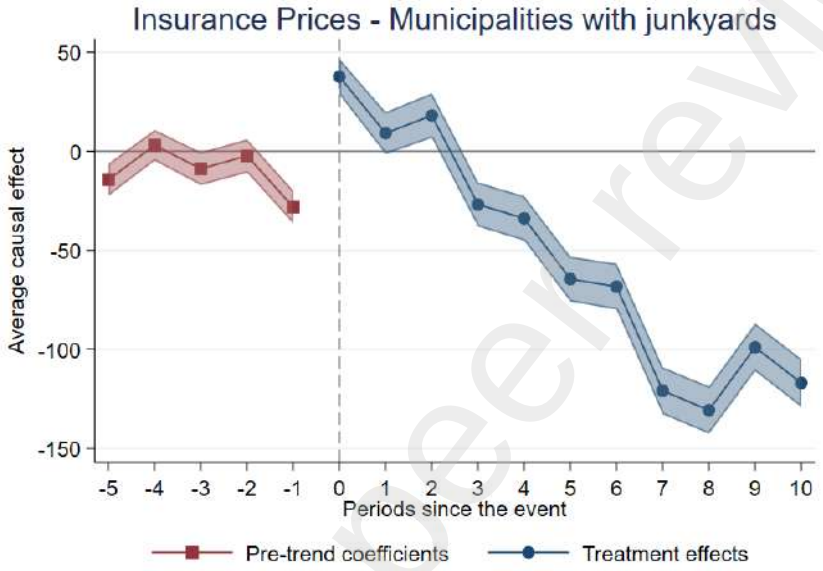


Figure B.8: District Level - Closed Junkyards



Notes: These graphs plot estimated coefficients to the distance of junkyard clusters (top row) and closed junkyards (bottom row) for equation 2. The sample includes 14,479 census tracts in São Paulo. Covariates include census tract, district, year, and month fixed effects. Errors are clustered at the district level. Dots represent point estimates, and the bar represents a 95% confidence interval.

Figure B.9: Event Study - Insurance Prices



Notes: The effect of the Junkyard Law on vehicle insurance prices is 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 treatment in my differences-in-differences design is given by the variable *"Junkyard Law* $\times$ *Presence of Junkyard"* that assumes value one from July 2014 only to municipalities in São Paulo that have at least one junkyard.