Let There Be Light! Improved Public Lighting and Nighttime Crime: Evidence from Brazil

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Abstract

This paper studies a recent infrastructure improvement program in São Paulo City, Brazil, to estimate the causal impact of improved public lighting on nighttime crime. Exploiting the phased roll-out of the program - as well as its unexpected abandonment - to alleviate selection bias, I find that lighting improvements reduce nighttime crime and "non-homicide" crimes, a measure that includes property and violent crimes, both in the districts that received lights as well as in neighboring districts. Yet, there is some evidence that daytime crime rises as a result of the improved lighting, possibly due to an increase in total economic activity in the areas that received the lamps. Overall, it appears that better public lighting is an important catalyst for reducing crime in dense urban areas in middle-income countries.

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1 Introduction

The existing literature on crime prevention is primarily based on the "rational choice" perspective, despite the shortcomings of this approach.[1] This theory holds that a potential criminal will choose to commit a crime if the expected utility from committing the offense is higher than the expected utility from using his/her time and resources for another activity (Becker, 1968). Because of this, research on methods to deter crime usually focuses on factors that can function either through decreasing the benefits of or increasing the costs of crime (Fajnzylber et al., 2002). Not in total opposition to this, the "situational crime prevention" theory focuses on the settings for crime, and advocates for changes in the physical environment in which crimes occur to reduce the opportunity for them to happen (Clarke, 1997; Mayhew and Clarke, 1980; Heal and Laycock, 1986, *apud* Atkins et al., 1991).[2]

Viewed through the lens of either of these theories, the *ex ante* impact of improved public infrastructure such as street lights on crime is ambiguous. On the one hand, enhanced visibility at night could deter crime through increasing the expected cost of committing it (for instance, by increasing the probability that the criminal is caught). Moreover, the public investment could act as a boon to social cohesion, community pride and positive image of the area, also negatively affecting criminal activity there (Taub et al., 1984; Fowler and Mangione, 1986; Lavrakas and Kushmuk, 1986; Taylor and Gottfredson, 1986; Wilson and Kelling, 1982, *apud* Painter and Farrington, 1999).[3]

However, it could be instead that improvements in lighting help potential offenders to successfully commit crimes, either during the day or at night. For nighttime crime, an increase in the number of people leaving their homes at night could increase the number of empty homes available for burglary and the number of potential victims on the streets (Painter and Farrington, 1997). Increased visibility could allow the criminal better judgment of the valuables carried by and defenses available to potential victims, as well as better perception of the proximity of potential witnesses. Furthermore, if newly illuminated areas attract criminal activities at nighttime, it could be the case that these areas also attract more attention for such activities during daylight hours.

Although the literature in economics on the relationship between public lighting and crime is not new, there is a paucity of studies in the last two decades, particularly exam-

[1]This approach has been criticized for its failings in measuring the non-pecuniary benefits of crime, for assuming equivalent costs and benefits for different types of crimes, and for not taking into account the unpredictable events that drive some crime, among other things.

[2]This theory differentiates itself from classical theories of modern criminology in the sense that the latter focus either on explaining criminal behaviour and how certain groups of society would be more inclined to commit crimes (Gottfredson and Hirschi, 1990, *apud* Clarke, 1997), or on how to deal with the criminal (Wilkins, 1990, *apud* Clarke, 1997). For more information on the origins of the "situational crime prevention" theory, see Jeffery (1977) and Newman (1972).

[3]Note that this mechanism would predict reductions not only in nighttime crime, but also in daytime crime. I return to this shortly.

ining areas outside the United States and the United Kingdom.[4,5] In the U.S., findings of studies focused on public lighting improvements across numerous cities are mixed, likely owing to impediments to causal identification (Farrington and Welsh, 2002).[6] In the U.K., research evaluating relighting programs that were implemented across London during the 1970s, 1980s, and 1990s generally finds reductions in crime, as well as reductions in the fear of crime and disorder, and increases in the usage of public streets (Painter, 1994), though studies examining such investments in other parts of the U.K. have mixed results (Poyner and Webb (1991), Shaftoe (1994), Poyner and Webb (1997), Herbert and Moore (1991), Davidson and Goodey (1991), Burden and Murphy (1991), and Ditton et al. (1992)).

Yet, nearly all of these studies in the U.S. and the U.K. utilize simple before and after comparisons, or linear regressions with controls and interactions, to study the relationship between public lighting and crime.[7] The use of this approach does not allow one to distinguish the effects of the relighting programs from other policies, programs, and events that may also affect crime. In addition, this approach can mask the impact of time trends on criminal activity, as well as possible variations in crime over different periods (Campbell and Cook, 1979, *apud* Painter and Farrington, 1997).

Recent work attempts to better achieve causal identification. A randomized experiment in New York City found reductions in outdoor nighttime crime of 36 percent, and in overall indices of crime of 4 percent, in communities that received temporary streetlights (Chalfin et al., 2019). In a rare example of research outside of a high-income country, Arvate et al. (2018) use an instrumental variables strategy to evaluate the effect of a rural electrification program (*Luz Para Todos* - "Light for All") on violent crime in northeastern Brazil. The results indicate a decrease of 92 cases of outdoor homicides per 100,000 inhabitants as a result of the policy.

The present study seeks to shed further light on this issue (pun intended!), by exploiting unusual features of a recent public lighting improvement program in São Paulo City, Brazil to achieve causal identification. Using a differences-in-differences approach that takes into account both the phased roll-out and early abandonment of the program, I find that improved

[4]Studies using U.S. data primarily focus on relighting programs undertaken in response to a wave of crime that took place around the country in the 1960s (see below). The U.K. endured a power crisis in the 1970s, which lead authorities to reduce public lighting there by 50% over a two-year period as part of an emergency plan. During this time, several areas reported increases in crime (Painter, 1996), and several studies using U.K. data seek to understand the relationship between subsequent relighting and crime (see below).

[5]Several studies in the economics literature on crime have attempted to demonstrate the effectiveness of other public policies designed to combat crime, including studies of bike patrols in commuter lots in Vancouver (Barclay et al., 1996), police presence in municipalities in the U.S. (Levitt, 2002; McCrary, 2002) and in Buenos Aires, Argentina (Di Tella and Schargrodsky, 2004), and dry laws in São Paulo, Brazil (Biderman et al., 2009).

[6]Cities studied include Kansas City, Missouri (Wright et al., 1974), Atlanta, Georgia (Atlanta Traffic Engineering Dept and United States of America, 1974), Milwaukee, Wisconsin (Department of Intergovernmental Fiscal Liaison, 1973, 1974), Portland, Oregon (Inskeep and Goff, 1974), Harrisburg, Pennsylvania (Harrisburg Police Department, 1976), New Orleans, Louisiana (Sternhell, 1977), Fort Worth, Texas (Lewis et al., 1979) and Indianapolis, Indiana (Quinet and Nunn, 1998).

[7]See for instance Atkins et al. (1991); Painter and Farrington (1999, 1997).

public lighting decreases nighttime cell phone thefts and robberies, and homicides, with cell phone robberies being reduced by 26% ($p<0.05$) and homicides by 29% ($p<0.05$). Total crime and "non-homicide crimes" at nighttime each fall by approximately 11% monthly ($p<0.05$ in both cases). Furthermore, I find positive spillovers of the lighting program on neighboring districts (particularly for cell phone thefts and homicides). There is some evidence that total and daytime crimes increase, possibly due to increased overall economic activity or other policy changes going on at the same time as the infrastructure improvement program.

The rest of the paper is organized as follows: Section 2 discusses the context in which the lighting improvement program was developed, and how it was rolled out. Section 3 describes the data and the estimation strategy. Section 4 presents results of the analysis and a set of robustness checks. Section 5 discusses the mechanisms driving the results, and Section 6 concludes.

2 The "Programa LED nos Bairros"

In 2014, the mayor of São Paulo, Fernando Haddad, proposed an infrastructure improvement plan that aimed, if implemented, to change the paradigm of the city. One central idea was to revitalize public lighting by replacing every street lamp in the city with an LED (Light-Emitting Diode) bulb and by expanding the overall lighting net. Among other advantages, LED technology is more efficient (and thus lower cost), can better control light distribution, and is less likely to be damaged by electrical disturbances (Philips and AES Serviços TC, 2013).

One of the requirements imposed by city administrators prior to implementation of this program was that the replacement of bulbs should begin in certain "priority zones", defined as regions with higher social and economic vulnerabilities and higher population densities. The public authorities believed that the new lighting system would decrease crime rates, especially for crimes facilitated by darkness. It was believed that because citizens living in these areas were more likely to move around either on foot or using public transportation, they would benefit greatly from better lighted sidewalks (ILUME, 2015). The program thus would begin in places that had high crime rates, high social vulnerability and high demand for public lighting (Chiovetti, 2018).

Following this requirement, the first districts to receive the new LED bulbs were chosen based on an index entitled the *Índice Paulista de Vulneravilidade Social* (IPVS). Created by the *Fundação Sistema Estadual de Análise de Dados* (SEADE) in 2010, the index included socioeconomic and demographic characteristics of districts.[8]

[8]Elements of the index include: average income per capita, average income of female-headed households, percentage of households with income at or below 1/2 the minimum wage, percentage of households with a literate household head, percentage of household heads aged 10-29, percentage of female-headed households where the head is aged 10-29, average age of household head, and percentage of kids aged 0-5.

The mayor announced the launch of public bidding to undertake this program in May of 2015 (Santiago, 2015). However, due to fraud suspicions, operations for a full-scale program were suspended (and remain so). Instead, a pilot program known as "Programa LED nos Bairros" (PLNB) was launched in December of 2015 with the installation of LED lamps in 2 districts. Following the successful completion of installation in these districts, 7 more districts received the new lighting technology between December 2015 and June 2016[9]. A second phase of the program, launched in June 2016, aimed to include 11 more districts, but ended up completing only 5 more due to insufficient budget[10]. Figure 1 displays the districts where lights were installed ("treated"), the districts that were chosen for inclusion in the program but where installation was never actually conducted ("would be treated"), and districts that were not included in the program ("non-treated").

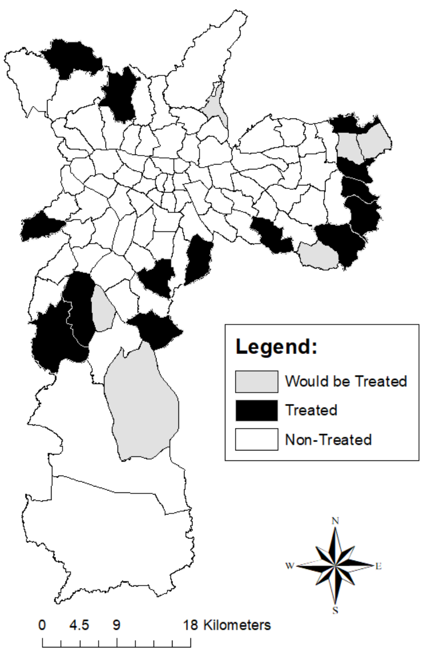

Figure 1: Treatment Status by District for "Programa LED nos Bairros, 2015-2016"

Although all of the districts that received the new LED lamps are on the outskirts of the city, almost every region in the city had at least one district considered for the program, except for the center[11]. In the analysis that follows, the 14 districts that received the program will be considered the analysis "treatment" group. Although all other districts in São Paulo will be considered the control group in some estimations, the main analysis will exploit the

[9]The first phase included *Heliópolis* (1,300 bulbs replaced) in the district of Sacomã, *Jardim Monte Azul* (534) in Jardim São Luis, Brasilândia (9,400), Lajeado (6,800), Sapopemba (11,300), Raposo Tavares (5,340), Jardim Ângela (11,200), Jardim Helena (5,900) and Pedreira (6,600) (ILUME, 2016).

[10]The second phase aimed to include Cidade Tiradentes (6,200), Guaianases (5,300), part of Jabaquara (2,500), Iguatemi (7,200), part of Grajaú (3,300), Perus (5,500), São Rafael (8,000), Socorro (6,000), Jaçanã (5,300), Itaim Paulista (9,800) and Vila Curuçá (7,800) (Secretaria Especial de Comunicação, 2016), but ended up delivering to only Cidade Tiradentes, Guaianases, Perus, Iguatemi and Jabaquara (partially) (Chiovetti, 2018; ILUME, 2016)

[11]This is, among other factors, because some of the streets in the center of the city already had LED lamps.

6 districts that were announced to be in the program but did not ultimately receive lights as a better defined control group.

3 Data and Estimation Strategy

3.1 Data

Several sources of data were used in the following analysis. These sources can be divided into two categories: a) data related to the lighting improvement program and characteristics of the districts; and b) data related to crimes.

3.1.1 Data on District Characteristics and the PLNB Program

Information related to the PLNB is available on the São Paulo city hall website, including the list of treated districts and the lamp installation schedule (for the first phase of the program). Reports, news and social media posts were used to confirm this list, as well as to generate the installation schedule for the second phase of the program.[12] The city hall website also includes information on studies that were conducted before the release of the Public-Private Partnership, and details of the lamps that would be installed in each district. Further information on program development was obtained through personal interviews with program authorities and consultation of a book launched by the Services Secretary in 2018 that presents some details on the program (Chiovetti, 2018). Zonal-level IPVS data was extracted from the *SEADE*'s website, and combined with files publicly provided by the city hall website (GeoSampa, 2018) in order to generate district-level data.

Table 1 presents summary statistics for selected characteristics of the districts of São Paulo in 2014, one year before the start of the PLNB program. Statistics are presented first for the full set of districts in the city (column 1), and then separately for those that received lamps during late 2015 and 2016 ("treated districts", column 2), those that did not receive lamps through the PLNB ("control districts", column 3), and districts that were selected to receive lamps but did not due to unexpected program abandonment ("would be treated districts", column 4, which is a subset of the districts in column 3). Columns 5 and 6 test for statistically significant differences between columns 2 and 3, and columns 2 and 4, respectively.

From this table, one can see that prior to the launch of the lightning improvement program, the districts that received lamps were more populous and had higher population density, on average, than those that did not receive lamps. Treated districts also had lower high school enrollment, and lower formal employment rates, although penetration of social

[12]I define months that each district began to receive the LED lamps as those that are reported by at least two news articles or media posts.

programs was fairly similar across the two groups. Revenue from taxes on services[13] was significantly lower for the districts that received lamps, representing approximately 32.2% of the total revenues from the same source in the non-treated group.

Table 1: District Characteristics, 2014

	(1) All Districts	(2) Treatment	(3) Control	(4) Would Be Treated	(5) (2)-(3)	(6) (2)-(4)
Total population	119,936	195,377	107,056	172,300	88,321***	23,077*
	(71,685)	(75,280)	(62,574)	(107,499)	(-16)	(-1.9)
Fraction male	.47	.48	.47	.48	.0091***	.0016*
	(.012)	(.006)	(.013)	(.0082)	(-9.1)	(-1.7)
Area (in km^2)	16	17	16	25	1.7	-7.3***
	(27)	(7.6)	(29)	(31)	(-.74)	(2.9)
Population/km^2	.011	.012	.011	.011	.0016***	.0016**
	(.0052)	(.0049)	(.0052)	(.0058)	(-3.7)	(-2.2)
Total number of lamps (1)	6,224	7,696	5,973	8,185	1,723***	-489
	(2,513)	(2,342)	(2,456)	(3,950)	(-8.5)	(1.2)
Lamps/km^2	618	494	639	531	-144***	-37
	(323)	(171)	(337)	(191)	(5.4)	(1.5)
High school enrollment rate (2)	.7	.51	.73	.63	-.22***	-.12***
	(.35)	(.083)	(.37)	(.24)	(7.7)	(5.8)
Spots in social programs	359	378	356	351	23	27
	(322)	(445)	(297)	(382)	(-.84)	(-.46)
Formal employment rate	.66	.099	.75	.22	-.65***	-.13***
	(.94)	(.077)	(.99)	(.32)	(8.6)	(4.8)
Taxes on services (3)	8,065,781	2,885,665	8,961,110	4,034,694	-6,075,445***	-1,149,029
	(14,783,408)	(5,888,212)	(15,651,003)	(8,032,951)	(5)	(1.2)
IPVS value (4)	2.5	3.6	2.4	3.4	1.2***	.18***
	(.89)	(.52)	(.81)	(.74)	(41)	(3.7)
Nº of Districts	96	14	82	6	96	20

Notes: Columns (1) through (4) depict the means and standard deviations (in parentheses) for selected district characteristics. Column (4) contains a subset of districts in column (3), namely those districts who were chosen for program inclusion but did not receive any lamps due to early abandonment of the program. Columns (5) and (6) show mean differences, respectively, between columns (2) and (3), and columns (2) and (4), with standard errors in parentheses. Superscripts *, ** and *** represent statistical significance at p<0.1, p<0.05, and p<0.01, respectively.
(1) Total number of lamps and, consequently, Lamps/km^2 use data from the year 2016, the only source of data available.
(2) The high school enrolment rate is calculated by dividing the number of students enrolled in high school by the population of individuals aged 15-19.
(3) Data on taxes on services are available only for 2014 and 2105 and the results are calculated with values in 2014 as the base year. In addition, this measure is missing for 1 district in columns 1 and 3.
(4) Values of IPVS are fixed and derived from 2010.

Although it could just mean that there are more commercial places in non-treated areas, it mostly reflects the types of economic activity in each area, with more developed activities being located in non-treated districts, suggesting economic vulnerabilities in the treated districts. Note that although the total number of lamps is higher in treated districts, the

[13]This tax represents 5% of service provided by companies and self-employed persons, and thus is a good proxy variable for economic activity at the district level.

number of lamps per km^2 is lower in treated areas than in non-treated areas, suggesting a need for the PLNB in those selected districts. Finally, as expected, the IPVS is 1.2 point (50%) higher for the districts that received the new LED lamps.[14]

Importantly, differences between the districts that received lamps and those that should have but did not due to early abandonment of the program (column 6) are generally smaller and less statistically significant than when compared to the full control group. In particular, the sets of districts that were chosen for program inclusion are similar in size, in initial lamp density, and in measures of economic activity (sales tax revenues). With respect to population density, high school enrollment rate and the share of the population in formal employment, although differences are statistically significant, magnitude differences are substantially smaller compared to those in column (5). The group of districts that were among the ones chosen to receive the new bulbs but did not is indeed more similar to the group that actually received the LED lamps. I exploit this fact in the following analysis.

3.1.2 Data on Crime

Data on crime is taken from the website of the Public Safety Secretary for the Government of São Paulo (SSP, 2017). For five categories of crimes (cell phone thefts, cell phone robberies, vehicle thefts, vehicle robberies, and homicides), the PSS makes available monthly records. The data was collected from victims who accessed the website to register the crimes. Each record includes information on the nature of the crime, as well as the date, time, location (including GPS) , and an indicator on the period (night, morning, and afternoon) of its occurrence. For crimes related to vehicles, detailed information on the vehicle is also included. The present study uses available crime data for the years 2013-2017, three years before and one year after the start of the PLNB program.[15]

Despite its level of detail, a key limitation of this data is that not all crimes committed are actually registered in this system. In 2018, for example, it is estimated that 52% of robberies against a person in the city of Sao Paulo, 64% thefts against a person, 13% of vehicle robberies, and 22% of vehicle thefts were not reported to the police (Amâncio, 2018). Under-reporting could be attributed to lack of belief that a stolen item will be recovered, a belief that the value of the item is not sufficiently high to cover the costs (financial, temporal, and/or emotional) of reporting and pursuing the matter, or a feeling of distrust in public authorities (Amâncio, 2018). The under-reporting of crime likely contributes to several months with zero crimes recorded in the district-level data, and presents a problem

[14] The index classifies areas according to their socioeconomic vulnerability into 7 groups, being 1 the group with lower vulnerabilities and 7 those areas part of the group with higher vulnerabilities. Non-classified areas receive a zero value and are dropped from the calculus on the average IPVS for each district.

[15] Duplicates in the data (the same crime counted twice or more) are eliminated based on the crime registration number. In the case of homicides, they are eliminated based on the ID number of the victim, which is also provided in the public data set. Besides, for instance, if a cell phone robbery was followed by a homicide, although the crime is counted for both categories of crimes separately, they are not double counted in total nor "non-homicides crimes".

for estimation, in particular to the extent that there are unobservables that are possibly correlated with different reporting rates across districts.[16]

Table 2: Summary Statistics on Crime Prior to Announcement of the PLNB

	(1) All Districts	(2) Treatment	(3) Control	(4) Would Be Treated	(5) (2)-(3)	(6) (2)-(4)
Nighttime Cell Phone Thefts	16.63	7.81	18.13	7.00	-10.32***	0.808*
	(26.16)	(5.63)	(27.94)	(4.29)	(1.39)	(0.48)
Nighttime Vehicle Thefts	12.47	10.49	12.81	11.26	-2.319***	-0.774
	(8.54)	(7.42)	(8.67)	(5.88)	(0.46)	(0.63)
Nighttime Cell Phone Robberies	28.04	32.56	27.27	26.60	5.293***	5.961**
	(26.56)	(27.46)	(26.33)	(20.57)	(1.42)	(2.32)
Nighttime Vehicle Robberies	21.91	33.35	19.95	31.97	13.39***	1.376
	(18.96)	(21.45)	(17.79)	(19.81)	(0.99)	(1.90)
Nighttime Non-Homicide Crimes	76.77	81.94	75.89	75.45	6.047**	6.488
	(51.80)	(47.89)	(52.40)	(38.91)	(2.78)	(4.11)
Total Non-Homicide Crimes	161.35	153.20	162.74	156.29	-9.539*	-3.083
	(96.91)	(87.02)	(98.45)	(78.79)	(5.20)	(7.67)
Nighttime Homicides	0.66	1.17	0.57	1.04	0.595***	0.125
	(1.23)	(1.66)	(1.12)	(1.37)	(0.07)	(0.14)
Nighttime Crime	77.36	82.99	76.40	76.43	6.592**	6.565
	(51.96)	(48.32)	(52.51)	(39.27)	(2.79)	(4.15)
Total Crime	162.27	154.89	163.53	157.94	-8.636*	-3.043
	(97.05)	(87.59)	(98.54)	(79.44)	(5.21)	(7.72)
№ of District-Months	2,784	406	2,378	174	2,784	580
№ of Districts	96	14	82	6	96	20

Notes: Data is presented at the level of district-month, and includes observations from from January 2013 to May 2015. Columns (1) to (4) present the mean (and standard deviation) of number of nighttime crimes reported. Columns (5) and (6) show mean differences from columns (2) and (3) and columns (2) and (4), respectively, with standard errors in parenthesis. "Total Non-Homicide Crimes" and "Total Crime" include crimes committed both during the day and at night. Superscripts *, ** and *** represent statistical significance at $p<0.1$, $p<0.05$, and $p<0.01$, respectively.

Table 2 presents summary statistics[17] on nighttime crime from January 2013 to May

[16] Appendix Figure A1 plots the distributions of crime, by category. Crime counts are skewed to the right. This right-skewness may be a result of a large amount of months with zero nighttime crimes registered. Yet, Appendix Table A3 suggests that this is unlikely to be the case, showing that the frequency of months with zero crimes registered at night across crimes is no larger than 12% (for cell phone robbery), with the exception of homicides, (where approximately 70% of months see zero crimes registered). In order to alleviate concerns of under-reporting for homicides, I compare the total number of homicides reported by the PSS with data from the National Department of Health (DATASUS) (see Appendix Figure A2). Although the figure suggests that indeed homicides are understated in the PSS data, both data sets seem to follow the same trends pre and post PLNB program implementation for treated and "would be treated" groups. Furthermore, regressions of total homicides across both data sets result in very similar coefficients (not shown), supporting the evidence described in the main results below.

[17] "Non-Homicide crimes" include property and violent crimes as defined by the FBI (FBI, 2016a,b).

2015[18], prior to the announcement of the bidding process for the lighting program.[19] Results from t-tests of mean differences in column (5) suggest that crime is generally more frequent in districts that ultimately received lights, compared to those that do not. The total amount of nighttime crime is, on average, 6.6% higher in treated districts than in the non-treated ones before the announcement of the program, while total crimes committed (regardless of time of day) are slightly lower in treated districts. Importantly, there is very little evidence of differences in crime rates between districts that were chosen for lamps and received them and districts that were chosen for lamps but did not ultimately receive them (column 6), which is the comparison I use in the main analysis.

3.2 Estimation Strategy

This paper seeks to estimate the causal impact of improved public lighting on nighttime crime in São Paulo, Brazil. Additional analysis, derived from this main one, will explore possible spatial displacement of crime due to the program, as well as changes in daytime crime.

The key identification issue in estimating the causal impact of improved public lighting on crime is one of omitted variables. As described above, districts were not randomly selected for program inclusion; instead, those considered more socially and economically vulnerable were the ones chosen to receive the new LED lamps. In order to alleviate this estimation problem, I exploit the timing of the phased roll-out to different districts, including a treatment indicator and district fixed effects in the basic regression specification. The fixed effects absorb district characteristics that do not change over time, limiting omitted variables to those that vary within districts over time. These regressions are summarized by:

$$crime\_night_{imt} = \gamma_0 + \gamma_1 crime_{i(m-1)t} + \gamma_2 crime\_day_{imt} + \gamma_3 D_{imt} + \gamma_4 time + X_{it}\gamma_5 + \theta_i + \theta_m + \theta_t + \xi_{imt}$$

where $crime\_night_{imt}$ is the count of crimes reported in district i, month m and year t that occurred at nighttime; $crime_{i(m-1)t}$ is the number of crimes reported in the previous month, included to account for possible inertia or learning effects of criminal activity in a given district (Fajnzylber et al., 2002); D_{imt} is an indicator for the district having received LED lamps during or before that month; $time$ is a linear time trend capturing aggregate trends over time; and X_{it} is a set of time-varying district-level control variables including high school enrollment, formal employment and total population. θ_i, θ_m, and θ_t are respectively district, month and year fixed effects. Results from Hosmer–Lemeshow goodness-of-fit tests suggest that the data suffers from overdispersion. For this reason, results from both linear and Poisson regressions, in which the log count of nighttime crime is regressed on the vector

[18] Appendix Table A1 provides an extended set of summary statistics through December 2015, and Appendix Table A2 provides summary statistics on daytime crimes from January 2013 to May 2015.

[19] As the program announcement, even prior to the start of implementation, could affect crime rates (Barclay et al., 1996, *in* Clarke et al., 1996), the data extracted before this period can better depict baseline crime levels.

of covariates[20], will be presented.

My primary specification additionally includes $crime\_day_{imt}$ as a control, representing the count of daytime crimes reported in the district-month-year. This measure is included to control for unobserved changes related to overall crime that are happening in the districts over time, such as new business openings (increasing overall economic activity) and other policy changes (such as changes in policing in these districts). However, to the extent that the lighting program also affects day crime, inclusion of this measure may generate a problem in estimation. This could happen, for example, if the new lights increased economic activity during both night and daytime, for instance by attracting new businesses that are also open during the day (Dinkelman, 2011). I return to this issue in Section 4.1.2 below.

In order to further limit concerns of omitted variables, I present regression results that limit the districts included in the control group to only those that were supposed to receive the LED lamps but did not - the "would be treated" group. I call the sample including only districts that were chosen to receive the LED lights the "restricted sample". As already seen in Tables 1 and 2, the districts that received the lights and those that were chosen to receive lights but did not receive them are very similar according to their observable characteristics - indeed, the only reason the latter group did not receive the new LED lamps was due to unexpected program abandonment. Appendix Figure A3 provides additional evidence of these similarities, showing that trends in crime in the treated and "would be treated" districts are almost identical prior to the launch of the program. By using these districts as a better identified control group, it is expected that the endogeneity generated from the non-random choice of districts to receive the program would be drastically attenuated and we should expect, therefore, more reliable results.

I present the results of this restricted sample first and foremost, but, given sample size limitations, I additionally present results using the full set of districts that did not receive the improved LED lights as a control group, in what I refer to as the "full sample". Appendix Figure A4 shows relatively similar trends in crime - although very different levels of crime - prior to the launch of the PLNB across this larger set of control districts and the treated districts, suggesting the estimates using this full sample still provide useful results. Thus, γ_3 can still be interpreted as the effect of the program on the monthly number of cases registered in each category of crime.

[20] In order to take into account the presence of zeroes, for the Possion specifications, I use $\ln(crime\_day_{imt} + 1)$ and $\ln(crime_{i(m-1)t} + 1)$ on the RHS of the equation

4 Results and Robustness Checks

4.1 Results

Table 3 reports estimates from linear (odd columns) and Poisson (even columns) regressions using the equation specified above. Panel A considers the restricted sample (districts who were supposed to receive lamps only), and Panel B considers the full sample (all districts).

Across the restricted sample presented in Panel A, we see negative point estimates for nearly all categories of crime across both regression models, and statistically significant negative impacts for total nighttime crime, "non-homicide crimes", cell phone robberies, and homicides.

The magnitude of impacts is also substantial. The results presented in Panel A suggest that receiving improved LED lights reduces total nighttime crimes by 11.1% overall ($p<0.05$) in the linear model, and results are also negative in the Poisson model with a 1.8% ($p<0.01$) decrease (columns 1 and 2). "Non-Homicide Crimes" (columns 3 and 4) were reduced by 10.9% ($p<0.05$) and 1.8% ($p<0.01$) in linear and Poisson specifications respectively. Cell phone thefts (columns 5 and 6) have negative point estimates, respectively 9.4% and 2.6% for the two different specifications, though results are not statistically significant in either model. On the other hand, the magnitude of the coefficient for cell phone robberies in the linear model suggest that the PLNB may have reduced this type of crime by 25.7% ($p<0.05$), while the magnitude reaches 4.4% ($p<0.05$) in the Poisson specification. The estimate for vehicle robberies, although non significant, points to a decrease in cases by around 0.4% in both models. Finally, results for homicides (columns 13 and 14) points to a 29% and 22% reductions in cases ($p<0.05$ for both specifications)[21]. Thus, even when changing the model specification, results seem to sustain previous findings: as a response to the PLNB, crimes were reduced in treated districts.

Table 3, Panel B presents results from linear (odd columns) and Poisson (even columns) regressions using the full sample of districts in São Paulo. The results are generally similar to those discussed in Panel A in terms of direction of estimated effects, with the improved LED lights having a negative impact on cell phone thefts and robberies, vehicle robberies, and homicides. In fact, results from the fixed-effect model using the full sample suggest a decrease of 3.5% of total crimes and 3.3% of "non-homicide" ones, although not statistically significant. On the other hand, for these two categories of crime, coefficients derived from the Poisson model point to reductions of 1.7% ($p<0.01$) and 1.8% (p.0.01) respectively. Cell phone thefts (columns 5) are highly negatively impacted by the new LED lamps, with a 26.4% reduction in such crimes monthly in treated districts ($p<0.01$). In addition, while coefficients from the fixed-effect model indicate non-significant reductions in cell phone robberies (-5.9%), the Poisson model suggest a 10% decrease in this category of crimes ($p<0.01$). Finally, results

[21] Percentages for the coefficients derived from the Poisson specifications are calculated by: $(e^{\gamma_3} - 1) \times 100$.

for homicides suggest decreases of 25.1% and 6% respectively for the fixed-effect and Poisson models. Therefore, if compared to the fixed-effect model, the Poisson specifications present identical directions for crimes, except for cell phone thefts and vehicle robberies. (Though recall that point estimates were aligned in direction in the restricted sample, discussed above.)

Taken together, the results presented in Table 3 provide compelling evidence that the lighting improvement program reduced crime in treated districts.

4.1.1 Spatial Spillovers

The crime literature suggests that criminals generally target their activities in particular areas, such as transportation nodes, or areas where their surroundings are familiar (e.g. near their homes) (Barclay et al., 1996). To the extent that infrastructure changes affect these areas by pushing crime out, the impact on neighboring areas is unclear - criminals may move their activities to these neighboring areas (nearby to where they were working before, thereby increasing crime in neighboring areas), or may move elsewhere altogether (thereby also decreasing crime in neighboring areas). Because of that, I now investigate if the PLNB created spillover impacts (positive or negative) for neighboring districts. If the program was indeed effective in reducing crimes in neighboring areas, taking into account only decreases in crimes in treated districts would underestimate the total, and real, impact of the program.

In order to study this question, I add to the main regression model (presented in the equation above) an indicator variable that equals 1 if any given district neighbors a treated district and that district that it neighbors has started being treated. Since five out of six "would be treated" districts neighbor at least one treated district, the entire sample is included in the estimation. Table 4 shows the results. Estimates suggest that crime is generally reduced in areas neighboring those that received improved lighting - coefficients are negative for the most part, and statistically significantly so for cell phone thefts, vehicle robberies and homicides. Results suggest that the program reduced approximately total and "non-homicide crimes" by about 0.9% and 0.8% respectively (not statistically significant). For cell phone thefts (column 3) and homicides (column 7), estimates indicate a reduction of respectively 25.4% and 26.3% of cases monthly in neighboring districts ($p<0.01$ and $p<0.05$, respectively). Finally, the new LED bulbs seem to have diminishing vehicle robberies by 5.5% in neighboring districts ($p<0.1$)

Therefore, two findings seem to be important to be highlighted when comparing the main results found in Table 3 with the ones in Table 4. First, with the exception for coefficients for cell phone and vehicle thefts and vehicle robberies, all other estimates for neighboring districts are lower than those for treated districts, which is reasonable given that we should expect the treatment effect to be stronger in districts that actually received the treatment. However, it is not entirely a puzzle having coefficients for neighboring districts greater in magnitude than those for treated districts given a possible treatment effect without treatment already found in the literature.[22] Secondly, the reduction of both total and "non-homicide"

[22] One example of that is a decrease of auto thefts registered in Vancouver that were registered only as an

Table 3: Effect of Improved Lighting on Nighttime Crimes

	Total Crime		Non-Homicide Crimes		Cell Phone Thefts		Vehicle Thefts		Cell Phone Robberies		Vehicle Robberies		Homicides	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Panel A: Restricted Sample														
LED lamps	-8.486**	-0.019***	-8.254**	-0.019***	-0.661	-0.026	0.152	0.001	-6.825**	-0.045**	-0.136	-0.004	-0.301**	-0.248**
	(3.360)	(0.006)	(3.340)	(0.006)	(0.474)	(0.022)	(0.643)	(0.017)	(3.021)	(0.019)	(1.182)	(0.016)	(0.121)	(0.120)
Nº of Nighttime Crimes$_{(m-1)}$	0.508***	0.103***	0.512***	0.105***	0.183***	0.051***	0.096**	0.016	0.399***	0.120***	0.320***	0.038***	-0.043	-0.056
	(0.067)	(0.007)	(0.067)	(0.008)	(0.033)	(0.016)	(0.037)	(0.015)	(0.021)	(0.020)	(0.052)	(0.011)	(0.032)	(0.049)
Nº of Day Time Crimes	0.548***	0.153***	0.544***	0.154***	0.132***	0.069***	0.048	0.065***	0.835***	0.513***	0.573***	0.325***	0.090***	0.143***
	(0.092)	(0.008)	(0.091)	(0.009)	(0.017)	(0.021)	(0.042)	(0.013)	(0.069)	(0.022)	(0.051)	(0.023)	(0.028)	(0.051)
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted-R^2	0.707		0.708		0.363		0.094		0.798		0.525		0.018	
Pseudo-R^2		0.024		0.025		0.045		0.034		0.206		0.058		0.086
Nº of Months	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180
Nº of Districts	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Panel B: Full Sample														
LED lamps	-2.651	-0.017***	-2.537	-0.018***	-4.784***	0.010	0.535	0.019	-1.618	-0.106***	-0.506	0.017	-0.143	-0.061
	(2.706)	(0.004)	(2.695)	(0.004)	(1.145)	(0.013)	(0.385)	(0.013)	(1.284)	(0.013)	(1.065)	(0.012)	(0.109)	(0.088)
Nº of Nighttime Crimes$_{(m-1)}$	0.284***	0.096***	0.285***	0.096***	0.142**	0.046***	0.207***	0.061***	0.353***	0.141***	0.342***	0.064***	-0.005	-0.013
	(0.063)	(0.004)	(0.063)	(0.004)	(0.069)	(0.007)	(0.020)	(0.007)	(0.026)	(0.009)	(0.031)	(0.006)	(0.018)	(0.034)
Nº of Day Time Crimes	0.627***	0.137***	0.626***	0.141***	0.559***	0.131***	0.117***	0.100***	0.857***	0.509***	0.595***	0.276***	0.034**	0.077**
	(0.092)	(0.006)	(0.092)	(0.006)	(0.102)	(0.009)	(0.023)	(0.007)	(0.051)	(0.010)	(0.038)	(0.010)	(0.016)	(0.037)
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted-R^2	0.575		0.576		0.415		0.162		0.759		0.473		0.009	
Pseudo-R^2		0.039		0.040		0.098		0.057		0.212		0.103		0.137
Nº of Months	5,664	5,664	5,664	5,664	5,664	5,664	5,664	5,664	5,664	5,664	5,664	5,664	5,664	5,664
Nº of Districts	96	96	96	96	96	96	96	96	96	96	96	96	96	96

Notes: The level of analysis is the district-month level. Separate regressions are run for each different type of crime. Coefficients for fixed-effect and Poisson specifications are depicted respectively on odd and even columns within crime category. Regressions include controls for the log number of teenagers enrolled in high school across districts, log of population and log of formal employees per year, as well as month, year and district fixed effects. Robust standard errors are in parenthesis, clustered at the district level for the fixed-effect models. Superscripts *, ** and *** represent significance ate 10%, 5% and 1% respectively.

Table 4: Effect of Improved Lighting on Nighttime Crimes in Neighboring Districts

	Total Crime	Non-Homicide Crimes	Cell Phone Thefts	Vehicle Thefts	Cell Phone Robberies	Vehicle Robberies	Homicides
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
LED lamps	-2.9	-2.7	-6.5***	.62	-.95	-.88	-.19*
	(3.013)	(3.000)	(1.588)	(0.416)	(1.293)	(1.029)	(0.107)
Neighbor District	-.66	-.59	-4.6***	.24	1.8	-1.1*	-.15**
	(2.670)	(2.659)	(1.562)	(0.379)	(1.138)	(0.599)	(0.067)
Nº of Nighttime Crimes$_{(m-1)}$	.28***	.28***	.14**	.21***	.35***	.34***	-.0061
	(0.063)	(0.063)	(0.068)	(0.020)	(0.025)	(0.031)	(0.017)
Nº of Day Time Crimes	.63***	.63***	.56***	.12***	.86***	.59***	.034**
	(0.092)	(0.092)	(0.102)	(0.023)	(0.051)	(0.038)	(0.016)
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted-R^2	0.575	0.576	0.416	0.162	0.759	0.473	0.010
Nº of Months	5,664	5,664	5,664	5,664	5,664	5,664	5,664
Nº of Districts	96	96	96	96	96	96	96

Notes: The model is derived from the main estimation explained in section 3. The "Neighbor District" variable is added as an indicator variable that equals 1 if any given district neighbors a treated district and that district that it neighbors has started being treated. For more information, see Table 3. Robust standard errors are in parenthesis and clustered at the district level. Superscripts *, ** and *** represent significance ate 10%, 5% and 1% respectively.

Table 5: Effect of Improved Lighting on Daytime Crimes

	Total Crime (1)	Non-Homicide Crimes (2)	Cell Phone Thefts (3)	Vehicle Thefts (4)	Cell Phone Robberies (5)	Vehicle Robberies (6)	Homicides (7)
Panel A: Treated VS Would be Treated							
LED lamps	5.148^{***}	5.164^{***}	1.128	1.041	3.133^{**}	0.840	-0.037
	(1.656)	(1.650)	(0.856)	(0.663)	(1.200)	(1.543)	(0.121)
Nº of Nighttime Crimes$_{(m-1)}$	0.678^{***}	0.680^{***}	0.397^{***}	0.694^{***}	0.687^{***}	0.475^{***}	0.007
	(0.033)	(0.033)	(0.068)	(0.139)	(0.027)	(0.059)	(0.035)
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted-R^2	0.581	0.583	0.463	0.529	0.657	0.284	0.005
Nº of Months	1,180	1,180	1,180	1,180	1,180	1,180	1,180
Nº of Districts	20	20	20	20	20	20	20
Panel B: Full Sample							
LED lamps	6.116^{**}	6.145^{**}	-2.286	1.207^{***}	3.900^{***}	0.038	-0.064
	(2.903)	(2.880)	(2.010)	(0.431)	(0.942)	(0.931)	(0.088)
Nº of Nighttime Crimes$_{(m-1)}$	0.384^{***}	0.384^{***}	0.207^{***}	0.471^{***}	0.636^{***}	0.397^{***}	-0.013
	(0.066)	(0.066)	(0.050)	(0.066)	(0.016)	(0.043)	(0.019)
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted-R^2	0.277	0.278	0.119	0.312	0.578	0.215	0.002
Nº of Months	5,664	5,664	5,664	5,664	5,664	5,664	5,664
Nº of Districts	96	96	96	96	96	96	96

Notes: See Table 3. Robust standard errors are in parenthesis and clustered at the district level. Superscripts *, ** and *** represent significance ate 10%, 5% and 1% respectively.

crimes in neighboring districts represent around 7% of the reduction of nighttime crimes in treated districts for both categories. At the same time, reductions in homicides in neighbor districts are around 50% of the effect of the PLNB on treated districts, while cell phone thefts seem to be reduced more in neighboring districts, 4.6 cases ($p<0.01$), than in treated ones. Therefore, estimating the effect of the program only on treated districts seems to underestimate the real treatment effect of PLNB.

4.1.2 Daytime Crime

Regressions to this point employ daytime crime as a control measure, as a proxy for other policies or circumstances that are changing that may affect overall crime at the district level. Yet, it could be the case that the infrastructure improvement program also impacted crimes committed during the day, either positively or negatively. For instance, improved lighting during the nighttime may increase economic activities in the district - by increasing the flow of customers, or increasing the number of businesses locating there. This may increase crime during the day, due to an increase in the number of potential targets for criminal activity. Alternatively, as Section 4.1.1 concludes that the program decreased crime in neighboring districts, it could be that it similarly lowers crime in the treated districts even during daytime hours (if for instance, criminals are deterred by the nighttime changes and opt to move their activities elsewhere).

In Table 5, I estimate the relationship between the lighting program and daytime crimes. Note that these estimates should be interpreted with caution. By using day crime as the dependent variable, there is no other independent variable that accounts for time variant changes happening in each district that may impact crime.[23] Interestingly, the estimates in Table 5 suggest a positive relationship between receipt of improved LED lamps and crime, in both the restricted and full samples of districts. In particular, it looks as though vehicle thefts and cell phone robberies increased as LED lights were installed, suggesting that either criminals moved their activities to the daytime (temporal displacement of crime), or that something else was changing in these districts over time that increased crime there (such as increased economic activity, or a policy change that increased daytime crime).

Table 6 provides estimates of the relationship between lighting program receipt and nighttime crime, without the daytime crime control (so re-estimation of the results in Table 3 without the daytime crime control). As in Table 3, odd columns depict the results of the fixed-effect specification, while even ones show the coefficients resulted from the Poisson specification. Estimates using the restricted sample of districts (Panel A) and the full sample of districts (Panel B) suggest somewhat mixed results. Consistent across the two panels and regression models, we do see a positive relationship between nighttime crime and the relighting program in particular for vehicle thefts, and a negative relationship for homicides.

effect of a publicity campaign on TV about the future program to be implemented (Barclay et al., 1996).

[23] The lack of a proxy variable used for this purpose comes from the fact that it is extremely hard to find district-level data on a monthly basis.

The findings derived from Table 6 seem to clarify the ones in Table 5, with the increase in crimes during day time possibly being caused by an increase of potential victims due to a growth of economic activity (day and night) in the treated districts as a response to the PLNB. The suggested higher number of vehicle thefts may also be a result of more vehicles parked in those areas, a consequence of a higher economic activity generated by the program. Thus, in absolute terms, crimes in general seem to be increasing due to the PLNB, but nighttime crimes are falling relative to day time crime due to the brighter lights. The evidence suggests not only that the PLNB has changed the environment of treated districts at night, but also created an increase in economic activity during day and night in these districts. However, it is not possible to entirely rule out some weak evidence that crimes committed under natural light are increasing due to compensations of the decreases found during the night (temporal displacement).

4.2 Robustness Checks

In this section, several alternative models are run in order to provide extra evidence to support the results found in the previous section. First, the outcome measure is changed to the rate of crime for every 100,000 residents[24], and the regression is run using the linear model only. Table 7 depicts the results for this estimation strategy. Estimates are similar to those presented in Table 3. The signs are exactly the same as the one in the main estimation strategy, for both the restricted sample and the full sample. This supports the previous finding that the program negatively impacted crimes committed during nighttime, except for vehicle thefts, which never present negative coefficients. Coefficients for total and "non-homicide crimes" in Panel A suggest reductions respectively of about 19.9 and 19.5 cases per 100,000 inhabitants, significant at 5% level, which represent reductions of 18.5% and 18.3% respectively (results even higher than the ones presented in Table 3.

The second important aspect to take into account for the robustness of the estimation is the fact that, although LED lamps accounted for only 2% of the lighting system of the city in March of 2014 (as cited in section 2), it means that some of the districts used in the main estimation strategy as the control group cannot be entirely considered as non-treated ones. The fact that these districts already had part of their territory illuminated by LED lamps means that the effects observed on the districts contemplated by the PLNB could already have happened in those districts, even in lower magnitudes. If the changes in the environment caused by better infrastructure were enough to generate changes in behavior by the criminals and the population (as observed in the previous section), it would generate doubts on the validity of the results for including in the non-treated group districts that should be considered at least as partially treated ones.

Additionally, some districts that indeed received the new lamps through the PLNB were only partially treated. Not the entire lighting system of of these districts were replaced by LED lamps. This is the case of *Jardim São Luis*, *Sacomã*, *Jabaquara* and *Iguatemi*. The

[24]Because of that, population was removed as a control on the RHS of the equation.

Table 6: Effect of Improved Lighting on Nighttime Crimes - Without Day Crime Controls

	Total Crime		Non-Homicide Crimes		Cell Phone Thefts		Vehicle Thefts		Cell Phone Robberies		Vehicle Robberies		Homicides	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Panel A: Restrict Sample														
LED lamps	-0.286	0.006	-0.171	0.007	-0.385	-0.017	0.345	0.010	0.007	0.079***	0.648	0.013	-0.305**	-0.254**
	(2.388)	(0.007)	(2.353)	(0.007)	(0.545)	(0.022)	(0.694)	(0.017)	(1.928)	(0.025)	(1.231)	(0.022)	(0.125)	(0.119)
Nº of Nighttime Crimes$_{(m-1)}$	0.720***	0.169***	0.723***	0.171***	0.228***	0.058***	0.099**	0.020	0.730***	0.420***	0.468***	0.096***	-0.048	-0.065
	(0.020)	(0.008)	(0.020)	(0.008)	(0.035)	(0.016)	(0.038)	(0.016)	(0.018)	(0.026)	(0.045)	(0.018)	(0.031)	(0.049)
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted-R^2	0.613		0.616		0.334		0.083		0.692		0.354		0.013	
Pseudo-R^2		0.023		0.023		0.044		0.034		0.161		0.034		0.085
Nº of Months	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180
Nº of Districts	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Panel B: Full Sample														
LED lamps	2.378	0.002	2.492	0.002	-5.491***	0.033**	0.753*	0.030**	3.404***	-0.000	-0.256	0.041**	-0.145	-0.065
	(3.231)	(0.005)	(3.211)	(0.005)	(1.636)	(0.014)	(0.405)	(0.013)	(1.135)	(0.018)	(1.060)	(0.016)	(0.111)	(0.088)
Nº of Nighttime Crimes$_{(m-1)}$	0.478***	0.144***	0.479***	0.146***	0.260***	0.066***	0.225***	0.068***	0.684***	0.426***	0.462***	0.103***	-0.006	-0.017
	(0.059)	(0.004)	(0.059)	(0.004)	(0.088)	(0.007)	(0.019)	(0.007)	(0.014)	(0.011)	(0.034)	(0.008)	(0.018)	(0.034)
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted-R^2	0.383		0.385		0.166		0.116		0.632		0.324		0.009	
Pseudo-R^2		0.038		0.039		0.097		0.056		0.170		0.088		0.137
Nº of Months	5,664	5,664	5,664	5,664	5,664	5,664	5,664	5,664	5,664	5,664	5,664	5,664	5,664	5,664
Nº of Districts	96	96	96	96	96	96	96	96	96	96	96	96	96	96

Notes: See Table 3. Robust standard errors are in parenthesis and clustered at the district level for the fixed-effect models. Superscripts *, ** and *** represent significance ate 10%, 5% and 1% respectively.

reasons that led to this condition of partially treated districts vary. In *Sacomã*, for example, the first district that received the LED lamps in December of 2015, the goal was to illuminate a specific vulnerable area known as *favela de Heliópolis*, where months before the installation of the LED lamps, female residents protested against the lack of lighting and the fear they felt by walking on the streets of their neighborhood. On the other hand, in *Jabaquara* and *Iguatemi*, lack of resources of the city hall was the main reason for incomplete implementation of the new LED technology.

Because of these factors, I re-estimate the main model, this time restricting the sample by dropping all of these *partially treated districts* on both sides (treated and control groups). Thus comparing only "full treated" regions with "full non-treated" ones. Although we should expect stronger results once we remove this districts, the fact that the sample size is now about 1/3 lower than the one used in the main estimation strategy could affect the statistical significance of the results. However, the direction of the estimates should not change and still point to a reduction in crimes (except for vehicle thefts, as already highlighted in section 4), following the trends of the previous specifications. Panels A and B in Table 8 depict the results.

In both panels, the directions of the results are indeed exactly the same as in the main estimation strategy (Table 3), as we should expect. The only change for this evaluation is the magnitude and significance of the results. While in Panel B, results are not statistically significant, except for cell phone thefts, following the same pattern as the one presented in the same panel in Table 3, when the control group is narrowed, not only is the previous pattern confirmed, but magnitudes of statistically significant coefficients increase. Estimates point to a reduction of 13.9% and 13.76% respectively in total and "non-homicide crimes" by month, significant at 5% level. Cell phone thefts and robberies appear to have been reduced respectively in 0.89% (not significant) and 35.9% (significant at 5% level). Vehicle robberies decreased by 3.67% (not significant) and homicides were reduced by 38.32% ($p<0.05$).

Table 9 depicts coefficients resulted from a model where the treatment dummy (D_{imt}) is interacted with a measure of light intensity[25]: a) the percentage of bulbs replaced in each district (panels A and B), and b) the amount of bulbs per km^2 (panels C and D). Thus, estimates in Panels A and B should be interpreted as the average monthly effect of a 1% increase in replaced bulbs on crime i, while the ones in Panels C and D should be interpreted as the average effect of one extra LED lamp per km^2 on crime i per month.

Coefficients presented in Table 9 follow the same pattern observed previously. Aggregate crimes are highly affected by the replacement of bulbs using the two different measures of intensity. Furthermore, besides vehicle thefts[26] and robberies, all the other types of crimes report decreases in cases across every panel and specifications, although not statistically significant.

[25]Both measures include not only the original number of lamps that were replaced by LED lamps, but those that were added to the lighting system of each treated district. Because of that, the percentage of replaced bulbs may surpass the 100% mark for some districts.

[26]Although in Panel A the coefficient for vehicle thefts turns to be negative (column (8) with the addition of day crimes in the set of controls).

Table 7: Effect of Improved Lighting on Rate of Nighttime Crimes

	Total Crime (1)	Non-Homicide Crimes (2)	Cell Phone Thefts (3)	Vehicle Thefts (4)	Cell Phone Robberies (5)	Vehicle Robberies (6)	Homicides (7)
Panel A: Treated VS Would be Treated							
LED lamps	-19.862**	-19.534**	-1.321	0.366	-18.541*	-1.069	-0.492*
	(8.654)	(8.617)	(1.819)	(1.603)	(9.203)	(2.708)	(0.276)
Nº of Nighttime Crimes$_{(m-1)}$	0.577***	0.580***	0.249***	0.104**	0.415***	0.295***	-0.036
	(0.085)	(0.083)	(0.043)	(0.046)	(0.019)	(0.042)	(0.040)
Nº of Day Time Crime	0.493***	0.490***	0.168***	0.022	0.947***	0.636***	0.068**
	(0.115)	(0.113)	(0.019)	(0.028)	(0.113)	(0.068)	(0.024)
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted-R^2	0.710	0.711	0.399	0.073	0.814	0.496	0.011
Nº of Months	1,180	1,180	1,180	1,180	1,180	1,180	1,180
Nº of Districts	20	20	20	20	20	20	20
Panel B: Full Sample							
LED lamps	-4.759	-4.598	-4.087***	1.771**	-5.379	-0.497	-0.398
	(3.231)	(3.208)	(1.436)	(0.687)	(3.782)	(1.795)	(0.271)
Nº of Nighttime Crimes$_{(m-1)}$	0.472***	0.474***	0.109**	0.191***	0.394***	0.357***	-0.001
	(0.078)	(0.078)	(0.055)	(0.025)	(0.030)	(0.042)	(0.026)
Nº of Day Time Crime	0.580***	0.578***	0.462***	0.065	0.926***	0.700***	0.037*
	(0.088)	(0.087)	(0.072)	(0.042)	(0.059)	(0.068)	(0.019)
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted-R^2	0.652	0.654	0.321	0.114	0.793	0.505	0.009
Nº of Months	5,664	5,664	5,664	5,664	5,664	5,664	5,664
Nº of Districts	96	96	96	96	96	96	96

Notes: Robust standard errors are in parenthesis and clustered at the district level. Superscripts *, ** and *** represent significance ate 10%, 5% and 1% respectively.

Table 8: Effect of Improved Lighting on Nighttime Crimes - Treated vs Non-treated Districts

	Total Crime	Non-Homicide Crimes	Cell Phone Thefts	Vehicle Thefts	Cell Phone Robberies	Vehicle Robberies	Homicides
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: Treated VS Would Be Treated							
LED lamps	-10.626**	-10.386**	-0.621	0.158	-9.550**	-1.173	-0.228**
	(3.859)	(3.870)	(0.670)	(0.750)	(3.420)	(1.104)	(0.088)
Nº of Nighttime Crimes$_{(m-1)}$	0.539***	0.543***	0.144***	0.108**	0.376***	0.375***	-0.022
	(0.076)	(0.076)	(0.042)	(0.040)	(0.018)	(0.051)	(0.037)
Nº of Day Time Crimes	0.537***	0.532***	0.140***	0.031	0.907***	0.725***	0.071**
	(0.113)	(0.112)	(0.022)	(0.036)	(0.079)	(0.047)	(0.031)
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted-R^2	0.704	0.704	0.373	0.092	0.806	0.525	0.014
Nº of Months	885	885	885	885	885	885	885
Nº of Districts	15	15	15	15	15	15	15
Pannel B: Full Treated vs Full Non-treated							
LED lamps	-0.886	-0.794	-2.470**	0.549	-1.422	-0.425	-0.100
	(2.926)	(2.910)	(0.969)	(0.420)	(1.681)	(1.302)	(0.082)
Nº of Nighttime Crimes$_{(m-1)}$	0.422***	0.422***	0.105*	0.204***	0.376***	0.360***	0.003
	(0.056)	(0.057)	(0.055)	(0.025)	(0.024)	(0.038)	(0.017)
Nº of Day Time Crimes	0.478***	0.478***	0.272***	0.087***	0.826***	0.665***	0.025
	(0.080)	(0.079)	(0.099)	(0.025)	(0.037)	(0.053)	(0.017)
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted-R^2	0.550	0.551	0.150	0.138	0.762	0.486	0.010
Nº of Months	3,599	3,599	3,599	3,599	3,599	3,599	3,599
Nº of Districts	61	61	61	61	61	61	61

Notes: Robust standard errors are in parenthesis and clustered at the district level. Superscripts *, ** and *** represent significance ate 10%, 5% and 1% respectively.

Table 9: Effect of Improved Lighting on Nighttime Crimes - Intensity Measures

	Total Crime	Non-Homicide Crimes	Cell Phone Thefts	Vehicle Thefts	Cell Phone Robberies	Vehicle Robberies	Homicides
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Panel A: % Replaced Bulbs $\times D_{imt}$ - Treated VS Would Be Treated							
Intensity of Replacement	-6.1**	-5.9**	-.36	-.06	-4.7*	-.5	-.013
	(2.819)	(2.782)	(0.440)	(0.584)	(2.643)	(1.229)	(0.157)
Adjusted-R^2	0.706	0.707	0.362	0.094	0.797	0.525	0.015
Nº of Months	1,180	1,180	1,180	1,180	1,180	1,180	1,180
Nº of Districts	20	20	20	20	20	20	20
Panel B: % Replaced Bulbs $\times D_{imt}$ - Full Sample							
Intensity of Replacement	-2.2	-2.1	-4.2***	.41	-1.2	-.81	-.018
	(2.850)	(2.837)	(1.062)	(0.403)	(1.357)	(1.254)	(0.091)
Adjusted-R^2	0.575	0.576	0.414	0.162	0.759	0.473	0.009
Nº of Months	5,664	5,664	5,664	5,664	5,664	5,664	5,664
Nº of Districts	96	96	96	96	96	96	96
Panel C: $lamps/km^2 \times D_{imt}$ - Treated VS Would Be Treated							
Intensity of lamps	-.012**	-.011**	-.00059	.00087	-.01**	.00066	-.00039*
	(0.005)	(0.005)	(0.001)	(0.001)	(0.005)	(0.002)	(0.000)
Adjusted-R^2	0.706	0.707	0.362	0.095	0.797	0.525	0.017
Nº of Months	1,180	1,180	1,180	1,180	1,180	1,180	1,180
Nº of Districts	20	20	20	20	20	20	20
Panel D: $lamps/km^2 \times D_{imt}$ - Full Sample							
Intensity of lamps	-.0033	-.0031	-.008***	.0011*	-.0032	.0001	-.00027*
	(0.005)	(0.005)	(0.002)	(0.001)	(0.002)	(0.001)	(0.000)
Adjusted-R^2	0.575	0.576	0.414	0.162	0.759	0.473	0.009
Nº of Months	5,664	5,664	5,664	5,664	5,664	5,664	5,664
Nº of Districts	96	96	96	96	96	96	96

Notes: Robust standard errors are in parenthesis and clustered at the district level. Superscripts *, ** and *** represent significance ate 10%, 5% and 1% respectively.

Table 10: Effect of Improved Lighting on Nighttime Crimes - Placebos

	Total Crime (1)	Non-Homicide Crimes (2)	Cell Phone Thefts (3)	Vehicle Thefts (4)	Cell Phone Robberies (5)	Vehicle Robberies (6)	Homicides (7)
Panel A: Treated VS Would Be Treated							
LED lamps	1.473	1.496	-1.564	-0.761	1.160	1.034	-0.012
	(4.113)	(4.077)	(1.574)	(0.832)	(1.994)	(1.898)	(0.160)
Nº of Nighttime Crimes$_{(m-1)}$	0.302***	0.304***	0.119***	0.223***	0.374***	0.431***	-0.088***
	(0.070)	(0.072)	(0.017)	(0.046)	(0.029)	(0.056)	(0.027)
Nº of Day Time Crimes	0.533***	0.532***	0.479***	0.137***	0.823***	0.527***	0.072**
	(0.011)	(0.012)	(0.009)	(0.025)	(0.059)	(0.032)	(0.034)
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted-R^2	0.667	0.667	0.653	0.162	0.755	0.446	0.026
Nº of Months	1,180	1,180	1,180	1,180	1,180	1,180	1,180
Nº of Districts	20	20	20	20	20	20	20
Panel B: Full Sample							
LED lamps	-1.292	-1.267	-2.115	-0.157	1.026	0.204	0.019
	(3.289)	(3.282)	(1.491)	(0.455)	(1.695)	(1.267)	(0.126)
Nº of Nighttime Crimes$_{(m-1)}$	0.284***	0.285***	0.143**	0.207***	0.352***	0.342***	-0.004
	(0.063)	(0.063)	(0.069)	(0.020)	(0.026)	(0.031)	(0.017)
Nº of Day Time Crimes	0.626***	0.625***	0.559***	0.118***	0.854***	0.595***	0.035**
	(0.091)	(0.091)	(0.102)	(0.023)	(0.051)	(0.038)	(0.016)
Time Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted-R^2	0.575	0.576	0.414	0.162	0.759	0.473	0.009
Nº of Months	5,664	5,664	5,664	5,664	5,664	5,664	5,664
Nº of Districts	96	96	96	96	96	96	96

Notes: Robust standard errors are in parenthesis and clustered at the district level. Superscripts *, ** and *** represent significance ate 10%, 5% and 1% respectively.

In a final robustness check presented in Table 10, I run placebo tests in order to confirm that patterns and results presented are indeed evidences of causality of the PLNB on crimes and not derived solely by chance. In order to do so, I first randomly select 14 districts (out of the 96) in the sample to be the treated ones. Then, I follow the chronological order of treatment assignment in order to, once again, randomly assign the time of treatment among the selected placebo districts[27]. By doing so, I create fake treatment and control groups and re-create Panel B of Table 3. Finally, I drop the fake treated districts of the sample and randomly select 6 districts to be part of the fake "would be treated" group and re-create Panel A of Table 3. Results are depicted in Table 10.

None of the estimates are significant. Although, results point to a decrease in aggregate of crimes in the Panel B, when we move to Panel A, results does not follow the pattern observed so far and remain statistically not significant. I also apply a Monte Carlo simulation running the same experiment 100 times, selecting different "fake treatments", and, in the case of Panel A, "would be treated", for each different category of crime. Even though within the sample of coefficients derived from the simulation, some of them are reported to be statistically significant at 10% level (maximum of 23 for vehicle robberies in Panel B, and 16 for homicides and vehicle robberies in Panel A), none of the averages of the coefficients are significant at any significance level. Therefore, results are highly robust to different specifications and provide strong evidences that the PLNB indeed was responsible for the decreases in crimes.

5 Discussion

The PLNB had a significant impact on "non-homicide" and total crimes (results driven in particular by the "non-homicide crimes"), but it seems that different types of crimes are affected differently by the program. Taking into account results presented above and the high percentage of under-reporting of cases of cell phone robberies and thefts (highlighted in Section 3), these kinds of "non-homicide crimes" appear to be highly affected by the program (mainly robberies). This may be the case due to the fact that most of these crimes are committed by surprise, with the victim not noticing the criminal's position and, therefore, not having time to protect from the act. Thus, better lights would improve the ability of people walking on the streets to identify possible offenders, and inhibit the criminal's action by creating more difficulties for hiding (before and after the crime). Potential witnesses also may influence the decision of committing these types of crimes, since, for the criminal, it will be more difficult to get away without being caught or recognized by someone. These hypotheses, raised by the "situational crime prevention" theory, can be confirmed by several testimonies of treated districts residents:

"Now I can walk down the stairs on the streets [where I live] because I can even

[27] The chronological order is the following: three districts received the new LED lamps in December of 2015, one in February, two in March, two in April, one in May and five in June of 2016.

see if there is someone hiding around", resident of Lajeado (Simao Pedro, 2016).

> "The difference in our lives is huge. I've spent years here, with my baby son, without being able to be out of my house at night due to the lack of lighting. When he was sick, it was horrible. Now we can be outside, stay later on the streets and go back home safer", resident of Raposo Tavares (Jornal Zona Leste News, 2016).

> "It got 70% better. In the past it was way darker. Now, the streets are brighter, what makes it easier to see if someone is coming", resident of Cidade Tiradentes (de Alencar, 2016).

These are just some of several testimonies given by residents of the PLNB districts that provide context in favor of the hypotheses highlighted in section 1. Indeed there are more people on the streets at night enjoying the public spaces like squares and even in local businesses until later in the night. Some of the testimonies point out that the neighborhood is now "more alive" (Gomes, 2016) or even "more beautiful" (Prefeitura de São Paulo, 2016), what may be perceived as an increase in the pride of the population and in the sense of community. This mechanism also helps to explain what may be happening in those districts that received the new LED lamps that is driving the number of crimes related to cell phones downwards.

On the other hand, estimates for crimes related to vehicles do not point to significant reductions in these types of crimes. Better lights could in fact discourage criminals, but, alone, this policy does not seem to be enough to generate significant results. In order to understand what has happened in the districts with the PLNB, we first need to look at the logic behind the opportunities that open space for these specific types of crimes related to vehicles. One of the main reasons that creates "hot spots" for vehicle thefts is unattended vehicles in areas near major roadways, with easy transit access (Barclay et al., 1996, *apud* Clarke et al., 1996). The period of the day that people leave their cars unattended is mostly when they go to work. They normally park their cars for several hours on the streets and only come back in the end of the day so they can go back home. Therefore, within this interval, criminals would have time to act with no fear. Results in Table 3 and Table A2 confirm this assumption by showing that vehicle thefts are indeed committed more frequently during day time for all the three different groups. Thus, vehicle thefts committed at night could still be affected by the new lights, but given that the frequency of vehicle thefts is higher during day time, and that the "hot spots" are still the same, it is reasonable not to expect drops in results for vehicle thefts committed at night.

Another factor that pushes criminals to commit crimes related to vehicles is the ease with which they can get rid of them after the crime (Laycock, Webb *apud* Clarke, 2005). Because of that, aiming to act in decreasing the high rates of vehicle thefts and robberies in the state, in January of 2014, the State Assembly of the state of São Paulo approved a law that restricted the number of car shops authorized to resell car parts. According to the law, only certified car shops would have the authorization to keep their businesses and all the car parts sold would have to be registered informing the public authorities and the customer about their origin (Assembleia Legislativa do Estado de São Paulo, 2014). Therefore, shops considered illegal by the public authorities would have to close their doors. As an immediate consequence, several car shops were closed (G1 São Paulo, 2015) in the capital, São Paulo. If we expect that this law indeed reduced the number of crimes related to vehicles (both thefts and robberies), which seems to be the case (Ribeiro and Carvalho, 2018; Pagnan, 2019), it would then absorb most of the impact on these crimes[28], and the LED lamps would not generate significant results, for vehicle thefts or robberies committed at night, which is consistent with the results shown in this paper.

Finally, we come to homicide, which is not considered a crime of opportunity. It is normally motivated by other reasons such as fights (for instance, in bars and parties), revenge, drug trafficking, or premeditated executions (Secretaria de Segurança Pública do Estado de São Paulo, 2019). It also may be motivated by domestic alterations and by the police (Moraes et al., 2019). High magnitudes related to this specific type of crime are mostly explained by the already low number of cases registered in comparison to other crimes.

On the other hand, three possible mechanisms may explain the observed decreases in homicides. First, simply by reducing violent crimes (as seen for vehicle and cell phone robberies), the probability of homicides as a consequence of these types of crimes is also reduced. Secondly, if reductions in crimes in total also result in both less trafficking and more criminals being arrested, less criminals inclined to commit homicides are on the streets. Third, mental health of residents could have increased as a consequence of the improvement in quality of life caused by improvements in lighting in the neighborhood, as supported by residents testimonials. If this is true, a decrease in cases of homicides makes sense.

6 Conclusion

The biggest challenge in the literature on crime and infrastructure, particularly with regard to lighting improvements, is to develop a study that provides technically supported evidence of causality. This paper addresses this question by investigating the effects of a lighting improvement program that occurred in the city of São Paulo, in 2015 and 2016, named "Programa LED nos Bairros". By exploiting the phased roll-out of the program and a pool of districts that were supposed to receive the program but did not as a control group, it is possible to mitigate concerns of endogeneity and thus present persuasive estimates of the impact of the PLNB on crime.

[28] Although the law was approved more than one year before the PLNB, we should expect that it takes time to make it work. Thus, supervision and the following closing of illegal car shops would not have an immediate effect and, in fact, would continue to have effects over time. Consequently, the results for vehicle related crimes could be influenced by a late response of the law.

Data was collected for all crimes registered in the city on a monthly basis from 2013 to 2017. Estimates indicate a large negative impact of the new LED lamps on crime, particularly for cell phone robberies (25.7%) and homicides (58.9%). Aggregate measures of "non-homicide" and total crimes also suggest significant reductions in cases as a result of the program, at 11.1% and 10.9% respectively. Neighboring districts seem to be affected by the program, with almost all categories of crime studied, except for vehicle thefts and cell phone robberies, being reduced (significant for cell phone thefts, vehicle robberies and homicides) in what is interpreted as a positive "spillover effect". Finally, although carefully interpreted, I find weak evidence of daytime crime increasing.

The robustness of these findings is confirmed by using multiple estimation strategies, variations in the definition of the outcome measure, different control groups and running placebo tests. All the results suggest that the main empirical strategy applied in this study in fact provides evidence of causality between the PLNB and reductions in crimes observed in treated districts. The main limitation of this paper is, however, the impossibility to obtain monthly data on each district and, therefore, not being able to attest the effect of the program on day crimes, although providing a few signs of weak temporal displacement.

In brief, results suggest that better light infrastructure has an important role in combating crime through environmental changes that affect the behaviour of both potential criminals and victims. As stated by the "crime prevention theory", the complexities of different types of crimes are such that the same measure may work for some, while not affecting others even within the same type of crime for different goods (for example cell phone and vehicle thefts). Although not homogeneous across crime categories, an improved public lighting system can be an effective way to reduce certain types of crimes committed at night in both treated and neighboring areas.

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Appendix

Table A1: Summary Statistics 2013 - November, 2015

	(1) All Districts	(2) Treated Districts	(3) Non-Treated Districts	(4) Would Be Treated	(5) (2)-(3)	(6) (2)-(4)
Cell Phone Thefts Day	28.43	15.30	30.67	16.25	-15.36***	-0.944
	(31.38)	(10.69)	(33.15)	(10.97)	(1.51)	(0.89)
Cell Phone Thefts Night	17.21	8.13	18.76	7.20	-10.63***	0.931**
	(26.93)	(5.78)	(28.75)	(4.34)	(1.30)	(0.44)
Vehicle Thefts Day	25.15	14.38	26.99	19.67	-12.61***	-5.294***
	(19.18)	(11.64)	(19.61)	(22.32)	(0.91)	(1.29)
Vehicle Thefts Night	12.75	10.54	13.12	11.76	-2.585***	-1.223**
	(8.71)	(7.38)	(8.87)	(5.95)	(0.42)	(0.58)
Cell Phone Robberies Day	21.26	23.48	20.88	22.95	2.595***	0.525
	(18.38)	(19.53)	(18.15)	(17.72)	(0.90)	(1.57)
Cell Phone Robberies Night	31.33	36.97	30.37	31.50	6.605***	5.478**
	(27.81)	(29.14)	(27.46)	(24.54)	(1.35)	(2.30)
Vehicle Robberies Day	14.62	23.26	13.15	27.53	10.11***	-4.272**
	(14.41)	(19.01)	(12.90)	(22.36)	(0.68)	(1.66)
Vehicle Robberies Night	21.44	32.23	19.60	31.50	12.63***	0.726
	(18.22)	(20.83)	(17.08)	(19.12)	(0.86)	(1.68)
Non-Homicide Crimes Day	87.79	74.80	90.01	85.03	-15.21***	-10.23***
	(53.30)	(45.01)	(54.28)	(45.42)	(2.59)	(3.72)
Non-Homicide Crimes Night	80.61	85.80	79.72	80.70	6.079**	5.095
	(53.31)	(48.45)	(54.05)	(41.99)	(2.60)	(3.84)
Total "Non-Homicide Crimes"	168.40	160.60	169.73	165.73	-9.134*	-5.135
	(100.53)	(90.28)	(102.13)	(82.60)	(4.91)	(7.26)
Homicides Day	0.38	0.69	0.33	0.76	0.366***	-0.0653
	(0.89)	(1.17)	(0.83)	(1.40)	(0.04)	(0.10)
Homicides Night	0.63	1.14	0.55	1.07	0.593***	0.0741
	(1.20)	(1.62)	(1.09)	(1.42)	(0.06)	(0.13)
Total Crime Day	88.11	75.42	90.28	85.69	-14.86***	-10.27***
	(53.30)	(45.10)	(54.29)	(45.65)	(2.59)	(3.73)
Total Crime Night	81.18	86.84	80.21	81.71	6.625**	5.129
	(53.47)	(48.83)	(54.18)	(42.44)	(2.61)	(3.88)
Total Crime	169.29	162.26	170.50	167.40	-8.239*	-5.143
	(100.68)	(90.75)	(102.25)	(83.34)	(4.92)	(7.31)
Nº of Months	3,360	490	2,870	210	3,360	700
Nº of Districts	96	14	82	20	96	20

Notes: Columns (1) to (4) depict the mean coefficients with standard deviation in parenthesis for all the different types of crimes and the time of the day they were committed. Columns (5) and (6) show mean differences from respectively columns (2) and (3) and columns (2) and (4) with standard errors in parenthesis. Superscripts *, ** and *** represent significance ate 10%, 5% and 1% respectively.

Table A2: Summary Statistics on Daytime Crimes Prior to Announcement of the PLNB

	(1) All Districts	(2) Treated Districts	(3) Non-Treated Districts	(4) Would Be Treated	(5) (2)-(3)	(6) (2)-(4)
Cell Phone Thefts Day	27.46	14.68	29.64	15.49	-14.96***	-0.812
	(29.45)	(10.14)	(31.07)	(10.73)	(1.56)	(0.94)
Vehicle Thefts Day	25.03	14.52	26.82	20.02	-12.30***	-5.498***
	(19.22)	(11.96)	(19.65)	(24.37)	(1.01)	(1.51)
Cell Phone Robberies Day	19.07	20.37	18.85	19.31	1.513	1.057
	(17.32)	(17.51)	(17.28)	(14.04)	(0.93)	(1.50)
Vehicle Robberies Day	14.79	23.40	13.32	27.50	10.08***	-4.103**
	(14.30)	(17.75)	(13.07)	(22.60)	(0.74)	(1.75)
Non-Homicide Crimes Day	84.58	71.27	86.86	80.84	-15.59***	-9.571**
	(51.09)	(42.40)	(52.10)	(45.06)	(2.73)	(3.92)
Homicides Day	0.39	0.71	0.34	0.79	0.376***	-0.0731
	(0.91)	(1.18)	(0.84)	(1.44)	(0.05)	(0.11)
Total Crime Day	84.91	71.90	87.13	81.51	-15.23***	-9.608**
	(51.09)	(42.52)	(52.10)	(45.28)	(2.73)	(3.93)
Nº of Months	2,784	406	2,378	174	2,784	580
Nº of Districts	96	14	82	20	96	20

Notes: Data on the table is presented on a month level and the period ranges from Janury 2013 to May 2015. Columns (1) to (4) of Table 1 depict the mean of monthly number of each category of crime committed per district on the period of the day with standard deviation in parenthesis. Columns (4) and (5) shows mean difference from respectively columns (2) and (3) and (2) and (4) h standard errors in parenthesis.Superscripts *, ** and *** represent significance ate 10%, 5% and 1% respectively.

Table A3: Frequency of Months With Zero Crimes Registered at Night

	(1) Total Crime	(2) Non-Homicide Crimes	(3) Cell Phone Robbery	(4) Cell Phone Theft	(5) Vehicle Robbery	(6) Vehicle Theft	(7) Homicide
Not Zeros	99.65	99.58	88.11	98.28	95.82	98.68	30.24
Zeros	0.35	0.42	11.89	1.72	4.18	1.32	69.76
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Nº of Months	5,760	5,760	5,760	5,760	5,760	5,760	5,760

Figure A1: Kernel Densities by Crime and Period of the Day.

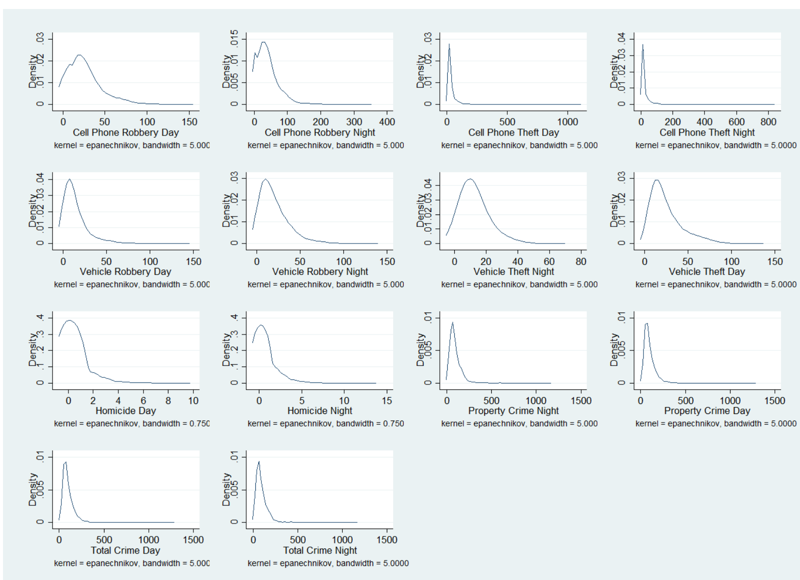

Figure A2: Total Homicides by Groups by Data sets

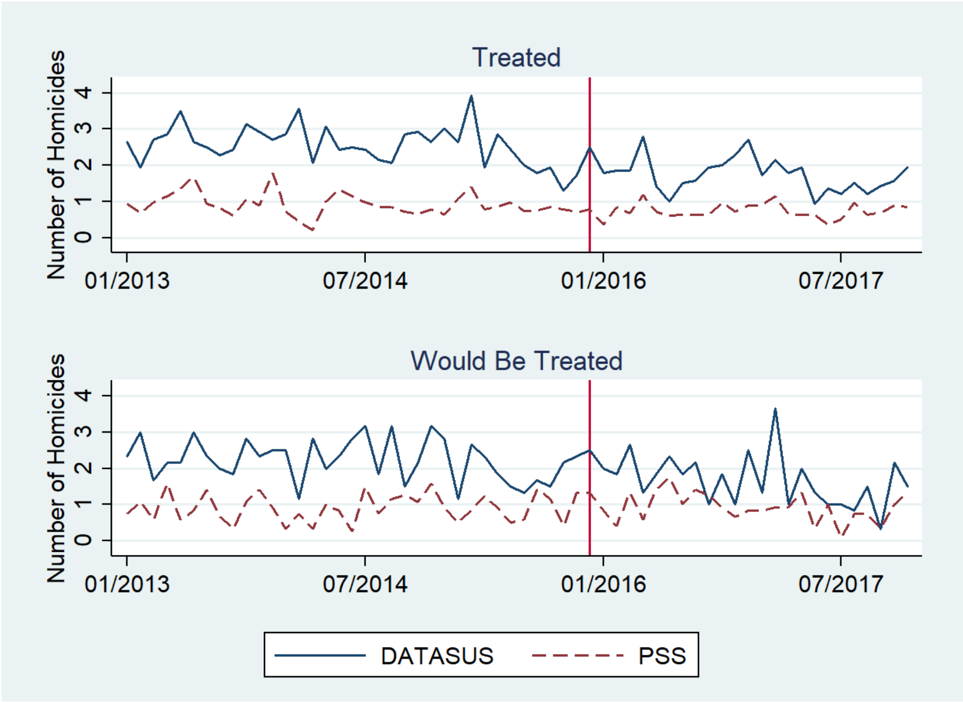

Figure A3: Mean of Night Crimes Over Time by Group

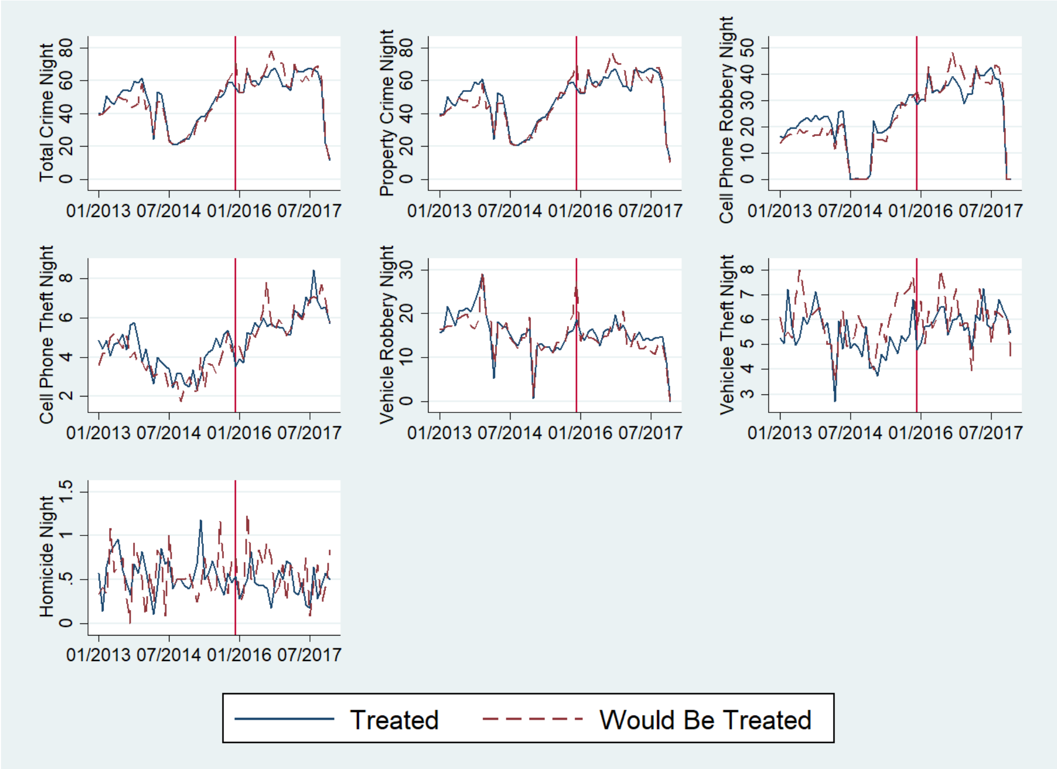

Figure A4: Mean of Night Crimes Over Time by Group