RELATIONSHIP BETWEEN PUBLIC LIGHTING AND CRIMES AGAINST PROPERTY IN BRAZIL*

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ABSTRACT

Deterrence mechanisms are established in Becker's seminal 1968 study and literature as potential inhibitors of crime progression. Among these mechanisms, public lighting stands out, although its relationship with crime remains ambiguous and underexplored, particularly in the Brazilian context. Thus, this article aims to analyze the relationship between the quality of public lighting and property crimes, with a specific focus on home robberies and thefts in Brazil. Using data from the Continuous National Household Sample Survey (PNADC) for the fourth quarter of 2021, two Probit models were estimated to assess this relationship. Results indicate that improvements in public lighting are associated with a reduction of these crimes, likely due to increased physical surveillance and informal social control. This greater visibility facilitates the identification of potential offenders, thereby discouraging criminal activities. These findings contribute to an ongoing debate on public security policies, emphasizing the importance of urban infrastructure improvements as a means of deterring illicit activities.

KEYWORDS

Crimes against property, Public Lighting, Probit, Brazil.

JEL CLASSIFICATION

C25, I31, Z18.

CONTENTS

Introduction, 1. Theoretical and empirical evidence, 2. Methodology, 3. Results, 4. Final considerations, References.

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RELACIÓN ENTRE LA ILUMINACIÓN PÚBLICA Y LOS DELITOS CONTRA LA PROPIEDAD EN BRASIL

RESUMEN

Los mecanismos de disuasión se establecen en el estudio seminal de Becker (1968) y en la literatura como posibles inhibidores de la progresión del crimen. Entre estos mecanismos, destaca la iluminación pública, aunque su relación con la criminalidad sigue siendo ambigua y poco explorada, particularmente en el contexto brasileño. Así, este artículo tiene como objetivo analizar la relación entre la calidad de la iluminación pública y los delitos contra el patrimonio, con un enfoque específico en robos y hurtos a residencias en Brasil. Utilizando datos de la Encuesta Nacional por Muestra de Domicilios Continua (PNADC) del cuarto trimestre de 2021, se estimaron dos modelos Probit para evaluar esta relación. Los resultados indican que la mejora de la iluminación pública está asociada con una reducción en la ocurrencia de estos delitos, probablemente debido al aumento de la vigilancia física y del control social informal. Esta mayor visibilidad facilita la identificación de posibles infractores, lo que desalienta la práctica de actividades delictivas. Estos hallazgos contribuyen al debate continuo sobre las políticas de seguridad pública, destacando la importancia de las mejoras en la infraestructura urbana como forma de disuasión de actividades ilícitas.

PALABRAS CLAVE

Delitos contra la propiedad, Iluminación pública, Probit, Brasil.

CLASIFICACIÓN JEL

C25, I31, Z18.

CONTENIDO:

Introducción, 1. Evidencia teórica y empírica, 2. Metodología, 3. Resultados, 4. Consideraciones finales, Referencias.

RELAÇÃO ENTRE A ILUMINAÇÃO PÚBLICA E OS CRIMES CONTRA O PATRIMÔNIO NO BRASIL

RESUMO

Os mecanismos de dissuasão são estabelecidos no estudo seminal de Becker (1968) e na literatura como possíveis inibidores da progressão do crime. Entre esses mecanismos, destaca-se a iluminação pública, embora sua relação com a criminalidade ainda seja ambígua e pouco explorada, particularmente no contexto brasileiro. Assim, este artigo tem como objetivo analisar a relação entre a qualidade da iluminação pública e os crimes contra o patrimônio, com foco específico em roubos e furtos a residências no Brasil. Utilizando dados da Pesquisa Nacional por Amostra de Domicílios Contínua (PNADC) do quarto trimestre de 2021, foram estimados dois modelos Probit para avaliar essa relação. Os resultados indicam que a melhoria da iluminação pública está associada à redução na ocorrência desses crimes, provavelmente devido ao aumento da vigilância física e do controle social informal. Essa maior visibilidade facilita a identificação de possíveis infratores, o que desencoraja a prática de atividades criminosas. Esses achados contribuem para o debate contínuo sobre as políticas de segurança pública, destacando a importância das melhorias na infraestrutura urbana como forma de dissuasão de atividades ilícitas.

PALAVRAS-CHAVE

Crimes contra o patrimônio, Iluminação pública, Probit, Brasil.

CLASSIFICAÇÃO JEL

C25, I31, Z18.

CONTEÚDO

Introdução, 1. Evidências teóricas e empíricas, 2. Metodologia, 3. Resultados, 4. Considerações finais, Referências.

INTRODUCTION

Violence and crime are chronic problems in Brazil that affect millions of people's everyday lives. Particularly about patrimonial crimes[1], just from 2018 to 2021, 3.7 million cases of cell phone theft or robbery were reported. Moreover, only in 2021, 334.643 vehicles were stolen. The increase in robbery rates of business establishments, homes, financial institutions, and cargo robbery from 2020 to 2021 also indicates an outlook of the advance of crime in the country (Fórum Brasileiro de Segurança Pública, 2022).

According to Soares and Naritoni (2010), crime dynamics have direct and indirect consequences on people's quality of life. These consequences include a shortening of their lifespans and a feeling of insecurity. Moreover, an increase in crime generates significant costs for society, including public and private expenses for prevention, financing of criminal and prison systems, and a decrease in productivity. These costs may harm the economy, with fewer investments in physical and human capital, due to smaller planning horizons.

Criminality is an object of study in several Sciences, including Economic Science. Hence, an economic analysis of crime, whose ascension occurred with Becker's seminal work (1968), has posed a new field of study in Economics, called "Economics of Crime", which has been rising in recent decades.

Following this line, it is important to highlight that economic studies on crime perform a crucial role by establishing causal relations between factors that influence criminality and by developing effective strategies for the prevention and fight against crime. Several factors have been highlighted as capable of influencing criminality, and they are mostly variables capable of creating the deterrence effect, among which public lighting is stressed.

As highlighted by Welsh *et al*. (2022), public lighting is part of the physical landscape and the infrastructure of most industrialized countries. It has several purposes, such as pedestrian and traffic security, in addition to crime prevention itself. However, as Painter (1994) indicated, despite it being a tangible alteration to surroundings, public illumination is not a physical barrier to crime, and its capacity to affect it depends on the possibility of altering agents' behavior, primarily perpetrators' potential. Thus, public illumination may have a significant impact on crime, whose effects will depend on how this infrastructure influences agents.

More precisely, the impact of public illumination on crime may occur in several ways and with diverse dimensions. On the one hand, the improvement in the quality

of public lighting may affect crime positively by increasing crime opportunities. As Welsh and Farrington (2008) have highlighted, proper lighting in a certain location may attract potential victims to the surroundings and facilitate criminals' better assessment of their marks. Likewise, a higher level of people's activity outside may also make their homes available, facilitating home robbery and theft.

On the other hand, the improvement of the quality of the public lighting may have a deterrent effect on crime. In this case, public lighting has the potential to attract people to certain locations, which increases the natural surveillance of the surroundings, discouraging criminal activities (Welsh *et al*., 2022). Moreover, the improvement of the quality of public lighting may signal that investments are being made in the area, which may boost a community's pride, social cohesion, and the refinement of the informal social control mechanisms, with a consequent reduction of crime (Welsh & Farrington, 2008).

Ultimately, how public lighting affects crime is fundamentally empirical. Its results depend on diverse conditions, such as characteristics of the location, residents, and program design (Welsh and Farrington, 2008). In this sense, some papers have been produced to identify the relation between public lighting and crime, and results are not consensual, since they vary depending on the method, location of the study, and variables utilized.

In literature, most of the studies focus on the quality of public lighting and its impact on crime. In this line, some studies verified that public lighting could affect crime negatively (Chalfin *et al*., 2021; Mihale-Wilson *et al*., 2019), and some others did not find a significant statistical relationship (Morrow and Hunton, 2000). Moreover, some studies denote that public lighting does not affect all types of crime in the same way (Davies & Farrington, 2020; Fotios *et al*., 2021). It is still worth noting the presence of recent meta-analyses, such as Welsh *et al*.*'s* (2022), which verified the capacity of public lighting to reduce crime.

In turn, national literature is relatively scarcer, with a reduced number of works that seek to examine the relation empirically. Arvate *et al*.'s (2018) work must be stressed, for it verifies the impact of the "Luz Para Todos" [Light for Everybody] program on the homicide rates in the municipalities qualified for the program. The authors found a desirable impact of the program, i.e., less crime, in certain regions of the country.

Based on the above, this study aims to analyze how the quality of public lighting is associated with property crime rates in the country, with the underlying hypothesis that this relationship can be either positive (Welsh & Farrington, 2008) or negative

(Welsh et al., 2022). Hence, data from the Continuous National Household Sample Survey (PNADC) is used, referring to the fourth quarter of 2021. Thus, this study's key contribution is to aggregate the literature, not yet consolidated, since it still has not sufficiently analyzed the nuances referring to public lighting and its impact on crime. Thus, the paper is divided into four sections, in addition to this introduction. Theoretical and empirical evidence on the relationship between public lighting and crime is analyzed in the following section, followed by sections on methodology, results, and final considerations.

2. THEORETICAL AND EMPIRICAL EVIDENCE

Based on Gary Becker's (1968) seminal work, the Economic Theory of Crime is considered the most appropriate framework to explain economically motivated crimes, such as property crimes, which are the focus of this study. Becker (1968) argues that individuals rationally choose whether to commit a crime based on certain costs and benefits, to maximize their expected profit. In the context of this study, the quality of public lighting serves as a deterrent mechanism, which tends to increase costs and, consequently, reduces the likelihood that an individual will commit property crimes.

Based on Becker's (1968) conception, the literature seeks to investigate how public lighting is associated with crime rates in various regions. Such a relation is not random and derives from the very characteristics of the lighting system. As Welsh and Farrington (2008) highlighted, the improvement of public lighting is destined to affect several factors, including crime prevention itself. Nonetheless, it is necessary to stress, according to Painter (1994), that public lighting does not constitute a tangible barrier to crime itself, and its capacity to affect crime depends on the way public lighting can modify public behavior.

It is important to point out that there are nuances that should be considered when assessing how public lighting can affect crime. As Welsh and Farrington (2008) highlighted, the effects of public lighting vary in different conditions. Specifically, impacts may be more significant in the case where the present lighting is insufficient if there is a substantial increase in lighting. Moreover, it is plausible that the effect varies according to regional and residents' particularities, space planning, public lighting planning, and the place receiving it. Thus, public lighting may perform as a catalyst for crime reduction, as it may also expand the chances for a potential criminal, so that such a relation is, a priori, ambiguous.

Some theoretical perspectives aim to justify the channel of transmission between public lighting and crime. One of those is the situational approach of crime, whose

theoretical framework suggests that a public lighting expansion can reduce crime, since it alters potential perpetrators' perception, with an increase in perceived risks and a reduction of expected compensation (Welsh & Farrington, 2008).

According to Welsh *et al.* (2022), theories that highlight natural surveillance corroborate a situational approach. In this sense, by having more people circulating the streets, there is a higher probability that criminals are noticed, and their crimes are hindered. In addition to this, the fact that there are other people around may also inhibit perpetrators' actions, for they will feel more exposed and vulnerable.

Moreover, other theories suggest that the improvement in public lighting may enhance collective effectiveness in locations, enabling crime reduction. This happens because light improvement may show the community that there is an increased investment in the region. With this, there is an indication for the residents that there is an effort to improve the location's quality of life, so there is an increase in the feeling of pride, union and informal social control within the community, and the result is a possible drop in crime rates (Fotios *et al.*, 2021; Welsh *et al.*, 2022).

On the other hand, it is necessary to point out that public lighting may also increase crime opportunities instead of reducing them. This happens since lighting may attract both potential victims and perpetrators to the same area, thus increasing the opportunities for their interaction (Fotios *et al.*, 2021). Moreover, as highlighted by Welsh and Farrington (2008), an improvement in public lighting may increase visibility, allowing a more accurate analysis of the situation and victims' attraction. Likewise, by allowing more leisure, the improvement of public lighting creates more social activities outside the house, making them more vulnerable to potential criminals.

It is possible to conclude, therefore, that, as stated above, the relation between public lighting and crime is ambiguous and may be interpreted in different ways, according to the adopted theory. Consequently, the real interaction between these variables is an issue that must be analyzed empirically. It is important to highlight that the literature on the subject still has not been completely explored; however, it is possible to declare that the studies approaching this theme show divergent results (Welsh *et al.*, 2022).

Regarding international literature, Chalfin *et al.* (2021) show experimental evidence that public lighting can reduce nocturnal crime rates. As per criminal complaint data of the New York Police Department, in the United States, from March 2011 to August 2016, the authors performed an experimental field study and, through

a randomization process, they concluded that public lighting has led to at least a reduction of 36% in outdoor nocturnal crime indexes.

Mihale-Wilson *et al.* (2019) have also verified the presence of a negative and statistically significant impact of public lighting on crime. Using a complete set of data on the felonies that occurred in the United States, particularly in San Diego, from May 1, 2017, to April 30, 2018, the authors examined the crime indexes before and after the implementation of smart lights in this region. By the estimation of an econometric model of Differences in Differences (DID), they concluded that the implementation of smart lights reduces 45% of the total number of nighttime crimes.

In turn, Davies and Farrington (2020), using a quasi-experimental approach, did not find an unequivocal relation between public lighting and crime. The authors compared the Maldon district in Essex, England, where there has been a public lighting shutdown policy, with the Braintree district, where the lights remained on. The authors concluded that the public lighting shutdown does not inevitably increase crime. In this sense, while robbery has decreased 30% in Braintree and only 13% in Maldon, violent crimes decreased 15% in Maldon, while they increased 7% in Braintree.

In the same line, Fotios *et al.* (2021) found ambiguous results regarding the Crime Open Database (CODE). More specifically, data from cities in the United States, over 10 years, from 2010 to 2019, were used. They concluded that the improvement of lighting in public streets can reduce the incidence of three types of felonies, like robbery, criminal arson, and curfew violations, that tend to occur more frequently in dark locations. Therefore, the lack of lighting may have an opposite effect regarding the other three types of crimes as disorderly behavior, non-violent family offences, and prostitution, and, for those cases, the improvement of road lighting may nullify the reduction of these felonies.

Different to previous works, Chalfin *et al.* (2022) have found few significant effects of public lighting on crime. The study was based on a natural experiment caused by a lack of public lighting and public lighting repairs to comprehend the sensitivity of crime to a short-term change for eight years in the United States. The authors concluded that there is little evidence that most crimes have suffered significant changes in those areas affected by disrupting the lighting system.

Regarding national literature, Arvate *et al.*'s (2018) work is noteworthy. The study aimed at examining possible benefits stemming from an increase in access to the electric network, so it assessed if the implementation of the program "Luz Para Todos", a program developed to attend rural regions with little electric infrastructure,

contributes to the reduction of criminal activities. With panel data estimated by fixed effects for the period 2000-2010, the authors have found that the expansion of access to electric energy in homes has generated significant reductions in crime rates in the Northeast of the country. It was estimated that the municipality of the region that transitioned from no access to full electrification would have a drop of 91.76 violent deaths per 100 thousand inhabitants in public areas.

In a nutshell, the literature analyzed shows diverse results, which signal that the impact of public lighting on crime is heterogeneous and depends on diverse factors. It is necessary to highlight, therefore, that current meta-analyses like Welsh *et al.'s* (2022) corroborate the theories that stress the capacity of an improvement in public lighting to reduce crime. However, it is important to stress that literature on the theme has not yet been consolidated. Some nuances may influence the interaction between these variables, especially when the impact on specific crimes is assessed.

3   METHODOLOGY

3.1 Database

For this study, the base utilized stems from the Continuous National Household Sample Survey (PNADC), performed in 2021, more specifically in the fourth quarter of that year. It is important to highlight that the victimization survey, essential for conducting the study, was made available specifically for the fourth quarter of 2021 and has not been replicated in previous or subsequent quarters up to this point.

PNADC was implemented in a final form in January 2012, with its sample being structured at a home level. Its information has national comprehensiveness and aims to verify quarterly fluctuations and evolution over time of key economic development variables, such as labor-market-related variables (IBGE, 2023).

3.2 Empirical strategy and selected variables

This study uses the Probit model to verify the association of public lighting and crimes against property in Brazil. As Silva *et al*. (2019) point out, Probit is beneficial when the dependent variable is dichotomic, i.e., it assumes a value equal to 1 when the event occurs, and 0 otherwise.

Particularly, this study uses two models with distinct dependent variables. The first model (Model 1) seeks to analyze how the quality of public lighting affects victimization by theft, in such a way that the dependent variable assumes a value equal to 1 in case an individual has had any object robbed from his home in the last

12 months, and, otherwise, value 0. In the second model (Model 2), the dependent variable assumes a value that equals 1 if the individual has had any belongings robbed from their home through threat or aggression and assumes a value of 0 otherwise.

As presented by Wooldridge (2010), the Probit model belongs to a class of binary response variable models, which can be represented by equation (1):

$$P(y = 1 \mid x) = G(\beta_0 + \beta_1 x_1 + \cdots + \beta k\, x_k) = G(\beta_0 + x\beta) \qquad [1]$$

where G is a function that takes values between 0 and 1. The advantage of this model is that it ensures that the estimated probabilities are between 0 and 1, as they should be. In the Probit model, G is the cumulative distribution function of the standard normal variable, which can be represented by (2):

$$G(z) = \varnothing(z) \equiv \int_{-\infty}^{z} \varnothing(v)\, dv \qquad [2]$$

where ɸ(z) is the standard normal density and can be expressed as in (3):

$$\varnothing(z) = \frac{1}{\sqrt{2\pi}} \exp\!\left(\frac{-Z^2}{2}\right) \qquad [3]$$

It is important to understand this model accurately, as it is crucial to calculate marginal effects, as the model's coefficients are not ideal for direct interpretation. According to Wooldridge (2010), if x_j is approximately continuous, its partial effect on p(x) = P (y = 1| x) can be obtained by the partial derivative given in (4):

$$\frac{\partial p(x)}{\partial x_j} = g(\beta_0 + x\beta)\beta_{j,}\, g(z) \equiv \frac{dG}{dz}(z) \qquad [4]$$

It is still worth highlighting that those two models are estimated, because, as aforementioned, it is aimed at analyzing how public lighting affects victimization by theft and robbery, i.e., two distinct dependent variables. Besides this, only answers from people of reference are utilized regarding their homes (home robbery and theft). It is necessary to point out that a domicile identifier was created to avoid data duplication, ensuring it was represented only once in the sample. Moreover, considering the complexity of the sample, substantial variables were considered during the estimation.

Table 1 below shows the descriptions and expected signals regarding the variables inserted in this study. We must stress that all explanatory variables considered were chosen according to the literature and their relevance regarding the theme.

Table 1. Explanatory variables used in the econometric model and their expected signals.

Variable	Description	Expected Signal
Lighting quality	T*his is a* D*ummy* variable that assumes a value equal to 1 when public lighting is great, good, 0 in the case it is bad or terrible.	Given the literature, an ambiguous signal is expected for this variable.
gender	T*his is a* D*ummy variable that assumes* a value equal to 1 when an individual is female, and 0 in the case the individual is male.	A negative signal is expected for this variable, since being male is associated with a higher probability of victimization (Salvato *et al*., 2016).
police	T*his is a* D*ummy variable that assumes* a value equal to 1 when there is policing near homes, 0 otherwise.	Compatible with Becker (1968), a negative signal is expected for this variable, given the deterrence effect policing causes.
abandoned	This is a Dummy variable that assumes a value equal to 1 when there is an abandoned building, house, or warehouse near homes, and 0 otherwise.	A positive signal is expected for this variable. Especially, the presence of abandoned buildings and locations increases the chances of one becoming a victim (Beato *et al*., 2004).
Electric fence	This is a Dummy variable that assumes a value of 1 if the household or condominium has an electric fence, and 0 otherwise."	A negative signal is expected for this variable, given the ability of property security systems to reduce theft and burglary (Garcia, 2010)
color	T*his is a* D*ummy variable that assumes* a value equal to 1 if an individual is White or Yellow, and 0 in the case he is Black, Brown, or Indigenous.	A negative signal is expected for this variable, since being White or Yellow is associated with a lower probability of victimization (Silva, 2015).
south	T*his is a* D*ummy variable that assumes* a value equal to 1 in the case an individual is from any state of the southern Brazilian region, and 0 otherwise (basis: Northern region).	
northeast	T*his is a* D*ummy variable that assumes* a value equal to 1 when an individual is from any state of the Northern Brazilian region, and 0 otherwise (basis: Northern region).	A negative signal is expected for these variables, since regarding people, the Northern region has a great concentration of crimes against property, especially thefts (IBGE, 2021).
southeast	T*his is a* D*ummy variable that assumes* a value equal to 1 if an individual is from any state of the southeastern Brazilian region, and 0 otherwise (basis: Northern region).	
center-west	T*his is a* D*ummy variable that assumes* a value equal to 1 when an individual is from any state of the central-western Brazilian region, and 0 otherwise (basis: Northern region).	

Variable	Description	Expected Signal
vacant	T*his is a* D*ummy variable that assumes* a value equal to 1 when there is vacant land or vacant lot near homes, and 0 otherwise.	A positive signal is expected for this variable because of the presence of abandoned lands or lots signals the deterioration of neighborhoods (Beato *et al.,* (2004).
Family income	Continuous variables represent an individual's household income.	An ambiguous signal is expected for this variable, since an increase in income level enables more opportunities to adopt safe methods and habits (Silva *et al.,* 2019).
urban	This is a Dummy variable that assumes a value equal to 1 if an individual lives in the urban area, and 0 otherwise.	A positive signal is expected for this variable because living in urban areas is related to more exposure and proximity to criminals (Silva *et al.,* 2019).
educ1	T*his is a* D*ummy variable that assumes* a value equal to 1 when an individual has no education or has incomplete basic education, and 0 otherwise (basis: having complete higher education).	It is expected that these variables have a negative signal, because individuals with higher education levels are generally more attractive targets for criminals, due to the prospect of the expected return (Souza & Cunha, 2015).
educ2	T*his is a* D*ummy variable that assumes* a value equal to 1 if an individual has incomplete basic education or incomplete secondary education, and 0 otherwise (basis: having complete higher education).	
educ3	T*his is a* D*ummy variable that assumes* a value equal to 1 when an individual has complete secondary education or incomplete higher education, and 0 otherwise (basis: having complete higher education).	

Source: own elaboration. (2024).

It is important to highlight that the expected signal from the explanatory variable regarding public lighting may reduce crime against property (*light quality*), which is the focus of this study, is ambiguous. On one hand, public lighting may reduce crime against property, expanding natural surveillance in these locations and consequently deterring potential criminals. Similarly, lighting infrastructure changes may signal an increase in investments made by the authorities, in a way it increases a community's pride and social control, which could reduce crimes (Welsh *et al.,* 2022).

However, public lighting may also increase crimes against property. More illuminated areas may attract more people, including criminals, expanding the possibilities of victim-aggressor interactions. Likewise, more illuminated regions may allow the

criminals to further examine their potential victims, increasing their expected return. Likewise, if better-lit conditions attract individuals to leisure activities, homes will probably be empty more frequently, and this may increase the opportunities for crime against property (Welsh & Farrington, 2008).

4 RESULTS

4.1 Descriptive analysis

Table 2 below presents the descriptive statistics regarding the variables included in the estimates of Models 1 and 2. Regarding the dependent variables, it is possible to verify that between the 62,019 individuals of reference in the sample, only 1.91% reported have being victims of home burglaries, while 0.23% have stated having been robbery victims.

Regarding the public lighting variable, it is noticeable that 88.61% of the sample considers public lighting as being great, good, or regular, while 11.39% consider it bad or terrible. In turn, regarding the characteristics of homes and neighborhoods, 76.92% reported policing near their houses. About 18.45% of the individuals have pointed out that there were abandoned buildings, houses, or warehouses near their houses. Moreover, in terms of protection systems, approximately 10.94% of the sample uses electric fences in their residences.

Table 2. Descriptive statistics of the variables included in the estimates of Models 1 and 2.

Variable	Observations	Average	Standard Deviation
theft	62,019	0.0191	0.0007
robbery	62,019	0.0023	0.0002
light quality	62,019	0.8861	0.0018
gender	62,019	0.5264	0.0028
policing	62,019	0.7692	0.0023
abbandoned	62,019	0.1845	0.0022
electricfence	62,019	0.1094	0.0019
color	62,019	0.4593	0.0027
north	62,019	0.0662	0.0005
south	62,019	0.1599	0.0008
northeast	62,019	0.2435	0.0011

Variable	Observations	Average	Standard Deviation
southeast	62,019	0.4503	0.0013
center-west	62,019	0.0801	0.0005
vacant	62,019	0.3133	0.0026
familyincome	62,019	1910.41	15.3598
urban	62,019	0.9313	0.0006
educ1	62,019	0.3224	0.0024
educ2	62,019	0.1351	0.0019
educ3	62,019	0.3318	0.0027
educ4	62,019	0.2107	0.0024

Source: own elaboration. (2024).

Regarding the characteristics of the people of reference in homes, approximately 52.64% are women, while the remaining, 47.36% are men. Almost 45.93% are people who identify themselves as White or Yellow, while 54.07% consider themselves Black, Brown or Indigenous. In addition, 15.99% live in the South of the country, 24.35% in the Northeast, 45.03% in the Southeast, 8.01% in the Center-West, and 6.62% in the North of the country.

Moreover, most of the homes are in urban areas, about 93.13% of the sample. Likewise, 32.24% of the people of reference of the homes do not have education or have not completed basic education, 13.51% have completed basic education or have incomplete secondary education, 33.18% have completed secondary education or incomplete higher education, and 21.07% reported to have completed higher education. It must be stressed that the average household income of the sample is R$1910.41.

In addition to those statistics, Table 3 below shows the conditional averages of the explanatory variables, i.e., the average of the explanatory variables conditioned on each category of the dependent variable. This information is crucial, since it allows a detailed relation of the variables, enabling a comparison of the averages among the groups and the identification of patterns or differences.

Table 3. Conditional averages of the explanatory variables inserted in the estimates of Models 1 and 2.

Variable	Theft = 0	Theft = 1	Robbery = 0	Robbery = 1
light quality	0.8873	0.8238	0.8864	0.7945
gender	0.5453	0.5420	0.5450	0.6137
policing	0.7669	0.7405	0.7664	0.7635
abandoned	0.1868	0.2618	0.1881	0.2566
electric fence	0.1076	0.0772	0.1071	0.0543
color	0.4634	0.4258	0.4628	0.4284
south	0.1592	0.1680	0.1594	0.1501
north	0.0715	0.1667	0.0730	0.1825
northeast	0.2532	0.2175	0.2523	0.3401
southeast	0.4369	0.3554	0.4359	0.2172
centerwest	0.0792	0.0924	0.0794	0.1100
vacant	0.3185	0.4177	0.3201	0.4182
family income	1765.41	1499.15	1761.76	1226.16
urban	0.9264	0.9347	0.9266	0.9068
*educ*1	0.2935	0.3440	0.2946	0.2729
*educ*2	0.1593	0.1694	0.1595	0.1916
*educ*3	0.3551	0.3478	0.3547	0.4424
*educ*4	0.1920	0.1388	0.1913	0.0930

Source: own elaboration. (2024).

Regarding the variable *light quality*, the conditional average of this variable is lower among those who were victims of theft compared to those who were not. Thus, those who had any belongings stolen from their homes have more frequently pointed out that public lighting near their houses is bad or terrible, compared to those who reported not having been victims of theft. It may suggest, at first, that there is an inverse relation between the quality of public lighting and the probability of victimization by theft in the homes analyzed.

This apparent negative relation is also verified in the second model, since those who have had any belongings stolen from their homes have more frequently pointed out that public lighting near their houses is bad or terrible, compared to those who reported not having been victims of theft. Thus, *a priori*, the quality of public lighting

seems to have an inverse relation with crimes of theft and robbery, a relation that may or may not be confirmed by the econometric results.

Notably, the *police*, *electric fence*, *color*, *family income*, and *educ*4 variables show this relation in both models. Thus, neighborhood policing, having electric fences at home, being White or Yellow, living in the South, having a higher household income, and completing higher education seem to be negatively associated with the probability of having one's house broken into or robbed.

On the other hand, other variables have a higher average in the group of victims that had a crime in their house, like robbery or theft, suggesting a positive association with an event, such as *abandoned*, *north*, *center west*, *vacant*, and *educ*2 variables. Consequently, the presence of abandoned buildings, houses, or warehouses near homes seems to be positively correlated with the probability of having the home broken into or robbed, such as living in the North or Central-West regions, having vacant lots near homes, and having complete basic education or incomplete secondary education.

Furthermore, some variables show a divergent relationship regarding crimes against property. The variable *gender* has the lowest average among the people of reference in their houses who reported being victims of theft, so being female seems to be negatively correlated with the probability of having a house robbed. However, being female seems to be positively correlated with a higher probability of having a house robbed. On the contrary, living in the South seems to be positively correlated with a higher chance of having a home robbed (compared to people who live in the North), but it seems to be negatively associated with the probability of being a robbery victim.

Likewise, living in the Northeast is negatively associated with the probability of having a home robbery, but positively associated with the probability of being a robbery victim. The same relation may be verified for those who have completed secondary education or incomplete higher education, as indicated by the *educ*3 variable. On the contrary, living in the urban region (*urban*) and not having education or incomplete basic education (*educ*1) seems to be positively associated with the probability of experiencing a residential burglary.

4.2 Econometric results

Table 4 below shows the econometric results on the estimates of Models 1 and 2, presenting the estimated coefficients and the marginal effects of the variables. Initially, it was verified that the estimated coefficient for the *light quality* variable

was negative and statistically significant in both models, which means that public lighting improvement is associated with a lower probability of home break-ins and robberies. Particularly regarding marginal effects, it was found that public lighting being considered great, good, or fair reduces by 0.79 percentage point (p.p.) and 0.17 percentage points (p.p.) the probability of reference persons having their homes burglarized and robbed, respectively, compared to those who reported that public lighting was poor or very poor.

Therefore, the econometric estimation indicated an inverse relationship between public lighting quality and victimization by property crimes. This result is like those found in the United States by Chalfin et al. (2021) and Mihale-Wilson et al. (2019), as well as the Brazilian study by Arvate *et al*. (2018).

The capacity of public lighting to reduce crimes against property may also be explained by two factors. On the one hand, public lighting improvement may increase the risk perception by potential perpetrators, influencing the risk they perceive and reducing criminal activities, offering a lower expected compensation for the crime (Welsh & Farrington, 2008). In the same sense, the improvement of public lighting increases the natural surveillance of the locations, since it allows more people to circulate on the streets. Thus, the chance of criminals being identified is increased, which probably inhibits criminal action (Welsh & Farrington, 2008).

Table 4. Econometric results of Models 1 and 2.

Variable	Model 1 (Theft)		Model 2 (Robbery)	
	Coefficients	Marginal effects	Coefficient	Marginal effects
light quality	-0.1595*** (0.0526)	-0.0079*** (0.0030)	-0.2297*** (0.0859)	-0.0017** (0.0008)
gender	-0.0661** (0.0328)	-0.0029** (0.0015)	0.2143*** (0.0779)	0.0012*** (0.0004)
policing	-0.0378[NS] (0.03765)	-0.0017[NS] (0.0017)	0.0818[NS] (0.0828)	0.0004[NS] (0.0004)
abandoned	0.0793* (0.0433)	0.0036* (0.0021)	0.1155[NS] (0.0914)	0.0007[NS] (0.0006)
electric fence	-0.1010[NS] (0.06872)	-0.0040[NS] (0.0025)	-0.3366** (0.1337)	-0.0013*** (0.0004)
color	0.0071[NS] (0.0369)	0.0003[NS] (0.0016)	0.0900[NS] (0.0759)	0.0005[NS] (0.0004)
south	-0.2589*** (0.0546)	-0.0094*** (0.0017)	-0.1985* (0.1117)	-0.0009** (0.0004)

Variable	Model 1 (Theft)		Model 2 (Robbery)	
	Coefficients	Marginal effects	Coefficient	Marginal effects
northeast	-0.3519*** (0.0481)	-0.0128*** (0.0015)	-0.1284[NS] (0.0913)	-0.0006[NS] (0.0004)
southeast	-0.3538*** (0.0524)	-0.0151*** (0.0021)	-0.3896*** (0.1110)	-0.0021*** (0.0005)
centerwest	-0.2384*** (0.0561)	-0.0084*** (0.0016)	-0.2044[NS] (0.1281)	-0.0008** (0.0004)
vacant	0.1448*** (0.0367)	0.0067*** (0.0018)	0.0813[NS] (0.0753)	0.0005[NS] (0.0004)
family income	4.95e-07[NS] (7.04e-06)	2.15e-08[NS] (0.0000)	5.30e-07[NS] (0.0000)	2.94e-09[NS] (0.0000)
urban	0.1369*** (0.0470)	0.0053*** (0.0016)	0.1237[NS] (0.1170)	0.0006[NS] (0.0005)
educ1	0.2250*** (0.0590)	0.0107*** (0.0031)	0.0627[NS] (0.1429)	0.0004[NS] (0.0008)
educ2	0.2216*** (0.0628)	0.0114*** (0.0038)	0.2121[NS] (0.1632)	0.0015[NS] (0.0014)
educ3	0.1628*** (0.0565)	0.0075*** (0.0028)	0.2252[NS] (0.1440)	0.0014[NS] (0.001)
constant	-1.9325*** (0.0870)	-	-2.934*** (0.1819)	-

Note: *** significant to 1%; ** significant to 5%; * significant to 10%; NS non-significant. Source: own elaboration. (2024).

Another channel that explains the capacity of the improvement of public lighting to reduce crimes against property is related to the capacity of lighting to increase informal social control in each community. This happens because changes in the lighting infrastructure may signal the expansion of authorities' investments, allowing an increase in community pride and in informal social control. Thus, there is a reduction in crimes in the location (Fotios, Robbins, and Farral, 2021; Welsh *et al*., 2022).

Regarding the other control variables, the gender variable showed a negative signal for its coefficient and was statistically significant for Model 1. Thus, being female was associated with a lower probability of having one's home burglarized compared to homes in which the people of reference were men. However, for Model 2, the Variable had a positive and significant signal. In this case, the probability of having a home robbery is higher for women compared to men. The variable *police* did not show statistical significance in any of the estimated models, and this indicates that having policing in a neighborhood is not effective in generating a deterrence effect.

Regarding the *abandoned* variable, it showed a positive and statistically significant signal for its coefficient in Model 1. Thus, the presence of abandoned buildings, houses, or warehouses near homes was associated with a higher probability of victimization by theft, Model 1. Therefore, the variable did not show statistical significance in Model 2, which indicates that the presence of abandoned buildings, houses, or warehouses did not show to be able to affect the probability of victimization by robbery.

The presence of electric fences at homes, represented by the *electric fence* variable, did not show to be significant in affecting the probability of home thefts, Model 1. For Model 2, the relation was significant and negative, indicating the effectiveness of the electric fence as a protection system in reducing the probability of home robberies. The *color* variable did not show statistical significance in any of the two estimated models, such as the family income variable (*family income*).

Regarding regional dummies, the variables *south*, *northeast*, *southeast*, and *center-west* showed a statistically significant and negative relation with the probability of home thefts (Model 1). Thus, living in a distinct region of the North of the country was associated with a lower probability of people of reference reporting that their houses had been robbed. However, for Model 2, only the *south* and *southeast* variables were significant, in addition to having a negative signal, indicating that living in these regions is associated with a lower probability of having home robberies compared to the North.

The *vacant* variable showed a positive and statistically significant estimated signal for its coefficient in Model 1. In this sense, the presence of vacant lots or lands near homes expands the probability of individuals having their burglarized homes. Therefore, this relation did now show statistical significance for Model 2, which signals a lack of a significant relation between the probability of people of reference having a home robbery and the presence of abandoned lots or lands near their home. Likewise, the *urban* variable showed a positive and statistically significant effect because of its estimated coefficient in Model 1. However, it did not show significance for the second model. Consequently, living in urban areas was associated with a higher probability of having home robberies, but not of being burglarized.

Lastly, the dummies related to the level of education of the people of reference, *educ*1, *educ*2, *educ*3 were significant and showed a positive signal for the first model. Thus, having a lower level of education than those who have completed higher education was associated with a higher probability of having houses burglarized. This result goes in the opposite direction of the expected signal. One explanation

for such a result would be that having less education would prevent individuals from experiencing the effects of socialization and the protective capacity of education. Beato, Peixoto, and Andrade (2004) mention this effect for the probability of the individual to suffer aggression, but this effect may also influence crimes against property. It is also worth emphasizing that, in the case of Model 2, none of the education dummies showed statistical significance.

5   FINAL CONSIDERATIONS

This study aimed to assess the relationship between the quality of public lighting and crimes against property in Brazil, especially theft and robbery. For such, the study considered data from the Continuous National Household Sample Survey (PNADC) of the fourth quarter of 2021. Specifically, two Probit models were estimated, and this enabled us to verify how the quality of public lighting would be able to affect the crimes of home break-ins and robberies, according to reports by people of reference.

The results pointed out that the quality of public lighting has a negative relation with the probability of a person of reference having home break-ins and robberies. Thus, it is deduced that public lighting can inhibit crimes against property. This result is legible insofar as public lighting affects the perceived risk of potential perpetrators, reducing the expected return on crimes and, therefore, criminal activities. Moreover, public lighting may increase the natural surveillance of the locations, allowing the police to identify criminals more easily and consequently discouraging them. Public lighting also allows an increase in informal social control in each location, which contributes to crime reduction.

This work has also utilized other controls in the estimated models. In this sense, being female and living in any region of Brazil other than the North has been significantly associated with a lower probability of having houses burglarized. On the other hand, the presence of a vacant building, house, or warehouse in the surroundings was significantly associated with a higher probability of having houses burglarized. The same positive and significant relation was found for those who live in the urban region and do not have a complete higher education.

Similarly, the presence of electric fences in homes was significantly associated with a lower probability of having home robberies. Likewise, residents in the South and Southeast have a lower probability of having home robberies than residents in the North. It is also stressed that being female was significantly associated with a higher probability of having home robberies.

Given the exposed, it is expected that this study's outcomes are useful in the possible elaboration of public policies that aim to reduce crimes against property. Especially, by indicating public lighting has the capacity of reducing crimes against property, the importance of policies that improve its quality in the regions where it is precarious or does not even exist is highlighted to provide safer environments for the resident population.

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