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Criminality spread: a "Boomerang effect" of public transport improvements?*

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Abstract

The relationship between accessibility or the degree of improvement of urban transport and criminality has been underestimated and close to forgotten. This paper aims to reveal the importance of public transport policies in the evolution of crime configuration in a city. The hypothesis that the probability of transport improvements in a zone depends on some of its socio-economic characteristics is adopted. The use of the propensity score matching technique reveals that the presence of improvements of public transport in a zone of the city has a direct and significant impact on the increase of some types of crime. Likewise, spatial econometrics results expose that crime tends to be contagious in neighbouring zones. The presence of the Transmilenio system in Bogotá may share out criminality to other zones of the city. Negative externalities like the better mobility of offenders and, then, their possible choice to expand their criminal activities to new zones, can spoil the positive effects of enhancement of public transport. Far from suggesting not developing public transport or isolating some "dangerous" neighbourhoods or inhabitants, this article shows that improvement of public transport may not only generate positive externalities; policy makers should take into consideration the mutation and shift of criminal behaviours in order to identify possible solutions such as the construction of more establishments providing health, welfare and sporting activities, as is evoked in the results. In this way, the "boomerang effect" of the improvement to transport will be reduced.

JEL Codes: C31, K42, R12, R15
Keywords:Urban Public Transports improvements; Propensity Score Matching; Crime contagion; Spatial dependence.

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1 INTRODUCTION

A long line of theory in public economics has suggested that urban transport plays an important role in social configuration and therefore, in urban structure (Glaeser 2003; Bruekner and Largey 2006). The landscape of the urban and social structure can change significantly because of these reactions. Urban transport and accessibility play a central role, because social interactions are at the centre of this scheme. In effect, as Glaeser and Scheinkman (1999) establish, 70% of the spatial variation of crime can be explained by social interactions and 30% can be justified by local attributes.

Another line of thought, in sociology, suggests that inequality and social interactions play important roles in districts' crime rates (Hipp 2007). Furthermore, crime and inequality have a strong relationship with social interactions and, hence, with urban and social structure (Glaeser 2008; Bruekner, Thisse and Zenou 1999). In effect, as various authors have argued, inequality and crime depend on the degree of social interactions. By transitivity, this research emphasizes the fact that criminality and social interactions are directly related to urban transport. However, it seems rather contradictory that the relationship between urban transport and criminality has not been the subject of profound development in economics, given that transport is considered as a vital instrument to delineate and to control the growth of cities and to fight inequality and poverty (Cervero 2003, 2004). Actually, the greater the level of transport accessibility, the higher the level of social interactions, and the higher the probability of individuals interacting with their neighbours (Putman 2000).

In other words, when accessibility of transport increases in a district or in a neighbourhood, inhabitants have more opportunity to interact with other people in the city. The probability of greater levels of social interaction may be higher with public policies looking to stimulate the development of urban transport (Holtz-Eakin and Schwartz 1995). Thus, in a local context, urban transport has to be considered as a local attribute which influences local social interactions.

Consequently, the significance of social interactions in crime behaviour could be considered essential. Jens Ludwig and Jeffrey R. Kling (2006) confirmed that crime is contagious in areas where there are already criminals[1]. Regarding this, we can suggest that this conduct can take a worse dye when we consider social interaction behaviour as a social multiplier (Glaeser, Sacerdote and Scheinkman 1999, 2003). In consequence, social interactions may lead to more crime and could be a factor that encouraged people to go to low-density tracts.

As Brueckner and Largey (2006) stipulated, in opposition to Putman (2000), social interaction could not to be automatically in zones with high density maybe, because it is in those zones that criminality rates are generally higher.

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[1] See also the broken windows theory: Wilson, J. Q. and Kelling, G. L. (1982)

People are briefly distant from their neighbours in high-densities tracts maybe because of a higher supply of entertainment activities attracting criminals or maybe because of their fears. In effect, when a person lives in a high-density neighbourhood, he will promptly perceive a higher level of criminality.

This perception may encourage people to live in areas with a high presence of security controls (guards, cameras, etc.), which will lead to a rise in households' or enterprises' expenditures. Another possible consequence of this perception is that people will decide to move to areas with low density as a mechanism to flee offenders. These areas are generally located far from the city centre, in the suburbs; this will motivate the growth of "edges cities", which will be adapted as new sub-centres of the city (Alonso 1964, Anas 1990). Generally, people who want to avoid criminality decide to shift to zones considered more secure, which will translate to higher land prices. People who have "high" economic resources can choose to move, but these are a minority; a large part of people cannot move to an area with these characteristics because of their limited budget.

If urban transport has to be considered as a local attribute and social interactions are strongly linked with urban transport, it seems reasonable to say that crime can be effectively robustly associated to urban transport. However it cannot be forgotten that other variables such as population, income, employment rate and workforce, among several other factors, delimit social interactions and, therefore, crime rates.

This research focuses on analysis of different kinds of crimes in a city of a developing country: Bogotá. This city has been known for its high criminality rates in the past, as well as for the implementation of an ingenious and innovative Bus Rapid Transport (BRT) system called Transmilenio (TM) in 2000. The purpose of the present paper is to take advantage of these features and to identify the magnitude of the nexus between crimes and improvement to urban transport in each zone of the city.

In this respect, studies have demonstrated that transport infrastructure in the roads and highways of a city has a positive impact on employment and economic growth (Holtz-Eakin and Schwartz 1995; Barr 2000). Similarly, Moreno (2005) makes a spatial econometric analysis of the impact of TM on criminality alongside a TM corridor. He demonstrated that global criminality is smaller closer to the corridor, but also that there are some types of crime which are more frequent if the distance to the BRT corridor is less. However, there is no research that has tried to differentiate criminality configuration between zones that benefit from improvements of public transport such as a BRT system and zones that do not benefit from it, which represents the principal added value of this study.

This research also differs from others because it attempts to make a cross-section analysis of the impact of public transport improvements on criminality

levels using the propensity score matching (PSM) methodology. In addition, in order to reinforce results from the PSM methodology, a spatial autocorrelation analysis of each type of crime between the 112 zones composing the "bogotanian" landscape will also be done.

The paper proceeds as follows. Section 2 reviews the literature about the link between social interaction, transport and criminality, as well as some studies about Bogotá. Section 3 put lectors in context about Bogotá and its urban transport system emphasizing on Transmilenio. The fourth section describes data and the econometric methodologies approaches used in the paper. Empirical findings are presented in section 5 and conclusions are offered in section 6.

2 Social interaction, criminality and mobility

2.1 Criminality and social interaction

As many authors have revealed, social interactions are crucial in the behaviour of an individual (Glaeser 1996, Freedman 1996). An individual is more stimulated to become a criminal if their peers are criminals. In opposition, the same motivation is not present if his peers are not criminals. This behaviour depends directly upon social interactions and distance from jobs and residential zones.

Concerning the difference in types of crime, violent crime and property crime are more common in big cities than in small ones (Glaeser and Sacerdote 1999). In addition, crime rates are higher in central cities than in suburbs (Bears 1996) because of larger unemployment and density rates. In fact, as Putman (2000) suggests, density is a factor which determines the level of social interaction; low density reduces social capital and therefore social interaction.

Individuals' behaviours are not only a function of their desires but also a function of their entourage. Considered as a behaviour, criminality and its progress depends on spatial structures in neighbourhoods and zones, thus it also depends on social interactions. Glaeser, Sacerdote and Scheinkman (1996) argue that 30% of criminality depends on local attributes and Zenou suggest that 70% is associated with social interactions. However, social interactions depend also upon local attributes such as amenities like transport accessibility, parks and entertainment places, among others.

If we consider urban transport as a local attribute we can say that it can also determine social interactions. If accessibility of transport increases in a neighbourhood, inhabitants will have more opportunity to interact with other people in the city. The probability of growth of social interactions is higher in the

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presence of public policies which stimulate the development of urban transport. Density will be higher and with more people to interact with, individuals find more opportunities to relate.

Nevertheless, if we take into consideration Brueckner's suggestion (2003), this type of behaviour can also lead people to think that anybody can be a criminal. In high-density zones, every neighbour is suspicious which, in turn, encourages a decline in social interaction and induces people to search out zones of low density which are, generally, far from the centre of the city.

Additionally, with enlarged accessibility, heterogeneity of neighbours or districts during the day will be higher and socio-economic differences will be more perceptible. According to Hipp (2007), this will lead to a higher feeling of exclusion or injustice within the society, which can have negative consequences such as criminality as an instrument with which to pronounce one's feelings.

Hipp (2007) shows the different effects of the distribution of classes in crime levels. He proposes six different "theories of crime" to illustrate the link between crime rates and social sharing of the district. He concluded that in Seattle, income inequality increases the scale of several types of crime in a neighbourhood. It supposes that people compare themselves with respect to other people living or not in the same neighbourhood. If they consider that they are in an unfair or an unequal economic and social condition, they will react aggressively against those who live in better economic and social conditions: they will have a tendency to "equalize the gap" within the district. This is called by Hipp the "Relative Deprivation Theory".

Another "theory of crime", verified by Hipp, is "Routine Activity Theory". In fact, he proved a positive relationship between general inequality in a district and crime. Growth of inequality leads to an increase in the number of "potential targets" (those who have high incomes) and "motivated offenders" (those who don't have a high socio-economic level). If these two types of agents live more closely, criminality index will tend to go up. Criminals will be obligated to choose between stealing from a neighbour (and being recognized by him) or from an individual who doesn't live in his quarters or in his district. According to that, we can say that commuting cost, as well as reputation effect, can play an important role in criminal behaviour. Offenders will face a cost-benefit analysis which will depend on their commuting cost but also the probability of being recognized by someone who lives in the same neighbourhood and, so, the probability of being arrested or rejected by the society.

As stated above, if districts are composed by different social groups and if social heterogeneity is significant, social interaction can decrease. Hipp (2007) and Putman (2000) found in their studies a positive relationship between a small level of social interaction and criminality. In fact, they saw a low level of social interaction in neighbourhoods with low homogeneity. Hipp named this

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behaviour "The social distance and social disorganization theory". In fact, this social distance will be a consequence of an income inequality and heterogeneity of races in a same district. A higher inequality level in a district can lead to higher crime rates because of a reduced level of social interaction. What Hipp means is that income inequality is more significant than inequality per se. His model reveals a positive relationship between inequality and crime, but this link is reduced when he takes into consideration the income inequality. Nevertheless, he does not reject inequality as a significant factor.

In addition, the high social multiplier implies that crime and its effects will be significant (Becker and Murphy 2000; Glaeser, Sacerdote and Sheinkman 2002; Ludwig and King 2006). From the point of view of criminals, this social multiplier can create positive externalities. In fact, the spread of crime in a district or in a specific zone of the city decreases the probability of being arrested. So, criminals profit from this multiplier, but it also has a negative externality: their earnings decrease because of the entry of more competitors in the market (more criminals). The crime market is reduced as well as commuting costs lowering.

2.2 Criminals' mobility and jobs' centers

The impact on offenders' earnings of the distance travelled to commit their crimes has been studied by some authors. As is shown in Morselli and Royer's (2008) research, distance can be perceived as a factor of criminal achievement. Mobile offenders seem to report higher financial earnings from crime than immobile offenders. Many authors have established that property crimes require greater distance than violent crimes. Indeed, violent crimes like homicide or crime with predatory violence require short distances to be achieved, in opposition to shoplifting or commercial crimes which need higher distances. Between these we found motor vehicle thefts, which do not need to be accomplished so far from home but need a greater distance for resale of the auto parts.

From this perspective, we can see that compensation between the probability of arrest and perception of higher earnings can stimulate offenders to travel long distances. In effect, there is a positive correlation between distance from house and earnings. But distance is also related to commuting costs. In fact, distance represents a cost because it also signifies time and time has a value. When time of transportation within a city decreases, costs also decrease. So, if a criminal sees their commuting costs decrease, he will be more stimulated to travel and to commit crimes in zones connected to the transport network.

In addition, as Morselli shows, criminal earnings and individual crime commission rates have a positive relationship (Tremblay and Morselli 2000; Morselli and Royer 2008). But the relationship between criminal earnings and distance

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travelled can be positive. In effect, the highest gains from a highest distances travelled by offenders, rouse to a more efficient criminal involvement and, as a consequence, the rate of crime commission decreases.

Considering the age of delinquents, Morselli and Royer (2008) found mobile offenders and immobile offenders have different ages. Those who travel to commit their crimes are younger and have more contact with other criminals. When a criminal travels to commit their crimes, generally he will have contact with other criminals, which can be a source of learning and can grow into a criminal network with higher earnings. The difference in gains between mobile and immobile offenders is clearly demonstrated.

Actually, mobile criminals report much higher earnings, according to Morselli and Royer (2008). Their conclusions were: (i) there is a positive and strong relationship between criminal earnings and offending perimeter, (ii) lifestyle and age have significant impacts on criminal earnings, (iii) criminals' gains are not significantly influenced by costs of crime (Morselli and Tremblay 2004), (iv) crime type is very important to typify the magnitude of the relationship between gains and offending perimeter, (v) immobile offenders have lower earnings.

Criminals are confronted with a trade-off between going to an area with high density and less probability of arrest but where they will probably obtain low earnings or going to low-density areas with higher earnings but also higher probability of going to prison.

Indeed, earnings will change in function of the situation of the place in the city. Generally, those earnings will be superior in places with a high density of jobs; therefore the productivity of a zone may also determine the levels of crime rates. Criminals are supposed to follow jobs-quarters where density is upper the mean of the city and where probability to be caught is lower.

Zenou (2003) shows that individuals have a tendency to commit more crimes in Central Business Districts (CBD) than in suburbs. This is almost true when we take in consideration some North American CBD's but it is not the same on some European CBD like in Paris or in London[2]. Actually, when commuting costs of accessing the CBD are low, criminals will be encouraged to go there as a result of high density and low probability of being arrested (monocentric city). Crime is elevated in the CBD because criminals, generally, live in poor neighbourhoods placed in suburbs.

Nevertheless, when poor people live in the CBD and the accessibility to other areas of the city from CBD increase, which is in some respects the case in Bogotá and other cities in developing countries, the probability of observing the same behaviour that Zenou shows can also increase.

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[2]See criminal reports of both cities

2.3 Some studies about BRT system and its effects in Bogota

Since 2000, some effects of the new BRT system in Bogota have been studied. The most common studies are related to the impact of Transmilenio on the property and land values (Perdomo, Mendoza, Mendieta and Baquero 2007; Mendieta and Perdomo 2007; Rodriguez and Targa 2010). Other studies have focused their interest on the impact of the Transmilenio system on inhabitants' accessibility and on inequalities (Rodriguez and Targa 2004; Bocarejo and Oviedo 2012).

Nonetheless, few studies have examined the relation between criminality and transport in Bogota and in other cities over the world using spatial data. Moreno (2005) made the only spatial econometric analysis of criminality in Bogota related to urban transport. It involved surrounding TM zones one year before and one year after the opening of this new public transportation system in the city. His findings represent a good indication of what can be expected from this research. He found that global criminality decreases alongside the TM corridor but a "sub-regional" spatial analysis of data showed that some surrounding TM zones experience an intensification of some type of crimes such as thefts from people, robberies of commercial establishments and robberies of houses. In addition, according to socio-economic characteristics, the zones with worsts socio-economic conditions present higher levels of criminality, which was expected.

On the other hand, Estupiñan and Rodríguez (2008) demonstrated that the support to build an adaptable environment for the use and the boardings to the BRT system stations represents an important barrier to private car use and has a positive effect on urban transport use. Nevertheless, while it was not the core of their research, they also found "unexpected" characteristics in their results. In effect, "lack of safety and insecurity (factor 3, $p<0.01$) unexpectedly is related to transit use, with high insecurity and low safety was associated with higher transit use". These observations, coupled with the different studies quoted above, reinforce the main subject of this research[3].

3 Bogotá: Public transports development

Bogota is the most populous city in Colombia, with more than 7 million inhabitants. From the 1970s to the end of the 1990s, density grew by 50%, from 100 inhab/ha in 1973 to 150 inhab/ha inhabitants in 1993 and 170inhab/ha in 2005.

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[3] "Low income pricing and crime" "Delincuencia en Bolivia",

The social structure in the city changed in turn. The gap between rich people and poor people is also bigger than in the 1970s. Rich people and poor people live in different zones and different neighbourhoods divided into six different socio-economic strata. Those who live in strata 5 and 6 (the richest strata) are placed in the north and north-east of the city and they represent 6% of the population. The south, centre and west of the city are composed of strata 1, 2 and 3 (the "poorest" population) which represent 81% of the population; strata 4 represents 13% and characterizes the population of the middle class who live in the west and north-west of the city.

Since the 1960s, inhabitants have revealed the desire to live close to the "rich" people who, in their turn, decided to settle in the north of the city. Because of this evolution and transformation of social and urban structure, population spread took place. In addition, a degradation of urban transport conditions was inevitable. Before the 1960s Bogotá had a tramway system service ensured by the public administration. However, because of the spread of different social classes, with "rich people" finding the north and east of the city a "desirable" place to live, we saw a sprawl of the urban structure and hence a decline of the efficiency of urban transport system in the city, notably in the case of the tramway. The tramway disappeared because of this loss of efficiency and also because of lobbying from private entrepreneurs who revealed their intentions to participate in the public transport system in the city as suppliers of the service.

After the tramway declined, the public administration gave the right to assure the service with buses to private entrepreneurs: this was the nature of the expansion of Bogotá's public transport system and hence the expansion of public buses until the end of the 1990s.

In the 1990s, the city's public transport system was composed of private entrepreneurs assembled into about 60 private enterprises assuring the provision of the service in the city. The public administration played no part in the utilities other than its regulatory role.

At the beginning of the 1990s, as a consequence of the growth of the urban territory, the government decided to differentiate and decentralize the city into 20 different districts (localidades), adopting in this way a sort of "Parisian mould of decentralization". One of those districts comprises part of the rural zone of the city (Sumapaz) and the others compose the urban area.

Since this reorganization, several planning policies have been suggested by the government, with the development of an urban transport system the more relevant of those: Transmilenio[4].

Today, Transmilenio is an integrated Bus Rapid Transit (BRT) system, using bus-ways (84 km), stations (114) and terminals (7) connected by an inter-urban

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[4] www.transmilenio.com

transport system. It is adapted for articulated buses (1262 buses) with the capacity to carry 60–120 passengers, but they move almost 150 passengers in peak hours. The system moves about 1.7 million passengers per day at a mean speed of 27 km/h.

The Transmilenio system was implemented in 2000 and today is one of the most popular and successful Bus Rapid Transit (BRT) systems in the world. After its implementation, mobility in Bogotá changed radically. Travel time decreased by 66% (from 1h30 to 30 min) and hence, accessibility also increased considerably, connecting the north and the south of the city in about 50min per trip[5].

The implementation of this BRT system led reorganization of the public transport network in Bogotá. With the Transmilenio system, the transportation system of the city is shifting to a public–private partnership mechanism. The public administration ensures the construction and maintenance of corridors and stations and the private sector assures the operation of the system under concession contracts.

This new transport system encouraged a change of the social and urban structure in the city. Rich and poor neighbourhoods are now easily connected directly by Transmilenio, which can have a direct effect on the social and urban configuration, as in the 1960s.

4 Data and methodology

4.1 Descriptive statistics and available data

The data collected for this study consider all 112 zones of the city as of December 2007. Several characteristics of each zone were taken into consideration in order to explain the criminality rates. This research was able to access a very rich database of all crimes committed in the city[6] in 2007. These crimes were spatial-referenced with the exact addresses where the incident took place. In order to make a cluster analysis with respect to the zones of the city, each crime was assigned to one of those zones depending on the address at which it happened. In addition, crimes were differentiated into six different types: homicides, thefts from people, robbery against people with violent aggression, burglaries of commercial establishments, house breakings and bank robberies.

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[5]Before Transmilenio or today in a private car, this same trip take around 2,5 hours at less. The route is of at least, 20 kilometers

[6]A big thank to the Conflict Analysis Resource Center (CERCAC) that furnished this database and enriched this research with the permission of the Metropolitan Police of Bogota (MEBOG).

Because of the low number of bank robberies in each zone, this type of crime could be confused with a dummy variable, so this study decided not to take into consideration this kind of crime. There remain five types of crimes which will be the subject of the analysis: they represent the variables to explain.

Table 1 : Descriptive Statistics

Variable	Label	Obs	Mean	Std. Dev	Min	Max
Thefts to people	crimeteft	112	110,05	92,34	3,00	569,00
Burglaries to commercial Establishments	crimecom	112	37,71	38,44	2,00	302,00
House Breakings	crimehouse	112	44,34	38,67	1,00	244,00
Homicides	homicides	112	11,46	11,25	0,00	53,00
Robbery to people with violent aggresions	lesiones	112	73,17	74,87	0,00	515,00
Presence of Transmilenio Station	presencetm	112	0,54	0,50	0,00	1,00
Area of the zone in hectares	hectares	112	375,47	180,08	79,83	992,33
Number of small enterprises	smallenter	112	65.77679	128.7845	0,00	1110,00
Number of inhabitants per hectare	density_hec	112	181.1607	105.2794	1,00	526,00
Number of jobs on each zone	employment	112	13997,52	16632,94	197,00	142052,00
Mean Income of people of each zone	income	112	689235,80	566579,90	196821,00	3032604,00
Average cost of travels for people of each UPZ	aver_cost_travel	112	1878,35	704,86	332,00	6080,00
Establishments providing Cultural activities	culture	112	8,12	8,18	0,00	40,00
Establishments promoting Welfare	soc_welf	112	63,25	63,83	0,00	288,00
Establishments provinding Health	health	112	3,53	3,24	0,00	15,00
Number of households on each zone	households	112	16448,11	13249,69	2,00	73794,00
Working Force	w_force	112	28543.31	39705.63	0,00	257862
Have at less one car	have_a_car	112	6778.813	6065.128	0,00	27569
Wealth	wealth	112	.6339286	.4838944	0,00	1

Author's calculations

As stated above, the core of this paper is to analyse Transmilenio's impact on crime rates in each zone of the city. The presence of these improvements to public transport was defined as the presence of at least one station of the TM system in a zone. Nevertheless, most TM stations are placed on the intersection

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of two or more zones and in corridors of the TM system that separate two adjacent zones. In these cases, this research considers that a TM station acts as part of both zones. Following this method, data reveal that there are 61 zones that benefit from the presence of TM and 51 without a TM station.

In order to evaluate the impact of other variables on crime rates, secondary data were also included in this analysis: the number of jobs in each zone of the city, the average income of inhabitants of each zone as equal as the average cost of travel for an inhabitant from each zone and the extension on hectares of each UPZ, conform the socio-demographic and socio-economic group of variables. This data was taken from the census conducted in the city in 2007 by the city's Department of Planning[7]. It was not possible to find more recent information because the city hall has not made other censuses for subsequent years.

Other kinds of information, such as the number of establishments providing health services (hospitals, clinics, radiological centres, etc) and the number of establishments promoting welfare (nursing homes, rehabilitation centres, orphanages, etc) and cultural events (cinemas, theatre, malls) represent amenities of each zone.

4.2   Models and methodology

Several researchers have studied the impact of transportation infrastructure on land values and on the accessibility on a city. These studies generally used a multiplicity of mathematical and statistical methods (Salon and Shewmake 2011) that involve hedonic regressions, 2 SLS regressions, propensity score matching and spatial regressions among several others. Regarding criminology, it is also common to find several studies focusing on the identification of causal effects of socio-demographic and socio-economic characteristics on different kind of crimes (Apel and Sweeten 2010). Those studies also use the same econometric techniques and several of them take a "treatment effects" approach to projects or policies in order to make causal effect estimations.

The methodology used in this paper encloses two different techniques: Propensity Score Matching (PSM) and spatial regression analysis. The use of these two methodologies aims to find:

- How criminality rates depend on some characteristics of each zone and how they are comparable to other zones.

- How thiscriminality is spatially auto- correlated between zones (not time that conduct to make a cross- section regression and not a panel data analysis).

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[7]Encuesta de Calidad de Vida para Bogotá (ECV) 2007. Secretaria de Planeación del Distrito de Bogotá.

Each type of crime will be regressed with respect to some variables that represent some socio-economic, demographic and infrastructure indices of each zone of the city.

The model applied and followed in both PSM and spatial econometric analysis is:

$$
\begin{aligned}
Crime_i^t \ = \ & \beta_0 + \beta_1 presence_i + \beta_2 hectares_i + \beta_3 density\_hec_i + \\
& + \beta_4 employment_i + \beta_5 income_i + \beta_6 culture_i + \beta_7 soc\_welf_i + \text{(1)} \\
& + \beta_8 health_i + \beta_9 aver\_\cos t\_travel_i + \varepsilon_i \qquad\qquad\qquad \text{(2)}
\end{aligned}
$$

where:

- $Crime_i^t$ is the number of crimes of type t committed in zone i.

- $presence_i$ is a dummy variable that takes a value of 1 if there is at less one TM station on zone i and 0 if not.

- $hectares_i$ is the area of each zone measured in hectares.

- $density\_hec_i$ is the density of zone i.

- $employment_i$ is the number of jobs in zone i.

- $income_i$ is the average income of inhabitants of each zone.

- $culture_i$ is the number of establishments promoting cultural activities, soc_welf_i is the number of establishments providing social welfare, $health_i$ is the number of establishments providing health and $aver\_\cos t\_travel_i$ is the average cost of travel to reach zone i.

4.2.1 Propensity Score Matching modeling

This article adopts the methodology used in Heckman et al. (1997). It tries to compare criminality rates in zones with TM stations with criminality in zones that do not have TM stations. Generally, this comparison could be possible if each zone has the same set of covariates but, because of spatial dimensions, it is no possible to do so unless using a statistical matching technique such as PSM. The fact that each zone has some similar characteristics makes the comparison plausible. In effect, the matches are selected on the basis that those characteristics have a great degree of resemblance. It assumes that there is no selection bias based on unobserved characteristics. Thus, when each zone of

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the city has those characteristics, it will have a greater or lesser probability to benefit from the TM system.

A logistic model has to be estimated previously in order to use the results from those estimations as the basis of propensity score matching.

The dependent variable of the logistic regression reflects the probability that a zone has at least one station of TM with respect to some socio-economic characteristics of each zone (match on the basis of the propensity score). The binary variable takes two different values: $Y = 0$ if the zone does not benefit of the presence of TM and $Y = 1$ if there is at least one TM station. It can be expressed as follows:

$$\Pr ob(Y = 1) = F(X, d), \Pr ob(Y = 0) = 1 - F(X, d) \tag{3}$$

where d is a vector that reflects the impact of independent variables (X) on the probability that a zone has a TM station.

This logistic regression is defined as follows:

$$\begin{aligned}
\Pr esence_i &= \beta_0 + \beta_1 housholds_i + \beta_2 hectares_i + \\
&\quad + \beta_3 w\_force_i + \beta_4 wealth_i + e_i
\end{aligned} \tag{4}$$

Where $housholds_i$ is the number of households in zone i, w_force_i is the workforce in each zone and $wealth_i$ is a dummy variable revealing if the population of zone i is on average "rich" or "not rich"[8].

Once this probability is estimated, the criminality rates in zones with presence of TM is contrasted with the crime rates in zones without TM presence. The criteria of comparison is done by the similar probability (nearest neighbour search) of having a TM station that the sample has estimated through socio-economic and geographic characteristics.

Theoretically, it supposes that there is a difference between criminality rates in treated group Y_i^1 and criminality rates in the untreated group, Y_i^0 (with $(1 < i < 112)$.

Mathematically, the PSM technique pairs observations (treated and un-treated) on the estimated probability to being treated (propensity score). Then,

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[8] Bogota is segmented on 6 socio economic stratus. If a neighbor is considered as stratum 1, it means that the population is poor. In contrast, if the neighbor is stratum 6 it means that there are more rich people than poor people. In this study, the variable $wealth_i = 1$ if the average stratum of the zone is 5 or 6. If $wealth_i = 0$ it means that people is not rich.

the effects related to the fact that there is at least one station of TM will reflect an increase or a decrease in crime rates. The difference (Δ) of the contrast variable regarding criminality rate is denoted as: $\Delta = Y_i^1 - Y_i^0$, where Δ is unknown because of the impossibility to observe (simultaneously) crime for each zone, with the assumption that every zone may benefit or not from the TM system[9].

The criminality rate for each zone i is estimated as a function of observable characteristics (X_i) of each zone and unobservable characteristics ($e_i^1 \; e_i^1$):

$$Y_i^1 = X_{i1}B^1 + e_i^1 \tag{5}$$

$$Y_i^0 = X_{i0}B^0 + e_i^0 \tag{6}$$

As stated above, Y_i^1 and Y_i^0 represent the criminality rate in zones with and without TM presence. Vectors B^1 and B^0 are the coefficients associated with X_i observable characteristics and e_i^1 and e_i^0 represent the error terms.

To evaluate the impact of public transport improvement on zones' crime rate, PSM uses statistical averages called "Average Treatment Effect on the Treated" (ATT). In order to determine the ATT, the average treatment effect (ATE) must first be defined, which is the average response to treatment for a random sample from zones defined by:

$$ATE = E\left[\Delta\right] = E\left[Y_1 - Y_0\right] \tag{7}$$

where

$$
\begin{aligned}
E\left[Y_1 - Y_0\right] \quad = \quad & E\left[Y_1 \mid D = 1\right]\Pr(D = 1) + E\left[Y_1 \mid D = 0\right]\Pr(D = 0) - \\
& \left\{E\left[Y_0 \mid D = 1\right]\Pr(D = 1) + E\left[Y_0 \mid D = 0\right]\Pr(D = 0)\right\} \tag{8}
\end{aligned}
$$

Thus, the ATT is note as:

$$ATT = E\left[\Delta \mid X_i, D = 1\right] = E\left[Y_1 - Y_0 \mid X_i, D = 1\right] \tag{9}$$

$$ATT = E\left[Y_i^1 - Y_i^0 \mid X_i, D = 1\right] = E\left(Y_i^1 \mid X_i, D = 1\right) - E\left(Y_i^0 \mid X_i, D = 0\right) \tag{10}$$

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[9]It is not possible to know what could be the crime rate on a zone z_i that benefits from TM system if it do not benefit from it.

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ATT is presented as the expected value of the difference of crime rates given the characteristics X_i of each zone that benefits from the TM system. This is equal to the difference between the expected value of the crime rate in zones with the TM system and the expected value of the crime rate in zones without the TM system. Then the information for the untreated group (the zone without the TM system) is used as a tool to compare this information with treated groups (zones with the TM system). *ATT* is the average response to treatment for a sample of zones treated.

Figure 1: PSM different steps

Step 1	Step2	Step3	Step4
Estimation of a Logit model to estimate the probability of the presence of TM as a function of observable characteristics	Use predicted values from logit to generate propensity scores for treatment and comparison group members	Match pairs: Restricted sample to common support (by wealth) using Nearest neighbors	Calculate impact by comparing the means of outcomes accross zones and their pairs

Author's elaboration

If there are statistically significant differences between the crime rates in zones with and without presence of the TM system, it is possible to conclude that the system has an effect on UPZ with TM station and the crime rates. The impact is positive or negative if the match differences of means on crime rates of each treated and untreated group are positive or negative modeling.

4.2.2 Spatial Econometric modeling

After estimation of the impact of improvement to the TM system on crime rates, this paper considers also that it could be a spatial correlation of different types of crimes. In order to evaluate this, the paper has contemplated the use of econometric techniques from a spatial econometric approach. Results from this econometric procedure will show if there may be a contagion or diffusion effect of crime between different zones.

Some studies (Anselin 1999; Moreno and Vaya 2008) emphasize the fact that cross-section and panel data analysis may have some spatial effects. Those effects have to be taken in consideration in order to improve econometric analysis.

Spatial dependence or spatial autocorrelation takes place if a variable of a zone, in this case the crime rate of zone i, is related to the same variable in other zones. This autocorrelation may be positive if the presence of a specific phenomenon in a zone (crime) leads to a spread of it in other zones. Conversely,

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if it leads to a reduction in other zones, it is a negative autocorrelation. If the variable (crime) is randomly distributed, there is no spatial autocorrelation.

Even if OLS estimation can be done with cross-section data, there must be independence within observations. However, if data are geographically differentiated, the probability of multidirectionality problems is high (Moreno and Vaya 2008) and so OLS estimations may lose their meaning.

If the spatial dependence is taken into consideration, and in order to solve the multidirectionality problem, spatial associations among variables (crime) have to be quantified. To identify and validate the presence of global autocorrelation the Global Moran's I and Global Geary's G tests were used. Those tests allow the study to contrast the presence or absence of spatial dependence of each dependent variable (type of crime). Results of those tests will show if the variable (type of crime) is randomly distributed across space or if, in contrast, if there is a significant association of similar or dissimilar values within regions.

After defining the presence of spatial autocorrelation, the study proceeds to definition of the most adaptable model type. The Lagrange multiplier test and the robust Lagrange multiplier test for spatial lags and for spatial errors are the diagnostic tests for identification of the model.

To develop this kind of analysis, a spatial weights matrix W_{ij} has to be defined. With this matrix, the examination will be able to reflect the degree of interdependence that may exist between each pair of zones i and j[10].

In effect, it is possible that, in the context of a regression model, spatial dependence is observed as a consequence of spatial correlation of some variables (spatial lag dependence) or as a consequence of the existence of spatial dependence on the error term (spatial error dependence) of each model. These two scenarios introduce two kinds of spatial models:

- The spatial lag model that fits covariates or spatial lag to describe mean.

- The spatial error model that assesses the residuals and specifies error dependence structure inference.

The spatial lag model supposes that each location is correlated with every other one, while spatial error supposes that each error is correlated with every other one.

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[10] Anselin 1988.

5 Results

5.1 Results from PSM methodology

PSM methodology suggests that a Probit or Logit model should be used in order to generate propensity scores for treatment from predicted values. These models allow researchers to determine the probability that a zone benefits, at least, from the presence of one Transmilenio station even if this station is placed in the zone or along the border of the zone. This study used a logistic function; the dependent variable is Presencetm=1 if there is at less one TM station and 0 if not. The presence of Transmilenio in a zone, even if as an independent variable in the main model (equation 1), depends on other variables (see subsection 4.2.1). It denotes that Presencetm is like an endogenous variable that depends on some other variables[11].

Results of the estimation of the Logit model, the marginal effects and the elasticity of each regressor are shown in table 2. The probability that a zone benefits from the presence of at least one TM station increases with the number of households in each zone.

Table 2: Logit model, marginal effects and elasticity

VARIABLES	Presencetm	Marginal effects	Elasticity dy/dx
Constant	-0.08092		
	(0.574)		
households	0.00005***	.0000134***	.2208132***
	(0.000)	.00001	.08429
hectares	-0.00433***	-.0010762***	-.404088***
	(0.002)	.0004	.14846
w_force	0.00001*	2.83e-06*	.0808714*
	(0.000)	.00000	.04297
wealth	1.02476**	.2507054**	.1614141**
	(0.460)	.10781	.07249
Log likelihood	-66,932795		
Prob>chi²	0,0004	LR chi² (4)	20,51
Observations	112	Pseudo R²	0,1328

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Authors' calculations

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[11] To demonstrate endogeneity of Presencetm a 2SLS analysis was made before for each kind of crime; results do not appear on this paper because it does not make part of the aim of the article.

In the same way, this positive relation is observed with respect to the workforce and "social belonging": if the population of a zone is on average "not poor", the probability that Transmilenio will pass within or along this zone is higher. In contrast, the probability that a zone benefits from improvement of public transport decreases with respect to its size.

Elasticity of each independent variable has to be interpreted partially and held constant with all other things. It signifies that an increase of 1% of the number of households in each zone increase by 0.22% the probability of having a TM station in a zone. In parallel, if the workforce or the average of "not poor" people increases by 1% in a zone, the probability that this zone benefits from public transport improvements may increase by 0.08% and 0.16% respectively. Instead, if the area of the zone rises on 1%, the probability to have a TM station on that zone may drop on 0.40%.

Precedent results were used in the propensity score matching analysis. Five-Nearest-Neighbour option was used to create the sample for analysis[12].

Table 3: PSM - differences between matched and unmatched variables

Variable	Sample	Treated	Controls	Difference
crimeteft	Unmatched	133.065574	82.5294118	50.536162
	ATT	133.065574	78.4786885	54.5868852***
crimecom	Unmatched	45.8688525	27.9607843	17.9080681
	ATT	45.8688525	25.7672131	20.1016393***
crimehouse	Unmatched	49.7704918	37.8431373	11.9273545
	ATT	49.7704918	36.4098361	13.3606557*
lesiones	Unmatched	72.3934426	74.0980392	-1.70459659
	ATT	72.3934426	67.9803279	4.41311475
homicides	Unmatched	11.4754098	11.4509804	.024429444
	ATT	11.4754098	10.7868852	.68852459

Authors' calculations

Table 3 displays PSM results. It can be denoted that the number of "Thefts from people" committed in zones that benefit from TM is on average 133 while the average number of thefts from people in zones without TM is 78. The biggest difference in thefts committed between these two kinds of zones in 2007 is approximately 54. Those results are statistically significant at 1% level.

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[12] Results of PSM were found using the nearest neighbor method which is based on the comparison of the criminality of each zone with TM with the criminality of each zone that do not has a TM station and that has the closest value of the propensity score. The result of estimation is then the average of comparisons of criminality rates over all zones with TM station (ATT).

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Regarding the number of thefts from commercial establishments, it can also be seen that the number of events is bigger in zones that benefit from TM than in zones which do not benefit from this transport system (45.86 vs 25.76).

Results for this type of crime are also statistically significant at 1% level.

On the other hand, there are more house breakings in zones benefiting from the TM system: on average 49.7 house breakings in zones with TM presence and 36.4 in zones without the TM system. These results are also statistically significant but at 10% level.

Finally, regarding the number of robberies against people with violent aggression and homicides, it is also found that they are most frequently perpetrated on UPZ with at least one Transmilenio station. Nonetheless, these results are not statistically significant. However, differences in the number of occurrences of the event are very shallow, which may imply that such types of crime do not depend in large proportion or do not take a big influence from the improvement of public transport.

Table 4: OLS results

Scope of analysis	Variables	Crimeteft	Crimecom	Crimehouse	Lesiones	Homicides
	Constant	-7.938	0.771	-21.459	-85.320***	-7.104*
		(31.029)	(11.017)	(15.315)	(23.488)	(3.937)
Improvements	presence TM	27.992**	3.012	12.849*	20.468*	1.258
		(13.780)	(4.893)	(6.801)	(10.431)	(1.748)
	hectares	0.105***	0.021	0.084***	0.138***	0.011**
		(0.036)	(0.013)	(0.018)	(0.027)	(0.005)
	smallenter	0.346**	0.103**	0.162**	-0.041	0.003
		(0.138)	(0.049)	(0.068)	(0.105)	(0.018)
	density_hec	0.055	0.003	0.089**	0.213***	0.042***
Socioeconomic		(0.079)	(0.028)	(0.039)	(0.060)	(0.010)
and demographic	employment	0.001	0.001***	-0.001**	0.000	0.000
		(0.001)	(0.000)	(0.000)	(0.001)	(0.000)
	income	0.000	0.000	0.000**	-0.000	-0.000
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	aver_cost_travel	0.010	0.001	0.003	0.008	0.001
		(0.010)	(0.004)	(0.005)	(0.008)	(0.001)
	culture	2.849***	0.560	0.530	2.706***	0.137
		(0.993)	(0.353)	(0.490)	(0.752)	(0.126)
Amenities	soc_welf	-0.243	-0.031	-0.035	0.360***	0.037*
		(0.147)	(0.052)	(0.073)	(0.112)	(0.019)
	health	-1.084	-0.259	-1.343	-0.390	0.463
		(2.290)	(0.813)	(1.130)	(1.734)	(0.291)
Observations		112	112	112	112	112
R-squared		0.568	0.686	0.400	0.624	0.532

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Authors' calculations

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On the other hand, in order to confirm the impact of the presence of improvement of public transport on the level of crime in each zone of the city, equation 1 was also regressed as an OLS model. Table 4 denotes that the presence of TM always has a positive impact on crime rates. Actually, among all the independent variables, "Presencetm" has the biggest impact on the variable to be explained.

OLS results confirm previous findings. In effect, TM presence has the biggest impact on the number of thefts from people, the number of robberies against people with violent aggression and the number of house breakings. In contrast, crimes in which TM presence has lower incidence in absolute terms are homicides and burglaries of commercial establishments.

Like the PSM methodology, OLS results reveal that the presence of TM in a zone has statistical significance to thefts from people and house breakings. In contrast, table 4 displays that the presence of TM in a zone has also a statistical significance in the level of robberies with violent aggression and does not have statistical significance to burglaries of commercial establishments.

5.2   Results from Spatial econometric methodology

Given that this paper uses geographical data and tries to study differences and similarities between zones of the city, a spatial analysis from an econometric point of view may be useful to complete this approach.

According to spatial econometrics analysis, this research proceeds first to establish if there exists a spatial autocorrelation of the different types of crime. To carry out this first step, the most traditional approximation to study the effect of spatial dependence is the calculation of global statistics (Moran and Getis tests). These statistics allow the contrast of the hypothesis (null hypothesis, H_0) that says a variable is randomly distributed on space or if in contrast there exists a significant spatial likelihood of variables.

Moran's I statistics have as the null hypothesis (H_0), that variables (crimes) are randomly distributed in the space. The null hypothesis for Getis's G statistics tries to contrast if there is no a spatial concentration of a variable. A rejection of the null hypothesis in both cases suggests that crime there is a spatial dependence and a concentration of crime and so, that crimes on a specific zone may affect or are related with crime rates of neighbouring or closest zones.

Table 5: Moran's I and Getis' G

Variables	I - Moran	G - Getis
crimeteft	0.065***	0.930***
crimecom	0.050***	0.959
crimehouse	0.103***	0.871***
homicides	0.024***	0.974*
lesiones	0.019***	0.944**

*** p<0.01, ** p<0.05, * p<0.1

Authors' calculations

Table 5 exposes that, for the case of Bogotá, for every kind of crime, Moran's I statistics are significant at 1% level, indicating that all types of crime have a spatial dependence. Getis's G statistics suggest that every type of crime presents a geographical concentration except for burglaries of commercial establishments.

Given previous results of global spatial autocorrelation tests, it can be asserted that crimes are directly spatially auto-correlated. Each type of crime in a zone of the city of Bogotá has an impact on the number of crimes in contiguous zones.

Once spatial autocorrelation is corroborated, spatial regression has to be done in order to determine the spatial dependency between the dependent variable and regressors.

To define the spatial regression model, it is advisable to do some diagnostic tests. The Lagrange multiplier test and the robust Lagrange multiplier test for spatial lags and spatial errors were used as diagnostic tests in order to identify the better model for each type of crime.

Table 6: Diagnostic identification tests

Test	Crimeteft	Crimecom	Crimehouse	Lesiones	Homicides
Spatial error					
Moran's	3.474***	0.760	4.846***	6.030***	0.120
Lagrange multiplier	0.988	0.188	2.944*	5.469**	0.593
Robust Lagrange multiplier	1.051	0.134	0.692	8.951***	0.497
Spatial lag					
Lagrange multiplier	3.905**	0.064	7.731***	0.597	0.201
Robust Lagrange multiplier	3.969**	0.010	5.478**	4.079**	0.106

Authors' calculations

Table 6 reveals that LM error statistic is significant for "robbery against people with violent aggression". It implies that there is a spatial dependency on

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the error term and hence, the most adaptable model should be a spatial error model. On the other hand, LM lag statistics are significant for "thefts from people" and "house breakings", which suggests that the spatial dependence is observed as a consequence of a spatial correlation of some variable (spatial lag dependence; thus, a spatial lag model may be most adaptable to these types of crime.

Conversely, the identification test has no statistical significance regarding burglaries of commercial establishments and homicides. It does not give information about the model that should be used for these types of crime. Nevertheless, a spatial lag model will be made in view of the fact that LM lag and robust LM lag statistics are lower than LM error and robust LM errors.

Table 7: Spatial regress results

Scope of analysis	Variables	Crimeteft	Crimecom	Crimehouse	Lesiones	Homicides
	Constant	-63.343	4.466	-44.369***	-70.578**	-7.118**
		(40.866)	(17.794)	(16.370)	(29.710)	(3.594)
Improvements	presence TM	25.074*	3.160	11.221*	16.738*	1.244
		(12.965)	(4.680)	(6.308)	(9.839)	(1.597)
	hectares	0.108***	0.020*	0.077***	0.128***	0.011***
		(0.033)	(0.012)	(0.016)	(0.027)	(0.004)
	small-Enter	0.348***	0.102**	0.156**	-0.039	0.005
		(0.129)	(0.047)	(0.063)	(0.096)	(0.017)
Socioeconomic	density_hec	0.066	0.001	0.090**	0.214***	0.045***
and demographic		(0.074)	(0.027)	(0.036)	(0.056)	(0.009)
	employment	0.001	0.001***	-0.001**	0.000	0.000
		(0.001)	(0.000)	(0.000)	(0.001)	(0.000)
	income	-0.000	0.000	0.000*	-0.000	-0.000
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
	aver_cost_travel	0.008	0.001	0.002	0.005	0.001
		(0.010)	(0.003)	(0.005)	(0.007)	(0.001)
	culture	2.923***	0.554*	0.624	2.786***	0.153
		(0.929)	(0.335)	(0.454)	(0.696)	(0.118)
Amenities	soc_welf	-0.259*	-0.029	-0.040	0.354***	0.032*
		(0.138)	(0.050)	(0.067)	(0.104)	(0.018)
	health	-1.103	-0.262	-1.302	-0.178	0.455*
		(2.140)	(0.772)	(1.044)	(1.593)	(0.273)
Observations		112	112	112	112	112
Sigma		59.440***	21.440***	28.993***	44.319***	7.572***
Statistics Spatial Lag or Spatial Error						
Rho / Lambda		0.571*	-0.106	0.680***	0.789***	-1.057
Log likelihood		-616.83691	-502.23973	-536.66689	-584.57169	-386.34701

Authors' calculations

Results for spatial regressions are described in table 7. It can be seen that, as for OLS results, for spatial lag models the presence of Transmilenio improvement

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in a zone is the variable that has the biggest impact on every type of crime. In parallel, the Presencetm coefficient is statistically significant at 10% level for types of crimes for which LM lag and/or LM error statistics are statistically significant (Thefts from people, house breakings and robbery against people with violent aggression). Besides, even if the impact is positive, improvement of public transport seems not to have a statistically significant impact on the level of homicides and on the number of burglaries from commercial establishments.

For the case of socio-economic and demographic variables, spatial regressions results suggest that the area of the zone (hectares) is, from a statistical point of view, determinant on the level of every kind of crime studied in this paper.

Regarding the number of small enterprises in each UPZ, results indicate that it has a positive and statistically significant impact on crimes without violent aggression against people (thefts from people, burglaries of commercial establishments and house breakings). It suggests that the more small enterprises there are in a zone, the more the number of these types of crime will increase, and vice versa with crimes with violent aggression.

Conversely, density of each zone has the opposite effect. In effect, the bigger is the density in a zone, the bigger is the impact of this characteristic on the number of crimes with aggression and the biggest is the number of house breakings. Regarding the other socio-economic and demographic variables, even if they have a positive impact on the number of crimes, their impact is weak.

Finally, table 7 indicates that two of the three variables denoting amenities in each zone have a negative impact on the number of crime. Sometimes they are statistically significant; sometimes not. It suggests that the greater the number of establishments that promote and provide welfare and health in a zone, the lower will be the number of crimes. The impact of establishments providing cultural activities such as cinemas and theatres, which are generally placed near big malls, on the number of crimes is positive and statistically significant. It means that crime will be greater in zones with a big number of that kind of establishment and it can be explained because of the large number of people who frequent these places.

As expected, inasmuch as diagnostic tests reveal, there is no preferable model for burglaries from commercial establishments and homicides; their spatial autoregressive parameter (Rho) for spatial regressions is not statistically significant. It suggests that the model proposed do not capture the spatial dependence which is transmitted to the error terms. Nevertheless, it does not imply that there is no spatial correlation (the Moran and Getis tests showed this before); rather it suggests that the model is not the better one for these kinds of crime.

Conversely, the spatial autoregressive parameter (Rho) for "thefts from people" and "house breakings" and the coefficient on the spatially correlated errors

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(Lambda) for "robberies against people with violent aggression" are positive and statistically significant. This signifies that there is a spatial dependence in the data and that spatial regression models are a better alternative than OLS models. Models are well designed and capture the effect of spatial dependence.

6   Conclusions

This research demonstrated throughout that there exists a positive and significant relation between public transport improvement and the level of crime in each zone of the city of Bogotá.

Firstly, a PSM approach revealed significant differences in the average numbers of any type of crime between the treated zones that benefit from Transmilenio and those which do not. The zones of the city benefiting from improvement of public transport always have bigger crime rates than those where TM is not provided.

Based on observed predictor obtained from the precedent logistic regression, PSM results confirmed that the presence of Transmilenio in a zone has a positive impact on the level of crime rates in each treated zone. It suggests that improvement to public transport raises the level of any type of crime, with statistical significance for crimes without violent aggression. A causality relationship is almost demonstrated.

Important differences are shown regarding crime without violent aggression against people. Burglaries of commercial establishments are 78.02% more frequent in zones with at least one Transmilenio station. Regarding the number of thefts from people, the difference is close to 69%, and it is 36.7% for house breakings.

Regarding crimes with "violent aggression", results showed that there are also more crimes in zones where Transmilenio passes. Nonetheless, differences are smaller (6.4% for both). It suggests that even if crimes with violence are most recurrent in zones served by Transmilenio, these types of crime seem not to depend in an important proportion on public transport provision in a zone. Murderers will not go to a zone to perpetrate their crimes in Transmilenio but they may benefit from the. This seems to not be the case for crimes without violence.

Offenders who do not use Transmilenio may also benefit from those improvements to public transport. Actually, with the construction of Transmilenio there was an upgrading of corridors alongside Transmilenio corridors, which led to an enhancement of travel by private cars along TM corridors.

These results have to be interpreted with a lot of care. The fact that this study does not include a dynamic analysis over time does not reveal concrete conclusions. Indeed, these results may also signify that transport policies in the city were focused on the development of improvement of public transport in zones with high crime levels. However, PSM results demonstrate that if the time characteristic is not taken into consideration, predictors based on a logistic regression that defines the presence of TM stations in a zone have a positive and causal relation with crimes not featuring violence in any zone of the city.

As for the results of logistic regression, the importance of wealth appears to be significant in the probability that a zone is served by the TM system. It may explain why crimes without violence, the principal causes of which are economic, are situated in zones benefiting from the Transmilenio system.

Once the importance of public transport improvement to crime had been demonstrated, it was also very important to know if there is a diffusion or contagion effect of delinquency among the zones composing the city.

Global spatial statistics reveal that, regardless of their type, crimes are always spatially correlated. Zones with higher crime rates spread these rates systematically to adjacent zones.

Regarding spatial regressions, diagnostic tests suggest that when thefts from people, house breakings and robberies against people with violent aggression are regressed with respect to some characteristics of zones, there is a clear spatial dependence with high levels of concentration of those crimes.

Other types of crime, such as homicides and burglaries of commercial establishments, do not reveal a concrete spatial concentration when they are regressed with respect to the same variables. It is important to insist that it does not reflect the "absence" of spatial dependence of these types of crime, but it may suggest that for these crimes, explanatory variables could be other than those proposed in the models suggested.

Explanatory variables that represent "socio-economic and demographic characteristics" always have a positive effect and, in some cases, statistical significance to the level of crime. Variables from this group that have a higher impact on crime rates with statistical significance were "the area in hectares" of zones (for any type of crime), the number of small enterprises (regarding crimes without violent aggression) and the density of each zone (regarding crime with violent aggression and house breakings). It suggests that the more small enterprises there are in a zone, the higher will be the rates of crime without violent aggression. It could be explained because, generally, small enterprises in Bogotá are part of the commerce and services sectors. If there are more small enterprises in a zone, density will be higher during the day and so the potential victims for that type of crime will be higher. Streets and commercial establishments will be

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most frequented and hence, it will make it easier for offenders to commit their crimes. The number of establishments promoting cultural events has the same effect on crimes, perhaps for the same reason as the number of small enterprises.

Conversely, the other two variables grouped into "amenities" do not have the same impact on crime levels. In effect, the number of establishments providing welfare and health appear to be good instruments to decrease the number of crimes without violent aggression in zones. It suggests that if more of those sort of establishments are present, offenders will be less motivated to commit crimes, in line with the thesis of Hipp (2007) regarding the six theories of crime.

Finally, regarding improvements to public transport, like in OLS models, spatial regressions suggest that, among the variables considered, it represents the principal characteristic of the zone that make raise crime rates regardless the type of crime. As explained above, this variable is statistically significant only for the three types of crime for which diagnostic tests are statistically significant (spatial lag model and/or spatial error model). However, this research demonstrates the large and direct effect of public transport enhancement on crime rates.

Unfortunately, socio-economic data for periods before and after the operation of the system could not be compiled and represents the next step to deepen research on the subject. After the compilation of those data it may be possible to determine the exact impact of public transport improvements in crime rates of any zone of the city. However, despite the fact that this research could not make an analysis over time, it represents an important study with strong evidence of what can be called a "boomerang effect" of improvement of public transport.

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