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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 transports and criminality was underestimated and even almost forgotten. This paper aims to reveal the importance of public transport policies in the evolution of crime configuration on a city. The hypothesis that the probability to have transports improvements in a zone depend on some socioeconomic characteristics of itself is adopted. The use of Propensity Score Matching technique reveals that the presence of improvements of public transports in a zone of the city has a direct and a significant impact on the increasing of some types of crime. Likewise, spatial econometrics results expose that crime tends to be contagious on neighboring zones. The presence of Transmilenio system in Bogotá may share out criminality to other zones of the city. Negatives externalities like the better mobility of offenders and then, their possible choice to expand their criminal activities to new zones, can spoil positives effects of enhancements of public transports. Far from suggesting to not develop public transports or to isolate some “dangerous” neighborhoods or inhabitants, this article shows that improvements of public transports may not only generate positive externalities. Policy makers should take in consideration the mutation and the shift of criminal behaviors in order to identify possible solutions like the construction of more establishments providing health, welfare and sportive activities as is evoked on results. By this way, the “boomerang effect” of the improvements transports will be reduced.

JEL Codes: C31, R12, R15, R49

Keywords: Urban Public Transports improvements; Propensity Score Matching; Crime contagion; Spatial dependence.

1 INTRODUCTION

A long line of theorizing in public economics has suggested that urban transport plays an important role in social configuration and therefore, in urban structure, (Glaeser 2003, Bruekner, Largey 2006). Urban and social structure landscape can change significantly because of these reactions. Urban transport and accessibility play a central role because social interactions are at the center 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 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, Zenou 1999). In effect, as various authors have argued, inequality and crime depend on the degree of social interactions. By transitivity, this research emphasizes on the fact that criminality and social interactions are directly related with urban transports. However, it seems rather contradictory that the relationship between urban transports and criminality was not profoundly developed in economics even more when transports are 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 level of transport accessibility is, the higher level of social interactions is, and the higher probability of individuals to interact with their neighbors is, (Putman 2000).

In other words, when accessibility of transport increases in a district or in a neighborhood, inhabitants have more opportunity to interact with other people in the city. The probability of greater levels of social interactions may be higher with public policies looking to stimulate the development of urban transport (Holtz-Eakin, 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 behavior could be considered as essential. Jens Ludwig and Jeffrey R. Kling (2006) confirmed that crime is contagious in areas where there are already criminals¹. Regarding this, we can suggest that this conduct can take a worse dye when we consider social interactions behavior as a social multiplier, (Glaeser, Sacerdote, Scheinkman 1999, 2003). In consequence, social interactions may lead more crime and could be a factor that encouraged people to go to low-density tracts.

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

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

higher. People are briefly distant from their neighbors 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 neighborhood, 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 a rise of 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 center, in the suburbs, which will motivate the growth of "edges cities", which as well, will be adapted as new sub centers of the city, (Alonso 1964, Anas 1990). Generally, people who want to run away criminality decide to shift to zones more securely which will be translated in higher prices of the land. People who have "high" economic resources can choose to move but they still been a minority; large part of people cannot move to an area with these characteristics because of their limited budget.

If urban transports have 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 transports. However it cannot be forgotten that other variables like population, income, employment rate, work force among several other factors, delimit social interactions and therefore, crime rates.

This research focuses on an analysis of different kind of crimes on a city of developing country as Bogota. This city is known for its high criminality rates in the past and the implementation of an ingenious and innovative Bus Rapid Transport (BRT) system called Transmilenio (TM) on 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 the improvements of urban transports on each zone of the city.

In this respect, studies have demonstrated that transport infrastructures traduced on roads and highways of a city have a positive impact on employment and economic growth (Holtz-Eakin, Schwartz 1995, Barr 2000). Similarly, Moreno (2005) makes a spatial econometric analysis about the impact of TM on criminality alongside a TM corridor. He demonstrated that global criminality is smaller closer 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 are no researches that have tried to differentiate the criminality configuration between zones that benefit from improvements of public transports like 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 pretends 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 interactions, transports and criminality and 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 on the paper. Empirical findings are presented in section 5 and conclusions are offered by section 6.

2 Social interaction, criminality and mobility

2.1 Criminality and social interaction

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

Concerning the difference kind 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, the density is a factor which determines the level of social interaction; low density reduces social capital and therefore social interaction.

Individual behaviors are not only in function of their desires but also in function of their entourage. Considered as a behavior, criminality and its progress depend of spatial structures on neighborhoods and zones, thus it also depends of social interactions. Glaeser, Sacerdote and Scheinkman (1996) argue that 30% of criminality depends of local attributes and Zenou suggest that 70% is associated to social interactions. However, social interactions depend also from local attributes like amenities as 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 neighborhood, inhabitants will have more opportunity to interact with other people in the city. The probability of grow of social interactions is higher in presence of public policies which stimulate the development of urban transport.

Density will be higher and with more people to interact, individuals find more opportunities to relate.

Nevertheless, if we take in consideration Brueckner's suggestion (2003), this type of behavior can also lead the people to think that anybody can be a criminal. In high-density zones, every neighbor is suspicious which, at his turn, encouraged a decline of social interaction and induce people to search zones with low-density which are, generally, far from the center of the city.

Additionally, with an enlargement of accessibility, heterogeneity of neighbors or districts during the day will be higher and socioeconomic differences will be more perceptible. According to Hipp (2007), this will lead to a higher filling of exclusion or injustice within the society which can have negatives consequences like criminality as an instrument of pronouncement about their felling.

Hipp (2007) shows the different effect 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 neighborhood. It supposes people compare themselves with respect to other people living or not in the same neighborhood. If they consider that they are in an unfairly 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; it is called by Hipp as 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 on a district and crime. A growth of inequality, make rise 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 closer, criminality index will tend to go up. Criminals will be obligated to choose between stole a neighbor (and be recognize by him) or stole an individual who doesn't live in his quarter or in his district. According to that, we can say that commuting cost, as well as reputation effect, can play an important role on criminal behavior. Offenders will be in front of a cost-benefit analysis which will depend of their commuting cost but also the probability to be recognized by someone who lives in the same neighborhood and so, the probability to be 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 on neighborhoods with low homogeneity. Hipp named this behavior "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 higher crime rates because of a reduced level of social interactions. 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 in consideration the income inequality. Nevertheless, he does not reject the inequality as a significant factor.

In addition, high social multiplier implies that crime and their 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 decrease the probability to be 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). Crime market is reduced as well as commuting cost fall down.

2.2 Criminals' mobility and jobs' centers

The impact of the distance traveled by offenders to commit their crimes on their earnings was studied by some authors. As is shown in Morselli and Royer (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 established that property crimes require greater distances than violent crimes. Indeed, violent crimes like homicides or crime with predatory violence, required short distance to be achieved in opposition also with shoplifting or commercial crimes which need higher distances. On the center we found motor vehicle thefts which do not need to be accomplished so far from home but need a greater distance to resale the auto parts.

From this perspective, we can see that compensation between the probability to be arrested and to perceive 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 with 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 see their commuting costs decrease, he will be more stimulated to travel and to commit crimes in zones connected to 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 relationship between criminal earnings and distance traveled can be positive. In effect, highest gains from a highest distances traveled by

offenders, rouse to a more efficient criminal involvement and, as a consequence, the rate of crime commission decreases.

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

Actually, mobile criminals report much higher earnings, (Morselli and Royer, 2008). Their conclusions were: (i) there is 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 significant 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 to a trade-off between to go to an area with high density and less probability of arrest but where they will probably obtain low earnings or go to low-density areas with higher earnings but also higher probability to go to prison.

Indeed, earnings will change in function of the situation of the place in city. Generally, those earnings will be superior in places with high density of jobs therefore productivity of a zone may also determine the level 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), show that individuals have a tendency to commit more crimes in the 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 London². 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 neighborhoods placed in suburbs.

Nevertheless, when poor people live in the CBD and the accessibility to other areas on the city from CBD lift up, which is in some aspect the case of Bogotá and other cities of developing countries, the probability to observe the same behavior that Zenou shows, can also increase.

²See 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 were studied. The most recurrently 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 Transmilenio system on the accessibility of inhabitants and inequalities (Rodriguez, Targa 2004; Bocarejo, Oviedo 2012).

Nonetheless, no many studies have examined the relation between criminality and transports in Bogota and in other cities over the word using spatial data. Moreno (2005) made the only spatial econometric analysis of criminality on Bogota related to urban transports. It involves 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 it can be expected on 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 have an intensification of some type of crimes like thefts to people, robberies to commercial establishments and robberies to houses. In addition, according to socio-economic characteristics, the zones with worsts socio-economics conditions present higher levels of criminality, which was expectable.

In 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 have a positive effect on urban transports use. Nevertheless, even if it was not the core of their research, they also found “unexpected” characteristics on 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 research³.

3 Bogotá: Public transports development

Bogota is the most populated city of Colombia with more than 7 millions of inhabitants. From the 70’s until the end of 90’s, density grew by 50% passing from 100 inhab/ha in 1973 to 150 inhab/ha inhabitants in 1993 and 170inhab/ha in 2005.

³ “Low income pricing and crime” “Delincuencia en Bolivia”,

The social structure in the city changed at his turn. The gap between rich people and poor people is also bigger than in 70's. Rich people and poor people live in different zones and different neighborhoods divided on six different socio-economic strata. Those who live in strata 5 and 6 (the richest strata) are placed on the north and north-east of the city and they represent 6% of the population. The south, the center and the west of the city is composed by strata 1, 2 and 3 (the "poorest" population) which represent 81% of the population; strata 4 represents 13% and it characterizes the population of the middle class who live on the west and north-west of the city.

Since 60's, inhabitants revealed the desire to live close the "rich" people who, at their turn, decide to settle the north of the city. Because of this evolution and this transformation of social and urban structure, a spread of population took place. In addition, a degradation of urban transport conditions was inevitable. As a matter of fact, before 60's Bogotá had a tramway system service ensured by the public administration. However, because of the spread out of different social classes where "rich people" found in the north and the east of the city a "desirable" place to live, we saw a sprawl of urban structure, and hence, a decline of the efficiency of urban transport system in the city, notably of the tramway. The tramway disappeared because of this loss of efficiency and also because of the lobby of private entrepreneurships who reveal their big intentions to participate in the public transport system in the city as suppliers of the service.

After the subtraction of the tramway, the public administration gave, to private entrepreneurships, the right to assure the service with buses: it was the expansion of public transport system of Bogotá and hence the expansion of public buses until the end of 90's.

In 90's, public transport system of the city was composed by private entrepreneurships assembled in about 60 private enterprises assuring the provision of the service in the city. Public administration didn't have a part on utilities; she only participates as a regulator.

On the beginning of 90's, as a consequence of the growth of the urban territory, government decides to differentiate and to decentralize the city in 20 different districts (localidades) adopting by this way, a sort of "Parisian mold of decentralization". One of those districts makes part of the rural zone of the city (Sumapaz) and the other ones compose the urban area.

Since this reorganization, several planning policies were suggested by the government with the development of urban transport system as the more relevant of those: Transmilenio⁴.

⁴www.transmilenio.com

Today, Transmilenio is an integrated Bus Rapid Transit (BRT) system, using bus-ways (84 kms), stations (114) and terminals (7) connected with inter-urban transport system. It is adapted for articulated buses (1262 buses) with capacity to carry 60-120 passengers but they move almost 150 passengers on peak hours. The system move about 1,7 millions of 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) system on the world. After its implementation, mobility in Bogotá has been changed radically. Travel time decrease in 200% (from 1h30 hour to 30 min) and hence, accessibility also increase in a considerable level connecting the north and the south of the city on about 50min per trip⁵.

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

This new transport system encouraged a change of social and urban structure in the city. Rich and poor neighborhoods are now most easily connected directly by Transmilenio which can have a direct effect on social and urban configuration like in 60's.

4 Data and methodology

4.1 Descriptive statistics and available data

The data collected for this study, consider all (112) zones of the city on December 2007. Several characteristics of each zone were taken in consideration in order to explain the criminality rates. This research was able to have access to a very rich database with all the crimes committed in the city⁶ on 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 where it happened. In addition, crimes were differentiated on six different types: homicides, thefts

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).

to people, robbery to people with violent aggressions, burglaries to commercial establishments, house breakings and bank robberies. Because of the fewer of bank robberies on each zone, this type of crime could be confused as a dummy variable so this study decided not to take in consideration this kind of crime. It remains five types of crimes which will be the subjects 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 aggressions	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 providing 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 analyze the impact of the Transmilenio on crime rates of each zone of the city. The presence of these

improvements on public transports was defined as the presence of, at less, one station of TM system on a zone. Nevertheless, most of TM stations are placed on the intersection of two or more zones and on corridors of TM system that separate two adjacent zones. On these cases, this research considers that TM station makes 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 on this analysis: the number of jobs on 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 were taken from the census conducted in the city in 2007 by the Department of Planning of the city⁷. It was not possible to have more recent information because the city hall has not made other census for subsequent years.

Another kind of information like the number of establishments providing health services (hospitals, clinics, radiological centers, etc) and the number of establishments promoting welfare (nursing homes, rehabilitation center, orphanages, etc) and cultural events (cinemas, theatre, malls) represent amenities of each zone.

4.2 Models and methodology

Several researches have studied the impact of transportation infrastructures on land values and on the accessibility on a city. These studies generally used multiplicity of mathematical and statistical methods (Salon, 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 economics characteristics on different kind of crimes (Apel R., Sweeten G. 2010). Those studies also use the same econometrics technics and several of them make a “treatment effects” approach of projects or policies in order to make causal effect estimations.

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

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

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

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

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

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

$$\begin{aligned}
 Crime_i^t = & \beta_0 + \beta_1 presence_i + \beta_2 hectares_i + \beta_3 density_hec_i + \\
 & + \beta_4 employment_i + \beta_5 income_i + \beta_6 culture_i + \beta_7 soc_welf_i \quad (1) \\
 & + \beta_8 health_i + \beta_9 aver_cost_travel_i + \varepsilon_i \quad (2)
 \end{aligned}$$

where:

- $Crime_i^t$ is the number of crimes of type t committed on zone i .
- $presence_i$ is a dummy variable that takes 1 value if there is at less one TM station on zone i and 0 if not.
- $hectares_i$ is the area of each zone measured on hectares.
- $density_hec_i$ is the density of zone i .
- $employment_i$ is the number of jobs on 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 establishments providing health and $aver_cost_travel_i$ is the average cost of travel to reach zone i .

4.2.1 Propensity Score Matching modeling

This article adopts the methodology used on Heckman et al. (1997). It tries to compare criminality rates on zones with TM stations with criminality on 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 not possible to do unless to use a statistical matching technique like PSM. The fact that each zone has some similar characteristics brings 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 the city has those characteristics, it will have a great or less probability to benefit from TM system.

A logistic model has to be estimated previously in order to use the results from those estimations as the basis of the Propensity Score Matching.

The dependent variable of the logistic regression is the probability that a zone has at less, 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 less, one station of TM and it can be expressed as follow:

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

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 follow:

$$\begin{aligned} \text{Presence}_i = & \beta_0 + \beta_1 \text{housholds}_i + \beta_2 \text{hectares}_i + \\ & + \beta_3 w_force_i + \beta_4 \text{wealth}_i + e_i \end{aligned} \quad (4)$$

Where housholds_i is the number of households on zone i , w_force_i is the working force on each zone and wealth_i is a dummy variable revealing if the population of zone i is in average “rich” or “not rich”⁸.

⁸Bogota 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 $\text{wealth}_i = 1$ if the average stratum of the zone is 5 or 6. If $\text{wealth}_i = 0$ it means that people is not rich.

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

Theoretically, it supposes that there is a difference between criminality rate on treated group Y_i^1 , and a criminality rate on untreated group, Y_i^0 .

Mathematically, PSM technique pairs observations (treated and untreated) on the estimated probability to being treated (propensity score). Then, the effects related to the fact that there is at less one station of TM will reflect an increase or a decrease of 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) the crime for each zone with the assumption that every zone may benefits and/or not from TM system⁹.

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^0):

$$Y_i^1 = X_{i1}B^1 + e_i^1 \quad (5)$$

$$Y_i^0 = X_{i0}B^0 + e_i^0 \quad (6)$$

As stated above, Y_i^1 and Y_i^0 represent the criminality rate on zone with and without TM presence. Vector B^1 and B^0 are the coefficients associated to X_i observables characteristics and e_i^1 and e_i^0 represent the error terms.

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

$$ATE = E[\Delta] = E[Y_1 - Y_0] \quad (7)$$

where

$$E[Y_1 - Y_0] = E[Y_1 | D = 1] \Pr(D = 1) + E[Y_1 | D = 0] \Pr(D = 0) - \{E[Y_0 | D = 1] \Pr(D = 1) + E[Y_0 | D = 0] \Pr(D = 0)\} \quad (8)$$

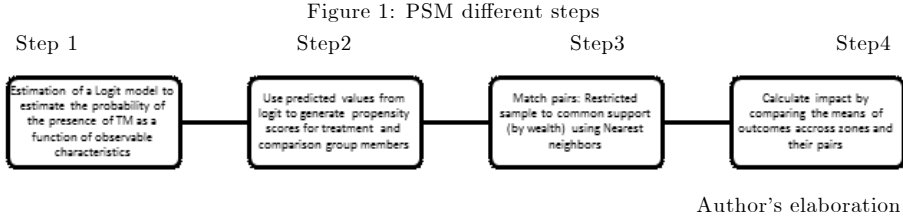
⁹It is not possible to know what could be the crime rate on a zone z_i that benefits from TM system if it do not benefit from it.

Thus, the ATT is note as:

$$ATT = E [\Delta \mid X_i, D = 1] = E [Y_1 - Y_0 \mid X_i, D = 1] \quad (9)$$

$$ATT = E [Y_i^1 - Y_i^0 \mid X_i, D = 1] = E (Y_i^1 \mid X_i, D = 1) - E (Y_i^0 \mid X_i, D = 0) \quad (10)$$

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



If there are statistically significant differences between the crime rates on zones with and without presence of 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.

4.2.2 Spatial Econometric modeling

Nevertheless, after the estimation of the impact of improvements of 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 it, this 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 a diffusion effect of crime between different zones.

Some studies (Anselin 1999; Moreno, Vaya 2008) emphasize on 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.

Thereon, the spatial dependence or the spatial autocorrelation took place if a variable of a zone, in this case if the crime rate of zone i , is related to the same variable on 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, if it leads to a reduction in other zones, it is a negative autocorrelation. Nonetheless, if the variable (crime) is randomly distributed, there is no spatial autocorrelation.

To not forget that, 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 to have multidirectionality problems is high (Moreno, Vaya 2008) and so, OLS estimations may lose their meaning.

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

To develop that 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.

After defining the presence of spatial autocorrelation, the study proceeds to the definition of the type of the most adaptable model.

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

- The spatial lag model that fit covariates or spatial lag to describe mean.
- The spatial error model that assess the residuals and specify error dependence structure inference.

¹⁰ Anselin 1988.

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

5 Results

5.1 Results from PSM methodology

PSM methodology suggests that a Probit or a Logit model should to 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 less, from the presence of one station of Transmilenio even if this station is placed into the zone or along the border of the zone. This study used a logistic function; the dependent variable, Presencetm=1 if there is at less one TM station and 0 if not. The presence of Transmilenio in a zone, even if is 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 variables¹¹.

Table 2: Logit model, marginal effects and elasticity

VARIABLES	Presencetm	Marginal effects	Elasticity dy/dx
Constant	-0.08092 (0.574)		
households	0.00005*** (0.000)	.0000134*** .00001	.2208132*** .08429
hectares	-0.00433*** (0.002)	-.0010762*** .0004	-.404088*** .14846
w_force	0.00001* (0.000)	2.83e-06* .00000	.0808714* .04297
wealth	1.02476** (0.460)	.2507054** .10781	.1614141** .07249
Log likelihood	-66,932795		
Prob>chi ²	0,0004	LR chi ² (4)	20,51
Observations	112	Pseudo R ²	0,1328

Standard errors in parentheses

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

Authors' calculations

¹¹To 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.

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

In the same way, this positive relation is observed with respect to the working force and the “social belonging”: if the population of a zone is in average “not poor”, the probability that Transmilenio pass within or along this zone is higher. In contrast, the probability that a zone benefits from improvements of public transports decrease with respect to its size.

Elasticity of each independent variable has to be interpreted partially and with all other things held constant. It signifies that an increasing of 1% of the number of households on each zone make rise on 0.22%, the probability to have a TM station in a zone. In parallel, if the working force or if the average of “not poor” people increase on 1% on a zone, the probability that this zone benefits of public transports improvements may increase on 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 on the Propensity Score Matching analysis. Five-Nearest-Neighbor option was used to create the sample for analysis¹².

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 to people” committed on zones that benefit from TM is, on average, 133 while

¹²Results 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).

the average number of thefts to people on zone without TM is 78. The biggest difference on thefts committed between these two kinds of zones on 2007 is approximately 54. Those results are statistically significant at 1% level.

Regarding the number to commercial establishments, it can also be seen that the number of events is bigger on zones that benefit from TM than on 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.

In the other side, there are more house breakings on zones benefiting of TM system. Actually, there is, on average, 49.7 house breakings on zone with TM presence and 36.4 on zone without TM system. These results are also statistically significant but at 10% level.

Table 4: OLS results

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

Finally, regarding the number of robberies to people with violent aggressions and homicides, it is also found that they are most frequently perpetrated on UPZ with at less one station of Transmilenio. Nonetheless, these results are

not statistically significant. However, differences of the number of occurrence of the event are very shallow which may implies that such types of crime do not depend in a big proportion or have not a big influence from the improvements of public transports.

In the other hand, in order to confirm the impact of the presence of improvements of public transports on the level of crime on each zone of the city, equation 1 was also regressed as an OLS model. Table 4 denotes that the presence of TM has always a positive impact on crime rates. Actually, among all the independent variables, is “Presencetm” which has the biggest impact on the variable to explain.

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

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

5.2 Results from Spatial econometric methodology

Given that this paper uses geographical data and that it 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 in a first time to establish if there exist a spatial autocorrelation of the different types of crime. To carry out this first step, the most traditional approximation to study the effect of the spatial dependence is the calculation of global statistics (Moran and Getis). These statistics allow the contrast of the hypothesis (null hypothesis, H_0) that says that a variable is randomly distributed on space or if in contrast, there exist a significant spatial likelihood of variables.

Moran’s I statistics has as null hypothesis (H_0), that variables (crimes) are randomly distributed in the space. Null hypothesis for Getis’s G statistics tries to contrast if there is no a spatial concentration of a variable. A rejection of null hypothesis on 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 neighboring 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 crimes, Moran's I statistics are significant at 1% level. It indicates that all type of crime have a spatial dependence. Getis's G statistics suggest that every type of crime presents a geographical concentration except for burglaries to commercial establishments.

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

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

To define the spatial regression model, it is advisable to make some diagnostics tests. The Lagrange multiplier test and the robust Lagrange multiplier test for spatial lags and for 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 to people with violent aggressions". It implies that there is a spatial dependency on the error term and hence, the most adaptable model should be a spatial error model.

In the other hand, LM lag statistics are significant for “thefts to 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, identification test do not have statistical significance regarding burglaries to 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 done 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 (40.866)	4.466 (17.794)	-44.369*** (16.370)	-70.578** (29.710)	-7.118** (3.594)
Improvements	presence TM	25.074* (12.965)	3.160 (4.680)	11.221* (6.308)	16.738* (9.839)	1.244 (1.597)
	hectares	0.108*** (0.033)	0.020* (0.012)	0.077*** (0.016)	0.128*** (0.027)	0.011*** (0.004)
	small-Enter	0.348*** (0.129)	0.102** (0.047)	0.156** (0.063)	-0.039 (0.096)	0.005 (0.017)
Socioeconomic and demographic	density_hect	0.066 (0.074)	0.001 (0.027)	0.090** (0.036)	0.214*** (0.056)	0.045*** (0.009)
	employment	0.001 (0.001)	0.001*** (0.000)	-0.001** (0.000)	0.000 (0.001)	0.000 (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 (0.010)	0.001 (0.003)	0.002 (0.005)	0.005 (0.007)	0.001 (0.001)
	culture	2.923*** (0.929)	0.554* (0.335)	0.624 (0.454)	2.786*** (0.696)	0.153 (0.118)
Amenities	soc_welf	-0.259* (0.138)	-0.029 (0.050)	-0.040 (0.067)	0.354*** (0.104)	0.032* (0.018)
	health	-1.103 (2.140)	-0.262 (0.772)	-1.302 (1.044)	-0.178 (1.593)	0.455* (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, like for OLS results, for spatial lag models, the presence of improvements of Transmilenio in a zone is the variable that has the biggest impact on every type of crime. In parallel, Presencetm coefficient is statistically significant at 10% level for types of crimes on which LM lag and/or LM error statistics are statistically significant (Thefts to people, house breakings and robbery to people

with violent aggressions). Besides, even if their impact is positive, improvements of public transports seem to not have a statistical significant impact on the level of homicides and on the number of burglaries to 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 on this paper.

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

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 people aggression and the biggest is the number of house breakings. Regarding the other socioeconomic 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 on each zone have a negative impact on the number of crime. Sometimes, they have a statistically significant sometimes not. It alludes that the more the number of establishments that promote and provide welfare and health are in a zone the less will be the number of crimes. Regarding the impact of establishments providing cultural activities like cinemas, theatres which generally are placed near big malls, their impact on the number of crimes is positive and statistically significant. It means that crime will be bigger on zones with a big number of that kind of establishments and it can be explained because of the big number of people who frequent these places.

As expected, inasmuch as diagnostics tests reveal, there is not a preferable model for burglaries to commercial establishment and homicides; their spatial autoregressive parameter (ρ) 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 a spatial correlation (Moran and Getis tests showed it before) but it suggests that the model is not the better one for these kinds of crime.

Conversely, spatial autoregressive parameter (ρ) for “thefts to people” and “house breakings” and the coefficient on the spatially correlated errors (λ) for “robberies to people with violent aggressions” 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

All along the paper, this research demonstrated that there exists a positive and significant relation of public transports improvements on the level of crime on each zone of the city of Bogotá.

Firstly, a PSM approach revealed significant differences on the average number 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 improvements of public transports have always 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 on a zone has a positive impact on the level of crime rates on each treated zone. It suggests that improvements of public transports makes raise the level of any type of crimes and this with a statistically significance for crimes without violent aggressions. A causality relationship is almost demonstrated.

Important differences are showed on crime without violent aggressions to people. Burglaries to commercial establishments are 78.02% most frequent on zone with at less, one Transmilenio station. Regarding the number of thefts to people, the difference is close to 69% and 36.7% for house breakings.

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

Offenders, which do not use Transmilenio, may also benefit from those improvements of public transports. Actually, with the construction of Transmilenio there is an upgrading of corridors alongside Transmilenio corridors which is traduced on an enhancement of travels made by private cars all along TM corridors.

Nevertheless, results have to be interpreted with a lot of care. The fact that this study has not 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 improvements of public transports on zones with high crime levels. However, PSM results demonstrate that, if the time characteristic is not taken in consideration, predictors based on a logistic

regression that defines the presence of TM stations on a zone have a positive and a causal relation with crimes without violence on any zone of the city.

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

Once demonstrated the big incidence of improvements of public transports on crime, it was also very important to know if there is diffusion or a contagion effect of delinquency among the zones composing the city.

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

Regarding spatial regressions, diagnostic tests suggest that when thefts to people, house breakings and robberies to 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.

The other types of crime like homicides and burglaries to 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 do not reflect the “absence” of spatial dependence of these types of crime but it may suggest that for these crimes, explain variables could be others than those proposed on models suggested.

Explain variables that represent “socio-economic and demographic characteristics” have always a positive effect and in some cases, a statistical significance on the level of crime. Variables from this group that have the 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 aggressions) and the density of each zone (regarding crime with violent aggressions and house breakings). It suggests that the more there are small enterprises on a zone, the higher will be the crime rates without violent aggression. It could be explained because of the fact that, generally, small enterprises in Bogotá make part of commerce and services sectors. Actually, if there are more small-enterprises on a zone, density will be higher during the day and so the potential victims of that type of crimes will be higher. Streets and commercial establishments will be most frequented and hence, it will make easier for offenders to commit their crimes. The number of establishments promoting cultural events has the same effect on crimes and could have also the same reason than the number of small-enterprises.

Conversely, the other two variables grouped as “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 aggressions on zones. It suggests that if there is more of that kind of establishments, offenders will be less motivated to commit crimes joining the thesis of Hipp (2007) regarding the six theories of crime.

Finally, regarding improvements of public transports, like on 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. According to what it was explained on precedent paragraphs, this variable is statistically significant only for the three types of crime on which diagnostics tests are statistically significant (spatial lag model and/or spatial error model). However, this research demonstrate the big and direct incidence of public transports enhancements 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 deep on the subject. After the compilation of those data it may be possible to determine the exact impact of public transports improvements on crime rates of any zone of the city. However, despite the fact that this research could not make an analysis along time, it represents an important study with strong evidences of what it can be called as a “boomerang effect” of improvements of public transports.

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