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Impact of urban public transport enhancements on crime rate: a diff-diff analysis for the case of Transmilenio

Carlos Augusto Olarte Bacares*

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Abstract

One of the biggest questions of agglomerations today focuses on the problem of the public transport supply. To deal with this, Bogota has developed a new urban transport system that has had worldwide recognition since 2000: Transmilenio. While most studies have focused on studying the impact of this new public transport system with respect to the environment, hedonic prices, employment and urbanism, among others, none (except one) have studied the question of the evolution of crime linked to the existence of Transmilenio. The aim of this article is to demonstrate that the evolution of urban transport, which is traduced on the construction and on the improvements of Transmilenio, has had a direct impact on the crime rates in the city. By collecting a set of spatially referenced data regarding crimes in 112 of the 117 planning zones that make up the city, this research follows a differences-in-differences methodology to test the causality of the transport system in the evolution of crime rates in each zone for different periods. After a deep descriptive analysis of data and the implementation of the econometric methodology suggested, results indicate that enhancement of the public transport system has had no clear impact on crime rates in all zones of the city. Depending on the zones and on the Transmilenio line in question, the transport system may increase or decrease the number of crimes on each zone beneficiaries or not from the improvement of the system. However, this research gives a non-negligible number of hints to take in consideration on further studies.

JEL Codes: K42, R23, R49

Keywords: Improvements of public transports; Crime; Causality; Differences in differences.

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1 INTRODUCTION

1.1 Literature review and research question

From the early seventies, crime began to be studied from the point of view of Economics¹. This new theory, called “the theory of crime”, was supported by the fact that criminals are rational and hence are able to compute their expected utilities with respect to the probability of being caught by the forces of law and order. In addition, this theory rests on the fact that criminals have the capacity to make a cost/benefit analysis between their expected utility when they commit a crime and their expected utility if they undertake another kind of “lucrative” activity at the same time.

Since this first study that gave birth to the theory of crime, several researchers have confirmed that the empowerment of police in the city has a negative effect on the spread of criminality (Ehrlich 1975, Bryett Freeman 1996, Glaeser 1996) between others. However, as Moreno (2005) remarked in his research, Cameron (1988) demonstrated that this effect is not very easy to underline because of the lack of data² on cities and also because the decision to increase police presence is also due to the fact that, generally, previous to empowerment of the police in zones, crime was rising³.

Nonetheless, the issue of urban crime has not been only considered from the theory of crime. Research by Glaeser, Sacerote (1999), Brueckner, Thisse, Zenou (1999) and Morselli, Royer (2008) has studied this topic from the point of view of the urban form and the urban transport in the city.

Those researchers, and several others, have well demonstrated that development and enhancement of public transport has a positive impact on the insertion into the employment market of inhabitants of a city and its surroundings (Donzelot 2004, Zenou 2000). The effect of this insertion of inhabitants into the job market has a direct effect on the criminality in cities⁴. In effect, this fact has as its consequence a decrease in crime rates in the city because of the lower motivation of inhabitants to commit crimes; thus, an increase in social interactions takes place (Glaeser, Sacerdote, Scheinkman 2004, Brueckner 2001, Zenou 2003). This reduction of crimes and increased social interaction is, in general, more evident in poor neighbourhoods than in rich ones (Donzelot 2004, Barse 1996).

¹Gary S. Becker. (1968). “Crime and Punishment: An Economic Approach” *Journal of Political Economy*, Vol. 76, No. 2, pp. 169-217

²Data are generally available for the entire city as a whole and not for each of the zones that compose the city” Moreno 2005.

³It perfectly follows the theory of “Broken windows”; Wilson J.Q. and Kelling G.L. 1982.

⁴Note that in this research, criminality and crime will enclose five types of criminal activities and do not take in consideration “large-scale crime”.

Additionally, studies about crime have incorporated a spatial approach that has taken on greater importance in the past two decades – see Freeman et al (1996), Anselin (1998), Cohen, Tita (1999), Formisano (2002), Di Tella, Zenou (2003), Schargrotsky (2004) and Moreno (2008), among others.

However, even if there are several studies that have already looked at the spatial dependence, spatial dissemination and/or spatial configuration of crime, no studies treating links between and the possible effect of public urban transport on crime evolution were found, except the study by Moreno (2005).

The originality of this research consists in proving that the evolution of urban crime could be boosted or decreased by the presence or lack of such of enhancements of public transport or by the development of new public urban transport. More precisely, this study intends to prove that, even if the total criminality in a city may decrease after the implementation of a new urban transport system, there could also be adaptation of criminals in some zones of the city. In other words, criminals may also enjoy the benefits of the new system in order to commit their crimes in zones which they could not access before. A spread of some types of crimes in some areas affected by the new transport system may take place. This research tries to prove that hypothesis.

1.2 Contextualization of the case of study

This study focuses on the city of Bogotá, which is one of the most densely populated cities in Latin America and the world but, paradoxically, does not have a subway system or a system of trams. The city has more than seven million inhabitants and was part of the group of cities considered the most dangerous in the world in the early 2000s.

Bogota is divided into 117⁵ zones composed of around 2350 neighbourhoods. Each neighbourhood has a socio-economic status which is calculated with respect to the amenities of each neighbourhood, the materials with which the house is built, the degree of accessibility for inhabitants of each neighbourhood and many other characteristics of the houses and the quarters correlated to the level of income of people. There are six socio-economic strata: stratum 6 denotes the population with the highest level of income and strata 1 denotes the poorest population of the city.

From 1960 until the end of the 1990s, the city had a chaotic urban transport system served by old buses and taxis of different kinds and different sizes. The service of public transportation was assured by private entrepreneurs (more than 60!) and public administration did not play a part in the utilities of

⁵UPZ in spanish “Unidades de Planeamiento zonal” or “zonal planning units”

the system. Its role was just that of “regulator”; it assigned and defined the buses’ lines as well as the companies that had to assure the service⁶. This method created inefficiencies regarding the quality and coverage of the service in all zones that compose the urban area, in parallel with several problems of corruption. Actually, some deputies that made part of the council of the city and that had as task to define the companies to assure the service on the city have been involved in affairs of corruption and clientelism.

At the end of the 1990s, the elected mayor⁷ decided to reform the public transport system managed by private entrepreneurs into a system managed by a public-private partnership. With the new system, public administration has a core role in the regulation of the system, allocation of lines, administration and the exploitation of the new system.

Since its opening in December 2000, this new public transport system, called Transmilenio (henceforth TM), based on an integrated Bus Rapid Transit (BRT) system, has had a reputation as one of the most popular and successful BRT systems in the world. Mobility in the city changed radically, with a notable reduction in travel times and continued expansion of the system to various zones of the city. Today the system reaches more than 50% of zones of the city, and although the old system with old buses is not closed, TM system moves about 1.8 million passengers per day, representing almost 15% of total daily trips in the city, at an average speed of 27 km/h.

As stated above, the objective of this research is to determine if the TM system induced positive or negative changes on levels of different types of crime. In order to face of this hypothesis, this research compares crime rates taking into account the period (after or before the opening of TM system) and also identifying the zones that benefit from the system or do not.

To treat the subject of this research, the paper proceeds as follows. After a brief literature review and a brief contextualization of the case under study in this first section, section 2 describes available data. Section 3 describes the econometric methodology used in the paper. Empirical findings are presented in section 4 and conclusions are offered in section 5.

⁶ Administration used to define the lines and to assign the “winner” entrepreneurship after doing a call of tender

⁷ Enrique Peñalosa was elected for a period of three years : 1998-2000

2 AVAILABLE DATA AND DESCRIPTIVE ANALYSIS OF DATA

This paper uses a big and very rich database of each crime in the city between 2003 and 2008⁸. The collection of crimes was possible through collaboration with the “Conflict Analysis Resource Center”⁹ and with the permission of the Metropolitan Police Department of Bogotá (MEBOG). It supposes that every crime was spatially referenced with the exact addresses and the exact day and time when each incident took place. In order to organize the information for each UPZ, this study clusters all the events to their respective UPZ.

This research is focused on five types of crime:

- Number of homicides
- Number of robberies carried out against people with violent aggression
- Number of thefts against people
- Number of burglaries of commercial establishments
- Number of house breakings

This research focuses on comparison of the number of crimes and on an econometric analysis of crimes committed in each UPZ before and after the opening of TM. Table 1 describes the statistics for each type of crime on zones that are benefiting and those that are not benefiting from the TM system.

In addition, this study captures data of crimes committed after the inauguration of the two first corridors, “Calle 80” and “Caracas”, on December 2000, but before and after the opening of the three other sections of TM¹⁰.

In effect, TM is a transport system planned to have more than 13 corridors. Three other corridors were opened after 2000. The first one is called “Americas” and was opened on December 2003. As this paper uses data from January 2003 to December 2008, the analysis takes into consideration crimes committed 12 months before the opening of the corridor called "Americas" (from January 2003 to 31 December 2003) and 12 months after its initiation (from 1 January 2004 to 31 December 2004).

⁸More than 150.000 incidents were recorded during the period between 2003-2008

⁹In spanish: Centro de Recursos para el Analisis de Conflictos - CERAC

¹⁰Transmilenio has today seven different main corridors: Troncal 80, Caracas, Autopista Norte, Americas, NQS and Suba. From 2012, two new corridors were opened (Carrera, 10 and Avenida 26)

Regarding the two other corridors that were opened later (NQS and Suba¹¹), this study takes into consideration data of crimes committed 18 months before and 18 months after their opening.

The last five lines of table 1 indicate some characteristics of each zone, such as amenities, area and density, among others. Nonetheless, these data were not available for every year and every UPZ of the city; thus, the study considers that they are constant over time. This study uses these data as control variables.

Table 1: Descriptive statistics before and after the opening of each corridor of TM

TM Section	Variable per UPZ	Label	Obs	Before TM				After TM			
				Mean	Std. Dev	Min	Max	Mean	Std. Dev	Min	Max
Americas	Thefts to people	crimeteft	112	72,5	43,68	16	138	50,7	30,8	14	123
	Burglaries to commercial Establishments	crimecom	112	43,5	23,61	12	77	41,9	25,65	15	99
	House Breakings	crimehouse	112	32,6	29,76	1	91	27,1	18,75	3	55
	Homicides	homicides	112	23,6	23,87	2	76	19,6	23,31	0	74
	Robbery to people with violent aggresions	agresions	112	87,22	67,79	3	226	87,36	79,35	2	285
NQS	Thefts to people	crimeteft	112	112,95	70,08	6	230	178,9	113,82	0	394
	Burglaries to commercial Establishments	crimecom	112	85,04	76,17	1	300	81,45	74,41	0	317
	House Breakings	crimehouse	112	56,81	39,58	0	131	51,27	39,26	0	155
	Homicides	homicides	112	23,4	20,05	0	76	19,27	17,83	0	74
	Robbery to people with violent aggresions	agresions	112	87,22	67,79	3	226	87,39	79,35	2	285
Suba	Thefts to people	crimeteft	112	231,30	122,19	14	387	230,13	112,09	18	399
	Burglaries to commercial Establishments	crimecom	112	126,30	75,35	6	239	125,87	84,76	18	308
	House Breakings	crimehouse	112	125,87	95,92	3	310	94,75	60,65	5	198
	Homicides	homicides	112	22,25	19,72	0	63	22,25	20,82	2	62
	Robbery to people with violent aggresions	agresions	112	181,25	175,12	25	539	223,62	242,42	18	728
Others	Area of the zone in hectares	hectares	112	375,47	180,08	79,83	992,33	375,47	180,08	79,83	992,33
	Number of inhabitants per hectare	density_hec	112	181,16	105,27	1,00	526,00	181,16	105,27	1,00	526,00
	Establishments providing Cultural activities	culture	112	8,12	8,18	0,00	40,00	8,12	8,18	0,00	40,00
	Establishments promoting Welfare	soc_welf	112	63,25	63,83	0,00	288,00	63,25	63,83	0,00	288,00
	Establishments provinding Health	health	112	3,53	3,24	0,00	15,00	3,53	3,24	0,00	15,00

Author's calculations

Regarding data from table 1, it can be observed that with respect to the “Americas” corridor the average number of every type of aggression decreased, except the average number of robberies against people involving violent aggression, which did not change. In the case of the “NQS” corridor, the average number of burglaries of commercial establishments, the average number of house

¹¹ “NQS” corridor opened on July 2005 and « Suba » corridor opened on May 2006.

breakings and the average number of homicides decreased. Nevertheless, the average number of robberies against people with violent aggression did not change and the average number of thefts from people increased. Finally, regarding the “Suba” corridor, just the average number of house breakings decreased after the opening of TM; the average number of robberies against people involving violent aggression increased significantly and the average number of the three other kinds of crime did not change.

Those remarks could suggest that the impact of TM on each type of crime depends on the moment, the zone and other characteristics of each zone. On the other hand, it may also suggest that the opening of TM did not have an effect on crime rates.

In effect, another fact, that there is non-negligible, is the difference in the number of amenities in UPZ with TM system and UPZ without TM system. Table 2 shows that UPZ which benefit from TM have a higher number of amenities than those which do not benefit from the system¹². These differences vary between 20% and 37%. Nonetheless, there are two kinds of amenities among the seven taken into consideration that are more numerous in UPZ without the TM system: the number of establishments providing cultural activities and the number of establishments providing social welfare, at 13% and 17% respectively.

Table 2: Amenities UPZ with vs without TM system

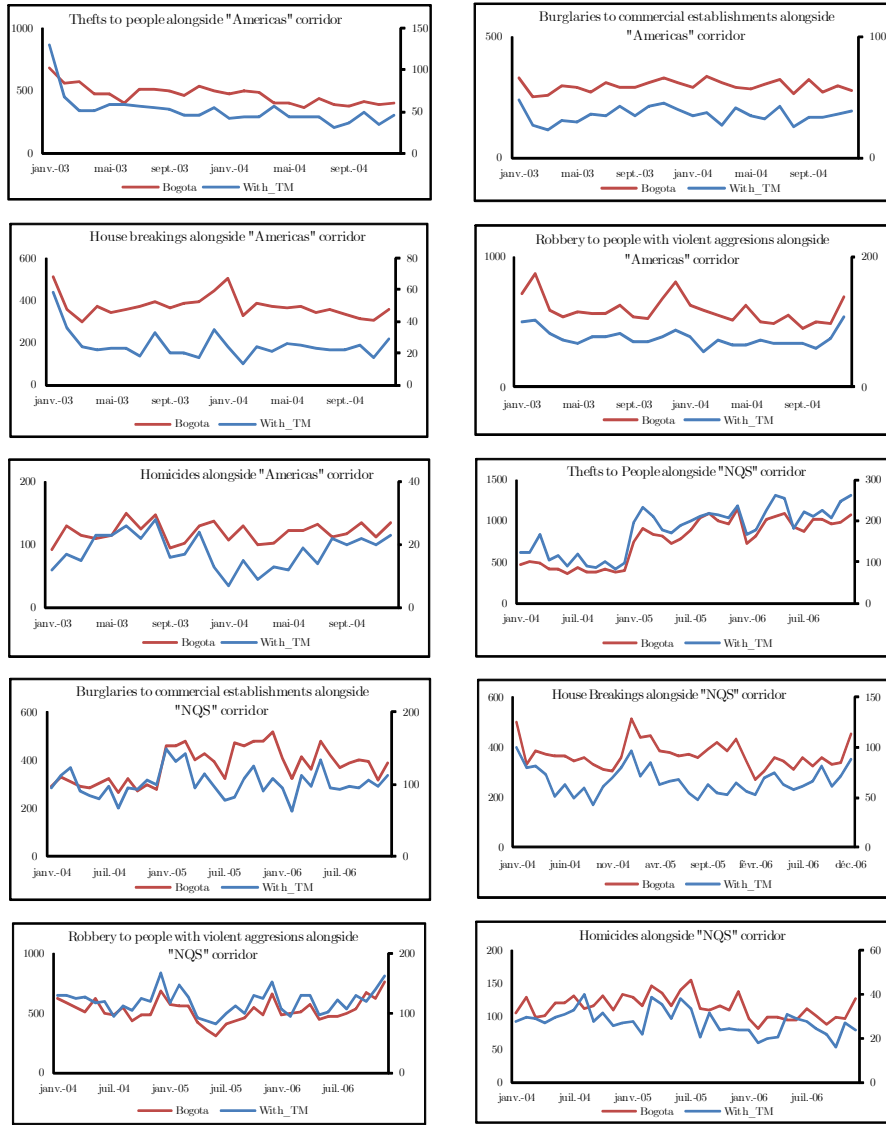
		sec	justice	rec	sport	culture	education	health	soc_welf	parks	Total
Americas	No TM	0,98		11,66		8,28	33,08	3,45	65,38	49,66	172,49
	TM	0,55		9,18		6,64	29,82	4,27	43,73	36,00	130,18
	Diff	-44%		-21%		-20%	-10%	24%	-33%	-28%	-25%
NQS	No TM	0,87		10,44		8,55	31,33	3,10	65,37	47,94	167,60
	TM	1,22		15,22		6,43	38,30	5,17	55,04	49,78	171,17
	Diff	41%		46%		-25%	22%	67%	-16%	4%	2%
Suba	No TM	0,92		10,91		8,04	31,70	3,60	61,07	45,60	161,84
	TM	1,13		18,00		9,13	46,50	2,63	91,63	83,75	252,75
	Diff	22%		65%		14%	47%	-27%	50%	84%	56%
All zones	No TM	0,88		10,15		8,49	29,76	3,14	67,04	44,50	163,95
	TM	1,05		13,89		7,39	38,61	4,29	55,87	55,76	176,87
	Diff	20%		37%		-13%	30%	37%	-17%	25%	8%

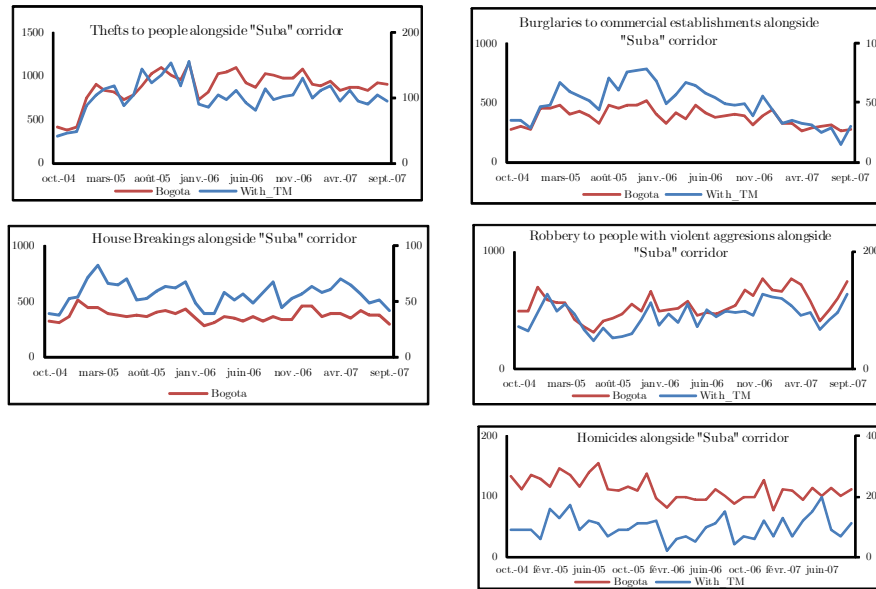
Authors' calculations

Regarding the differences of amenities between each TM corridor, table 2 shows that for the “Americas” corridor, zones that are beneficiaries of this transportation system have fewer amenities than zones not passed by the “Americas” corridor. On the contrary, with respect to two other corridors, the number of amenities is higher in zones benefiting from the “NQS” and “Suba” TM corridors.

¹²Last line of the table 2

Figure 1: Criminology on each zone vs criminality on citywide





Author's calculations

Graph 1 presents the dynamism of each type of crime in each of the three zones studied on that paper. This dynamism is shown by the evolution of each type of crime before and after the opening of the three TM corridors. As stated above, the analysis takes into account crime rates over 36 months (18 months before and 18 months after the opening of TM). However, because of the impossibility of gaining information on crimes in 2002, only 24 months were taken into account (12 months before and 12 months after) in the analysis of crime along the “Americas” corridor.

Regarding the evolution of crime with respect to the “Americas” corridor, graph 1 shows that every type of crime decreased after the opening of TM, with the exception of the number of homicides. In effect, contrary to table 1, graph 1 shows that after the inauguration of TM, the totality of homicides did not change in zones reachable by TM but increased citywide.

On the other hand, crimes in the “NQS” corridor had a different evolution. The number of thefts from people increased in zones reachable by TM and also in the other zones of the city after TM opened its service. Regarding the number of burglaries of commercial establishments and the number of robberies against people with violent aggression, crimes did not experience major changes after the implementation of TM. Similarly, these crimes increased when citywide data was taken. House breakings also increased in zones benefiting from TM after the implementation of the system; the opposite was the case with respect to the total number of crimes in the city. Finally, the number of homicides decreased after the opening of TM, both in zones reachable by TM and citywide.

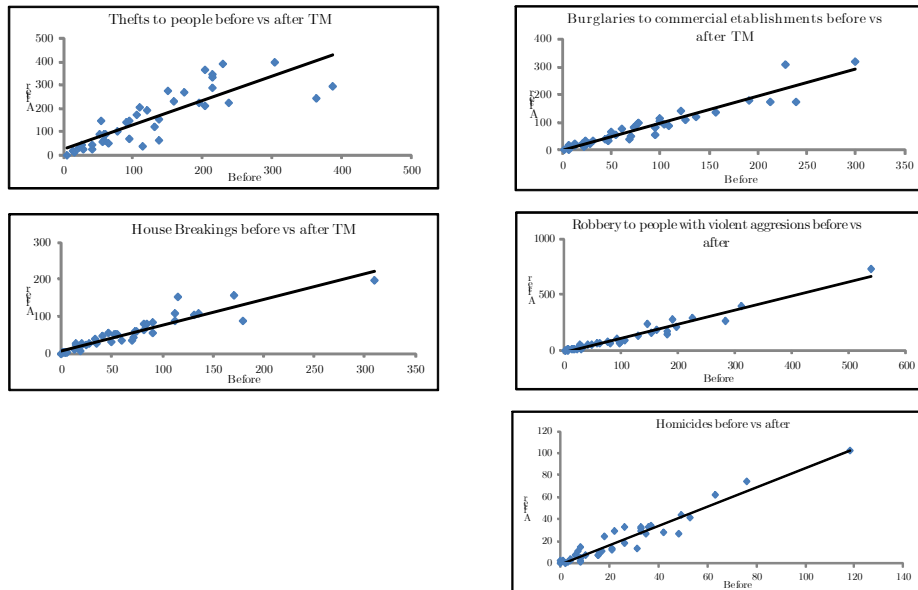
Regarding crimes in zones connected to the “Suba” corridor, except for a decrease in the total of burglaries of commercial establishments, crime rates did not change after the opening of the TM system. The same is the case for the rest of the city. It may be inferred that the TM system had a positive effect just on burglaries of commercial establishments; other types of crime were not influenced by this system of transport.

To complete the description of the available data by each type of crime, this article intended to establish a comparison of crime rates before and after the implementation of the TM system by UPZ just on the three zones that are the object of analysis. Graph 2 presents the levels of the five types of crime in each UPZ that benefited from TM before and after its opening.

Each point of the graphs represents one of 38 UPZ connected to at least one of the three corridors analysed. The horizontal axis denotes the number of crimes before the introduction of TM and the vertical one denotes the number of crimes after the opening of the TM system.

The dots placed above the diagonal are the areas where crimes increased after the inauguration of the transportation system. It means that if the level of crimes decreased in a zone, the point that represents this zone will be below the diagonal line.

Figure 2: Criminology on each zone that benefit before and after the opening of TM



Author's calculations

In graph 2 it can be observed that on 17 of 38 UPZ concerned, present an increasing of the number of thefts to people after the introduction of TM. In other words, almost the 45% of the zones connected to at less, one of these three corridors of TM, had an augmentation of this type of crime. Concerning the number of burglaries of commercial establishments, 16 of 38 UPZ (42%) experienced an increase in that type of crime, similar to the number of house breakings, which increased in 14 of the 38 UPZ (37%) connected to the three corridors concerned. The number of UPZ where crimes on that the integrity of the people is threatened (robberies to people with violent aggressions and homicides) increased on less UPZ (6/38 and 10/38, 16% and 26% respectively).

3 METHODOLOGY

This research is focused on establishing the possible effect (negative or positive) of three main corridors of the Transmilenio system with respect to the number of crimes in different zones that compose the landscape of Bogotá. In order to identify a possible causal relationship between the TM system and its effect on criminality, this article decided to implement the “Difference in Difference” method¹³.

This methodology, which has become widespread since the initial work by Ashenfelter and Card (1985), deepened by other researchers like Millainathan (2004), Hansen (2007a, b) among others, has as its principal objective to determine the causal relationship between the implementation of a policy and its possible outputs on different groups. The goal of this technique is to evaluate the impact of a policy on output over different groups in two time periods. Those groups are indexed by treatment status. One part of the sample is supposed to be a beneficiary of the treatment in the second period but not in the first period; this represents the treatment group. The other part of the sample is not supposed to benefit from the policy in either period but, even if they are not influenced by the policy, their characteristics are very similar; they represent the control group.

Mathematically, the outcome of interest for this study (total crime of each UPZ i), Y_i is denoted by:

$$Y_i = \alpha + \beta T_i + \gamma t_i + \delta(T_i.t_i) + \theta X_i + \varepsilon_i \quad (1)$$

¹³Diff-diff from now

With:

α = constant term

β = treatment group specific effect

T_i = binary variable: $T = 0, 1$ where 0 indicates zones i that do not benefit from TM system and 1 indicates zones i beneficiary from TM system

γ = time trend common to control and treatment groups

t_i = the two time periods: 0 represents the time period before the implementation of the policy and 1 represents the time period after the implementation of the policy

δ = diff-diff estimator which represents the true effect of the implementation of TM system

θ = effect of some explicative variables or covariates (in the model treated on this paper, they are constant¹⁴)

X_{ni} n explicative variable of each UPZ i .

ε_i random unobserved “error”. It supposes that the error term is on average zero: $E[\varepsilon_i] = 0$ and that it is not correlated to other variable of the equation.

As shown in Equation 1, the number of crimes committed in each UPZ i is denoted by the output Y_i over a sample of 112 different UPZ that compose the city. The diff-diff estimator δ is defined as the difference in average output in the treatment group before and after the opening of the TM system (those that benefit from the TM system) minus the difference in average output in the control group before and after the opening of TM in each UPZ (those that do not benefit from TM system).

Regarding the diff-diff estimator, it takes the following form:

$$\delta = Y_1^T - Y_0^T - (Y_1^C - Y_0^C) \quad (2)$$

Where:

Y_0^T and Y_1^T denote the sample averages of the outcome for the treatment group before and after the TM opening. Y_0^C and Y_1^C denote the sample averages of the outcome for the control group before and after the TM opening.

To verify if the criminality in the UPZ served by the three relevant different corridors of TM is determined by the opening of the system, Equation 1 is regressed. After regression of Equation 1, the significance of δ is tested in order to find the significance of the estimator. It will indicate if there are also differences in crime rates between treatment and control groups after and before

¹⁴Covariates are constant due to the impossibility to have this information for each zone and each year.

the opening of the system and if there is a positive or negative impact of the TM system on crime rates on each UPZ.

Regarding the regressions, this study makes one regression for each kind of crime with respect to each of three corridors of TM that are the subject of this research. It supposes one result for each type of crime for each corridor. There are five types of crime and three corridors, which means that there are 15 results (five for each corridor).

Equation 1 takes the following form:

$$Y_{ij}^k = \alpha + \beta T_i + \gamma t_i + \delta(T_i.t_i) + \theta X_i + \varepsilon_i \quad (3)$$

Where k = one of the five type of crime and j = one of the three corridors, “Americas”, “Suba”, “NQS”

Thus, Y_{ij}^k represents the number of crimes of type k committed on UPZ i and with respect to the corridor j .

4 RESULTS

After applying the diff-diff method, table 3 displays results for each corridor and for each type of crime.

Regarding the “oldest” corridor, “Americas”, which takes into account crimes 12 months before and 12 months after the opening of TM, it can be observed that there are two types of crime that increase because of the implementation of the system: the number of thefts from people and the number of robberies against people with violent aggression increase in the 12 months that follow the opening of TM. Nonetheless, this increase is not statistically significant.

On the other side, the amount of the other three types of crime decreased due to the implementation of the system. However, the only statistically significant estimator is the one regarding the number of homicides on that corridor. The others two do not have statistical significance.

Regardless of the type of crime, the total number of crimes increases due to the TM. Nevertheless, it is not statistically significant. It can be explained because of the big difference in the estimators between those which increase (thefts from people and robberies against people with violent aggression) which are not statistically significant, and those which do not increase (the rest).

Table 3: Diff-Diff results

Type of Crime	Americas (2003-2004)	NQS (2004-2006)	Suba (2005-2007)	All period (2003-2007)
Thefts to people	2,344	-1,516	-2,993	-1,810
Burglaries To Commercial Establishments	-0,255	-2,883***	-1,318	-1,363*
House Breakings	-0,587	-0,756	1,513	-0,010
Robbery to people with violent aggresions	0,516	0,007	1,746	2,654
Homicides	-0,772**	-0,429*	0,617**	0,288
Total type of crimes	0,650	-4,300*	-2,709	1,528

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

Authors' calculations

Concerning criminality with respect to the “NQS” TM corridor, table 2 shows that, contrary to what is observed for the “Americas” corridor, robberies against people with violent aggression represents the only type of crime that increases after TM. Nevertheless, this estimator is not statistically significant. It means that the number of thefts from people decreases, as does the number of burglaries of commercial establishments, the number of house breakings and the number of homicides.

However, just two estimators of these types of crime are statistically significant: those of the number of burglaries of commercial establishments and the number of homicides (statistically significant at 1% and 10% respectively).

This may infer that the implementation of the TM system on the “NQS” corridor led to a decrease, with statistical significance, of the number of those types of crime. In effect, these coefficients indicate that there is a difference on 2.883 and 0.429 crimes between the UPZ that benefit from TM and those that do not benefit from the system.

Results of the regression of the totality of criminality show that the number of crimes decreases statistically significantly (10%). It may be explained by the fact that just one kind of crime increases while the other four types of crimes fall.

Regarding the “Suba” TM corridor, results are also different. In effect, just two kinds of crime decrease due to the TM system: the number of thefts from people and the number of burglaries of commercial establishments. Nevertheless, these estimators do not have statistical significance.

Among the other types of crime that increase due to the TM corridor “Suba”, just the number of homicides has statistical significance (at 5%). The amount

of the other two types of crime grows but in a lower proportion with respect to the decrease in the other types of crime, which may explain the results for the total of crimes.

In effect, results from the regression of the total number of crimes with respect to this corridor indicate that the diff-diff estimator is negative. This means that the total number of crimes decreases due to the opening of the “Suba” corridor.

The last column of table 2 shows that, regardless of the TM corridor, between January 2003 and November 2007¹⁵ two types of crime increase because of the TM system. In effect, the diff-diff estimator shows that the number of robberies against people with violent aggression and the number of homicides are higher due to the implementation of the TM system in the city. Nonetheless, these estimators are not statistically significant.

The other three diff-diff estimators indicate that, due to the TM system, the amount of that type of crime was reduced. However, just one estimator among these three types of crime is statistically significant at 10%: the number of burglaries of commercial establishments.

Regardless of the type of crime and the corridor, the total number of crimes increased between January 2003 and November 2007, but the estimator is still not statistically significant.

A summary of table 3 may be provided. It shows that:

- TM causes an increase in the number of thefts from people just for the “Americas” corridor, but the diff-diff estimator for this variable is never statistically significant.
- The number of burglaries from commercial establishments decreases on every corridor and also for the period between 2003 and 2007 because of TM system; the diff-diff estimator is only statistically significant for the “NQS” corridor.
- House increase just with respect to the “Suba” corridor. The estimator has no statistical significance.
- The number of robberies against people with violent aggression increases on every corridor, and also regardless of the corridors (fourth column), due to the opening of the TM system. Nevertheless, this estimator has no statistical significance.

¹⁵Twelve months before the opening of « Americas » corridor and 18 months after « Suba » corridor

- The number of homicides with respect to the opening of TM corridors decreases on “Americas” and “NQS” corridors but increases on the “Suba” corridor. These estimators are always statistically significant.
- Regardless of the type of crime, criminality decreases on the “NQS” and “Suba” corridors but increases on the “Americas” corridor due to the opening of the TM system. Regardless of corridor and types of crime, criminality increases between 2003 and 2007 due to the implementation of the TM system.

Finally, as stated above, it can be noticed that the only corridor that presents an increase in criminality is “Americas”. In parallel, it is also the only corridor that presents fewer amenities in zones that benefit from TM with respect to the number of amenities in zones that do not benefit from the TM system. However, amenities are invariant for every period, which limits the analysis of this article regarding the importance of the impact of amenities on crime rates with respect to transport system enhancements.

5 CONCLUSIONS

Several researchers have studied the link between public transport and its impacts on urban density, urban employment and hedonic prices. This paper has tackled the impact of enhancement of public transport on five different types of urban crime in 112 different zones of Bogotá.

Results suggest that the enhancement of the public transport system represented by the introduction of a new public transport system has a causal effect on crime rates.

However, results are not homogeneous on all corridors regarding all types of crime. Even if a causality relation is demonstrated for some corridors of Transmilenio, it suggests that the impact of public transport improvements on crime rates for each zone of the city is not unidirectional.

Notwithstanding this, two types of crime have constantly evolved with respect to the opening of three different corridors of Transmilenio: the number of burglaries of commercial establishments and the number of robberies against people with violent aggression. The first one saw a reduction in the number of crimes while the second experienced an increase in the number of crimes.

Among the five types of crime that were the object of this paper, just one type has statistically significant results which imply that the TM system has a direct impact on that type of crime: homicides. However, the impact is not

the same on the three corridors that are object of this study, reinforcing the fact that, even if TM has a direct effect on crime rates, this effect does not only depend of the presence of TM. Other variables may influence this evolution.

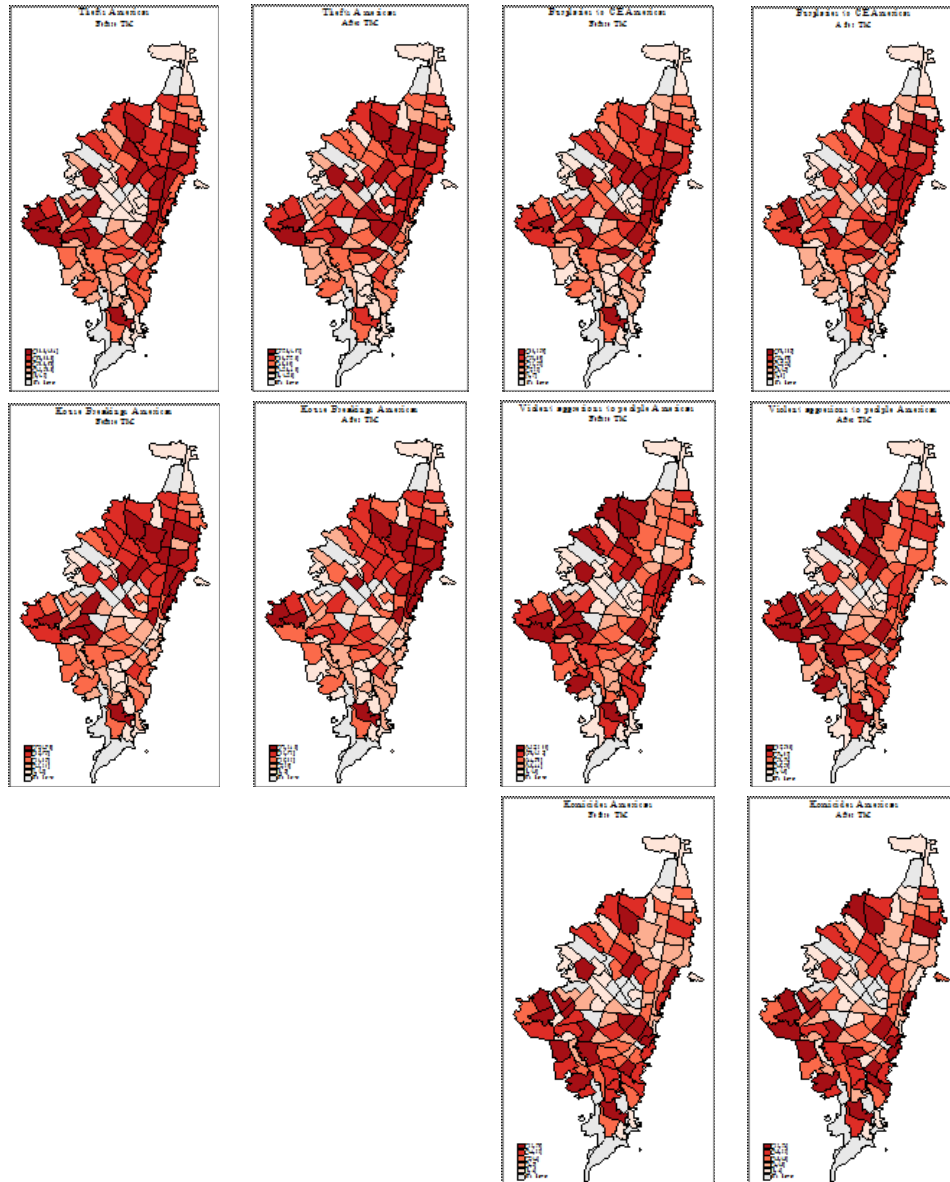
Regardless of the type of crime but taking into account total criminality on each corridor of the TM, this paper found that crimes increased in just one of those corridors due to the construction of TM: it is the case of zones that benefit from the “Americas” section. The Transmilenio system seems to be the principal cause of this increase. Nonetheless, an important question about this result emerges with respect to the amenities of each area that make up the city.

Along this Transmilenio section, the zones benefiting from the system have fewer amenities than the ones that do not. This may suggest that the number of amenities in each zone of the city has also an important effect on crime rates. Nevertheless, data regarding amenities are invariant because they are not available for each zone and for each period. A study with data for each zone and for each period should be done to confirm this hypothesis.

Finally, it is well known that behaviours like criminality may have a spatial dependence or a spatial correlation that may clarify in a better way the evolution of crime rates in different zones of a city. A study focusing on this last subject should be done.

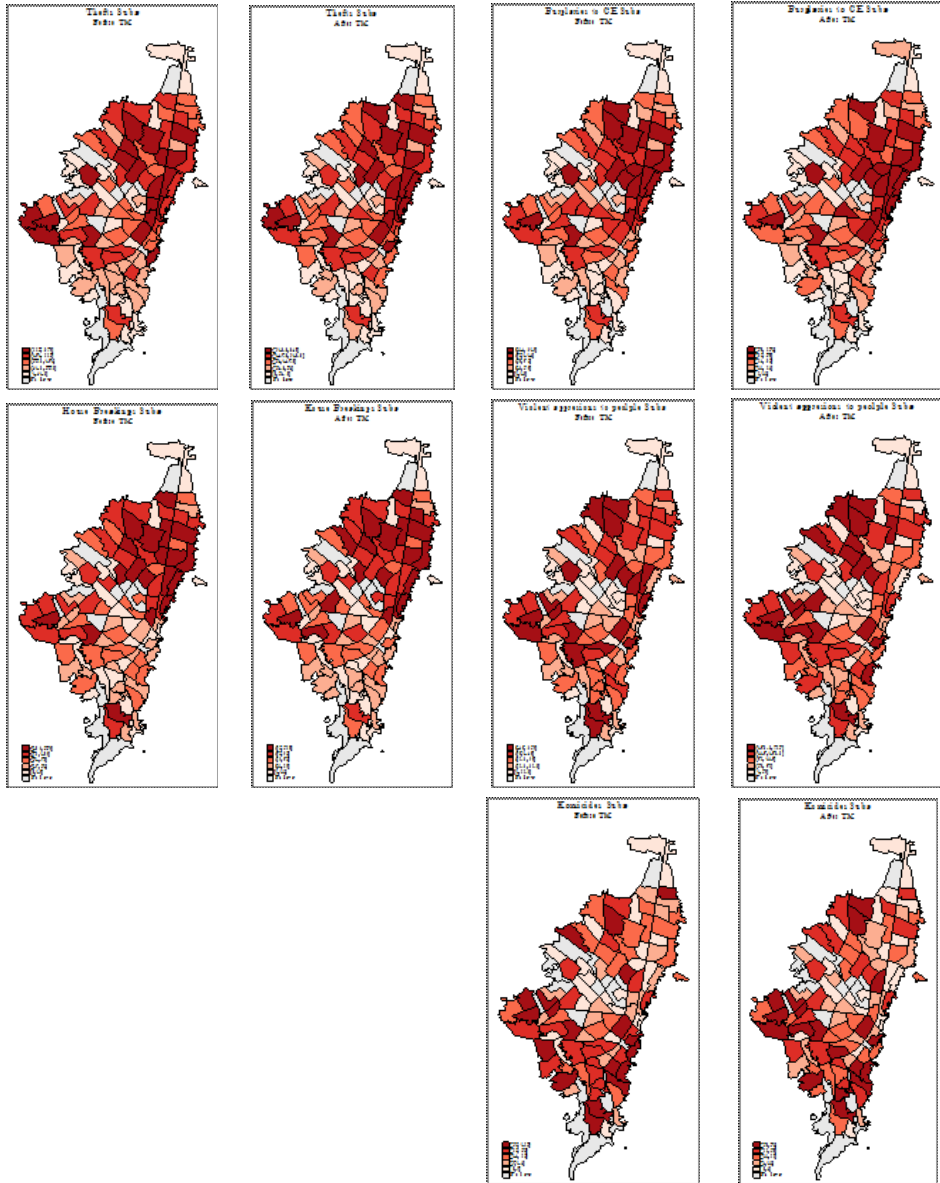
6 Annexes

Evolution of criminality on TM corridor “Americas”; before vs after



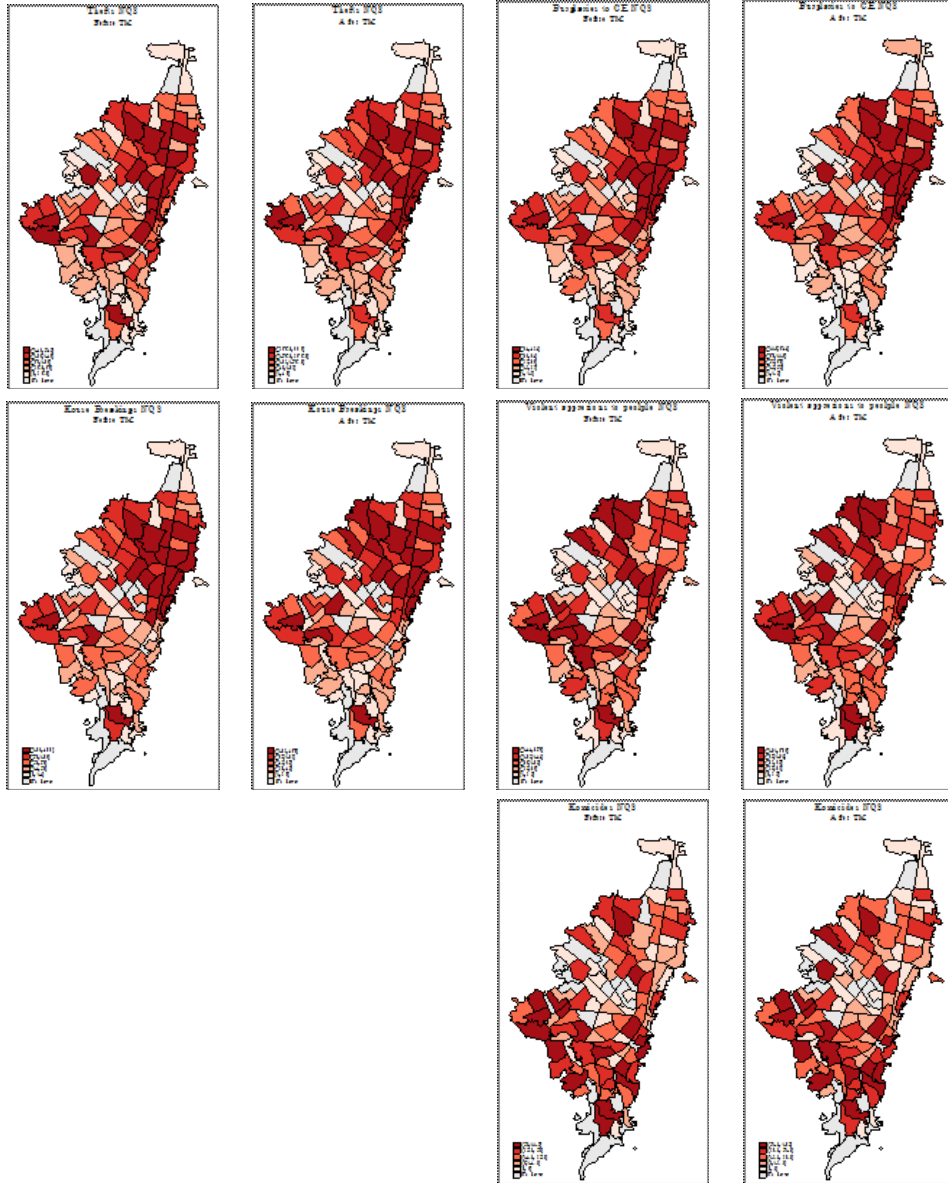
Author's calculations

Evolution of criminality on TM corridor "Suba"; before vs after



Author's calculations

Evolution of criminality on TM corridor "NQS"; before vs after



Author's calculations

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