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Research paper

Housing prices, buses and trams in Medellín (Colombia)

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ABSTRACT

This paper aims to establish the impact of two medium-capacity transportation systems (MCTS) on housing prices in Medellín (Colombia): Metroplús, a bus rapid transit (BRT) system, and Tranvía, a tramway system. Using repeated cross-sectional data from the Medellín Quality of Life Survey from 2008 to 2018 and difference-in-differences estimators, we find that Metroplús has a negative impact on the growth of rental prices, whereas Tranvía has a positive impact. We do not find any effect on several other outcomes, such as the perception of quality and coverage of the public transportation in the neighborhoods they serve, and the number of private vehicles in the household.

1. Introduction

Public transportation plays a critical role in the formation, working, and growth of cities. It is central to the decision of localization within urban areas because it provides access to all the benefits they offer, from jobs to physical amenities such as parks, libraries, and schools. As a result, the organization of economic activity and the urban quality of life within a city are crucially dependent on the transportation system. Theoretically, transportation is also associated with a range of externalities that can offset its positive impact: congestion, pollution, noise, and visual disamenities (Ahlfeldt, Nitsch, & Wendland, 2019). Beyond its direct effect on accessibility, urban transportation infrastructure is also crucial for public finance. Consequently, establishing how transportation improvements affect different dimensions of citizens' welfare, like housing prices, is an important public policy issue.

Despite its importance, in 2022, only half of the global urban population had convenient access to public transportation (Statistics Division of the United Nations Department of Economic and Social Affairs (UNSD), 2022). Urban sprawl, air pollution, and limited open public spaces persist in cities. This, combined with the need to create low-carbon, resilient, and inclusive cities, means that urban transportation will require major investments in the future, especially in cities that do not have rail systems. In such cases, Medium-Capacity Transport-Systems (MCTS) will be fundamental to achieving a sustainable transportation pattern (UN-Habitat, 2020). MCTS cover a wide range between low and high-capacity systems. They operate in streets with mixed traffic, using a reserved right-of-way, physically separated by curbs, barriers, or grade separation from other traffic, but with grade crossings for vehicles and pedestrians, including regular street intersections (Novales, Orro, Conles, & Anta, 2011).

This paper aims to study the impact that accessibility to Metroplús and Tranvía de Ayacucho, two MCTS, had on housing prices in Medellín.[3] We measure accessibility as the proximity to the closest station and follow the standard Rosen (1974) theoretical framework that estimates the value consumers attribute to different amenities through their willingness to pay (WTP) for their homes. Our identification strategy uses repeated cross-sectional data from the Medellín Quality of Life Survey (QLS) from 2008 to 2018, the City's Zoning Plans (Planes de

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[3] Metroplús is a Bus Rapid Transit (BRT) and Tranvía is a tramway (also known as a street railway).

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Ordenamiento Territorial — POT) 2006 and 2014 (Alcaldía, 2015), and demographic statistics from the National Administrative Department of Statistics (DANE).

To estimate the effect of Metroplús and Tranvía we compare rental prices in treated areas and control areas in a difference-in-differences setup. We define geographical areas that are treated by each MCTS. Our baseline treatment definition considers all properties located within three buffers of the closest station: 300 m, 600 m, and 900 m. For the control area, we consider all properties located beyond 900 m from the closest station. In both cases, we use the year when each system started operating as the moment of treatment, to capture the uncertainty associated with public project completion in the city. The results show a negative effect of the BRT and a positive effect of the Tramway on housing prices.

To understand the mediating mechanisms behind the causal relationship between MCTS and housing prices, we also explore their effect on ownership of private vehicles and the perception of coverage and quality of public transportation as well as safety and noise, air, and visual pollution in the area that capitalize on housing prices (Ahlfeldt et al., 2019). To do so, we use information from the perception section in the QLS. We find that neither of the systems influenced the ownership of cars and motorcycles or the perception of the quality and coverage of public transportation in their neighborhood. Additionally, we analyze the Origin-Destination Survey of Medellín (2017) and find that despite the investment in public transportation in the city, people still prefer using private vehicles.

Our research has policy implications. Among MCTS, BRTs are the most widely spread. Over the last two decades, BRTs have gained popularity worldwide as an effective alternative for sustainable urban transportation due to their lower cost, flexible implementation, and ability to transport big masses of people in similar times compared to rail systems. Empirical literature in the field of engineering suggests that while the construction of railway infrastructure is generally more expensive, experts differ concerning operational costs. Brunn (2005) finds that although BRT systems have lower per-mile expenses to build, their annual operating costs are about 24% higher than any type of rail transport, making it less cost-efficient in the long run. As Zhang, Yen, Mulley, and Sipe (2020) point out, this calls for new research to determine the real effects of BRTs on different dimensions of social welfare compared to other types of transit. The evidence we find for Medellín, a densely populated, highly polluted city with a fast-growing population,[4] and significant congestion problems (characteristics of other cities in the Global South) can be useful for urban planners.

We contribute to the existing literature by comparing the effects of a BRT system with a tramway, similar in capacity, speed, and the communities they serve inside the same city. To our knowledge, this is the first paper to carry out a comparison of MCTS. The literature on the effects of BRT systems on housing prices focuses on case studies of different cities in China (Yang et al., 2019; Zhang, Meng, Wang, & Xu, 2014; Zhang & Wang, 2013) and the Transmilenio System in Bogotá, Colombia (Munoz-Raskin, 2010; Perdomo, 2015, 2017; Rodríguez & Targa, 2004). The rest of the studies were carried out in Australia (Mulley, Ma, Clifton, Yen, & Burke, 2016; Zhang et al., 2020) the United States (Cervero & Duncan, 2002; Perk & Catalá, 2009), South Corea (Cervero & Kang, 2011), Canada (Dubé, Des Rosiers, Thériault, & Dib, 2011) and Argentina (D'Elia, Grand, & León, 2020). The evidence in Latin America focuses on capital cities such as Bogotá and Buenos Aires. Most studies find a positive effect, although the zero effect found in Los Angeles (Cervero & Duncan, 2002), as well as the negative effects found in Beijing (Zhang et al., 2014; Zhang & Wang, 2013), and Bogotá (Munoz-Raskin, 2010), suggest that the negative effects of BRTs can be a complex phenomenon and not just a local effect, explained by the dependence to private vehicles as in the case of Cervero and Duncan (2002).

Although not specific to tramways, there is extensive literature on commuter, heavy rail, and light rail transit. Recently, Gupta, Van Nieuwerburgh, and Kontokosta (2022) found price increases of 8% around the Q-Line in New York City while Ransom (2018) finds a positive impact for one station, negative impacts for two stations, and no impact for the rest when studying a new light rail in Washington. In the latter case, the author argues that the system was not a significant improvement relative to the bus lines that were serviced before the LRT. According to the literature, commuter rail and heavy rail premiums are 9.6% and 4.0% higher than light rail premiums, respectively (for a meta-analysis on the effects of rail transit on housing prices see Rennert, 2022).

Regarding the overall effects of the transportation systems, recently, Brooks and Denoeux (2022) identify three key conditions under which transit retrofitting could successfully occur, stating that transit needs all three to hold, to stand a fighting chance: (i) the mass transit option must exceed the speed of the private car, (ii) mass transit must serve sufficiently dense areas, and (iii) mass transit must take people where they want to go. To reach this conclusion, the authors compare two BRT systems: Transmilenio in Bogotá and Jarkarta's BRT system. The former is one of the most studied systems in the world, widely cited as a success: Tsivanidis (2022), for example, finds a welfare gain in the city of about 57% only from travel time saved. Jakarta's BRT system has a different story. According to Gaduh, Gračner, and Rothenberg (2022), proximity to the stations neither reduced vehicle ownership nor travel times, and it did not increase commuter flows. We analyze our results considering these conditions.

The rest of this paper is organized as follows. Section 2 presents background information on public transportation improvements in Medellín. Section 3 focuses on the effects of MCTS on housing prices in Medellín, the empirical framework and results. Section 4 explains the mediating mechanisms and discusses the results, and Section 5 concludes.

2. Public transportation improvements in Medellín

Medellín is in the northwestern part of Colombia, in the Aburrá Valley. With a population of around 2.8 million people and a metropolitan area of close to 4 million, it is the country's second-largest city. Its urban area covers 105 km^2, making it the third most densely populated city in the world, according to the World Economic Forum (2017). The city has 6 zones, 16 boroughs, and 249 neighborhoods (Fig. 1). One of its most important public policies is the SITVA (Sistema Integrado de Transporte del Valle de Aburrá), which began operating with lines A and B of its Metro train system in 1995 and 1996, respectively. In 2000, additional systems were planned to generate corridors and connect the suburbs and the hillside neighborhoods to the Metro, in a fishbone design. As part of this initiative, the Metrocable (cable-car system) Line K started operating in the northeastern zone (Z1) of the city in 2004, line J in the central-western zone (Z4) in 2008, and lines H and M in 2016. Lines 1 and 2 of Metroplús (BRT) were implemented in 2011 and 2012, respectively. In March 2016, a tramway called Tranvía de Ayacucho began operating in the central-eastern zone (Z3). Currently, the SITVA serves all boroughs of the city, except two in the northwestern area. Fig. 1 shows the complete system.

Metroplús crosses the city from the northeast (Z1) to the southwest zone (Z6), passing through the central-eastern zone (Z3) where it connects with lines A and B of the Metro. The system has two lines, each with 21 stations, and it is fueled by natural gas. Line 1 started operating in December 2011 and Line 2 in April 2012. Line 2 coincides with Line 1 in 13 of its 21 stations, except when it crosses the downtown area (Z3), where its buses share the road and bus stops

[4] Medellín adds about 50,000 people per year.

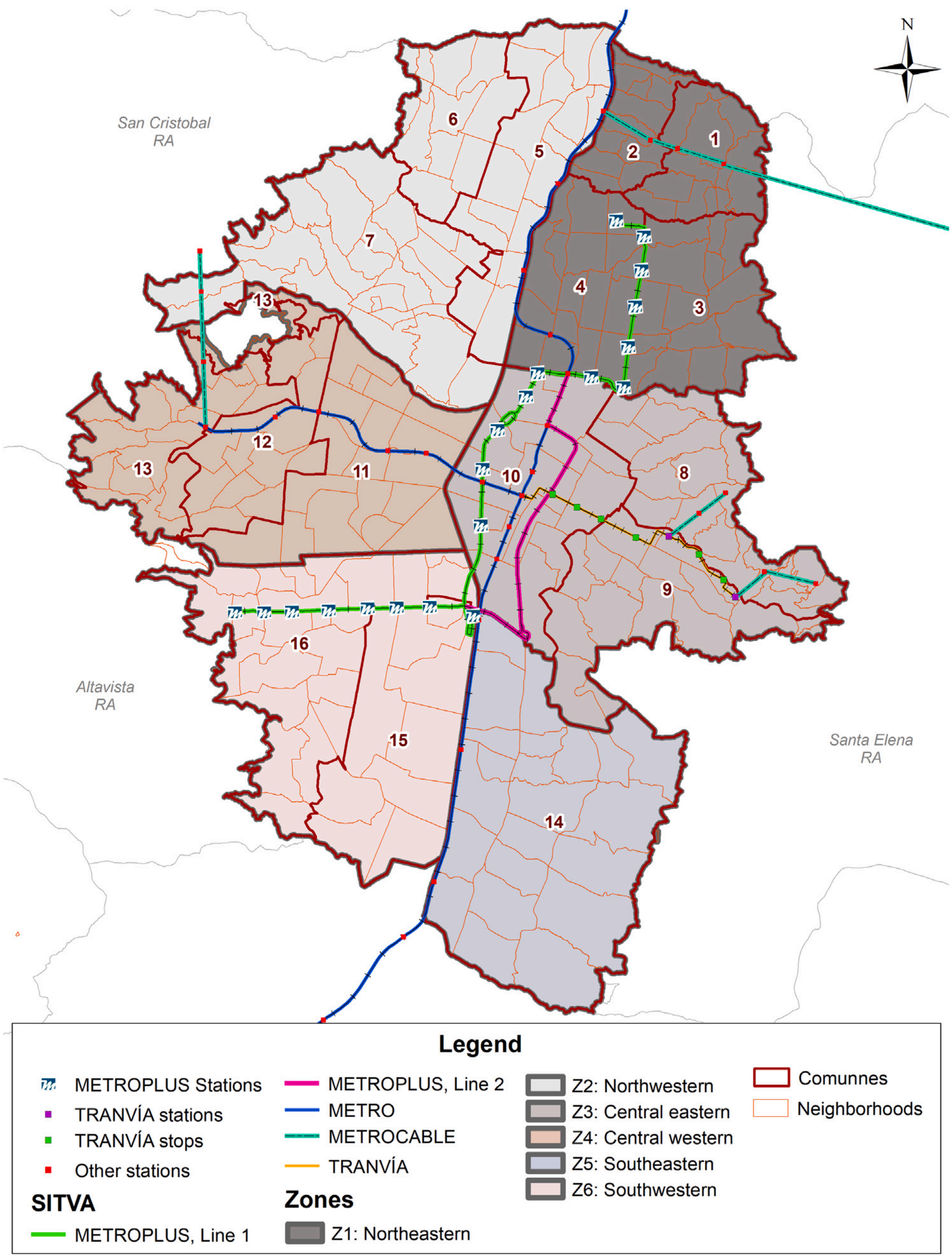

Fig. 1. SITVA and city zones.

with public transportation and private vehicles.[5] Hence, in line with the theoretical and empirical literature (Hensher & Mulley, 2015; Zhang & Wang, 2013) which highlights that BRT systems only have a significant impact when they have dedicated lanes and stations, making them faster and perceived as permanent, and inducing long-term behavior changes among commuters, we focus on line 1 of the Metroplús.

The Tranvía or Line *T* of the SITVA serves boroughs 8, 9, and 10, in the central-eastern zone (Z3) of the city, and it has 6 stops and 3 stations. It connects with the Metro Line A, enabling passengers to access the rest of the SITVA, and two lines of cable cars (lines M and H). The system made its first commercial trip on March 31st, 2016. In addition, the project included green areas, new public spaces, and 2241 trees, shrubs, and palms. Tranvía goes on the same road as the historic electric streetcar – initially mule-drawn – that operated in the city from 1887 to 1951.

These MCTS are comparable due to their capacity, speed, and the characteristics of the citizens they serve. Metroplús has a total capacity of 3270 passengers per hour (p/h), while Tranvía can transport 3807 p/h. Both systems travel at a speed of 16 km/h. The age, socioeconomic strata,[6] and reasons for traveling are similar in both cases: over 50% of passengers use these transportation systems to commute to work, and 19% use them to go shopping. Residents in strata 2 and 3 are the most common passengers, ranging from 37% to 43% of the total (Metro de Medellín, 2020).

Considering their characteristics and the zones they serve, both systems are expected to impact housing prices positively. Drawing

[5] The remaining stations of Line 2 starter operating in 2023.

[6] Socioeconomic strata in Colombia was conceived as an instrument that allows a municipality or district to classify its population into distinct groups with similar social and economic characteristics. It has six levels and one is associated with the lowest income and six with the highest income groups, respectively.

insights from the favorable outcomes observed in the literature with Transmilenio, the BRT system implemented in the capital city of Colombia, a similar positive effect can be expected in Medellin. More so because Metroplús connects the population to the Metro system, allowing more connectivity to the residents within the treated areas. In Zones 1 and 6, where there was previously no MCTS or comprehensive mass transportation infrastructure, we anticipate Metroplus to have an even higher positive effect.

In the case of Tranvía, a more localized impact is anticipated. Zone 3 functions as a transportation hub with multiple modes of transportation already in operation, including the Metro, Metroplús, and buses operated by private companies, before the introduction of Tranvía. As a result, the change in connectivity is expected to be concentrated around the Tranvía stations. Additionally, data from Medellin's Origin-Destination Survey (2017) reveals that in two out of the three boroughs within Zone 3 where the system is located, most trips are made on foot, with approximately half of the trips having destinations within the same zone. This high proportion of intra-zone trips can be attributed to the fact that this zone serves as the city's downtown and features a large commercial district. Finally, Tranvía has a smaller coverage area and fewer stations when compared to Metroplús.

3. The effects of medium-capacity transportation systems on housing prices

To study the effects of MCTS on housing prices, we estimate the following equation:

$$lnP_{ijt} = \lambda_t + \alpha_j + \beta D_{1it} + \rho_{jt} S_{ijt} + \gamma N_{jt} + \mu_{ij} \quad (1)$$

where factors vary by i households, j neighborhoods and time t. λ_t and α_j are time and neighborhood effects that capture unobservables and reduce the omitted-variable biases. lnP_{ijt} is the log of rental housing prices, S_{ijt} represents the structural characteristics of housing units, N_{jt} is a vector of neighborhood characteristics, and μ_{ij} is an error term with the usual properties.

To estimate the effect of interest, we use a canonical DiD estimator. If the moment of intervention is defined as $\tau_t = 1$ and if $t = \tau_t$, then $D_{1it} = \tau_t M_i$ (or $\tau_t T_i$) is the policy variable of interest, in which M and T represent accessibility to Metroplús and Tranvía and take values of 1 for units defined as treated, and 0 for control units. In other words, M and T capture the capitalization or economic gain of the homeowner for their accessibility to Metroplús and Tranvía services. In Section 3.4, this interacted variable will be called *Metroplús* and *Tranvía*, respectively.

In our baseline analysis, we identify neighborhoods whose centroids fall within a buffer zone of 300 m, 600 m, or 900 m to the nearest station of each system (M300, M600, and M900 for Metroplús and T300, T600, T900 for Tranvía). This is based on what we consider to be the maximum feasible walking time to a station (20–30 min) considering the altitude range in the city. For security reasons, the exact location of each household is unavailable in the QLS. Therefore, we define the treatment group using the centroid of each neighborhood. Using entire neighborhoods as a treated unit is a reasonable approximation for walkable distances because Medellín is a compact city, covering only 105 square kilometers. As a result, neighborhoods within these treated groups are small in size. After this, we analyze the treatment areas into three rings: 0 to 300 m, 300 to 600 m, and 600 to 900 m from the closest station to each system, to determine the differential effect at each distance. The control group is given by observations beyond 900 m of distance to the nearest station.

Fig. 2 shows the different treatment and control groups, the SITVA stations, and the zones of the city where the systems were implemented. To account for differences in the number of observations across neighborhoods, we weigh each specification by the number of observations in each neighborhood.

3.1. Time frame

We use the year when each system started operating as the moment of treatment, to capture the uncertainty associated with public project completion in Medellín. For the BRT system, we define the period before treatment as the years from 2008 to 2011 and the after-treatment as all years from 2012 to 2018, considering Metroplús started operating in December 2011. This also follows the literature that suggests a lag in the LVU after implementing a new BRT, which is more easily observable for relatively mature systems, i.e., at least three years old (Zhang & Yen, 2020). In the case of Tranvía, we define the period before treatment as 2008–2015 and the period after treatment as 2016–2018. We set 2016 as a period after treatment because the QLS was carried out in October and Tranvía started operating in March.

3.2. Data

To estimate the effect of accessibility to Metroplús and Tranvía on housing prices, this research uses repeated cross-sections from the QLS from 2008 to 2018. Explicitly, the data from this source includes rental prices reported by the heads of households, the usual structural characteristics of dwellings S_{ijt} suggested by the literature, and several neighborhood-level variables. The first variable in N_{jt} taken from the QLS is $Security$ which captures the interviewees' perception of security in their neighborhood. We take this instead of a crime rate because, in a city with a violent past like Medellín, the influence of security on the willingness to pay for housing may be more connected to the inhabitants' perception than the police statistics. The second one is $Minority$ which shows whether the interviewee identifies as part of an ethnic minority.

Vector N_{jt} also includes transportation (SITVA stations), education, culture and worship, health, and recreation amenities. These variables are determined based on their exact latitude and longitude available from the geodatabase of the POT 2006 and 2014. This allows us to control for the differences in amenities and access to transportation infrastructure across the city, a weakness of other studies identified by Ahlfeldt, Redding, and Sturm (2016). Moreover, accounting for the whole public transportation system helps minimize the risk that access to other types of mass public transportation confounds the estimates. We calculate population density per neighborhood using data on population from DANE. Finally, to study the causal mechanisms we believe can drive the results, we use the questions about the number of private vehicles (cars and motorcycles) in the household and the perception section from the QLS. Many households did not participate in this section of the survey and for this reason, there is a different number of observations when estimating the effect of the MCTS on other outcomes. Tables A.1–A.3 in Appendix A show the descriptive statistics of the data.

3.3. On the parallel trends assumption

The basic identification condition of the DiD strategy is the parallel trends assumption (PTA). The PTA establishes that if in the absence of treatment, the average outcomes for treated and control groups follow parallel paths over time, one can estimate the average treatment effect for the treated sub-population (ATT) by comparing the average change in outcomes experienced by the treated group and the average change in outcomes obtained by the control group (Callaway & Sant'Anna, 2021). In our study, the intuition is that housing prices trends would be the same in treatment and control zones in the absence of the interventions.

Given the critical importance of the PTA in identifying causal effects with the DiD design, authors tend to see it by looking at the raw data. The current way in which authors evaluate the pre-treatment dynamics between a treatment and control group with differential timing is to estimate a regression model that includes treatment leads and lags.

(a) Metroplús (b) Tranvía

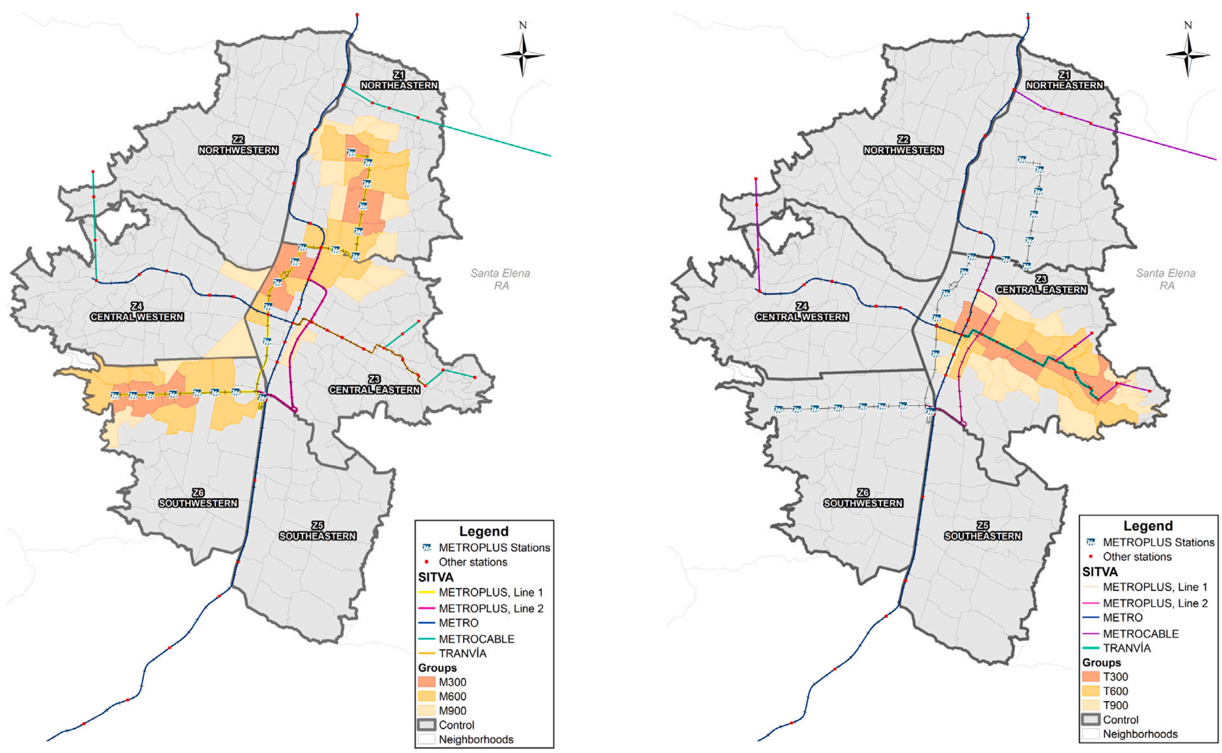

Fig. 2. Baseline scenario. Treated and control groups BRT system and Tranvía, SITVA stations, and Zones of the city. **Note:** The maps illustrate the treatment and control groups used in estimating the effects of Metroplús and Tranvía in the baseline analysis. Neighborhoods located in areas where the coverage of both Metroplús and Tranvía overlap are excluded from all estimations.

Including leads and lags into the DiD model allows us to check whether the two groups are comparable on outcome dynamics pre-treatment. Such event studies are not a direct test of the parallel trends assumption but they show that the two groups of units are comparable in dynamics in the pre-treatment period (Cunningham, 2021). The model takes the form:

$$lnP_{ijt} = \lambda_t + \alpha_j + \sum_{\tau=-q}^{-1} \gamma_\tau D_{i\tau} + + \sum_{\tau=0}^{m} \delta_\tau D_{i\tau} + \rho_{jt} S_{ijt} + \gamma N_{jt} + \mu_{ij} \tag{2}$$

Treatment occurs in year 0, and the equation includes q anticipatory effects and m lags or post-treatment effects. Under this specification, if the estimated γ_τ is simultaneously not significant for $\tau \leq 2011$ for the Metroplús specification and $\tau \leq 2015$ for Tranvía, we have evidence that differences between treatment and control are constant in the pre-intervention period, suggesting that the parallel trend assumption holds. All specifications include the covariate vectors S_{ijt} and N_{jt} as well as the neighborhood and year fixed effects.

The event study results use the log of rental prices as the dependent variable and 2012 and 2016 as the years of reference for all buffers and rings in the estimation. This specification includes the mentioned control variables and neighborhood and year-fixed effects. Regarding Metroplús, results in Table 1 show no significant estimated coefficients between 2008 and 2011, suggesting that the parallel trends assumption holds. Furthermore, they also show some (negative) significant estimated coefficients in 2014 (300 m buffer) and from 2016 to 2018, suggesting the presence of the causal impact of interest. For the case of Tranvía, results in Table 2 show only some pre-trends several years before its implementation (in Column 1 for 300 m buffer), but they vanish beyond the 600 m buffer. Overall, we believe that results for both MCTS show that the PTA holds for Metroplús and Tranvía, supporting the internal validity of our estimates.

However, further discussion can take place. As pointed out by Roth (2022), context-related information can help when the PTA does not seem plausible "(…) bringing economic knowledge to bear on how parallel trends might plausibly be violated in a given context will yield stronger, more credible inferences than relying on the statistical significance of pre-trends tests alone (…)" (Roth, 2022, p. 319). In this case, we believe that the control group for Tranvía can have some potential confounder variables, particularly close to the downtown area. According to Proantioquia (2017), the downtown area congregates several transport modes: Metro, Metroplús, Tranvía, and public buses operated by private companies. 76% of bus routes in the city circulate in the downtown area, which coincides with our control group because it is located beyond 900 m.

As stated by O'Neill, Kreif, Grieve, Sutton, and Sekhon (2011), when the parallel trends assumption seems implausible, methods that rely on alternative assumptions warrant consideration. To make estimates more robust to functional form misspecification and problems in the selection of the control groups, we carried out a robustness test using what we name the Geographical Approach (GA) focusing on specific zones considering that in these areas, locations may only differ in the treatment. Fig. B.1(a) and Fig. B.1(b) in Appendix B show how the treatment and control groups are defined in this case. For Metroplús, we carry out the estimations considering only the Northeastern zone (Z1), and for Tranvía we only take the central-eastern zone (Z3). Moreover, we combine DID and propensity Score Matching (PSM), using the single nearest neighbor on all explanatory variables to select our control group. PSM is expected to discard units that are not sufficiently similar to the treated units and to reduce bias from the potential misspecification of the subsequent regression model (Austin, 2011). In our final estimation, we combine GA and PSM.

Table 1
Event study for housing prices. Metroplús.

Dependent variable:	ln(Rent Prices)				
	[1] 0–300 m	[2] 300–600 m	[3] 0–600 m	[4] 600–900 m	[5] 0–900 m
D2008	0.047	−0.028	0.001	0.061	0.018
	(0.052)	(0.047)	(0.039)	(0.046)	(0.033)
D2009	−0.036	0.002	−0.013	0.031	−0.001
	(0.047)	(0.045)	(0.035)	(0.024)	(0.028)
D2010	0.032	−0.040	−0.012	0.033	−0.000
	(0.034)	(0.060)	(0.041)	(0.029)	(0.032)
D2011	−0.095	−0.025	−0.052	−0.011	−0.041
	(0.058)	(0.059)	(0.046)	(0.032)	(0.035)
D2013	−0.044	−0.146	−0.109	0.021	−0.071
	(0.044)	(0.105)	(0.069)	(0.037)	(0.051)
D2014	−0.109[c]	−0.026	−0.062	0.030	−0.035
	(0.064)	(0.054)	(0.045)	(0.034)	(0.036)
D2015	−0.026	−0.079	−0.060	0.035	−0.032
	(0.061)	(0.056)	(0.044)	(0.042)	(0.036)
D2016	−0.188[a]	−0.069	−0.113[b]	−0.015	−0.085[b]
	(0.046)	(0.066)	(0.049)	(0.059)	(0.042)
D2017	−0.146[b]	−0.063	−0.096[b]	−0.018	−0.073[c]
	(0.059)	(0.061)	(0.047)	(0.054)	(0.039)
D2018	−0.110[a]	−0.080	−0.091[b]	0.027	−0.057[c]
	(0.040)	(0.052)	(0.037)	(0.043)	(0.032)
Observations	60,924	64,758	68,746	62,498	74,308
R-squared	0.618	0.612	0.604	0.624	0.602
Time-variant neighborhood characteristics	Yes	Yes	Yes	Yes	Yes
Housing characteristics	Yes	Yes	Yes	Yes	Yes
Neighborhood FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Standard errors clustered at the neighborhood level are in parentheses.
[a] $p < 0.01$, [b] $p < 0.05$, [c] $p < 0.1$.

Furthermore, in Appendix C, we define the control group as neighborhoods whose centroids are at least 2000 m away from the closest Metroplús and Tranvía stations. In this trimmed control estimation, we exclude Zone 5 due to the high income of households from this zone, which skew the characteristics of the control group (see Fig. C.1). The results in Tables C.1 and C.2 remain consistent with our baseline analysis, indicating robustness across different control group definitions.

3.4. Results

Table 3 presents the estimates of the DiD strategy when we regress the log of housing prices on the interacted Metroplús variable for the three treatment groups that we established. In Column 1 we estimate Eq. (1) for the 300 m buffer and find a negative significant effect on housing prices. The effect decreases when we include more distant treated observations (Columns 2 and 3), suggesting that the impact depends on the treatment intensity, i.e., the closer to the Metroplús station, the higher the reduction of housing prices after treatment. In Column 4 we show the results when jointly including all three rings (0 to 300 m, 300 to 600 m, and 600 m to 900 m). We confirm the negative effect on housing prices for the first ring (300 m) and the stations. In particular, in the post-period housing prices were 5.7 p.p. == $(e^{0.055}-1)$ lower with no effect in the other two rings. These results confirm that the effect is concentrated closer to treated areas (properties) up to 300 m of the BRT stations.

Considering our discussion of the PTA in Section 3.3, we carry out some robustness checks. Notably, we contrast whether the estimation results are sensitive to the definition of the control by considering three more estimations with alternative methods that aim to redefine our control group and compare it with the buffer in 300 m. We present our results for the Geographical Approach (GA) in Column 5, the Propensity Score Matching (PSM) in Column 6, and the combination of both in Column 7. The estimates confirm that the effect of Metroplús on rental prices is negative and significant. The negative effect is puzzling because the BRT serves a zone with limited access to public transportation before it started operating, and it is a mature transportation system implemented in the densest zone of the city, one of the success conditions pointed out by Brooks and Denoeux (2022). These results can be related to increased traffic and congestion in the streets where one of the lanes was devoted exclusively to Metroplús and the negative externalities associated with the system such as noise, and visual and air pollution for households located closer to the system that may have surpassed the positive effects of improved accessibility. These findings can also show the emergence of disamenities closer to the system with no positive effect to offset them.

We now turn our attention to studying the effect of Tranvía on housing prices. Column 1 in Table 4 shows a positive significant effect in the first buffer (300 m). This effect does not hold for the 600 m and 900 m buffers in Columns 2 and 3 or the rings beyond 300 m as shown in Column 4. The positive effect is robust to the definition of the control group in Columns 5 to 7: in all cases, the effect of the Tramway system is positive. In particular, housing prices increased by 4.4 p.p. $(= e^{0.043} - 1)$ more in treated areas (properties) located up to 300 m from the BRT stations, showing that the effect of Tranvía is very localized. Our intuition is that this can be related to the fast connection to downtown that the Tranvía offers. As pointed out by Kahn (2007), public transportation systems in urban areas tend to have a higher impact when they are connected to a vibrant downtown. Other factors such as the convenience of closer stations, and the heavy investment in amenities closer to the tramway, could make the areas in the 300 m buffer more attractive.

4. Mediating mechanisms

To comprehend the mediating mechanisms and understand why the results for Metroplús deviated from our initial expectations while Tranvía's effect remained localized as anticipated, we analyze the responses of the heads of households in the QLS. We explore the effects of both MCTS implementations on what we refer to as transport-related

Table 2
Event study for housing prices. Tranvía.

Dependent variable:	ln(Rent Prices)				
	[1] 0–300 m	[2] 300–600 m	[3] 0–600 m	[4] 600–900 m	[5] 0–900 m
D2008	−0.111[b]	0.006	−0.042	0.045	−0.006
	(0.052)	(0.054)	(0.046)	(0.048)	(0.038)
D2009	−0.047	0.087	0.032	0.008	0.024
	(0.061)	(0.077)	(0.058)	(0.036)	(0.041)
D2010	−0.147[a]	0.001	−0.060	0.050	−0.016
	(0.031)	(0.064)	(0.048)	(0.033)	(0.035)
D2011	−0.049	0.077	0.025	0.027	0.027
	(0.066)	(0.069)	(0.055)	(0.036)	(0.038)
D2012	−0.075	0.115[b]	0.036	0.043	0.039
	(0.076)	(0.048)	(0.052)	(0.032)	(0.036)
D2013	−0.056	0.084	0.026	0.009	0.019
	(0.051)	(0.058)	(0.048)	(0.036)	(0.035)
D2014	−0.074	0.091[c]	0.021	−0.008	0.010
	(0.059)	(0.053)	(0.049)	(0.033)	(0.035)
D2015	−0.095	0.027	−0.025	−0.014	−0.020
	(0.096)	(0.057)	(0.058)	(0.043)	(0.040)
D2017	−0.068	0.035	−0.008	0.037	0.010
	(0.073)	(0.083)	(0.061)	(0.047)	(0.043)
D2018	−0.039	0.085[c]	0.032	0.032	0.032
	(0.061)	(0.051)	(0.044)	(0.023)	(0.029)
Observations	67,579	68,654	70,578	69,378	74,301
R-squared	0.707	0.707	0.703	0.710	0.702
Time-variant neighborhood characteristics	Yes	Yes	Yes	Yes	Yes
Housing characteristics	Yes	Yes	Yes	Yes	Yes
Neighborhood FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes

Standard errors clustered at the neighborhood level are in parentheses.
[a] $p < 0.01$, [b] $p < 0.05$, [c] $p < 0.1$.

Table 3
Effect of Metroplús on housing prices.

Dependent variable:	ln(Rent Prices)						
	[1] 0–300 m	[2] 0–600 m	[3] 0–900 m	[4] Rings	[5] Robust GA	[6] Robust PSM	[7] Robust GA+PSM
Metroplús	−0.057[a] (0.017)	−0.034[b] (0.016)	−0.027[c] (0.014)	−0.055[a] (0.016)	−0.084[a] (0.028)	−0.053[a] (0.017)	−0.070[b] (0.032)
Metroplús | 300 m to 600 m				−0.020 (0.022)			
Metroplús | 600 m to 900 m				−0.011 (0.023)			
Observations	60,917	68,739	74,301	74,301	11,701	38,627	7545
R-squared	0.716	0.704	0.702	0.702	0.513	0.728	0.529
Time-variant NC	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Housing characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Neighborhood FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors clustered at the neighborhood level are in parentheses.
[a] $p < 0.01$, [b] $p < 0.05$, [c] $p < 0.1$.

mechanisms, as well as aspects related to safety and environmental disamenities. Throughout our estimations, our policy variable of interest is D_{1it} and we specifically concentrate on observations within the 300 m buffer. We prioritize this distance as it effectively captures the impact for both systems (see column [4] in Tables 3 and 4). Our covariates include the socioeconomic strata of the housing unit, denoted by $Strata$, and a consistent set of neighborhood-level covariates represented by N_{jt}. Furthermore, we discuss the challenges of transportation in Medellín and analyze the results of this section in light of official information from the local government.

Transport-related mechanisms encompass private vehicle usage (PV_{ijt}), which denotes the number of private vehicles per household including motorcycles and cars. The literature indicates that socio-demographic factors, employment status, income, and spatial considerations are crucial for transitioning to public transportation once a new system or fare scheme for an existing one is implemented. Moreover, strong emotional ties associated with car use may impede modal substitutions (Busch-Geertsema, Lanzendorf, & Klinner, 2021). Recently, evidence suggests a significant decrease in subway usage and an increase in private car usage in developing countries influenced by changing commuting patterns after the COVID-19 pandemic (Khadem Sameni, Barzegar Tilenoie, & Dini, 2021). Regarding motorcycle usage, evidence remains scarce; however, we believe the behavior may be similar. Modal substitution can signal that the implemented system is attractive and in line with the expectations of the potential users, motivating them to give up their private vehicles. Given the negative effect found for Metroplús and the very localized effect of Tranvía, we expect a null effect of either MCTS on private vehicle usage.

$$PV_{ijt} = \lambda_t + \alpha_j + \beta D_{1it} + \rho_{jt} * Strata + \gamma N_{jt} + \mu_{ij} \quad (3)$$

The second transport-related mechanism involves the perception of the coverage and quality of public transportation (PT_{ijt}) (see Eq. (4)).

Table 4
Effect of Tranvía on housing prices.

Dependent variable:	ln(Rent Prices)						
	[1] 0–300 m	[2] 0–600 m	[3] 0–900 m	[4] Rings	[5] Robust GA	[6] Robust PSM	[7] Robust GA+PSM
Tranvía	0.043[b] (0.019)	0.004 (0.013)	0.007 (0.010)	0.042[b] (0.019)	0.112[a] (0.025)	0.045[b] (0.019)	0.113[a] (0.025)
Tranvía | 300 m to 600 m				−0.023 (0.016)			
Tranvía | 600 m to 900 m				0.010 (0.014)			
Observations	67,579	70,578	74,301	74,301	7838	61,536	7565
R-squared	0.707	0.703	0.702	0.702	0.637	0.696	0.610
Time-variant NC	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Housing characteristics	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Neighborhood FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors clustered at the neighborhood level are in parentheses.
[a] $p < 0.01$, [b] $p < 0.05$, [c] $p < 0.1$.

While perception may encompass not only aspects related to the characteristics of the systems but also specific characteristics of the users, according to the literature, perception appears to be more closely associated with the service received rather than the personal and economic conditions of commuters (Chica-Olmo, Gachs-Sánchez, & Lizarraga, 2018). Therefore, we anticipate that the results will align with the actual coverage and quality of the service, with positive effects expected if the MCTS had good coverage and quality.

$$PT_{ijt} = \lambda_t + \alpha_j + \beta D_{1it} + \rho_{jt} * Strata + \gamma N_{jt} + \mu_{ij} \quad (4)$$

Finally, visual, air, and noise pollution are disamenities that can impact housing prices and are influenced by the implementation of new MCTS. Theoretically, beyond the amenity of offering improved access, various transport-related disamenities can affect outcomes such as productivity, health, and annoyance levels (Ahlfeldt et al., 2019). In this case, both systems are electrified and have a dedicated right-of-way, leading us to expect the effects on pollution to be rather negligible. We anticipate a positive impact on the aesthetic appeal considering all the projects surrounding the MCTS construction aimed at improving the availability of parks and the number of trees close to the stations, while the noise generated by the operation of the MCTS is the primary disamenity we expect. Given these considerations, we estimate Eq. (5).

$$EP_{ijt} = \lambda_t + \alpha_j + \beta D_{1it} + \rho_{jt} * Strata + \gamma N_{jt} + \mu_{ij} \quad (5)$$

4.1. Transport-related

We explore the effect that both MCTS had on the number of cars and motorcycles in the household, as well as their perception of the coverage and quality of the public transportation in their neighborhood. Table 5 shows the results for Metroplús and Tranvía. For Metroplús we find no impact on the ownership of any type of private vehicle nor in the perception of coverage and quality of public transportation in their neighborhood. We find no significant effect of Tranvía in any of these outcomes either. We study the perception of public transportation. As shown in Figs. 3(a) and 3(b), the general perception of public transportation is higher in the zones where Tranvía operates. Although it seems that the percentage of people with a positive perception of public transportation in the city is decreasing.

The perception of the public transportation coverage in the areas with accessibility to Metroplús decreased after the implementation of Line 1 in 2011, suggesting that people did not perceive Metroplús as a way of improving public transportation. In the areas with accessibility to Tranvía, the perception of the quality of public transportation is higher than the average for the city and higher than in the areas close to Metroplús for the whole period, though it is also decreasing. In both cases, in 2014, there was a reduction in the number of people who considered the coverage and quality of public transportation as good and very good.

4.2. Safety and environmental disamenities

We analyze people's perceptions of noise, air and visual pollution (see Fig. 4). Less than 50% of the interviewees considered the level of air pollution and noise in their neighborhood to be good and very good, which reveals a generalized problem in the city. However, the perception of the level of air pollution and noise is, in general, lower for the areas served by Tranvía and Metroplús. In general, the perception of environmental disamenities worsened over the period suggesting that the implementation of the systems did not change the patterns in the perception of the surrounding environmental disamenities. The estimates in Table 6 show that neither Tranvía nor Metroplús had a significant effect on the perception of visual, air, and noise pollution.

Safety is also a crucial factor in choosing a mode of transport (Hidalgo, Pereira, Estupiñán, & Jiménez, 2013). Empirical evidence shows that the effect of MCTS on housing prices is closely related to its effect on personal safety (Rodríguez & Targa, 2004). We estimate the effect of MCTS on the perception of safety in the neighborhood using data from the QLS, and the results are presented in Table 6. Columns 1 and 5 show the effect of Metroplús and Tranvía, respectively. The estimates are not statistically significant.

4.3. The challenges of public transportation in Medellín

The results of the outcomes analyzed in Tables 5 and 6 provide insight into the causal mechanisms at play. Nevertheless, to better understand our main findings, we explore information from other sources. According to Medellín's Origin-Destination Survey (2017), between 2005 and 2017, the average commute time increased by 44% (11 min), meaning that the inhabitants of the metropolitan area spent an average of 420 h a year traveling. In the same period, the ownership of motorcycles increased by 207%, while private car ownership increased by 46%, despite the investment in public transportation intended to discourage the use of private modes of transport. Notably, the motorcycle tenancy grew and, by 2019, motorcycles made up to 59% of the total private vehicles in Medellín. Motorcycles in the city are attractive because they are less expensive. According to Medellín's Secretary of Mobility, in 2019 a person could spend 18% of the minimum wage using a motorcycle as a primary commuting mode and 35% using public transportation.

The main mode of transportation in most boroughs is walking and private vehicle usage. Concerning Metroplús, only in Boroughs 3 and 16, 6% of the people reported using it as their main mode of transport, followed by Borough 4 (3%). Despite operating for over 5 years at the time of the survey, indicating its maturity as a transit system. Tranvía, on the other hand, was reported as the main mode of transport by roughly 1% of people in borough 9, although when the survey

Table 5
Transport related mechanisms.

Dependent variable:	Private vehicle		Perception		Private vehicle		Perception	
	[1] Car	[2] Motorcycle	[3] Coverage	[4] Quality	[5] Car	[6] Motorcycle	[7] Coverage	[8] Quality
Metroplús	0.002	−0.019	−0.043	0.002				
	(0.018)	(0.020)	(0.076)	(0.072)				
Tranvía					−0.009	−0.043	−0.015	0.062
					(0.022)	(0.045)	(0.066)	(0.045)
Observations	62,071	62,071	51,182	51,182	62,071	62,071	51,182	51,182
R-squared	0.290	0.036	0.113	0.083	0.290	0.036	0.113	0.083
Time-variant NC	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Strata	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Neighborhood FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors clustered at the neighborhood level are in parentheses.
[a] $p < 0.01$, [b] $p < 0.05$, [c] $p < 0.1$.

Fig. 3. Perception of public transportation in the neighborhood in the last year: Percentage of people that considered it was good and very good.

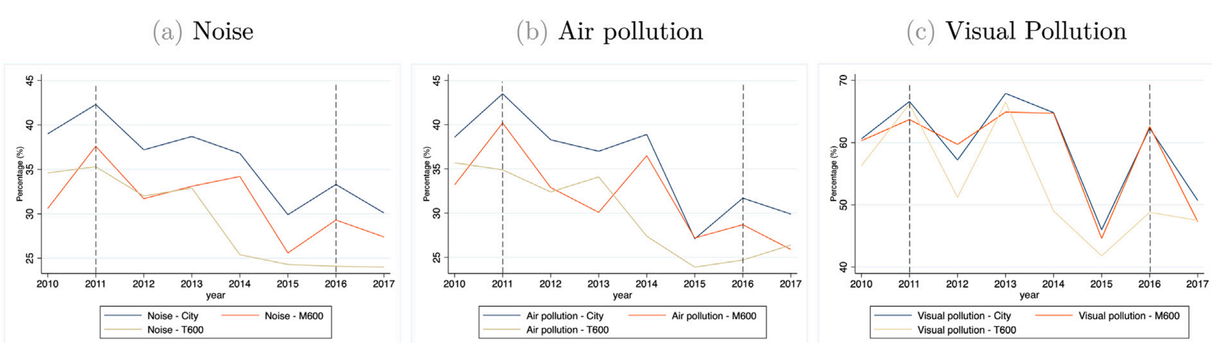

Fig. 4. Perception of externalities in the neighborhood in the last year: Percentage of people that considered it was good and very good.

was carried out, it had been in operation for less than 1 year. This is a generalized problem in the city. The AMVA (2020) identified that that there is an insufficient use of public transportation in the city, influenced by inefficient connectivity between some areas of the territory because it is difficult to provide public transportation service regularly, especially in the high hillside area.

This adds to a lack of reliability in terms of the schedules and frequency of non-segregated modes (such as integrated routes and feeder services), high travel times due to road congestion, and high costs for long journeys involving several transfers, which become barriers to access. Moreover, some conditions encourage the use of private vehicles: a wide range of free and affordable parking spaces and few possibilities for integration between private and public transport. Improving this situation requires a reduction in the incentives for private vehicle usage, as well as creating alternatives, especially achieving a public transportation system that can match the quality of accessibility provided by private motorized transport.

These challenges are closely related to what is known as “transportation gaps”, a concept first introduced by Bouladon (1968), who compared service capability to demand: there are places that people travel to but are too far to walk, so other types of transportation services should be available, enabling users not to drive. Transportation gaps might be more relevant in cities like Medellín where, due to the socioeconomic characteristics of the residents, the option to drive is limited and may generate opportunity gaps. As reported by the

Table 6
Externalities mechanisms.

Dependent variable:	Perception							
	[1] Safety	[2] Noise	[3] Visual	[4] Air	[5] Safety	[6] Noise	[7] Visual	[8] Air
Metroplús	0.036	0.069	−0.105	−0.048				
	(0.029)	(0.066)	(0.086)	(0.134)				
Tranvía					0.030	0.093	0.021	0.081
					(0.029)	(0.128)	(0.104)	(0.128)
Observations	62,071	51,182	51,182	51,182	62,071	51,182	51,182	51,182
R-squared	0.630	0.099	0.098	0.078	0.630	0.099	0.097	0.078
Time-variant NC	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Strata	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Neighborhood FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Standard errors clustered at the neighborhood level are in parentheses.
[a] $p < 0.01$, [b] $p < 0.05$, [c] $p < 0.1$.

interviewees in the Metroplús perception survey (2015), some areas are more difficult to reach after the implementation of Metroplús, creating transportation gaps that impact the most vulnerable population at the top of the hillside that Metroplús serves in Z1. This perception might affect the willingness to pay for housing in the closer areas and explain the negative estimated coefficient of Metroplús.

5. Conclusions

This paper aims to estimate the effect that accessibility to Metroplús and Tranvía have on housing prices in Medellín, using a hedonic approach. The results show a significant negative effect of Metroplús and a significant positive effect of Tranvía on rental prices for residents living in neighborhoods located within 300 m of a station. To study the mechanisms mediating the causal effect we estimate the effect of the MCTS on other outcomes. Our findings reveal that the implementation of a BRT system and a tramway in Medellín did not lead to a significant shift from private vehicles to public transportation. Additionally, we do not find any causal effect of these transportation systems on the perception of transit coverage and quality, as well as on visual, air, and noise pollution or safety.

Our analysis allows us to conclude about the key conditions for transit success identified by Brooks and Denoeux (2022), and it seems that only one of them holds: Metroplús serves Z1, the most densely populated zone of the city followed by Z3, where Tranvía operates. However, by 2018, neither Metroplús nor Tranvía was able to surpass the speed of private cars. During peak hours, the speed of private cars was between 21 and 31 km/h, while both Metroplús and Tranvía sustain a speed of 16 km/h throughout the day. Due to their design, multiple factors such as road accidents can make them go slower.

Finally, the negative change in the percentage of people who perceived the coverage and quality of public transportation as good and very good in the area close to Metroplús and Tranvía may suggest that people do not perceive that the systems are taking them where they want to go. This perception could be more pronounced for the BRT than the Tramway. While Tranvía connects to the Metro and two lines of cable cars, transporting residents to the hillside without paying an extra fee, people close to Metroplús are only connected to the Metro and can take feeder routes for an additional fee. This difference in connectivity options could further explain the divergent effects we found.

This paper faces limitations, mainly related to data availability. First, the dataset does not provide exact locations for each of the interviewed households, due to security concerns. Such data would have enabled a more precise connectivity measure, by establishing the distance from housing units to the closest station. Despite this, Medellín's urban area is compact, covering only 105 square kilometers. Therefore, neighborhoods within these treated groups are small in size. As a result, the furthest point to the closest station in the neighborhoods of M900 and T900 can still be considered a walkable distance. Additionally, our estimations show that the results are robust to different definitions of the treatment and control groups. While our current definitions appear reasonable based on this robust evidence, future estimations could benefit from more detailed data if it becomes available.

The second limitation of our data is the absence of sale prices, with only self-reported rental prices available. However, the use of rental prices is based on insights from the literature. Let us consider that the implementation of a new MCTS improves connectivity, making the location more attractive and therefore, increasing housing prices. "Although existing homeowners nominally benefit from higher asset prices, they are also in some sense adversely affected. They cannot realize the 'gains' unless they downsize housing consumption, give up owner-occupation and rent instead or sell their houses and move abroad" (Hilber & Vermeulen, 2016, p.359). Consequently, the positive effect on housing prices may only be observed immediately if there is a decrease in the demand for owner-occupied homes, an increase in the demand for rental homes, and a subsequent rise in rental prices. This scenario assumes a dynamic housing market for rentals.

In Medellín, a significant share of the population lives in rental properties, accounting for 36% of households in 2018. The high turnover rate in rental properties allows homeowners to quickly observe the gains or losses resulting from changes in housing prices. For instance, the highest turnover of rentals occurs in Borough 11 (Laureles – Estadio), with properties being rented out every 3 months, whereas Borough 14 (El Poblado) experiences a lower turnover rate, with an average turnover of 11 months.

CRediT authorship contribution statement

Miquel-Àngel Garcia-López: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Software, Validation, Writing – original draft, Writing – review & editing. **Luz Yadira Gómez-Hernández:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Software, Validation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Descriptive statistics

See Tables A.1–A.3.

Appendix B. Geographical approach (GA)

See Fig. B.1.

Table A.1
Average (and standard deviation) of rental housing prices ('000 COP).

	Before			After		
	Control	Treatment	Total	Control	Treatment	Total
	Metroplús					
Rental prices	525.86	521.60	525.69	363.74	347.83	363.02
	(475.93)	(306.61)	(470.39)	(612.82)	(434.49)	(605.92)
N	10,914	505	11,419	10,691	501	11,192
	(95.6%)	(4.4%)	(100.0%)	(95.5%)	(4.5%)	(100.0%)
	Tranvía					
Rental prices	622.21	554.29	620.79	778.98	656.30	776.88
	(537.97)	(310.29)	(534.25)	(725.14)	(376.43)	(720.75)
N	11,198	258	11,456	7729	165	7894
	(97.7%)	(2.3%)	(100.0%)	(97.9%)	(2.1%)	(100.0%)

Table A.2
Descriptive statistics. Metroplús M300. Covariates.

	2011			2013		
	Control	M300	Total	Control	M300	Total
	Housing characteristics					
Garage	0.187	0.190	0.187	0.192	0.140	0.189
	(0.445)	(0.431)	(0.444)	(0.489)	(0.364)	(0.484)
Living room	0.435	0.455	0.436	0.481	0.545	0.484
	(0.508)	(0.506)	(0.507)	(0.517)	(0.526)	(0.518)
Dining room	0.270	0.329	0.273	0.251	0.337	0.255
	(0.446)	(0.479)	(0.448)	(0.437)	(0.473)	(0.439)
Kitchen	1.001	1.000	1.001	0.995	0.996	0.995
	(0.036)	(0.000)	(0.035)	(0.098)	(0.063)	(0.097)
Bedrooms	0.255	0.250	0.254	0.309	0.297	0.308
	(0.521)	(0.497)	(0.520)	(0.627)	(0.545)	(0.624)
Bathrooms	1.533	1.505	1.532	1.538	1.377	1.531
	(0.838)	(0.751)	(0.835)	(0.846)	(0.600)	(0.837)
Gas line	1.364	1.335	1.363	1.266	1.204	1.263
	(0.481)	(0.472)	(0.481)	(0.442)	(0.403)	(0.440)
Type of housing unit						
Apartment	7656	337	7993	7737	340	8077
	(70.1%)	(66.7%)	(70.0%)	(72.4%)	(67.9%)	(72.2%)
House	3258	168	3426	2954	161	3115
	(29.9%)	(33.3%)	(30.0%)	(27.6%)	(32.1%)	(27.8%)
Strata						
1	1378	3	1381	1339	1	1340
	(12.6%)	(0.6%)	(12.1%)	(12.5%)	(0.2%)	(12.0%)
2	3654	56	3710	3453	54	3507
	(33.5%)	(11.1%)	(32.5%)	(32.3%)	(10.8%)	(31.3%)
3	2992	350	3342	2996	348	3344
	(27.4%)	(69.3%)	(29.3%)	(28.0%)	(69.5%)	(29.9%)
4	1316	68	1384	1348	71	1419
	(12.1%)	(13.5%)	(12.1%)	(12.6%)	(14.2%)	(12.7%)
5	1005	28	1033	1015	27	1042
	(9.2%)	(5.5%)	(9.0%)	(9.5%)	(5.4%)	(9.3%)
6	569	0	569	540	0	540
	(5.2%)	(0.0%)	(5.0%)	(5.1%)	(0.0%)	(4.8%)
	Neighborhood characteristics					
Education amenities	2.526	2.540	2.527	2.498	2.551	2.501
	(1.993)	(1.906)	(1.990)	(1.994)	(1.928)	(1.991)
Health amenities	0.468	0.159	0.455	0.467	0.176	0.454
	(0.756)	(0.366)	(0.746)	(0.772)	(0.381)	(0.761)
Culture and religion amenities	1.507	1.292	1.497	1.502	1.283	1.492
	(1.358)	(0.588)	(1.334)	(1.365)	(0.583)	(1.340)
Sports amenities	1.255	0.175	1.208	1.231	0.164	1.183
	(1.511)	(0.380)	(1.496)	(1.493)	(0.370)	(1.477)
ln(Population density)	3.312	3.223	3.308	3.305	3.181	3.300
	(0.571)	(0.487)	(0.568)	(0.584)	(0.493)	(0.580)
N	10,914	505	11,419	10,691	501	11,192
	(95.6%)	(4.4%)	(100.0%)	(95.5%)	(4.5%)	(100.0%)

Notes: The table reports means and standard deviations for continuous variables and counts and percentages for factor variables. The descriptive statistics are made for the year before the implementation of Metroplús and the year after.

Appendix C. Trimmed controls

See Fig. C.1.

C.1. Results

See Tables C.1 and C.2.

Table A.3
Descriptive statistics. Tranvía T300. Covariates.

	2011			2013		
	Control	M300	Total	Control	M300	Total
	Housing characteristics					
Garage	0.155	0.062	0.152	0.225	0.036	0.221
	(0.404)	(0.242)	(0.402)	(0.509)	(0.188)	(0.506)
Living room	0.891	0.868	0.891	0.678	0.600	0.676
	(0.463)	(0.402)	(0.461)	(0.591)	(0.504)	(0.589)
Dining room	0.794	0.853	0.796	0.397	0.364	0.397
	(0.412)	(0.376)	(0.411)	(0.497)	(0.495)	(0.497)
Kitchen	0.986	0.981	0.986	1.001	1.000	1.001
	(0.135)	(0.138)	(0.135)	(0.103)	(0.000)	(0.102)
Bedrooms	0.352	0.295	0.351	0.678	0.558	0.675
	(0.827)	(0.653)	(0.824)	(1.199)	(0.946)	(1.194)
Bathrooms	1.009	1.000	1.009	1.497	1.382	1.495
	(0.122)	(0.000)	(0.121)	(0.778)	(0.629)	(0.776)
Gas line	1.230	1.287	1.231	1.204	1.333	1.207
	(0.421)	(0.453)	(0.422)	(0.403)	(0.473)	(0.405)
Type of housing unit						
Apartment	5692	163	5855	4619	94	4713
	(50.8%)	(63.2%)	(51.1%)	(59.8%)	(57.0%)	(59.7%)
House	5506	95	5601	3110	71	3181
	(49.2%)	(36.8%)	(48.9%)	(40.2%)	(43.0%)	(40.3%)
Strata						
1	1322	25	1347	913	16	929
	(11.8%)	(9.7%)	(11.8%)	(11.8%)	(9.7%)	(11.8%)
2	3581	45	3626	2452	22	2474
	(32.0%)	(17.4%)	(31.7%)	(31.7%)	(13.3%)	(31.3%)
3	3326	139	3465	2250	99	2349
	(29.7%)	(53.9%)	(30.2%)	(29.1%)	(60.0%)	(29.8%)
4	1349	49	1398	986	28	1014
	(12.0%)	(19.0%)	(12.2%)	(12.8%)	(17.0%)	(12.8%)
5	1054	0	1054	728	0	728
	(9.4%)	(0.0%)	(9.2%)	(9.4%)	(0.0%)	(9.2%)
6	566	0	566	400	0	400
	(5.1%)	(0.0%)	(4.9%)	(5.2%)	(0.0%)	(5.1%)
	Neighborhood characteristics					
Education amenities	2.601	4.298	2.640	2.597	4.327	2.634
	(2.129)	(1.518)	(2.132)	(2.141)	(1.495)	(2.144)
Health amenities	0.437	0.988	0.449	0.429	1.055	0.442
	(0.713)	(0.972)	(0.725)	(0.724)	(0.964)	(0.735)
Culture and religion amenities	1.519	2.442	1.539	1.511	2.297	1.527
	(1.330)	(2.271)	(1.365)	(1.323)	(2.328)	(1.356)
Sports amenities	1.247	2.740	1.281	1.271	2.285	1.292
	(1.452)	(3.191)	(1.529)	(1.467)	(3.050)	(1.524)
ln(Population density per square km)	3.294	3.193	3.292	3.290	3.148	3.287
	(0.608)	(0.606)	(0.608)	(0.601)	(0.622)	(0.602)
N	11,198	258	11,456	7729	165	7894
	(97.7%)	(2.3%)	(100.0%)	(97.9%)	(2.1%)	(100.0%)

Notes: The table reports means and standard deviations for continuous variables and counts and percentages for factor variables. The descriptive statistics are made for the year before the implementation of Tranvía and the year after.

Table C.1
Effect of Metroplús on housing prices. Trimmed control results.

Dependent variable:	ln(Rent Prices)				
	[1] 0–300 m	[2] 0–600 m	[3] 0–900 m	[4] Rings	[5] Robust PSM
Metroplús	−0.054[a]	−0.034[a]	−0.028[c]	−0.051[a]	−0.040[a]
	(0.013)	(0.009)	(0.015)	(0.016)	(0.014)
Metroplús | 300 m to 600 m				−0.024	
				(0.023)	
Metroplús | 600 m to 900 m				−0.013	
				(0.025)	
Observations	30,248	38,058	45,779	45,779	18,754
R-squared	0.660	0.643	0.686	0.686	0.679
Neighborhood FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Housing characteristics	Yes	Yes	Yes	Yes	Yes
Time-variant neighborhood characteristics	Yes	Yes	Yes	Yes	Yes

Note: The table displays the results for the estimations with the trimmed control defined in Fig. C.1(a).
Standard errors clustered at the neighborhood level are in parentheses.
[a] $p < 0.01$, [b] $p < 0.05$, [c] $p < 0.1$.

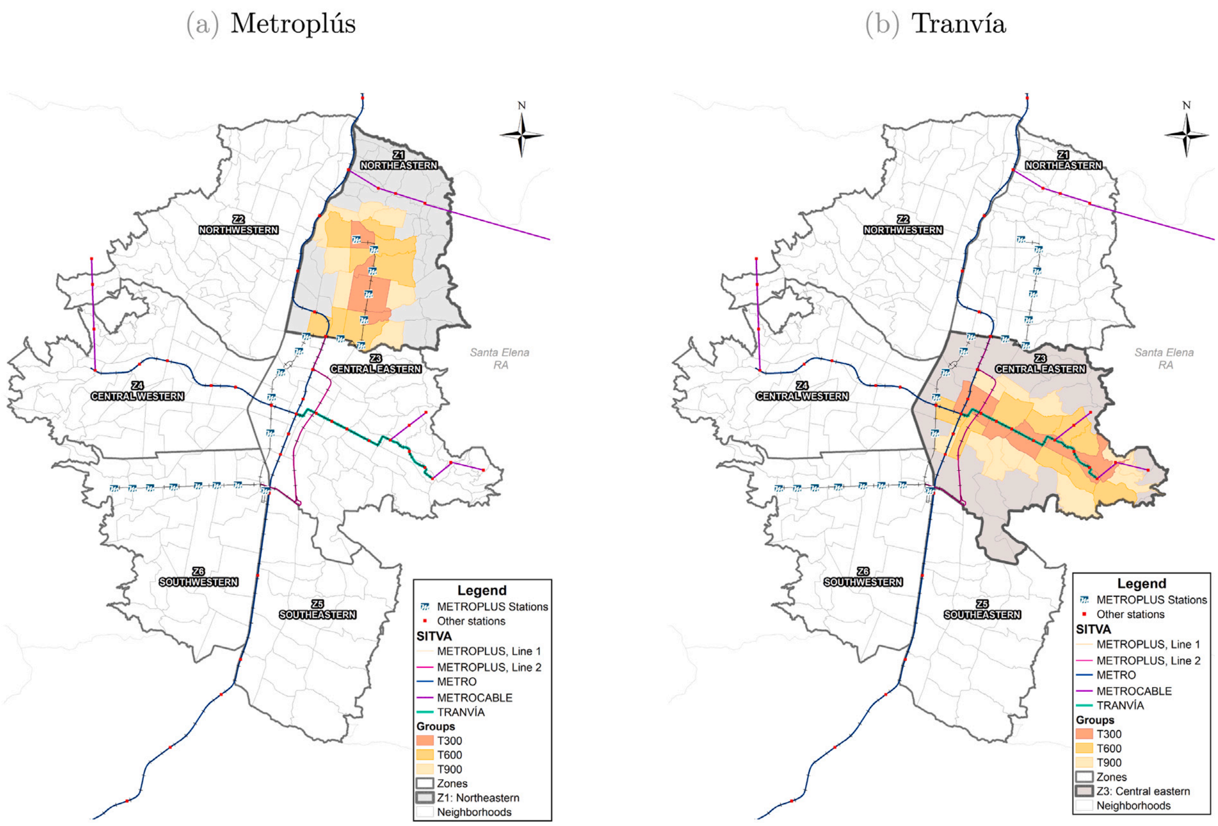

Fig. B.1. Geographical approach. Treated and control groups, BRT System and Tranvía, SITVA stations, and Zones of the city. **Note:** The figure illustrates the definition of treatment and control groups in the geographical approach, where the focus is on specific zones where locations are believed to differ only in the treatment. As a result, both groups are limited to these specific zones. For estimating the effect of Metroplús, the focus is solely on Zone 1. Similarly, for Tranvía, the estimation includes only observations in Zone 3.

Table C.2
Effect of Tranvía on housing prices. Trimmed control results.

Dependent variable:	ln(Rent Prices)				
	[1] 0–300 m	[2] 0–600 m	[3] 0–900 m	[4] Rings	[5] Robust PSM
d300T	0.032^{c}	−0.002	0.001	0.034^{c}	0.037^{c}
	(0.019)	(0.013)	(0.010)	(0.019)	(0.019)
d300T_600T				−0.024	
				(0.016)	
d600T_900T				0.003	
				(0.014)	
Observations	28,185	31,184	34,907	34,907	25,501
R-squared	0.660	0.652	0.653	0.653	0.641
Neighborhood FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
Housing characteristics	Yes	Yes	Yes	Yes	Yes
Time-variant neighborhood characteristics	Yes	Yes	Yes	Yes	Yes

Note: The table displays the results for the estimations with the trimmed control defined in Fig. C.1(b).
Standard errors clustered at the neighborhood level are in parentheses.
^{a} $p < 0.01$, ^{b} $p < 0.05$, ^{c} $p < 0.1$.

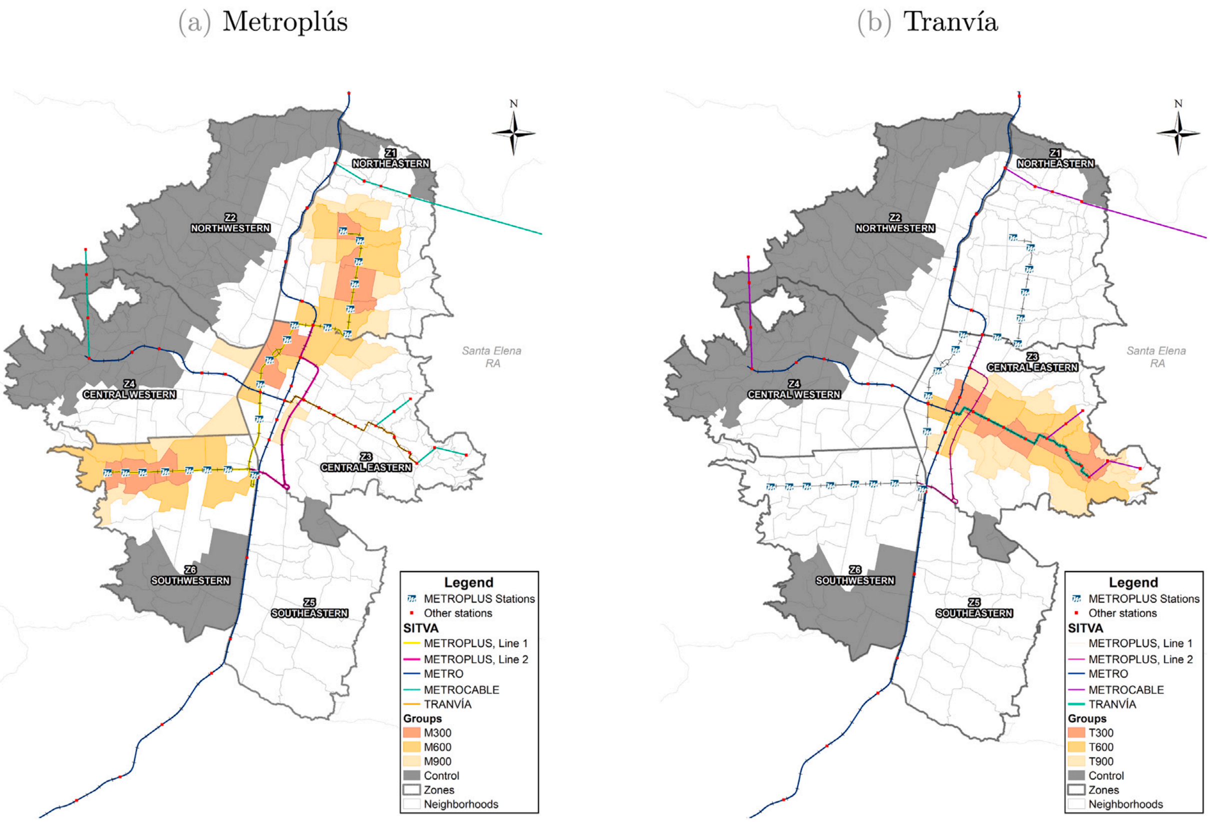

Fig. C.1. Trimmed control. Treated and control groups, BRT system and Tranvía, SITVA stations, and Zones of the city. **Note:** The figure displays a trimmed control group comprising neighborhoods whose centroids are 2000 m or more from the nearest Metroplús and Tranvía stations. Zone 5 was excluded due to the high-income households in this zone, which skewed the characteristics of the control group.

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