Transport Policy 126 (2022) 215–224

Contents lists available at ScienceDirect

Transport Policy

journal homepage: www.elsevier.com/locate/tranpol

The effects of public transport subsidies for lower-income users on public transport use: A quasi-experimental study

Luis A. Guzman [a,*], Philipp Hessel [b,c]

[a] Departamento de Ingeniería Civil y Ambiental, Universidad de los Andes, Grupo de Sostenibilidad Urbana y Regional, SUR, Colombia
[b] Escuela de Gobierno, Universidad de los Andes, Colombia
[c] Department of Epidemiology and Public Health, Swiss Tropical and Public Health Institute, Switzerland

A R T I C L E I N F O

Keywords:
Subsidy
Public transport
RDD
Ridership
Public transport pricing
Bogotá

A B S T R A C T

To increase public transport use, especially for individuals with lower incomes, many cities worldwide have introduced subsidies for public transport systems. However, quantitative evidence of their effects on actual ridership remains scarce, especially in Global South countries. Using a quasi-experimental regression discontinuity design (RDD) in combination with administrative data for all personalized travel cards of public transport users during the years 2017–2019 in Bogotá, Colombia, the present paper assesses the causal effect of a transport subsidy focused on low-income individuals on the number of trips that individuals undertake. Our results show that the subsidy, equaling 32% of the regular fare, significantly and substantially increases the total number of monthly public transport trips. However, the results suggest that the size of the subsidy's effect on ridership has decreased over time, while also evidencing a more pronounced effect among economically active individuals compared to inactive ones. Overall, our results suggest that public transport subsidies for low-income individuals can be an effective way for increasing public transport use among this population segment, which may translate into improved well-being because of improved access to local labor markets and recreational activities.

1. Introduction

In Latin America, about 42% of the population lives in conditions of poverty or extreme poverty. Those individuals move mostly by foot, bicycle, or public transport with active and public transport modes representing around 68% of daily urban trips in the region (Estupiñan et al., 2018). These trips are mostly made by low-income individuals who, in many cases, cannot easily afford public transport fares. As a result, cities face important challenges in providing public transport services with fares that are both financially sustainable and affordable, which often is a difficult balance to achieve.

To increase the use of public transport by low-income individuals so-called 'social' fares or subsidies have been implemented in many cities worldwide. Although these subsidies have been justified predominantly on equity grounds, it remains unclear how effective these subsidies are in increasing public transport use among low-income individuals (Rivas et al., 2018). This applies also to the integrated public transport system (SITP according to its Spanish acronym) in Bogotá, Colombia, where fares have constantly increased since 2000 to cover the rising operating costs and fleet renovation process. The system has a financial deficit of approximately USD 272 million in 2019 which was aggravated by the pandemic.

Public transport costs for low-income individuals in Bogotá are high, and potentially too expensive (Guzman et al., 2021c), in comparison with average incomes, consuming up to 25% of average incomes among this population (Guzman and Oviedo, 2018). It is mostly the inhabitants of the urban periphery (the poorest individuals), with informal jobs who use public transport daily to access the city center (Oviedo et al., 2019), even though the connections and the frequency of regular buses are deficient, with very long travel times, and relatively high costs, particularly for the Bus Rapid Transit (BRT).

In this context, Bogotá has tried to balance the needs for social and financial sustainability by introducing targeted transport subsidies for the poorest segment of the population. Currently, this subsidy includes a 32% fare discount for up to 30 trips per month and two transfers in a travel time window of 110 min. For the beneficiaries of this subsidy, the first 30 trips of the month are charged at the reduced fare. Once the 30 trips have been made at the subsidized fare, the following trips are charged at the regular fare. The subsidies were implemented to allow greater access to Bogotá's SITP to the population with the lowest paying

* Corresponding author.
E-mail addresses: la.guzman@uniandes.edu.co (L.A. Guzman), p.hessel@uniandes.edu.co (P. Hessel).

https://doi.org/10.1016/j.tranpol.2022.07.016
Received 12 January 2022; Received in revised form 16 June 2022; Accepted 18 July 2022
Available online 31 July 2022

capabilities and, as a result, facilitate access to services and economic opportunities. However, to date, it is unknown whether Bogotá's public transport subsidy for poor individuals is effective in increasing public transport use among its potential beneficiaries.

Therefore, the main motivation of this paper is to evaluate the causal effect of this subsidy for low-income individuals on the SITP ridership between 2017 and 2019 by using a quasi-experimental study design in the form of a regression discontinuity design (RDD). The RDD exploits the circumstance that eligibility for the city's public transport subsidy is assessed solely according to a composite poverty index called SISBEN (System of Identification of Social Program Beneficiaries), used by the Colombian government for targeting most social programs. Individuals below or above a specific cutoff score are eligible or ineligible to receive the public transport subsidy, creating a substantial discontinuity in terms of the probability to receive the subsidy around the cutoff as a result. We review the effectiveness of subsidies in the Bogotá public transport system, develop a methodology to quantitatively evaluate the causal effect of SITP subsidies, and discuss the fare policy implications.

2. Public transport subsidies effects in the world

Generally, public transport is thought of as a substitute and sustainable alternative to car use. Nevertheless, public transport requires public subsidies to be affordable and to exploit its full potential in congestion alleviation (Hörcher and Tirachini, 2021). Subsidies to public transport systems have traditionally been used to reduce the negative externalities, minimize users' costs, increase ridership (Gwilliam, 2008), and address social inequalities since public transport is used more by low-income people (Guzman et al., 2021c; Serebrisky et al., 2009).

Previous studies suggest that operating subsidies for public transport systems in London, Los Angeles, and Washington DC are warranted on efficiency grounds due to an increase in ridership (Parry and Small, 2009). In Brussels, some students obtain full repayment of the public transport season ticket, leading to an increase of 1.7 additional public transport trips per week among beneficiaries from this measure (De Witte et al., 2006). In Paris, it was found that reducing public transport fares induces individual gains (28 €/year per user) that were uniform across income groups. Nevertheless, those benefits represent a larger proportion of income for the poorest population (Bureau and Glachant, 2011). Bueno et al. (2016) found that the implementation of the travel pass and public transport subsidies in Madrid has a positive correlation with increased ridership among frequent users and the likelihood of attracting new ones. They also found that the use of public transport increases when the average income per capita decreases. In Stockholm where the average public transport subsidy rate is 44%, Börjesson et al. (2020) stated that subsidies are not effective in terms of its redistributive effects because different income groups get roughly the same subsidies. However, these subsidies continue to encourage public transport use in Stockholm, with public transport ridership increasing faster than car use.

There is also evidence that disagrees with the implementation of subsidies arguing that, for instance, dedicated bus lanes are a better stand-alone policy than subsidizing fares (Basso et al., 2011) since the cross price-elasticity between public transport cost and car use is quite low (Hensher, 1998). And there is an unsolved discussion about whether perhaps it would be preferable to subsidize health, education, or pensions instead of public transport (Oviedo and Guzman, 2020).

In Latin America, a region with high levels of social inequalities and poverty, there is a growing concern for social inclusion in transport planning and policymaking (Vecchio et al., 2020). In several cities of the region, governments build the infrastructure necessary for public transport operation and are in charge of the control and planning, while the private sector operates the service. However, covering the operating costs only with fares is not feasible since the vast majority of users could not afford it. Therefore, high-capacity public transport systems are heavily subsidized to support their operation (Rivas et al., 2020). Furthermore, in many Latin American countries, subsidies to public transport systems have been implemented as a means to achieve income redistribution (Basso and Silva, 2014), improve accessibility and affordability for the poorest individuals (Falavigna and Hernandez, 2016; Guzman and Oviedo, 2018; Rivas et al., 2018), to reduce mobility-related social exclusion, and promote public transport use (Lucas, 2012).

However, the evaluation of the effect of subsidies on increasing ridership in Latin America is scarce and inconsistent. In Buenos Aires, Argentina, evaluations between 2002 and 2006 have demonstrated that supply-side subsidies are important to maintain public transport usage, but are regressive because the proportion of subsidies given to middle and high-income households increased (Serebrisky et al., 2009). In Santiago, Chile, monetary transfers have been used to distribute public transport subsidies rather than supply-side subsidies, however, no evaluation of its effect on ridership was done (Gómez-Lobo, 2009). Also in Santiago, an experiment on working adults found that free-fare public transport led to an increase in the total number of trips mainly in off-peak periods without evidence of transport mode or period of day substitution (Bull et al., 2021). While in all those cases, the subsidies are supposed to encourage the use of public transport, even though there is little evidence for this in the current literature.

In Colombia, before 2015, public transport subsidies were not explicitly allowed. The 2014–2018 National Government Plan changed this, authorizing alternative sources of funding to local governments to support the public transport operation and changing the definition of transport systems from financial self-sustaining to sustainable. In Bogotá, previous research has shown that low-income individuals pay more relative to their income for using the system compared to more affluent individuals (Guzman et al., 2021c). This creates a situation where low-income individuals represent the largest share of public transport users in the city but on average conduct fewer daily trips than more affluent individuals.

As seen, there is little evidence on the effects of subsidies on public transport use and also this is not a straightforward task, especially when there is not enough money and the transport and access inequality gaps are evident, which is the case of Bogotá. Hence, what the previous literature has not accounted for, which is a contribution of the current paper, is an understanding of whether the targeted public transport subsidies in Bogotá have a causal effect on travel demand changes in the SITP for people with lower incomes using treatment and control groups. This provides a new assessment of the efficiency of subsidies from the point of view of public transport use encourage.

3. Bogotá's transport system and subsidy for low-income users

At the end of the last century, Bogotá had a public transport system based on buses operated by the private sector without centralized scheduling. This model counted more than 640 routes and had about 21,500 vehicles entering into crisis due to the locally known penny war (competition in the market), road congestion, air pollution, poor road safety, informality, and fares variability (Ardila, 2007). In 2000 it was proposed to reorganize the city's traditional public transport system into the SITP (integrated public transport system) which would be made up of the BRT, regular buses, cable car lines, and eventually metro and regional trains. The implementation of the SITP was proposed gradually, ensuring the provision of transport services in the city, which were fully implemented by the end of 2021. The SITP allowed having a single and flat fare with free transfers for those with a personalized travel card, which initially benefited the poorest who make longer trips and transfers between routes.

3.1. The SISBEN poverty classification scheme

The SISBEN is an index used by the Colombian government to assess and classify households, and their members, according to socioeconomic vulnerability to identify eligible beneficiaries for social protection programs. The establishment of SISBEN in 1995 went together with a shift towards a system in which most social policies became targeted mainly at the most vulnerable households or individuals. Hence, to become a beneficiary of different social policies individuals or households had to pass a means test. To implement the SISBEN the national government, every couple of years invites households to apply for inclusion in the SISBEN database. Based on a very comprehensive household survey, that includes more than 100 separate categories, e.g., the educational status of household members and the materials of which the walls of the residence are made, is implemented in the form of a visit of an interviewer to the household residence, the government attributes an index score (ranging between 0 [most vulnerable] to 100 [least vulnerable]).

An important feature of the system is that the weighting of the different categories is kept a secret so that it becomes significantly more difficult for households to manipulate their index score, e.g., by lying about their educational status. Starting with the distribution of the index score that ranges between 0 and 100, in the total population the national and regional governments periodically define cutoffs to define who is eligible to receive different aid programs. The latter also applies to Bogotá's public transport subsidy. For the present study, we use data on public transport use and eligibility for the transport subsidy for poor individuals for the years 2017–2019. During this time the SISBEN III was applied, and we, therefore, use the information on the latter for our analytical strategy.

3.2. Bogotá's transport system

In Bogotá and Colombia, residential land is classified into six categories known as socioeconomic strata (SES), which establish different rates for essential utilities. SES are defined by conditions in terms of the physical characteristics of buildings and the quality of urban space (Cantillo-García et al., 2019). SES 1 corresponds to households with less urban quality and SES 6 to the best conditions. Usually, the poorest population live in the lower SES (1 and 2) and tend to live far from the main economic opportunities. The urban structure and activity locations of the city play against the poorest people. This group must endure long travel times and expensive fares to get to their jobs or refrain from travel, a circumstance that aggravates social inequalities (Guzman et al., 2017), which was worse during the mandatory lockdowns as a result of the COVID-19 pandemic (Guzman et al., 2021b).

Before the pandemic, approximately 13.4 million trips[1] were made per day. Although the private vehicle fleet has grown 55% between 2011 and 2019 according to the latest mobility survey, the car-ownership rate in Bogotá is still low with just one of seven inhabitants having a car. In consequence, only 14.3% of daily trips in the city are made by car and 5.7% by motorcycle. The rest of the trips are made by active modes (42.7%) and by public transport (30.9%). Also, 42% of the high-SES population use the car for their daily work trips, while only 8% of employees of low-SES do (Peña et al., 2022). Of all public transport users, 86.4% belong to the lowest socioeconomic levels of the city (SES 1 to 3). Public transport is by far the most common transport mode for middle and low-SES groups.

The public transport ridership shows the sharpest peaks in the mornings at the periphery, where the densest residential zones are located, while in the evening, boardings occur on the eastern edge (Guzman and Gomez Cardona, 2021). The pricing scheme consists of a flat fare, which means that the fare is independent of the trip length. The fare strategy was originally designed to benefit poor users, supposedly by cross-subsidizing the long trips of the poor with the short trips of the wealthy. However, lower-income users are disproportionately penalized by a relatively high fare price (Guzman et al., 2021c). Another issue in the SITP is fare evasion. The only time evasion has been measured was in 2018 and only in the BRT system, finding evasion rates around 15.4% on average (Guzman et al., 2021a).

Until January 2022 the regular fare of SITP was COP (Colombian Pesos) 2500 (USD≈0.66) for the BRT services and COP 2300 (USD≈0.61) for regular bus services. This is a heavy burden on low-income households' budgets and therefore, the city introduced a pro-poor public subsidy that allows greater access to the SITP among this population. There are two travel card types in Bogotá's SITP: a basic and a personalized travel card. With the first one, the user will always pay the full fare. The second option allows having differential fares (subsidies), making it possible to make up to 2 transfers in 110 min and make credit trips. Personalized travel cards are more common than basic cards: 71% of all trips are paid for by personalized travel cards, while subsidized travel cards do not exceed 18% of the total on average. Therefore, to access the transport subsidy, it is necessary to have a personalized travel card and meet other mandatory requirements (please see next section).

3.3. Public transport subsidy for low-income users

In 2013, the city decided that people over 16 years of age with a SISBEN score of fewer than 40 points would have a special SITP fare. In 2014, the benefit reached up to a 66% discount in off-peak hours and in 2015 it was set at 50% of the value of the regular fare. From that date and for purely financial reasons, the requirements to access the subsidy became more demanding and its amount was reduced. Table 1 presents the historic fare prices for a regular user of the SITP and the SISBEN beneficiaries, after several regulatory adjustments. Of these norms, the current conditions of the subsidy were established in Decree 131 of 2017, which determined a SISBEN score of less than 30.56 to access the subsidy, a maximum number of subsidized monthly trips of 30, being over 16 years old, and not being a beneficiary of another incentive.

However, not all potential beneficiaries have accessed the transport subsidy. For example, employed persons have a bigger probability of accessing the benefit and women are 10% more likely to request the subsidy than men (Rodríguez et al., 2016). As of February 2020, the number of subsidized travel cards represents around 17.7% of total trips in the system (614,596 users). In terms of age, the younger population (younger than 35 years) has benefited the most since they represent about half of subsidized travel card users. The subsidy has been an important public investment by the city, costing a total of USD 22.7 million in 2019.

4. Data and methods

4.1. Data

To assess the causal effects of Bogotá's public transport subsidy for poor individuals on the number of trips per month we use data from three sources. First, data on the number of public transport trips as well as their exact time and date for each registered user in Bogotá's SITP was provided by TransMilenio S.A. (the entity that manages Bogotá's SITP). By definition, a trip is a travel card validation (boarding) in the system. If the same user validates their travel card in a time window of fewer than 110 min, it is a transfer. If they do it after 110 min it is an additional trip. This information does not include fare evaders. Second, data on demographic as well as sociodemographic characteristics for all 2,201,654 of the city's registered public transport users that are also registered in the SISBEN III database came from the Bogotá Mayor's Office (*Secretaría Distrital de Planeación*). The database contains information on the name, gender, unique personal identification number, economic activity, occupation, personalized travel card number (that allows tracking the travel patterns) as well as the type of user (i.e., whether an individual is receiving the public transport subsidy or not). A third database also came from the Bogotá Mayor's Office that contained

[1] Trips lasting longer than 15 min.

Table 1
Evolution of the SISBEN public transport subsidy.

Service	Period		Regular fare USD*		Subsidized fare USD*		Max. subsidized trips per month
			Peak hour	Off-peak hour	Peak hour	Off-peak hour	
BRT	mar-14	oct-14	$ 0.46	$ 0.38	$ 0.28	$ 0.19	21
	nov-14	jan-16	$ 0.49	$ 0.41	$ 0.24	$ 0.16	40
	feb-16	mar-17	$ 0.54		$ 0.27		40
	apr-17	jan-18	$ 0.60		$ 0.45		30
	feb-18	jan-19	$ 0.62		$ 0.47		30
	feb-19	jan-20	$ 0.65		$ 0.49		30
	feb-20	current	$ 0.68		$ 0.49		30
Regular bus	mar-14	oct-14	$ 0.38		$ 0.19		21
	nov-14	jan-16	$ 0.41		$ 0.16		40
	feb-16	mar-17	$ 0.46		$ 0.19		40
	apr-17	jan-18	$ 0.54		$ 0.39		30
	feb-18	jan-19	$ 0.57		$ 0.43		30
	feb-19	jan-20	$ 0.60		$ 0.45		30
	feb-20	jan-22	$ 0.62		$ 0.45		30

* USD exchange rate = COP 3,693.4
Notes: In COP, fare increased steadily over time. The grey background indicates the period included in our study.

information on whether an individual received the country's conditional cash transfer *Familias en Acción*. The latter represents a monthly cash transfer for low-income families with children (<18 years of age) provided by the Colombian government. The program uses the same means test and SISBEN III eligibility threshold as Bogotá's public transport subsidy meaning that individuals with children below the cutoff are automatically eligible to receive both programs.

The three databases were merged based on the personal identification number of each individual for the time covering April 2017 until December 2019. We do not include the time before April 2017 as this time coincides with the introduction of the SISBEN-based eligibility criteria in the current form. We do not include the time after 2019 as it mostly coincides with the beginning of the COVID-19 pandemic and a strict lockdown in the city that included substantial restrictions for public transport use (Guzman et al., 2021b). We only work with personalized travel card users.

4.2. Variables used

Based on a linkage of the aforementioned databases we constructed the following variables:

1. A series of linear variables that correspond to the total number of trips (boardings) of each user within the city's official public transport system per calendar day. The data of personalized travel cards are available by each use during the study period: date and hour of the boarding, value spent, type of user (with/without subsidy) and station/stop identification.
2. A series of linear variables that correspond to the total number of boardings of each user within the city's official public transport system during weekends (Saturday and Sunday for each day during the studied period).
3. The exact SISBEN III score of an individual. Please see Section 3.1.
4. A dummy capturing whether s/he receives the public transport subsidy. Please see 1)
5. A dummy capturing whether s/he receives the *Familias en Acción* benefit. To isolate the effect of the transport subsidy on ridership we, therefore, control for *Familias en Acción* receipt in the regression models and repeat the analyses for individuals not receiving *Familias en Acción.*
6. We also obtained information from the government's SISBEN III database on whether a registered public transport user was economically active or not (following the government's statistical classification). Economically active are classified as individuals that are either: working (at least 1 h in the reference week) or unemployed (while looking for work). Economically inactive are classified as individuals that are either: students, housewives/men, pensioners/retired, disabled (and unable to work), or unwilling to work/voluntarily out of the labor force.

4.3. Identification strategy

To identify the effect of the public transport benefit on the number of trips (per month and on weekends) we use an RDD strategy (Hahn et al., 2001; Imbens and Lemieux, 2008; Lee and Lemieux, 2010). This is a widely used quasi-experimental econometric technique for assessing the causal effects of interventions that relies on the existence of a distinct cutoff (or threshold) used to assign eligibility to an intervention. Using the information on observations located closely around the respective cutoff the RDD compares outcomes of interest of those observations, e. g., of individuals, below and above the cutoff to estimate the so-called Local Average Treatment Effect (LATE). RDDs are widely considered as having a very high level of internal validity, able to produce an unbiased estimate of the local treatment effect as good as a randomized control trial (RCT) (Chaplin et al., 2018).

In the present case, there exists a distinct eligibility cutoff in terms of an individual's SISBEN III score (≤30.56 points) that is used to determine whether an individual may or may not receive the city's public transport subsidy (in addition to residing in Bogotá). Hence, individuals that have SISBEN III scores ≥30.57 points should officially not receive the subsidy, whereas those with scores ≤30.56 points are eligible to receive it. The RDD relies on the assumption that the so-called assignment values, i.e., the SISBEN III eligibility cutoff, in this case, are essentially randomly assigned and that individuals cannot themselves manipulate it. If this is the case, and there exist no further discontinuities around the same cutoff (see discussion below), then the separation into eligible (treatment) and ineligible (control) individuals can be considered as good as random and allows for the estimation of the same treatment effects as standard RCTs in the form of mean differences in the outcome variable between individuals in the treatment versus the control group.

A limitation of RDD is that the results generally are only generalizable for observations with values of the assignment variable close to the cutoff. Therefore, the estimated quantity of RDD only is generalizable to the group if individuals that have SISBEN scores near the respective cutoff. In the present case, there exists strong support for the assumption that the eligibility cutoff for the transport subsidy is randomly assigned. Hence, the SISBEN III score of 30.56 is a practically arbitrary value (of a continuous index), which was based on budgetary considerations of the government aiming to grant the subsidy to a certain percentage of individuals in agreement to public funds being available. In other words, the cutoff of 30.56 itself does not reflect any distinct differences between population groups in terms of sociodemographic characteristics. Due to the latter, several studies have used this circumstance by using the SISBEN eligibility cutoffs in conjunction with RDD to estimate the causal effects of different government subsidies in Colombia (Barrientos and Villa, 2015; Melguizo et al., 2016).

A central assumption of the RDD strategy, on the one hand, is that individuals cannot determine the cutoff itself –which is the present case given that the cutoff is fixed on the city level– and, on the other hand, that individuals also cannot manipulate the mechanism used for deciding eligibility. On the other hand, another crucial assumption and requirement for the RDD is that there is a significant and substantial increase in the probability of being treated (i.e., to receive the subsidy) around the eligibility cutoff (i.e., the SISBEN III score of 30.57).

To assess the latter, we conducted two types of analyses. First, we use graphical evidence to visualize the existence of a substantial increase in the probability of receiving the public transport subsidy around the SISBEN III cutoff. Hence, Fig. 1 shows the estimated probability of receiving the public transport subsidy according to a person's SISBEN III score derived from a locally weighted polynomial regression. The vertical dotted line corresponds to the eligibility cutoff score of 30.57, whereas individuals with SISBEN III scores on the left side of the line (scores <30.57) should theoretically have a 100% probability of receiving the subsidy whereas individuals on the right side of the line should theoretically have a 0% probability of receiving the subsidy due to being ineligible. The dots correspond to clusters of individuals with similar values in terms of the probability of receiving the subsidy as well as the SISBEN III score. The lines represent a polynomial regression line and corresponding 95% confidence intervals.

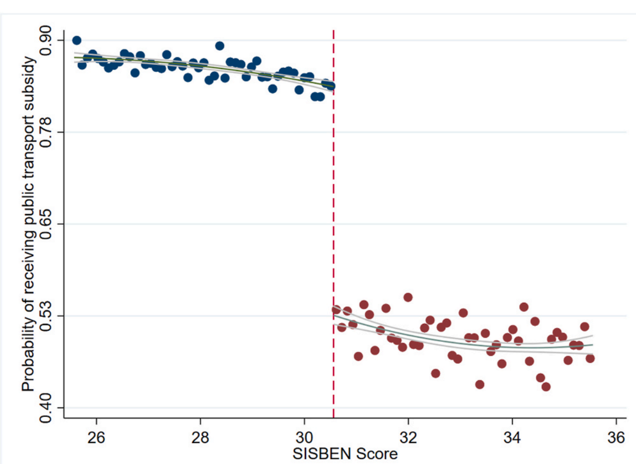

Fig. 1. Probability of receiving Bogotá's public transport subsidy according to SISBEN score around eligibility cutoff.
Notes: The figure shows the estimated probability of receiving the city's public transport subsidy according to individuals' SISBEN (System of Identification of Social Program Beneficiaries) score that is used to assess eligibility. A lower SISBEN score indicates that an individual lives in a poorer household). The vertical line represents the SISBEN eligibility cutoff for the public transport subsidy equal to a score of 30.56 points. A dot represents a cluster of individuals in this region of the distribution. Individuals were included in the model if their SISBEN score was ±5 SISBEN III points from the cutoff and if they were registered users of the city's public transport system at any moment between April 2017 and February 2020. Only including individuals with SISBEN III scores between 25.57 and 35.57 points (N = 361,744).

As Fig. 1 shows there is a substantial increase in the probability of receiving the subsidy around the respective SISBEN III threshold. Close to the cutoff (±5 SISBEN III points) the probability of receiving the subsidy nearly doubles, thus increasing from around 53%–85%. Fig. 1 also suggests that the take-up of the subsidy is very high among eligible persons and thus reaches well its target population. At the same time, the figure shows that there are some individuals with SISBEN III scores that are close to the threshold (30.57–35.56 points) that are officially ineligible but who receive the subsidy. While we do not find evidence for manipulation of the SISBEN scores around the eligibility cutoff (see Appendix Figure A1 (Cattaneo et al., 2020)). The latter circumstance may be due to administrative errors in the eligibility checks. Using the same sample, we also estimated a linear probability model that regresses a binary variable of whether an individual receives the subsidy on a linear version of the SISBEN III scores as well as a binary variable capturing whether an individual has a SISBEN III score below or above the eligibility cutoff. As Appendix Table A1 shows, being eligible for the subsidy according to the SISBEN III score significantly and substantially increases the probability of receiving the subsidy by 32.9% (p-value <0.0001).

Using the Stata package *rdrobust* (Calonico et al., 2017) we implemented the RDD by estimating the LATE using a non-parametric local regression of the following form:

$$\tau = \tau(\bar{x}) = \mathbb{E}\{Y_i(1) - Y_i(0) | X_i = \bar{x}\} + Z_i$$

whereas X_i is the running variable in the form of the SISBEN III score of individual *i*, $\bar{x}$ is the SISBEN III eligibility cutoff (score of 30.57), and Y_i refers to the observed outcomes of interest, here the number of public transport trips. $Y_i(1)$ and $Y_i(0)$ refer to the potential outcomes for each eligible and ineligible individual. Z_i is a variable capturing whether an individual receives the *Familias en Acción* conditional cash benefit.

Given that there are individuals that are officially ineligible to receive the subsidy but receive it as well as eligible individuals not receiving it (see Fig. 1), so-called non-compliance, we implement the RDD as a fuzzy set. For the main analyses, we restrict our sample to individuals with SISBEN III scores within the range of 5 points below or above the eligibility cutoff (30.57), i.e., those within the range of 25.57–35.57 points, whereas we also show the robustness of the results using alternative bandwidths. This agrees with other studies that have used SISBEN III eligibility cutoffs in conjunction with RDD to assess the causal effects of various government subsidies on different outcomes in Colombia (Miller et al., 2013). We also present robustness analyses using different bandwidths (see Appendix Table A2).

Analyses were performed separately to assess the effect of the public transport subsidy on the number of total trips as well as total trips during weekends in each calendar month between April 2017 to December 2019. We use the calendar month as the main unit of time due to the circumstance that travel patterns in Bogotá have substantial seasonal variations (Guzman et al., 2020). The separate analyses for trips on weekends were done as the latter may capture travel behavior for social or recreational purposes, different to travel for work/study-related purposes.

A key assumption of the RDD is that there exist no other relevant discontinuities around the respective eligibility cutoff. Due to the nature of the SISBEN III means test, which classifies households and their members, into a continuous score, and the arbitrary selection of the cutoff score for the public transport subsidy selection, which is not correlated with any individual characteristics in terms of age or gender, for example, we can reasonably assume that the control group (those with SISBEN III scores just above the cutoff) and treatment group (those with SISBEN III scores just below the cutoff) are de facto randomly assigned and that there exist no systematic differences in terms of sociodemographic characteristics between the two groups as a result, especially close to the cutoff. Unfortunately, due to the use of administrative data, we are unable to empirically assess whether there exist other discontinuities in terms of individuals' sociodemographic characteristics around the SISBEN eligibility cutoff, besides the dimension of economic activity status. As Appendix Figure A2 shows, there exists no discontinuity in terms of the probability of being economically active or not around the SISBEN eligibility cutoff for the city's public transport subsidy. As an additional robustness check, we also performed a series of placebo tests by using alternative SISBEN eligibility cutoffs following the suggestion by Imbens and Lemieux (2008) (see Appendix Table A3).

5. Results and discussion

5.1. Sample overview

Table 2 presents a descriptive overview of our sample, thus only including individuals with SISBEN III scores between 25.57 and 35.57 points (N = 361,744). Of individuals within this range, 41% receive the public transport subsidy. The average SISBEN III score is 30.04 points. Of the sample 10% receive *Familias en Acción*. Of the sample, 33% are economically active.

Table 2
Sample characteristics.

	N (total)	Mean	SD
Receiving public transport subsidy (yes)	361,744	0.4	0.5
SISBEN Score	361,744	30.0	2.9
Familias en Acción (yes)	361,744	0.1	0.3
Economically active (yes)	361,744	0.3	0.5

		Average monthly number of validations (total)			Average monthly number of validations (weekends)		
Year	**Month**	**N**	**Mean**	**SD**	**N**	**Mean**	**SD**
2017	APR	131,883	19.8	15.5	109,220	7.0	5.7
	MAY	130,740	20.7	16.8	103,982	5.7	4.3
	JUN	131,146	18.8	15.7	96,811	5.2	4.1
	JUL	134,953	18.7	15.5	119,496	8.1	6.1
	AUG	134,953	18.7	15.5	119,496	8.1	6.1
	SEP	144,581	20.9	16.9	107,866	5.1	3.9
	OCT	148,344	20.6	16.8	69,201	3.6	3.1
	NOV	155,674	20.1	16.5	116,057	5.4	4.2
	DEC	164,984	18.4	15.5	130,627	5.8	4.7
2018	JAN	164,947	18.1	15.5	121,026	4.7	3.7
	FEB	170,118	19.3	15.9	122,274	4.8	3.6
	MAR	174,286	19.3	15.9	134,691	5.7	4.6
	APR	178,796	21.6	18.0	130,777	5.3	4.3
	MAY	185,134	20.3	16.8	138,060	5.1	4.1
	JUN	185,300	16.8	14.1	142,487	5.3	4.3
	JUL	194,238	22.2	19.1	141,000	4.9	3.9
	AUG	203,894	20.6	17.3	151,998	5.3	4.2
	SEP	207,975	19.7	16.2	156,945	5.1	4.0
	OCT	216,054	21.2	17.4	158,542	5.0	3.9
	NOV	220,316	19.6	16.1	165,525	5.3	4.2
	DEC	230,700	18.6	15.5	182,456	5.5	4.5
2019	JAN	235,180	17.3	14.9	166,121	4.6	3.6
	FEB	242,082	16.7	15.5	172,906	4.7	3.5
	MAR	265,472	19.7	18.2	187,577	5.7	4.6
	APR	238,720	18.8	15.5	172,157	4.8	3.8
	MAY	239,971	20.6	17.3	174,736	5.0	3.9
	JUN	236,214	18.0	15.1	184,845	5.7	4.8
	JUL	233,378	17.2	14.4	163,808	4.3	3.4
	AUG	246,565	19.1	16.5	183,314	5.7	4.6
	SEP	238,230	20.2	16.6	173,032	4.9	3.8
	OCT	238,430	20.4	16.9	173,268	4.9	3.8
	NOV	231,374	17.8	14.6	169,189	4.9	3.9
	DEC	234,250	18.1	15.3	177,416	5.1	4.0

Notes: The sample included only individuals with SISBEN III scores between 25.57 and 35.57 points.

Table 2 also shows the monthly average number of trips as well as trips on weekends and holidays during the study period. As the table shows, the number of trips varies greatly during the year, with more trips undertaken in spring (March–May) and autumn (August–November) than summer (June–July) and winter (November–January). As the table also shows, the total number of monthly trips (in total as well as on weekends and holidays) has been decreasing over time from March 2019.

5.2. Regression discontinuity design results

Table 3 presents the estimated treatment effect (LATE) of the public transport subsidy on the total number of trips per month as well as the number of monthly trips obtained from the RDD. As the table shows, on average, there exists a significant positive effect of the public transport subsidy on the total average number of boardings (trips) in almost all months between April 2017 and December 2019. The results show that subsidy plays a significant role in public transport use. The lower the income level of the (subsidized) user, the greater the use of the service.

On average, in 2017, the subsidy increased the total average number of boardings by 16 per month. In 2018 the average effect of the subsidy on the total number of boardings was 7.5, with a statistically significant effect observed in all months. In 2019, the average effect of the subsidy on the total number of boardings was 5.4, while there existed no significant effect in February and March. In 2017 the average effect of 16 additional boardings per month is practically equal to one standard deviation (SD) of monthly boardings among individuals with SISBEN

Table 3
Effect of Bogotá's public transport subsidy on the number of total trips per month.

Year	Month	LATE	SE	LATE as % of SD
2017	APR	25.32***	3.67	164%
	MAY	24.00***	3.18	143%
	JUN	19.68***	2.65	125%
	JUL	18.01***	2.01	116%
	AUG	18.01***	2.01	116%
	SEP	16.30***	1.98	96%
	OCT	14.67***	1.63	87%
	NOV	12.49***	1.45	75%
	DEC	11.54***	1.44	75%
2018	JAN	10.72***	1.38	69%
	FEB	10.26***	1.34	65%
	MAR	9.188***	1.38	58%
	APR	9.362***	1.35	52%
	MAY	8.371***	1.13	50%
	JUN	5.121***	0.89	36%
	JUL	6.898***	1.09	36%
	AUG	6.022***	1.27	35%
	SEP	5.450***	1.14	34%
	OCT	7.244***	0.88	42%
	NOV	6.090***	0.77	38%
	DEC	5.361***	0.85	35%
2019	JAN	4.442***	0.65	30%
	FEB	5.837	9.66	38%
	MAR	11.37	7.59	62%
	APR	5.007***	0.81	32%
	MAY	6.458***	0.97	37%
	JUN	4.088***	0.84	27%
	JUL	4.217***	0.88	29%
	AUG	4.885***	0.85	30%
	SEP	4.863***	1.10	29%
	OCT	6.086***	1.19	36%
	NOV	3.101***	1.06	21%
	DEC	4.048***	1.04	27%

LATE = Local average treatment effect; SD=Standard deviation.
Notes: All models only include individuals with SISBEN scores ±5 points from the eligibility cutoff. Controls for *Familias en Acción* receipt. The column titled "LATE as % of SD" shows the size of the estimated effect relative to the SD of monthly trips made by individuals with SISBEN scores ±5 SISBEN III points from the cutoff (see Table 1 for information on SD per year and month).

scores between 25.57 and 35.57 points. In 2018 the estimated effect of the subsidy corresponds to 42% of SD of monthly validations, and in 2019 to 33% of SD of monthly validations among individuals in the same range of SISBEN score. What is evident from these results, and further highlighted in Fig. 2 (2017, top), is that the size of the effect of the subsidy has decreased over time, both in terms of the total number of trips as well as relative to the average number of trips per year and month. A particular drop in the size of the effect can be observed between the end of 2017 and 2018.

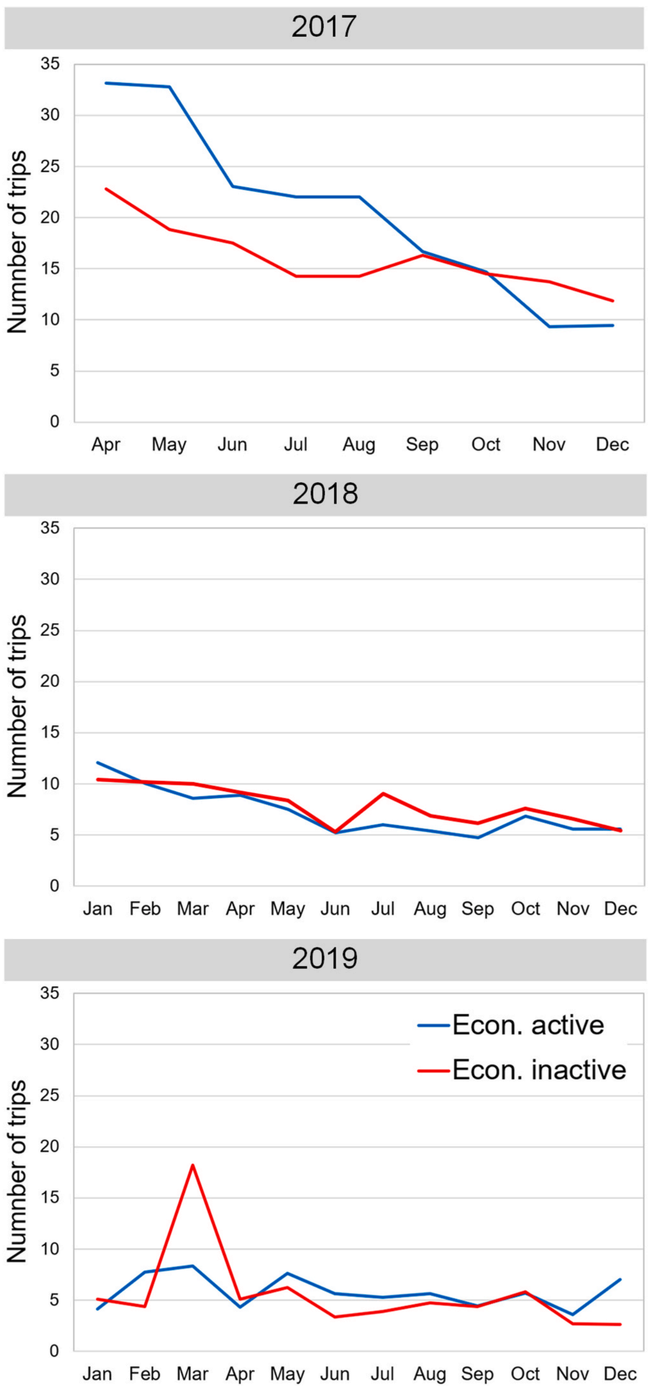

Fig. 2. Effect of Bogotá's public transport subsidy on the total number of monthly trips according to economic activity status.
Notes: All models only include individuals with SISBEN scores ±5 points from the eligibility cutoff. Controls for *Familias en Acción* receipt. The column titled "LATE as % of SD" shows the size of the estimated effect relative to the SD of monthly trips made by individuals with SISBEN scores ±5 SISBEN III points from the cutoff (see Table 1 for information on SD per year and month).

Table 4 presents the LATE of the public transport subsidy on the total number of monthly trips on weekends and holidays obtained from the RDD. As the table shows, on average, there exists a significant positive effect of the public transport subsidy on the number of validations on weekends and holidays in most months between March 2017 and December 2019. On average, in 2017, the subsidy increased the total average number of boardings on weekends and holidays by 2.9 per month. In 2018 the average effect of the subsidy was 0.85, with a statistically significant effect observed in all months except September. In 2019, there existed no statistically significant effect of the public transport subsidy. In 2017 the average effect of 16 validations on weekends and holidays per month is equal to 58% of monthly validations on weekends and holidays among individuals with SISBEN scores between 25.57 and 35.57 points. In 2018 the estimated effect of the subsidy corresponds to 18% of SD of monthly validations, and in 2019 to 2% of SD of monthly validations among individuals in the same range of SISBEN points. Similar to the effect of the subsidy on average monthly trips the effect on trips on weekends has diminished over time and especially after 2018 (see Figure 2 and 2018 middle).

While being robust to the choice of different bandwidths (see Appendix Table A2), we also assessed whether the results are robust to using different eligibility cutoffs as placebo tests. As Appendix Table A3 shows, when using alternative eligibility cutoffs, near the current cutoff, the results are consistently insignificant.

We furthermore assessed whether there existed a differential effect of the public transport subsidy on the number of trips between

Table 4
Effect of Bogotá's public transport subsidy on the number of trips during weekends and holidays per month.

Year	Month	LATE	SE	LATE as % of SD
2017	APR	6.120***	1.2	107%
	MAY	2.891***	0.8	67%
	JUN	3.378***	0.6	83%
	JUL	5.441***	0.8	89%
	AUG	5.441***	0.8	89%
	SEP	1.864***	0.4	48%
	OCT	−0.126	0.5	−4%
	NOV	1.994***	0.4	47%
	DEC	1.705***	0.4	36%
2018	JAN	1.567***	0.4	42%
	FEB	1.058***	0.4	29%
	MAR	1.344***	0.4	29%
	APR	1.124***	0.3	26%
	MAY	0.711**	0.3	17%
	JUN	0.534**	0.3	12%
	JUL	0.800**	0.3	20%
	AUG	0.699**	0.3	17%
	SEP	0.495	0.3	12%
	OCT	0.716***	0.3	18%
	NOV	0.611**	0.3	14%
	DEC	0.590**	0.3	13%
2019	JAN	0.310	0.2	9%
	FEB	0.276	0.2	8%
	MAR	0.429	0.3	9%
	APR	0.238	0.2	6%
	MAY	0.265	0.3	7%
	JUN	0.276	0.3	6%
	JUL	−0.0268	0.2	−1%
	AUG	0.127	0.3	3%
	SEP	−0.204	0.3	−5%
	OCT	0.104	0.3	3%
	NOV	−0.112	0.3	−3%
	DEC	−0.0265	0.3	−1%

LATE = Local average treatment effect; SD=Standard deviation.
Notes: All models only include individuals with SISBEN scores ±5 points from the eligibility cutoff. Controls for *Familias en Acción* receipt. The column titled "LATE as % of SD" shows the size of the estimated effect relative to the SD of monthly trips made by individuals with SISBEN scores ±5 SISBEN III points from the cutoff (see Table 1 for information on SD per year and month).

economically active and non-active individuals. As Fig. 2 shows, between April to September 2017 the effect of the public transport subsidy on the total number of trips per month was larger among economically active compared to non-active individuals. Since then, there exists no substantially different effect of the subsidy between the two groups.

6. Conclusions

To provide affordable public transport services for the poorest population despite the financial constraints, the local government of Bogotá implemented a pro-poor public transport subsidy scheme in 2013. This paper aimed to estimate the causal effect of Bogotá's public transport subsidy for poor individuals on the number of trips. To this end, we used detailed administrative data on public transport use (for the years 2017–2019) in combination with an RDD. We present evidence of the effects on public transport ridership of this subsidy, exploring the causal links between the subsidy and ridership outcome. As our results show, the effect of this subsidy has a significative and positive impact on the total trips made by subsidy beneficiaries, on both weekdays and weekends. However, the size of the subsidy's effect on the total number of trips per month as well as on trips during weekends has substantially diminished since 2017, with the effect on trips during weekends becoming insignificant in 2019. The subsidy's effect went from 16 more trips/month in 2017 to nothing (no significative effect) by the end of 2019, although for overall trips the effect remains significant throughout 2019.

A challenge of this study has been to identify the causes of the vanishing of the subsidy effect on ridership over time. In this context, it should be taken into account that during the studied period, the city's public transport system underwent the implementation of the new regular bus component and the dismantling of traditional bus routes. At the same time, travel times increased, particularly in public transport and the motorcycle fleet (a natural substitute for public transport in poor population segments) increased by 17% between 2017 and 2019. This situation encouraged bicycle use since most of the cyclists are also frequent users of public transport, and in 2017 for the first time in history the public transport demand stopped increasing. At the same time, there was a fare increase between 9 and 14% during the study period and the total public transport ridership decreased by approximately 10%.

These changes in user costs and ridership could have affected the subsidy effect on trips over time, thus diminishing its positive effect. Another speculative hypothesis for the reduction in the effect of the subsidy over time, and especially between April to December 2017, may be that many recipients of the public transport subsidy did not realize immediately that the maximum number of subsidized trips was reduced from 40 to 30 in April 2017. Hence, it is possible that many recipients of the subsidy continued using public transport for the better part of 2017 assuming that they would still get up to 40 trips subsidized. Therefore, we hypothesize that the combination of fare increases, limited subsidized trips, and partial unawareness of the reduction in subsidized trips in April 2017 explains that the effect of the subsidy on the number of monthly trips has diminished since then.

In summary, our results suggest that the public transport subsidy significantly and substantially leads to an increase in public transport use among low-income individuals, both in terms of the total number of monthly trips as well as for trips during weekends. These results of course are related only to Bogotá, hence the specific conclusions cannot easily be extrapolated to other cities. Therefore, further research on this question, including analyses of the impacts on mobility patterns, employment, and other aspects is needed.

6.1. Strengths and limitations

Besides the present study having several strengths, including a large sample size as well as a quasi-experimental identification strategy, some limitations should be taken into account.

First, the results from the RDD only represent a local treatment effect, i.e., one that is generalizable for individuals with SISBEN poverty scores close to the cutoff and not for the entire population of Bogotá. Second, due to the limitations of the available data, we are unable to assess whether, besides the receipt of the *Familias en Acción* program (which is included as a control variable) and economic activity, there exist other discontinuities around the same cutoff that may affect the results. While we are not aware of other government-sponsored programs that use the same eligibility threshold it is plausible that the SISBEN eligibility cutoff itself does not reflect any differences between individuals in terms of sociodemographic characteristics. E.g., it is highly likely that in its direct proximity there are as many men and women, or younger and older individuals, on either side of the SISBEN eligibility threshold, therefore resulting in effective randomization of treatment. Third, it is not possible to quantify the potential impact of the presence of fare evasion on the effect of the subsidy. According to the only study published on this question in Bogotá, fare price is relevant for users (Guzman et al., 2021a), meaning that an expensive fare encourages service dissatisfaction and hence, evasion. However, in this case, the subsidized fare lowers the cost for the user, and although it cannot be confirmed with total certainty, by having a lower fare the incentive to evade also decreases. And even though there exists no current information on fare evasion in the SITP, in this case, by having all the information on the personalized travel cards during the study period, no significative changes were observed in the travel card use patterns in this regard. Therefore, there could be a bias in our results due to evasion, but it is not possible to quantify its effect on the results. A final limitation of the present paper is that we are unable conclusively and definitively to assess the reasons why the effect of the subsidy has decreased substantially over time or alternative transport modes of users. We do present a reasonable explanation.

6.2. Discussion and policy implications

Based on the SISBEN classification, the results make it clear that public transport subsidies give special consideration to the poorest users. This reveals that the subsidy policy satisfactorily targets the poorest people, encouraging public transport usage. As seen, a targeted pro-poor subsidy can have a significant and positive effect on the benefited population, encouraging them to use public transport more, and hence, to participate in more productive and leisure activities. However, with the change in the conditions of access to the subsidy (lower SISBEN score and fewer subsidized trips), it was intended to target the intervention better, that is, subsidize the poorest among the poor. However, the current subsidy (in 2019) does not encourage more trips in the treatment group versus the control, and the SITP financial deficit is still increasing. An effective policy that initially works well, if it is not reviewed periodically, can lose its effectiveness or even may have negative effects over time.

The overall redistributive impact in terms of more public transport use could be key given an increase in accessibility and the large weight of the transport costs in the budget of poor households. Despite the criticisms it receives, the transport subsidy policy in Bogotá (and other Latin American cities) has a redistributive effect in terms of public transport use that benefits those with lower incomes. However, the population with SISBEN scores greater than 30.56 is still very poor, so they should also benefit from the subsidy. Given the positive impact in terms of public transport use among the city's poor individuals policymakers may consider expanding the eligibility criteria to increase overall public transport use among poor individuals. However, expanding the eligibility criteria, i.e., making the subsidy more inclusive, would reduce, *ceteris paribus*, the distributive effects of the subsidy. An effective and well targeted public transport subsidy is an alternative form of interpretation of the current social consequences of transport policy and planning and explicit recognition of differences in the capacity of social groups and individuals in urban mobility to take advantage of the opportunities offered by cities. Another issue is to find alternative sources to fund these types of policies.

An immediate policy implication of the main result of this study is an evident relation of subsidies to their potential implications for sustainable and inclusive development in cities like Bogotá, where social exclusion is deep and evident. However, the question about the extent to which such policy is effective over time remains to be answered. If it loses effectiveness, as is the case, other fiscal tools different from targeted subsidies would be more efficient in achieving the same redistributive effects. As an isolated measure, public transport subsidies may be an effective and temporary tool for increasing social well-being. Precisely due to the financial restrictions of the city, travel demand management measures such as congestion and parking charges, or even more dedicated bus lanes, could reduce the subsidy, mitigating road congestion and making public transport more attractive and competitive compared to private transport.

Author statement

Luis A. Guzman: Conceptualization, Supervision, Methodology, Writing- Original draft preparation, Writing- Reviewing and Editing. **Philipp Hessel**: Conceptualization, Methodology, Writing- Original draft preparation, Formal analysis.

Acknowledgements

We would like to express our gratitude to the Bogotá Urban Planning Department (www.sdp.gov.co), for the funding and general support given for the development of this study through agreement 369 of 2018. We thank Transmilenio S.A. (www.transmilenio.gov.co) for providing the information and data to carry out this study. We also thank student Carlos Felipe Luque for assistance with data curation and management that made possible the manuscript.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tranpol.2022.07.016.

References

Ardila, A., 2007. How public transportation's past is haunting its future in Bogotá, Colombia. Transp. Res. Rec. J. Transp. Res. Board 9–15. https://doi.org/10.3141/2038-02, 2038.

Barrientos, A., Villa, J.M., 2015. Antipoverty transfers and labour market outcomes: regression discontinuity design findings. J. Dev. Stud. 51, 1224–1240. https://doi.org/10.1080/00220388.2015.1010157.

Basso, L.J., Guevara, C.A., Gschwender, A., Fuster, M., 2011. Congestion pricing, transit subsidies and dedicated bus lanes: efficient and practical solutions to congestion. Transport Pol. 18, 676–684. https://doi.org/10.1016/j.tranpol.2011.01.002.

Basso, L.J., Silva, H.E., 2014. Efficiency and substitutability of transit subsidies and other urban transport policies. Am. Econ. J. Econ. Pol. 6, 1–33. https://doi.org/10.1257/pol.6.4.1.

Börjesson, M., Eliasson, J., Rubensson, I., 2020. Distributional effects of public transport subsidies. J. Transport Geogr. 84, 102674 https://doi.org/10.1016/j.jtrangeo.2020.102674.

Bueno, P.C., Vassallo, J.M., Herraiz, I., Loro, M., 2016. Social and distributional effects of public transport fares and subsidy policies: case of Madrid, Spain. Transp. Res. Rec. J. Transp. Res. Board 2544, 47–54. https://doi.org/10.3141/2544-06.

Bull, O., Muñoz, J.C., Silva, H.E., 2021. The impact of fare-free public transport on travel behavior: evidence from a randomized controlled trial. Reg. Sci. Urban Econ. 86, 103616 https://doi.org/10.1016/j.regsciurbeco.2020.103616.

Bureau, B., Glachant, M., 2011. Distributional effects of public transport policies in the Paris Region. Transport Pol. 18, 745–754. https://doi.org/10.1016/j.tranpol.2011.01.010.

Calonico, S., Cattaneo, M.D., Farrell, M.H., Titiunik, R., 2017. Rdrobust: software for regression-discontinuity designs. Stata J. Promot. Commun. Stat. Stata 17, 372–404. https://doi.org/10.1177/1536867X1701700208.

Cantillo-García, V., Guzman, L.A., Arellana, J., 2019. Socioeconomic strata as proxy variable for household income in transportation research. Evaluation for Bogotá, Medellín, Cali and Barranquilla. DYNA 86, 258–267. https://doi.org/10.15446/dyna.v86n211.81821.

Cattaneo, M.D., Jansson, M., Ma, X., 2020. Simple local polynomial density estimators. J. Am. Stat. Assoc. 115, 1449–1455. https://doi.org/10.1080/01621459.2019.1635480.

Chaplin, D.D., Cook, T.D., Zurovac, J., Coopersmith, J.S., Finucane, M.M., Vollmer, L.N., Morris, R.E., 2018. The internal and external validity of the regression discontinuity design: a meta-analysis of 15 within-study comparisons. J. Pol. Anal. Manag. 37, 403–429. https://doi.org/10.1002/pam.22051.

De Witte, A., Macharis, C., Lannoy, P., Polain, C., Steenberghen, T., Van de Walle, S., 2006. The impact of "free" public transport: the case of Brussels. Transp. Res. Part A Policy Pract 40, 671–689. https://doi.org/10.1016/j.tra.2005.12.008.

Estupiñan, N., Scorcia, H., Navas, C., Zegras, C., Rodriguez, D., Vergel - Tovar, E., Gakenheimer, R., Azan Otero, S., Vasconcellos, E., 2018. Transporte y Desarrollo en América Latina. Caracas.

Falavigna, C., Hernandez, D., 2016. Assessing inequalities on public transport affordability in two Latin American cities: montevideo (Uruguay) and Córdoba (Argentina). Transport Pol. 45, 145–155. https://doi.org/10.1016/j.tranpol.2015.09.011.

Gómez-Lobo, A., 2009. A new look at the incidence of public transport subsidies: a case study of Santiago, Chile. J. Transport Econ. Pol. 43, 405–425.

Guzman, L.A., Arellana, J., Camargo, J.P., 2021a. A hybrid discrete choice model to understand the effect of public policy on fare evasion discouragement in Bogotá's Bus Rapid Transit. Transp. Res. Part A Policy Pract. 151, 140–153. https://doi.org/10.1016/j.tra.2021.07.009.

Guzman, L.A., Arellana, J., Oviedo, D., Moncada Aristizábal, C.A., 2021b. COVID-19, activity and mobility patterns in Bogotá. Are we ready for a '15-minute city. Trav. Behav. Soc. 24, 245–256. https://doi.org/10.1016/j.tbs.2021.04.008.

Guzman, L.A., Beltran, C., Bonilla, J., Gomez Cardona, S., 2021c. BRT fare elasticities from smartcard data: spatial and time-of-the-day differences. Transp. Res. Part A Policy Pract 150, 335–348. https://doi.org/10.1016/j.tra.2021.06.018.

Guzman, L.A., Gomez Cardona, S., 2021. Density-oriented public transport corridors: Decoding their influence on BRT ridership at station-level and time-slot in Bogotá. Cities 110. https://doi.org/10.1016/j.cities.2020.103071.

Guzman, L.A., Gomez, S., Moncada, C.A., 2020. Short run fare elasticities for Bogotá's BRT system: ridership responses to fare increases. Transportation 47, 2581–2599. https://doi.org/10.1007/s11116-019-10034-6.

Guzman, L.A., Oviedo, D., 2018. Accessibility, affordability and equity: assessing 'pro-poor' public transport subsidies in Bogotá. Transport Pol. 68, 37–51. https://doi.org/10.1016/j.tranpol.2018.04.012.

Guzman, L.A., Oviedo, D., Rivera, C., 2017. Assessing equity in transport accessibility to work and study: the Bogotá region. J. Transport Geogr. 58, 236–246. https://doi.org/10.1016/j.jtrangeo.2016.12.016.

Gwilliam, K., 2008. A review of issues in transit economics. Res. Transport. Econ. 23, 4–22. https://doi.org/10.1016/j.retrec.2008.10.002.

Hahn, J., Todd, P., Klaauw, W., 2001. Identification and estimation of treatment effects with a regression-discontinuity design. Econometrica 69, 201–209. https://doi.org/10.1111/1468-0262.00183.

Hensher, D.A., 1998. Establishing a fare elasticity regime for urban passenger transport. J. Transport Econ. Pol. 32, 221–246.

Hörcher, D., Tirachini, A., 2021. A review of public transport economics. Econ. Transp. 25, 100196 https://doi.org/10.1016/j.ecotra.2021.100196.

Imbens, G.W., Lemieux, T., 2008. Regression discontinuity designs: a guide to practice. J. Econom. 142, 615–635. https://doi.org/10.1016/j.jeconom.2007.05.001.

Lee, D.S., Lemieux, T., 2010. Regression discontinuity designs in economics. J. Econ. Lit. 48, 281–355. https://doi.org/10.1257/jel.48.2.281.

Lucas, K., 2012. Transport and social exclusion: where are we now? Transport Pol. 20, 105–113. https://doi.org/10.1016/j.tranpol.2012.01.013.

Melguizo, T., Sanchez, F., Velasco, T., 2016. Credit for low-income students and access to and academic performance in higher education in Colombia: a regression discontinuity approach. World Dev. 80, 61–77. https://doi.org/10.1016/j.worlddev.2015.11.018.

Miller, G., Pinto, D., Vera-Hernández, M., 2013. Risk protection, service use, and health outcomes under Colombia's health insurance program for the poor. Am. Econ. J. Appl. Econ. 5, 61–91. https://doi.org/10.1257/app.5.4.61.

Oviedo, D., Guzman, L.A., 2020. Should urban transport become a social policy? Interrogating the role of accessibility in social equity and urban development in Bogotá, Colombia. In: Urban Mobility and Social Equity in Latin America: Evidence, Concepts, Methods. Emerald, pp. 11–32. https://doi.org/10.1108/S2044-994120200000012005.

Oviedo, D.R., Guzman, L.A., Oviedo, N., 2019. What is the contribution of public transport to productive inclusion? Examining job informality in the Bogotá region. In: Transportation Research Board 98th Annual Meeting. Washington D.C., 19–06063.

Parry, I.W.H., Small, K.A., 2009. Should urban transit subsidies Be reduced? Am. Econ. Rev. 99, 700–724. https://doi.org/10.1257/aer.99.3.700.

Peña, J., Guzman, L.A., Arellana, J., 2022. Which dots to connect? Employment centers and commuting inequalities in Bogotá. J. Transp. Land Use 15, 17–34. https://doi.org/10.5198/jtlu.2022.2100.

Rivas, M.E., Brichetti, J.P., Serebrisky, T., 2020. Operating subsidies in urban public transit in Latin America: a quick view. Inter-American development bank, Washington D.C. https://doi.org/10.18235/0002911.

Rivas, M.E., Serebrisky, T., Suárez-Alemán, A., 2018. How affordable is transportation in Latin America and the caribbean? Washington, D.C. https://doi.org/10.18235/0001530.

Rodríguez, C., Gallego, J.M., Martinez, D., Montoya, S., Peralta-Quiros, T., 2016. Examining implementation and labor market outcomes of targeted transit subsidies: subsidy by sistema nacional de Selección de Beneficiarios for urban poor in Bogotá,

Colombia. Transp. Res. Rec. J. Transp. Res. Board 2581, 9–17. https://doi.org/10.3141/2581-02.
Serebrisky, T., Gómez-Lobo, A., Estupiñán, N., Muñoz-Raskin, R., 2009. Affordability and subsidies in public urban transport: what do we mean, what can Be done? Transp. Rev. 29, 715–739. https://doi.org/10.1080/01441640902786415.
Vecchio, G., Tiznado-Aitken, I., Hurtubia, R., 2020. Transport and equity in Latin America: a critical review of socially oriented accessibility assessments. Transp. Rev. 40, 354–381. https://doi.org/10.1080/01441647.2020.1711828.