The effect of public transport subsidies on travel behavior and welfare: a large-scale randomized controlled field experiment in a developing context

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Abstract

Few studies have evaluated the impacts of public transport subsidies in Latin America, and even fewer studies have used randomized controlled field experiments on a large scale. Understanding the effectiveness of subsidies is important, especially in Latin American cities, where public transport systems are utilized by a large part of the population and particularly by those with low incomes, who have particular travel patterns and preferences, affordability issues, and financing issues. Here, a case study using a large-scale randomized controlled field experiment (N=1,607) is presented in Bogotá, Colombia. Using a unique controlled field experiment in which a randomly selected group of frequent public transport users received a transport voucher for four months, we estimate the causal mechanisms of the effects of providing cash transfers to travel cards on travel behavior and derived welfare. In this case study, public transport vouchers stimulate ridership more than the current fare discount public transport subsidy. We find that the vouchers increased ridership by up to 8.7% on average compared to the control group. This increase is concentrated during weekdays and peak hours. In addition, by measuring welfare using a consumer surplus approach, we found evidence that vouchers are effective when it comes to inducing positive welfare effects for commuters while a fare discount is not. This is most beneficial for low-fare-demand elasticity populations; these populations represent the main users of public transport. Overall, our results suggest that alternative public transport subsidies can be an effective way for increasing public transport use, which also translates into welfare gains, and cost-effective policy.

Keywords: Public Transport; RCT; Public transport pricing; Travel voucher; Bogotá

JEL: H24, R41, R48

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1. INTRODUCTION

Public transport services are subsidized in most countries; on average, subsidies represent around half the total operating costs of public transport services (Cervero, 2011). Motivations for implement public transport subsidies can include reducing social inequality, compensating for the under-pricing of private car/motorcycle use, efficiencies based on economies of scale, and gaining political support. However, efficient transport pricing is still rare (Eliasson, 2021) since the prices of car/motorcycle usage are lower than their social cost, creating an unbalanced competition with public transport. In large Latin American cities, which usually have high social and spatial segregation levels, transport subsidies are widespread, with the goal of increasing the affordability of transport (Rivas et al., 2018). In Latin America, the equality justification for public transport subsidies seems to be a key issue, mainly because regularly using these services can often be difficult for low-income populations. Given this situation, transport costs represent a heavy burden, especially for people from low-income households, who are the main users of public transport (Estupiñan et al., 2018).

According to the background of the research, the need to rethink subsidy schemes in Latin America is highlighted. Therefore, we evaluate the effectiveness of cash transfers (i.e., public transport vouchers) and their impact on ridership and user welfare, through a randomized controlled experiment in Bogotá, Colombia. We randomly selected a representative group of 1,607 regular public transport users with personalized travel cards who do not receive any kind of subsidy. The voucher consisted of a monthly cash transfer to their travel cards. This research had two main objectives. First, we obtain a causal estimate of the ridership changes due to the voucher. Second, we use the ridership causal estimates to understand the welfare impacts and equality trade-offs associated with the fare subsidy. This included the welfare impacts of introducing the vouchers and a policy effectiveness analysis.

We found that the vouchers are partially used for additional public transport trips, and participants reduced the overall amount of money they spent on the system. We also found that most of the extra trips took place on weekdays. Increases in welfare were higher for low-income users, indicating higher transport gains and demonstrating the conditions under which vouchers lead to an increase in welfare. Our results provide a rationale for re-evaluating the current public transport fare scheme for vulnerable users by targeting subsidies more effectively. This work contributes to the existing literature by generating new evidence from one of the largest public transport systems in Latin America to examine the impact of new forms of subsidies on public transport and their effectiveness. The study provides strong evidence through a large controlled field experiment.

2. SUBSIDIES AND WELFARE: AN UNEXPLORED TOPIC

In response to different motivations, public transport subsidies, including free fares, have gained attention from the academic community and policymakers. These subsidies increase government expenses, and, in some sectors, there is political dissatisfaction with the high cost of these subsidies. However, in cities where car use is under-priced (i.e., almost all cities), a public transport system without subsidies would cause the sector to be fully subject to market forces, causing supply distortions and a low quality of service. Therefore, subsidizing public transport fares could improve the general welfare, even if the price is under its first-best level due to externalities (Hörcher and Tirachini, 2021).

There are economic efficiency arguments for subsidizing public transport; they include scale economies and the first-best or second-best pricing of road traffic externalities (Hörcher and Tirachini, 2021). There are also justifications regarding distribution effects and equality arguments (Börjesson et al., 2020; Guzman and Oviedo, 2018). Some of the most well-known instruments that were designed to alleviate the financial burden of public transport systems for low-income households are fare discounts. Despite the prevalence of studies concerning free and subsidized public transport fares in developed economies, there are only a few studies about this in Latin America. The impact of subsidized public transport on ridership and the welfare of public transport users is not well documented. In the literature, there are mixed results regarding the impacts of subsidies on the population and their travel behavior. Most of the existing literature on subsidized public transport is generally based on cities in the Global North, with a focus on rail systems.

We review the literature concerning public transport subsidies highlighting that an affordable fare encourages public transport ridership and that, there are no studies concerning welfare impacts in Latin America, which reflects the lack of attention that these types of policies have received in that part of the world. Research in Latin America has mainly focused on exploring the effects of increasing ridership, with scarce and inconsistent evidence. In this context, we performed a thorough, systematic literature review of public transport subsidies and their effects finding two main categories: supply-side and demand-side subsidies. Within the supply-side subsidy papers, the most studied topic is the financial sustainability of public transport systems, particularly in Chinese cities. It has also been found this type of subsidy does not allow proper targeting and tends to be regressive.

There are empirical methods that were used to identify the subsidies' effects on the efficiency of the provision of transport services, financial sustainability, and infrastructure expansion (de Grange et al., 2012; Gupta and Mukherjee, 2013; Zhong et al., 2020). Other studies use structural models to identify the impact of supply-side subsidies on the provision equality of transport services and to evaluate the financial results of the public transport operators (Gómez-Lobo, 2009; Jin and Chen, 2011; Nilsson et al., 2016; Rambaldini-Gooding et al., 2021; Ševrović et al., 2015). These investigations show that supply-side subsidies have positive impacts on the users' welfare, improve route efficiency, increase the quality of service, and reduce financial problems. In addition, supply-side subsidies should not all be the same, since there are differences among routes; routes have different spatial locations, ridership, and cycle times (Luo et al., 2022). Therefore, great care must be taken when designing subsidy programs to balance the loss of operational efficiency and welfare gains (Yang et al., 2020).

Regarding demand-side subsidies, the most studied topic is the effect of this type of subsidy on the use of public transport systems (Batarce and Galilea, 2018; Brough et al., 2022; Bull et al., 2021; Bureau and Glachant, 2011; De Witte et al., 2006; Guzman and Hessel, 2022; Parry and Small, 2009; Zhou and Schweitzer, 2011) and their redistributive effects (Asensio et al., 2003; Börjesson et al., 2020; Bueno et al., 2016). This topic has been studied extensively, particularly in Europe and North America, including in several cities that have implemented free fares. Perhaps the best-known case is Tallinn, Estonia (Cats et al., 2017). More recently this policy was implemented in Luxembourg, where critical results have emerged regarding this type of policy (Carr and Hesse, 2020); for example, people with free fares walk more but cycle less (Pesola et al., 2022). Generally, the scale of implementation for free fares is small. For example, the federal state of Hesse (Germany) introduced a free public transport ticket for all state employees, which caused a substantial increase in the use of public transport for commuting and other trip purposes. Car use and availability, however, did not decrease (Busch-Geertsema et al., 2021). In short, the free fare experiment is just one case in a city with more than 500,000 inhabitants.

Other studies use panel models with experimental data, i.e., randomized controlled trials (RCTs) (Brough et al., 2022; Bull et al., 2021; Franklin, 2018; Hall et al., 2021; Mobarak and Reimão, 2020; Phillips, 2014; Webber et al., 2020; Zhou and Schweitzer, 2011). Still, there is little experimental evidence concerning the impact of subsidies in real-world public transport systems on ridership changes and welfare gains. Thus, the majority of the literature does not consider welfare-oriented subsidy impacts.

RCTs are prospective methods that measure the effectiveness of an intervention, and they are a key tool for studying cause and effect because randomization reduces bias and provides a rigorous tool that can be used to examine the causal relationships between an intervention and outcome. Just three studies use RCTs to evaluate the impact of subsidies on public transport ridership, and only one was performed in Latin America. The others were performed in the USA. Brough et al. (2022) studied the effect of a free fare program for 6 months in King County, Washington, creating panel data at the individual level in a vulnerable area. The results showed that the free fare program caused the participants to use public transport up to four times as often compared to the control group, mainly during off-peak hours. Zhou and Schweitzer (2011) evaluated UCLA employees' participation in a free-pass public transport program in Los Angeles, California. The program involved randomly giving the 12-week free pass to frequent car users. It was found that the program encouraged 33% of the participants to use public transport. These participants lived less than 800 meters away from a public transport station. In Santiago, Chile, the effect of assigning a free public transport pass for two weeks to a subsample of 200 workers was evaluated. An increase in ridership of 12% compared to the control group was found, with most of the increase taking place during off-peak hours (Bull et al., 2021).

Nevertheless, the analysis of the subsidies goes beyond studying their impacts on ridership. Other studies investigated the impact of a targeted public transport subsidy on the labor market (Abebe et al., 2021; Franklin, 2018; Phillips, 2014; Rodríguez et al., 2016), showing that subsidies affect labor market variables such as the labor income, the probability of getting a job, and the probability of working. Additionally, Webber et al. (2020) showed that public transport subsidies improved maternal care in Tanzania. Mobarak and Reimão (2020) showed that transport subsidies helped to reduce poverty levels in populations susceptible to drought in Bangladesh and Indonesia.

In Latin America, most of the public transport subsidies are supply-side subsidies covering infrastructure or operating costs, and they vary between 26 and 69% (Rivas et al., 2020). This is the case in Buenos Aires, Argentina, where subsidies cover more than two-thirds of the operating costs of the public transport system (Avner et al., 2017). In Colombia, the demand for public transport is price-sensitive and responds positively to speed and frequency improvements (Toro-González et al., 2020). In the specific case of Bogotá, the supply-side subsidies reached 619 million USD in 2021, while demand-side subsidies were just 3% of that figure. Nevertheless, there is evidence that subsidies improved work accessibility (Guzman and Oviedo, 2018). In Santiago, Chile, it was estimated that fares that could cover metro infrastructure costs would be 193% higher than current fares (Gómez-Lobo, 2009). On the other hand, demand-side subsidies are a common policy implemented in the region to increase the affordability of transport, especially for low-income groups. These subsidies have mixed and inconsistent results because of problems identifying and helping the target groups (Rivas et al., 2018). Despite their flaws, demand-side subsidies are still preferable because they can be used to target specific groups (Serebrisky et al., 2009). This is crucial in contexts in which government budgets are tight and there is institutional competition for money.

This literature review has shown that there is scarce research on the impact of public transport demand-side subsidies on welfare and policy effectiveness. There is little empirical and experimental work establishing causal links between public transport subsidies, the corresponding travel pattern changes, user savings, and welfare outcomes in Latin American cities. Cities should conduct in-depth analyses to improve the efficiency and effectiveness of subsidies for their public transport systems since the effective provision of public transport requires substantial and careful planning and huge financial costs. It is crucial to understand the wide impacts these subsidies will have on mobility patterns, local finances, and other aspects of society (Kębłowski, 2020). Efficient resource allocation is critical for the correct operation and affordability of the systems. More research is needed to understand subsidy effects across the Latin American region, considering the particular urbanization dynamics, which create more complex travel patterns (Sarmiento et al., 2021) for low-quality formal and informal transport services (Hidalgo and Huizenga, 2013). This transport scenario differs from transport scenarios in other regions of the world and makes it difficult to transfer subsidy impacts to different contexts.

This work aims to investigate the impact of public transport vouchers on the welfare of frequent public transport users in Bogotá, measuring their effectiveness in promoting public transport use and studying how they can generate welfare in terms of consumer surplus. Voucher schemes are particularly popular because they give people a certain element of choice while promoting desirable behaviors, which has positive effects (Minnich et al., 2022).

3. CASE STUDY AND DESIGN

The integrated public transport system (SITP in Spanish) of Bogotá is one of the largest systems in Latin America, with around 3.05 million trips per day. Currently, the system is bus-based (BRT and regular buses), although since late 2018, a cable car has been in operation with a daily travel demand of around 25,000 passengers (Guzman et al., 2022), and the first metro line is under construction. The SITP is the most common transport mode for middle-low and low socioeconomic population segments in Bogotá. Out of 100 SITP commuters, 87 live in the lowest socioeconomic strata (SES) areas, SESs 1 to 3. SES 1 corresponds to the poorest households and SES 6 corresponds to the wealthiest residents, who also live in zones with the best urban conditions (Cantillo-García et al., 2019). The SITP is widely available across the city; however, limited financial resources and low coverage in low-SES areas cause the urban periphery to have low accessibility levels (Guzman et al., 2017).

From a social inclusion and welfare perspective, in Bogotá, transport affordability is a big challenge, as transport expenses consume around 13.7% of a household's income on average. This percentage can reach up to 25% for the poorest households, who must also deal with long travel times and access costs (Guzman and Oviedo, 2018). This means that for most of the users of Bogotá's SITP, the fare is not very affordable. This is the main justification for the existence of demand-side subsidies. In total, SITP targeted subsidies exceeded 18.6 million USD in 2021 in Bogotá. However, recent evidence has shown that these subsidies' effect on ridership has decreased over time to the point that it does not have a significant effect when it comes to encouraging more trips (Guzman and Hessel, 2022). The city is spending a large amount of money on a program that is not completely fulfilling its main objective: to reduce costs and increase access to the SITP.

3.1 The SITP fare

The current pricing scheme has a flat fare, which means that the fare price is independent of the trip length. The regular fares in 2021 were 2,500 Colombian pesos (COP) (about 0.67 USD) for the BRT services and 2,300 COP (about 0.61 USD) for regular bus services. Nevertheless, there is a targeted subsidy scheme for vulnerable populations that offers a fare discount for users who meet certain requirements. The eligibility for subsidies varies according to a person's socioeconomic conditions. This scheme includes preferential fares for elderly people (older than 62 years old), people with physical disabilities, and the poorest segment of the population. The proposed evaluation focuses on the latter since 53% of the money spent in 2021 on subsidies was allocated to this segment. To identify eligible beneficiaries for this program, the city uses a social policy targeting mechanism called SISBEN[1] (Guzman and Hessel, 2022).

The subsidy scheme was established in 2013 by the city within the strategy for the financial sufficiency of the SITP (Decree 603 of 2013). This incentive sought to provide greater access for the part of the population with a low ability to pay and consisted of a 40% fare discount and up to 21 monthly trips for people over 16 years of age with a SISBEN score of lower than 40 points. This scheme was restricted over time until it reached a fare discount of 28%, a maximum SISBEN score of 30.56, and a maximum of 30 monthly trips (Decree 131 of 2017). In 2021 fares with the SISBEN benefit were 1,800 COP (0.48 USD) for BRT and 1,650 COP (0.44 USD) for regular buses. In addition, it is necessary to own a personalized travel card (*tullave plus* card). The current pro-poor subsidy policy is a fare discount for a maximum of 30 trips every month. However, as mentioned above, this subsidy scheme no longer encourages SITP use, and it continues to be active even though its other effects and cost-effectiveness are not well understood. Therefore, we propose a new subsidy scheme in the form of a voucher. The transport voucher consists of a monthly cash transfer to *tullave plus* cards for four months as part of our RTC. We then make a direct comparison between the two schemes (the current scheme and vouchers) in terms of ridership encouragement, welfare gains, and policy cost-effectiveness.

[1] This program score ranges between 0 (most vulnerable people) to 100 (least vulnerable).

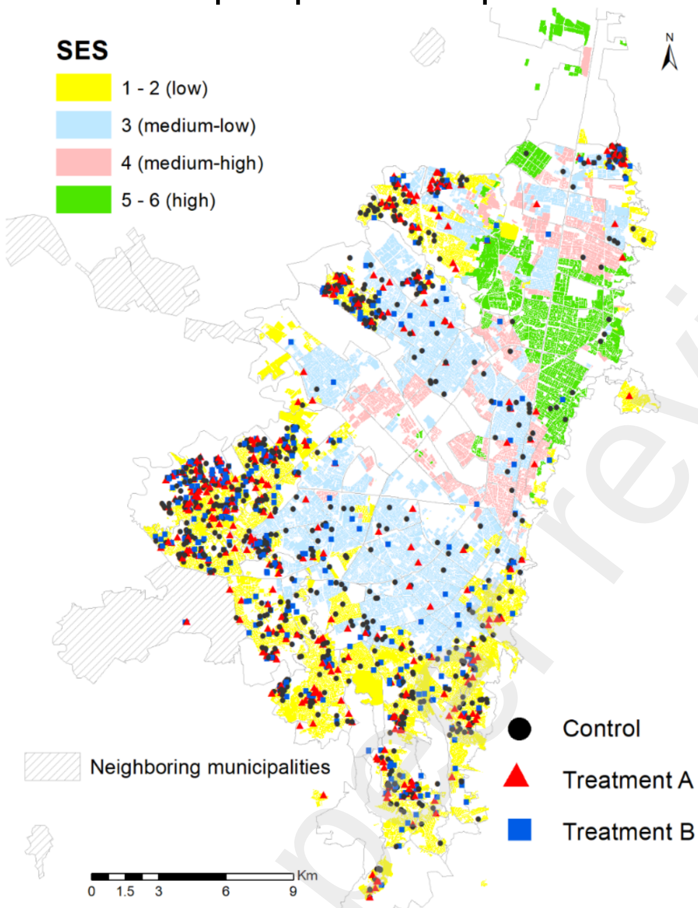
3.2 Experimental design

From the universe of approximately 176,000 frequent SITP users on a typical pre-pandemic day[2], we randomly selected a sample of 1,607 people (oversampling by 20%). Half of them (801) were randomly chosen to receive the vouchers on their travel cards. We randomly divided the participants into three groups: the treatment A group, who received a monthly transport voucher of 28,000 COP (7.5 USD); the treatment B group, who received a voucher of 21,000 COP (5.6 USD); and the control group. The voucher value corresponded to between 43 and 32% of participants' monthly public transport expenses. Participants in the control group were given an 8 USD grocery voucher at the end of the experiment if they participated throughout the intervention and continued to use the system at regular fares. Participants in each treatment group were informed about the incentives that they receive.

The experiment consisted of randomly assigning monetary transfers (transport vouchers) to the participants' personalized travel cards in May, June, July, and August 2021. Starting on the third week of each month, a new voucher was available, and participants in the treatment groups had to activate their vouchers. This money (voucher) behaves as a fresh cash recharge, and the travel card credit can be used to make trips at the regular fare prices. This randomized design allows us to derive an unbiased estimate of the impact of the transport vouchers on the travel demand and welfare changes for those individuals who were assigned to the treatment group. The final composition of the treatment groups was 402 participants in the treatment A group and 399 participants in the treatment B group. Before the experiment, the participants made an average of 37.8 trips on the SITP and recharged their travel cards with 68,300 COP (about 18.25 USD) every month. Among the participants, 81.8% live in SES 1 and 2 zones, as shown in Figure 1.

[2] Nine or more monthly trips during a typical work day in the time slot between 4:00 and 9:00 h.

Figure 1. Spatial distribution of the participants in the experiment



We focus our experimental design on low-income commuters since they use the SITP the most. These individuals have a less elastic price demand than the population with higher incomes (Guzman et al., 2021, 2020) and they value their public transport trips more. In our design, we collected data in waves. For the first wave, which took place during March and April 2021, we carried out a household survey of the entire sample. Information was collected on travel patterns (vehicles, activities, and travel times), quality of life (perceptions about life, safety, government, and public transport), and sociodemographic characteristics (type of housing, educational level, income, employment, and spending patterns). The second wave lasted four months; during this period, the intervention was carried out (delivery of the vouchers). Information regarding the expenses incurred and travel patterns was collected weekly by phone or instant messaging. Finally, in wave 3 (closing survey), the same information that was collected in wave 1 was collected.

The intervention period started when the first of the four vouchers was transferred (mid-May) and ended one month after the fourth voucher was activated (mid-September). We also have data for each participant on the number of trips (boardings) made, as well as the exact time, date, and station of each trip throughout the analysis period. The summary statistics for the socioeconomic characteristics of the different groups are presented in Table 1.

3.3 Empirical strategy

Given the randomized nature of this experiment, there are no expected systematic differences in SITP use in the different groups before the intervention. This implies that other factors that could influence SITP use are orthogonal to the treatment. This allows us to interpret causal links between the treatment and the observed changes. First, we estimate the ridership change produced by the vouchers. Second, using this result, we then calculate the impact on the economic welfare of those who received the voucher.

With this design, analyzing the effect of the voucher on the travel cards requires a comparison of the travel behavior of those receiving the treatment with the travel behavior of those in the control group. To do this, travel card data were obtained from each participant during the study period and consolidated by week. We apply the model described by Eq. (1) to estimate the average difference in SITP use between the treatment and control groups:

$$\mathrm{Y}_{it} = \gamma_i + \lambda_t + \sum_g (\beta_g \mathbf{T}_{it}^g + \tau_g \mathbf{P}_{it}^g) + \epsilon_{it} \tag{1}$$

where Y_{it} refers to the outcome variable: the average number of daily trips made using travel card i during week t. γ_i represents the individual fixed effect and refers to the average trips made using card i, making it possible to control for the use of the SITP. λ_t represents the weekly fixed effects and refers to the average level of trips during the week t, making it possible to control for factors that could have affected the travel demand in a particular week (e.g., strikes). g indicates the type of group, either control or treatment (A or B). T_{it}^g identifies the card i of group g in week t. This variable acts as a dummy that takes the value of one (1) for those travel cards assigned to group g during the intervention period. Otherwise, it takes the value of zero (0). P_{it}^g identifies the post-intervention period (after the end of the intervention), and it takes the value of one (1) for a card i assigned to the group g; it is equal to zero (0) in other cases. Finally, ϵ_{it} refers to the idiosyncratic error. The error term is clustered to account for the correlation of the error at the participant level. The parameters β_g recover and identify the average difference in SITP use due to the intervention; in other words, they capture the average difference in SITP use between the treatment and control groups. The parameter τ_g captures the average difference in SITP use among participants in the treatment groups after the intervention is complete.

The previous model estimates the intention of treatment effect (ITT), which refers to the average changes that are produced among the treatment groups (A or B). Another measure, the average treatment among the treated (ATT), excludes the participants in the treatment groups who did not activate the voucher. Thus, the ITT considers a mixture of participants who received and activated the voucher, and others who received and did not activate the voucher. The ATT estimates the increase in trips among those who effectively activated the voucher. The model is presented in Eq. (2):

$$\mathrm{Y}_{it} = \gamma_i + \lambda_t + \sum_g (\beta_g \widehat{\mathbf{ET}_{it}^{g}} + \tau_g \widehat{\mathbf{EP}_{it}^{g}}) + \epsilon_{it} \tag{2}$$

This is an instrumental variable regression in which, the T_{it}^{g} variable is replaced with ET_{it}^{g}, which is the result of calculating the probability that a participant in the treatment group activates the voucher. Mathematically, this is equivalent to rescaling the estimates of β_g by dividing it by the proportion of participants who activate the voucher, given that they belong to the treatment group. Thus, the results from Eq. (2) provide the difference in the number of trips made by participants who cashed the voucher and the number of trips made by the control group.

We use the previous models, together with the previously calculated fare elasticities (Guzman et al., 2021), to estimate the differential welfare effects on the participants. To estimate this effect, an approach based on the changes in the consumer surplus (CS henceforth), which is measured in monetary units, is implemented (Harberger, 1978). This concept is defined as the sum of the benefits and costs perceived by the participants, and it is the driving principle behind the literature concerning the optimal public transport supply (Hörcher and Tirachini, 2021). The idea behind the CS relies upon measuring the maximum benefit that the users obtain for the SITP trips that are made. It relies on the idea that although the price (fare) of all trips is the same, the values that a person gives to each one of the trips they make are not the same. Using this approach, it is possible to compare the costs of the intervention with the user's benefits, which are represented by the change in their SITP access/use.

Figure 2 shows typical inverse demand functions and explains how the quantity of trips demanded is determined according to the price. The first trip has a higher value and the commuters have a greater willingness to pay for the first trip than for the second one; they also have a greater willingness to pay for the second one than for the third, and so on. This is reflected in the negative slope of the inverse demand function. The CS is the difference between the willingness to pay for each trip made and the actual price, and it is defined by the area below the demand function and the price. Note that the size of the CS, which is defined by the shaded 'triangle' in Figure 2, is directly related to the slope of the inverse demand function. The higher the slope, the larger the CS. In economics jargon, this means that the higher the price elasticity of the trips (low slopes denote large travel demand changes with small price changes), the smaller the CS of the users. The CS embodies the intuitive idea that the more reluctant the reaction to a price change, the more valuable the trips are and vice versa.

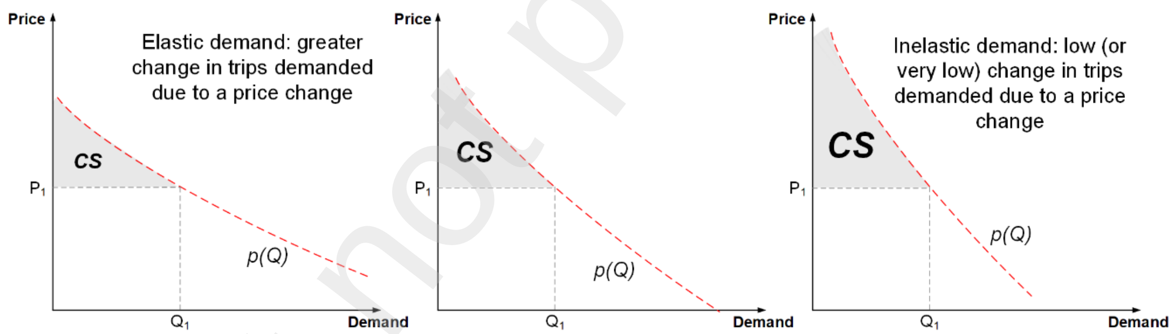


Figure 2. Transport demand and elasticity changes. Consumer surplus

The key measure is the CS change produced by an intervention rather than the overall CS. In this case, we want to estimate the change in the CS due to the transport voucher. This corresponds to the difference between the CS caused by a new quantity of trips and price changes (produced by the intervention) and the CS without intervention. The change in the CS (ΔCS) can be estimated using Eq. (3):

$$\Delta \mathrm{CS} = \int_0^{Q_2} P_2(Q)\mathrm{d}Q - p_2 \cdot Q_2 - \int_0^{Q_1} P_1(Q)\mathrm{d}Q - p_1 \cdot Q_1 \quad (3)$$

Eq. (3) shows the inverse demand function $P_k(Q)$ (a price that determines a defined number of trips). Q_1 and p_1 are the travel demand and price for the control group (no vouchers). Consequently, Q_2 and p_2 are the travel demand and price for treatment groups (with vouchers). The integral on the inverse demand function $\int P_k(Q)$ provides the area under the demand function that corresponds to a travel demand level Q_k. Then, we subtract the cost of making those trips ($p_k \cdot Q_k$). The CS change is given by the difference between the CS produced by the voucher, which defines the level of prices p_2 and trips Q_2, and the CS without the voucher (prices p_1 and trips Q_1).

As is standard in the literature, Eq. (3) is linearized and used to obtain the base values of the current price and travel demand, which in this case, are the fare p_1 and the trips Q_1 made in the control group. Therefore, we estimate the CS change using Eq. (4):

$$\Delta\text{CS} = \varphi_1 \cdot Q_1 + \frac{\varphi_1}{2}(Q_2 - Q_1) \tag{4}$$

$$\varphi_1 = p_1\left(1 + \frac{Q_1 - Q_2}{Q_1 \cdot \varepsilon}\right) - p_1 = p_2 - p_1 \tag{5}$$

where φ_1 is the difference between the trip price and the maximum price that a SITP user would be willing to pay for Q_2 trips after the voucher is cashed. Q_1 and Q_2 represent the monthly trips in the control group and the treatment group, respectively. In Eq. (5), the term ($p_1\left(1 + \frac{Q_1 - Q_2}{Q_1 \cdot \varepsilon}\right)$) is the maximum price for Q_1 trips according to the elasticity value ε, assuming the demand for p_2 is Q_2. Specifically, $Q_2 – Q_1$ corresponds to the β value obtained from the model described in Eq. (1): $\beta_g = Q_2 – Q_1$. Using φ_1 from Eq. (5), the CS change is calculated using the fare elasticity ε in Eq. (4).

To get a better perspective on this approach, we compared the welfare gains caused by the voucher policy and the current subsidy scheme policy (the fare discount), using the elasticity values for Bogotá's public transport. In this comparison, the base assumption is that the current policy increases ridership as much as the vouchers would. To obtain a useful representation of the welfare gains that each policy induces, the costs associated with vouchers and fare discounts should also be considered. The money spent to produce a given CS change must be taken into account. As the CS is measured in monetary units, it can be directly compared with the cost, resulting in an indicator that measures the net welfare produced. The net welfare is equal to the CS gains minus the costs. Eq. (6) can be used to estimate the welfare gains using the CS produced and the associated trip costs:

$$\Delta W = \Delta CS - costs \tag{6}$$

The *costs* variable from Eq. (6) corresponds to the money that must be spent to produce the change in the CS. In other words, it is the expense needed to get from a situation with prices p_1 and trips Q_1 to a situation with prices p_2 and trips Q_2 (see Figure 2). This approach allows us to estimate the welfare gain that the user experiences because of their use of the SITP. This welfare gain is due exclusively to changes in the use of the SITP (trip changes). This welfare analysis provides a framework that allows us to evaluate the impact of the vouchers and their associated costs and compare the results with the fare discount alternative.

However, the above does not provide information from a city perspective. As a complementary approach, we estimate an indicator of the effectiveness of the intervention, which is calculated as the ratio of the CS change to the costs necessary to implement the subsidy policy (by the city), as presented in Eq. (7).

$$\mathrm{E} = \frac{\Delta CS}{policy\ costs} \tag{7}$$

This approach allows us to determine whether or not the expenditure incurred by the city is surpassed by the benefits that the users receive. In this case, any value of E above 1 indicates that the total increase in the CS is higher than the cost of the policy for the city.

Finally, an affordability measure (Eq. (8)) is proposed to analyze the financial burden of SITP costs and the effect of the vouchers on the treatment and control groups before, during, and after the experiment[3]. Despite its limitations, this proposed indicator could be a useful approximation that can measure SITP affordability and the effectiveness of the vouchers in alleviating the financial burden of public transport costs for the participants:

[3] Before: January to April 2021. During: May to September 2021. After: October to December 2021.

$$Aff_g = \frac{\mathrm{f} \cdot T_g}{Ing_g} \tag{8}$$

where the observed affordability index per experiment group g (Aff_g) is expressed as a function of the price of trips (f), the trips made using the SITP per group g before, during, and after the experiment (T_g), and the monthly household income per capita (Ing_g). The income per capita is the reported household income from the closing survey divided by the corresponding household size. We consider all the trips made using the SITP since we have a detailed register of every trip made by the participants. The groups g are the treatment A group, the treatment B group, and the control group.

4. RESULTS

We first show that the control and treatment groups only differ in terms of the intervention (the vouchers). There are no pre-existing differences between the groups that could affect the outcome variable. Table 1 shows that the sample is balanced and complies with the identification assumptions. In other words, the variable means of the control and treatment groups do not differ statistically. Therefore, it is possible to conclude that we have sufficient statistical evidence that the randomization was carried out correctly. This allows us to recover the causal effect of the transport voucher.

Table 1. Summary statistics and balance between treatment and control groups

Variable	Control [Std. Dev.]	Treatment [Std. Dev.]	Mean difference (p-values)
Transport modes used to the main activity	1.79	1.76	-0.03
	[0.790]	[0.760]	(0.480)
Journey time (trip yesterday)	89.4	87.3	-2.11
	[80.51]	[69.95]	(0.610)
Journey time (regular trip)	99.4	90.7	-8.72
	[104.33]	[59.98]	(0.200)
Distance to transport - minutes	7.97	7.92	-0.05
	[7.390]	[7.640]	(0.910)
Distance to transport - blocks	4.3	4.6	0.30
	[3.830]	[4.560]	(0.210)
Waiting time	12.8	12.4	-0.41
	[9.99]	[8.91]	(0.450)
Fare price paid (trip yesterday) COP	3,150	3,225	74.94
	[4,034.7]	[3,747.8]	(0.740)
Weekly trips to the main activity	4.7	4.8	0.09
	[1.92]	[1.75]	(0.380)
Transport cost (all transport modes) to the main activity in COP	3,912	4,020	107.43
	[2683.72]	[2460.21]	(0.610)
Household size	3.6	3.8	0.16

	[1.45]	[1.51]	(0.030)
Age	43.8	43.3	-0.45
	[11.84]	[11.81]	(0.450)
Married	0.22	0.23	0.01
	[0.42]	[0.42]	(0.590)
Women	0.72	0.72	0.00
	[0.45]	[0.45]	(0.890)
Current worker	0.88	0.90	0.010
	[0.32]	[0.30]	(0.360)

According to the summary statistics of the sample shown in Table 1, most of the participants belong to the low-income segment and live in SES 2 areas (see Figure 1). The monthly household income is around 1,540,000 COP (about 412 USD) in a household made up of 3.7 people on average. This implies an average per capita monthly income of 416,200 COP (111 USD). In addition, 12% of the participants have a car at home, 10.2% have a motorcycle, 27.9% have a bicycle and 55.8% do not have any type of vehicle. Just 41.5% of the participants have a professional degree and work an average of 5.2 days a week for 9 hours a day. The results shown in Table 1 indicate that the two treatment groups and the control group are balanced and that the control group is correctly identified as a comparison group.

4.1 Ridership impacts

Table 2 present the results of the ridership changes caused by the vouchers according to the models presented in Eq. (1) and (2). The outcome variable is the average number of trips per day, which allows a direct comparison between the effects over a complete week and the disaggregated effects for working days and weekends. Columns (1) to (3) show the effects for the treatment groups, including the effects for those who did not activate the voucher (ITT). Columns (4) to (6) provide the results for only those participants who did activate the voucher (ATT), which produces, as should be expected, a larger effect (rows 1 and 3). To better understand these results, we provide the average value of the variable for the control group (row *Base value: control group*) and the corresponding effect of the treatment as the percentage changes relative to this base value (rows *Treatment B change [%]* and *Treatment A change [%]*).

Table 2. Voucher impacts on the average of daily trips

	Dependent variable: Boardings					
	ITT			ATT		
	Week	Working days	Weekends	Week	Working days	Weekends
	(1)	(2)	(3)	(4)	(5)	(6)
Treatment B	0.075**	0.097**	0.024	0.093**	0.120**	0.030
	(0.037)	(0.043)	(0.029)	(0.046)	(0.053)	(0.036)
Treatment A	0.084**	0.106**	0.024	0.101**	0.128**	0.030
	(0.037)	(0.043)	(0.029)	(0.044)	(0.052)	(0.034)
Post-treatment B	0.034	0.042	0.024	0.041	0.051	0.028
	(0.051)	(0.059)	(0.041)	(0.058)	(0.067)	(0.047)
Post-treatment A	-0.060	-0.046	-0.076	-0.065	-0.049	-0.085
	(0.052)	(0.060)	(0.039)	(0.059)	(0.068)	(0.045)
Base value: control group	1.16	1.33	0.71	1.16	1.33	0.71
Treatment B change [%]	6.50	7.27	3.36	8.04	8.98	4.15
Treatment A change [%]	7.22	7.93	3.39	8.73	9.58	4.13
N	62,446	62,446	62,446	62,446	62,446	62,446
R2	0.557	0.551	0.353	0.557	0.552	0.353
Fixed effects: individuals	Yes	Si	Si	Si	Si	Si
Fixed effects: week	Yes	Si	Si	Si	Si	Si
Standard errors cluster	ID	ID	ID	ID	ID	ID

Standard errors of the estimated coefficients are shown in parentheses. Columns 1-3 show the estimates of Eq. (1). Columns 4-6 show estimates of Eq. (2). Estimates are made using Ordinary Least Squares (OLS). The "base value: control group" row shows the average of the variables in each column using only the control group. Significance level: ***p<0.001 **p<0.01 *p<0.05, p<0.1.

The ATT results show weekly travel increases of 8.04% for the treatment B group and 8.73% for the treatment A group (column 4). These average effects are the results of additional trips made on work days, as there are no significant effects on the weekends. This is not in line with evidence from other contexts (Bull et al., 2021; Busch-Geertsema et al., 2021), which indicates that there is an increase in non-mandatory trips (trips in off-peak hours). If our participants had used the voucher to make non-mandatory trips, we would expect to observe more trips over the weekend, when most trips are not mandatory.

Table 3 presents results that have been disaggregated according to the time of the day; they have been separated into peak and off-peak hours. Additional trips are made predominantly during peak periods, with an increase between 15.8% and 16.9% for peak hours and an increase of 5.9% for off-peak hours (column (4), ATT, rows 10 and 11). Although after the intervention there are no differences in the total travel demand between the treatment and control groups, when the vouchers are no longer being provided, a trade-off between peak and off-peak periods arises. In other words, either there is a significant increase in peak-hour trips, with a non-significant decrease in off-peak trips (row 8, *Post-treatment B*), or there is a non-significant increase in peak-hour trips with a significant decrease in off-peak trips (row 9, *Post-treatment A*). Given that the total number of trips does not increase in the post-treatment period, this is most likely a reassignment of trips from off-peak to peak hours.

Table 3. Voucher impact on daily trips by the time of the day

	Peak-hours		Off-Peak hours	
	ITT	ATT	ITT	ATT
	(3)	(4)	(5)	(6)
Treatment B	0.094***	0.117***	-0.004	-0.005
	(0.032)	(0.040)	(0.025)	(0.031)
Treatment A	0.098***	0.118***	0.017	0.021
	(0.032)	(0.038)	(0.025)	(0.030)
Post-treatment B	0.104**	0.121**	-0.045	-0.051
	(0.048)	(0.054)	(0.031)	(0.036)
Post-treatment A	0.029	0.034	-0.068**	-0.075**
	(0.046)	(0.052)	(0.032)	(0.036)
Base value: control group	0.76	0.76	0.49	0.49
Treatment B change [%]	12.79	15.80	4.81	5.94
Treatment A change [%]	13.95	16.86	4.85	5.91
N	62,498	62,498	62,498	62,498
RMSE	0.60	0.60	0.53	0.53
Fixed effects: individuals	Si	Si	Si	Si
Fixed effects: week	Si	Si	Si	Si
Standard errors cluster	ID	ID	ID	ID

Standard errors of the estimated coefficients are shown in parentheses. Columns 1-3 show the estimates of Eq. (1). Columns 4-6 show estimates of Eq. (2). Estimates are made using Ordinary Least Squares (OLS). The "base value: control group" row shows the average of the variables in each column using only the control group. Significance level: ***p<0.001 **p<0.01 *p<0.05, p<0.1.

If this reassignment of trips from off-peak to peak hours did in fact take place, a possible explanation is that the extra trips made by the treatment group remain after the end of the intervention. Moreover, participants could be decreasing their off-peak trips to keep making these extra trips or to keep making at least some of them. Since not all coefficients are statistically significant, this is the only clear evidence that such a change is occurring. To further interpret these results, it is worth noting that the transport voucher is a direct cash transfer into the travel cards. This implies that this money can only be used for the SITP. However, this does not mean that the voucher is automatically converted into additional trips.

As the average monthly SITP expenditure per participant is higher than the voucher value, a rational user could make the same number of trips as before, or even make fewer trips, while spending the entire voucher. By doing this, they would also free up money from their budgets that would otherwise have been spent on transport. In fact, the value of the additional trips is less than the voucher value. This means that users save some of the money that was allocated to using public transport in their budgets, as shown in Table 4. Here, two outcome variables were used: the SITP expenses and travel card recharges. In the latter case, the recharge only includes the money paid directly by the user (not the voucher).

Table 4. Voucher impacts on public transport spending

	Dependent variable: expenses and recharges			
	ITT		ATT	
	Expenses	Recharge	Expenses	Recharge
	(1)	(2)	(3)	(4)
Treatment B	0.247**	-0.401***	0.305**	-0.496***
	(0.102)	(0.104)	(0.125)	(0.129)
Treatment A	0.299***	-0.592***	0.362***	-0.715***
	(0.103)	(0.104)	(0.123)	(0.127)
Post-treatment B	0.163	0.207	0.192	0.222
	(0.146)	(0.149)	(0.167)	(0.170)
Post-treatment A	-0.140	-0.091	-0.150	-0.114
	(0.144)	(0.148)	(0.163)	(0.167)
Base value: control group	3.54	3.55	3.54	3.55
Treatment B change [%]	6.96	-11.31	8.59	-13.98
Treatment A change [%]	8.44	-16.70	10.21	-20.15
N	62,446	62,446	62,446	62,446
R2	0.511	0.259	0.512	0.259
Fixed effects: individuals	Yes	Si	Si	Si
Fixed effects: week	Yes	Si	Si	Si
Standard errors cluster	ID	ID	ID	ID

Standard errors of the estimated coefficients are shown in parentheses. Columns 1-2 show the estimates of Eq. (1). Columns 3-4 show estimates of Eq. (2). Estimates are made using Ordinary Least Squares (OLS). The “base value: control group” row shows the average of the variables in each column using only the control group. Significance level: ***p<0.001 **p<0.01 *p<0.05, p<0.1.

Columns (1) and (3) show the amount of money spent on the additional trips by the participants in the treatment groups (in USD). Columns (2) and (4) show the amount of money that participants used to recharge their travel cards, excluding the voucher value. The additional trip expenses (+0.305/+0.362, column 3) are lower than the voucher value, leading to a decrease in the travel card recharges paid for by the participants (-0.496/-0.715, column 4). In short, participants in the treatment groups made more trips but had to spend less money to travel on the SITP. Participants in the treatment groups saved money on transport that they could use for other expenses.

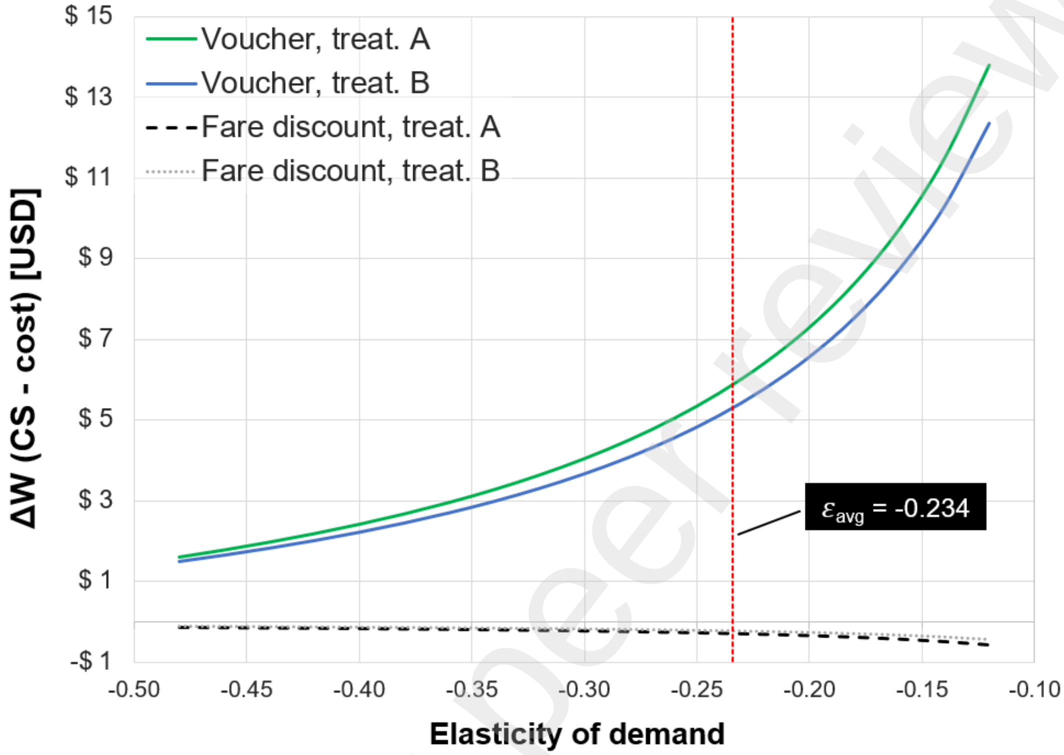
It is expected that giving transport vouchers to participants would increase SITP ridership. However, interpreting this travel demand increase is not a straightforward task, particularly from a policy perspective. Are these results good? Does it make sense to implement such a policy? To provide an answer to these questions we compared the voucher policy with the current subsidy policy (fare discount). We do this in the following section by considering a welfare perspective that allows a comparison between the additional travel demand value and the cost of reaching that travel demand.

4.2 Welfare changes

Figure 3 presents the changes in welfare as a consequence of the transport vouchers for an elasticity range in which Bogotá's public transport fare elasticities are included (Guzman et al., 2021, 2020). Focusing on the voucher policy, the results show larger welfare gains for lower elasticity values (i.e., values that are closer to zero), indicating a high valuation of SITP trips when users' responses to prices are limited (as mentioned in the experimental design section). It is worth noting that this welfare gain differs from the fare reduction policy, which produces welfare losses along the range of elasticities evaluated (Figure 3). In this case, there is a balance between the fare discount size and the elasticity values, where lower elasticities imply larger discounts.

It is important to note that in all cases, we are referring to a fixed number of additional trips; additional trips are the trips produced by the treatment. Figure 3 shows that the curves that represent the voucher policy (solid lines) always show a welfare gain, while the curves that represent the fare discount policy always show a welfare loss (dashed lines). The vertical dashed line represents the average elasticity of the city (-0.234). The result is clear: no matter what the elasticity value is (within the evaluated range), from a consumer surplus perspective, the voucher policy is always the better policy.

Figure 3. Welfare change (ΔW) as a function of the fare-price elasticity

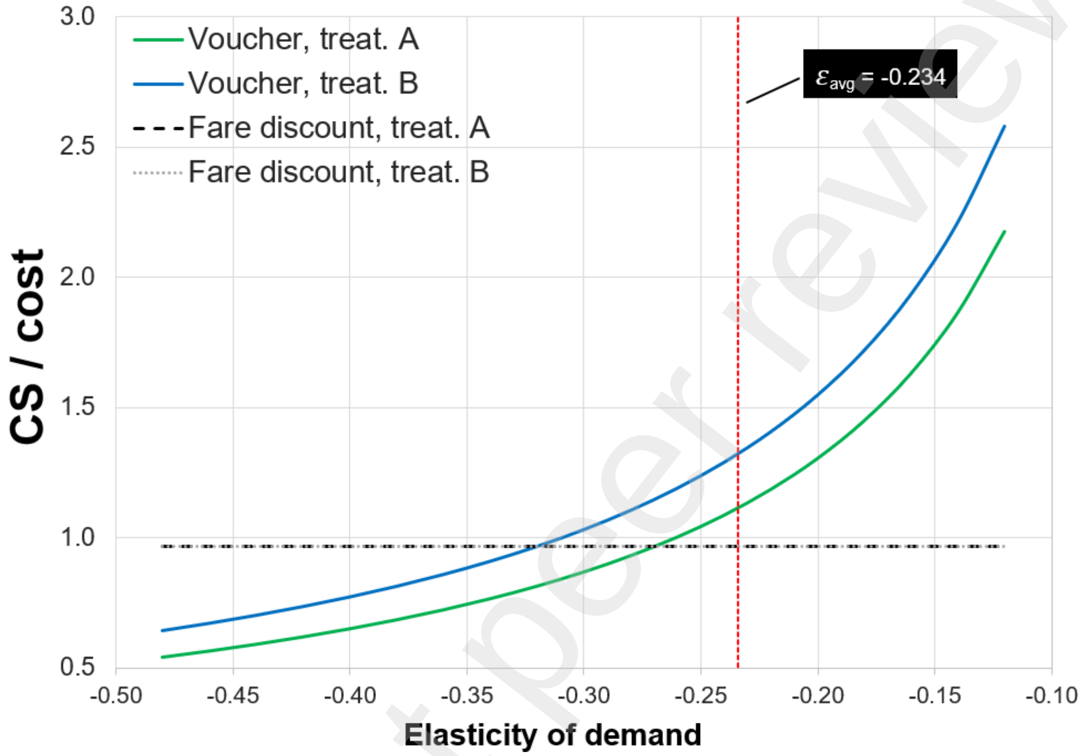


The referred costs used to calculate *ΔW* represent the money needed for the additional trips. This only includes the money that is meant to be used for SITP trips. For example, participants in the treatment A group, make 8.7% more trips than participants in the control group (see Table 2). The cost of these extra trips is the *extra trips x the fare*.

On the other hand, Figure 4 presents the subsidy scheme's effectiveness from the city's perspective. In other words, it shows whether or not the benefits generated are greater than the cost of implementing the policy, which is either the vouchers or fare discounts. The overall dominance of vouchers over fare discounts is no longer found. In this case, only if the elasticity value is sufficiently inelastic (close to zero) is it convenient for the city to implement the voucher policy rather than fare discounts.

The reason for this is that the costs are different from those in Figure 3. Here, the *policy costs* from Eq. (7) represent the totality of the money that the city needs to invest in the subsidy policy, although not all of that money translates into additional trips. In other words, these costs represent the money that the city has to invest for a user to make those 8.7% additional trips (the voucher cost).

Figure 4. Policy efficiency. CS as a proportion of the policy cost



It is worth noting that these results reflect the number of additional trips that are produced by the intervention, which means that the quantity of extra trips remains constant at each elasticity level; it is equal to an 8.7% increase in trips due to the vouchers in the treatment A group. For the treatment B group, the increase was 8.0%. If the intervention causes a higher SITP travel demand, this will cause the curves shown in Figure 4 to move upwards, making the intervention even more effective. Noticeably, elasticity changes do not cause important changes in the effectiveness of the current policy, the fare discount policy.

As has been seen, welfare gains and policy effectiveness depend on the fare elasticity values. As Bogotá has high spatial segregation and accessibility inequalities (Guzman et al., 2017), the average fare elasticity value is not uniform across the city. Previous studies have found that the fare elasticity varies according to income levels, the time of day, and the zone of the city (Guzman et al., 2021, 2020). This allows a comparison of the voucher policy benefits across the city. In summary, SITP stations located in the urban periphery, which is associated with low-income areas, show null or low responses to the fare changes, unlike the stations located in the wealthiest zones (central area). Table 5 shows the welfare and efficiency results, for the estimated elasticities in three different zones of the city.

Table 5. Welfare and voucher efficiency across the city

Zone	Avg. elasticity	Welfare change (USD avg. per user and month)		Voucher effectiveness	
		Treat. B	Treat. A	Treat. B	Treat. A
Peripheral zone	-0.113	12.3	13.8	2.58	2.17
Intermediate zone	-0.160***	8.7	9.7	1.93	1.63
Central zone	-0.377***	2.4	2.7	0.81	0.68

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

Table 5 presents evidence that the voucher policy has a more positive effect when it is applied in peripheral and intermediate zones, where lower-income residents usually live. In these zones, the policy effectiveness is greater than 1, so the added value in terms of the CS is higher than the cost of implementing the policy vouchers. This is not the case in the central area.

As the experiment sample mainly consisted of participants who live in the periphery or the intermediate zone, the welfare gains and policy effectiveness results are directly applicable to these areas. In any case, a reduction in the effects of the voucher policy for the central zone population could be expected, so the welfare and effectiveness values should be thought of as upper bounds rather than as averages for this zone.

4.3 Affordability

Table 6 shows the calculated affordability index per group during the experiment. This indicator represents about a quarter of the participants' per capita income. It must be considered that this index does not account for the costs of other transport modes. The results show some differences at a 99% confidence level concerning the control group. There are significant differences in affordability between the treatment groups and the control group when the transport vouchers are provided. In other words, the vouchers did have a significant and positive effect in terms of alleviating the financial burden of public transport for participants in the treatment groups compared to participants in the control group.

Table 6. SITP affordability indices according to groups and time

Group	Before	During	After
Control	19.1%	20.5%	23.6%
Treatment A	20.5%	16.3%***	24.3%
Treatment B	21.2%**	18.0%***	26.2%*

*** p-value < 0.01; ** p-value < 0.05; * p-value < 0.10 (treatment groups vs control group).

The results show that SITP vouchers have a positive impact on SITP affordability. This implies a monthly savings of 15,200 COP (about 4.1 USD) during the intervention, which the participants could have used for other things. After the intervention ended, the index worsened; it was even slightly worse than it was before the intervention began. This may be because, after the experiment, participants made more trips on the SITP. Depending on the group, between 5.2 and 7.6 more trips/month were made on average after the intervention ended.

5. POLICY ANALYSIS

The worldwide academic literature and the experiences of policymakers concerning the pricing and public transport suggest that fare subsidies are justified on efficiency grounds. In Colombia, although public transport subsidies have existed for more than a decade, the impacts of these subsidies on ridership and users' welfare are still unknown, mainly due to the (endless) discussion among politicians about investment priorities when budgets are tight. Since 2013, Bogotá has invested more than 228.4 million USD in demand-side subsidies, and the impact of these subsidies is not precisely known.

A subsidy scheme can play a key role in encouraging the use of public transport. However, the scheme must be carefully designed, have a certain flexibility, and have different objectives when it comes to setting fares for different vulnerable population groups. Since the provision and quality of public transport are positively related to the quality of life (Hybel and Mulalic, 2022), the reallocation of public funds in the form of a voucher subsidy scheme in Bogotá should improve affordability and encourage ridership, mitigating the welfare losses of the current anachronistic subsidy scheme. New and inventive public transport and subsidy schemes are opportunities to increase both accessibility and welfare of users. It is also time to introduce new pricing instruments for car and motorcycle users to obtain alternative revenue sources for public transport, despite the fact that this will inevitably lead to power struggles between politicians and drivers.

The results presented here show that the voucher subsidy outperforms the current fare-discount subsidy model in terms of ridership, welfare, and effectiveness. The vouchers encourage public transport use, particularly during weekdays and peak hours, which implies that they encourage high-value trips, perhaps for work or study purposes. Additionally, using a consumer surplus approach provided robust evidence that vouchers are effective in inducing positive welfare gains in commuters while a fare discount is not. We can also show that implementing a subsidy scheme that takes advantage of the possibilities of travel cards can improve the efficiency and value of subsidies.

The reallocation of money from the city budget to public transport subsidies could encourage an increase in ridership and create welfare improvements. We can guarantee, as is often argued in policy debates, that since public transport is used more by low-income groups, the proposed subsidies have a progressive distributional profile, as demonstrated in Table 5: the produced benefits are greater in the city periphery (where the poorest people tend to live) because SITP trips are more valued and there are fewer transport alternatives. However, we rarely see decisions about public transport pricing made according to the maximization of economic and social welfare. This requires great political and technical leadership, as it involves making decisions that may be politically unpopular.

To extend the main findings to obtain a broader discussion, it is necessary to make some assumptions. If public transport vouchers were applied throughout the city, the results imply that most welfare benefits would come from the increased mobility of those who live in the peripheral and intermediate zones. This policy would be more socially profitable in these zones than in the central zone. By considering the approximately 755,500 *tullave plus card* owners who use the SITP every week on average, we estimate that the cost of the program would be 5.38 million USD (for a voucher value of 7.5 USD) and that the program would produce 2.3 million extra trips per month. These values must be compared with the fare discount scheme. In this case, the subsidy cost would be 6.0 million USD per month. As discussed in subsection 4.2, the current fare discount subsidy scheme has a negative net welfare, while our proposal would result in a net welfare of 4.0 million USD each month.

However, if the vouchers are targeted vouchers, the city should target specific groups or areas according to equality concerns; for example, they could be given to those who are not as capable of paying for public transport services. In this alternative scenario, if the voucher is given to low-income users (e.g., users with less than or equal to 50 SISBEN points, a total of 399,950 cardholders), the voucher program will produce 1.2 million extra trips per month for a cost of 2.8 million USD, resulting in a net welfare of around 3.7 million USD, while the cost of the fare discount scheme would be 4.8 million USD. Note that the total welfare estimated for the general case (4.0 million USD) is similar to that estimated for the targeted case (<50 SISBEN points, 3.7 million USD), even though only 53% of the trips made in the first case are made. As explained in the methodology section, this comes from the lower elasticity in the second case and, consequently, the higher valuation for each extra trip. In other words, the low-income group of users requires a higher fare discount to reach the same quantity of trips as people with higher incomes. Thus, the city has spent an average of about 27.7 million USD per year on demand-side subsidies over the last 8 years with a very limited impact (Guzman and Hessel, 2022). The potential cost of providing vouchers to 400,000 users would be about 34.2 million USD per year (treatment A). This policy is more expensive than the cost of current subsidies, but it would have a positive social welfare value, in addition to being an effective policy. Of course, this subsidy could also better target groups in need of vouchers, and the voucher value could be reduced. It is clear that a more detailed analysis is necessary, and it could also be used to improve the quality of service to well above the current quality of service.

Finally, the discussion concerning whether or not subsidies are more profitable when it comes to an affordable public transport fares, or if it would be better to subsidize infrastructure, health, education, or pensions, is still open. Although answering this question is beyond the scope of this study, we show evidence of the effects that a subsidy has on commuters, highlighting the great positive impact that an affordable public service in a developing city has on its poorest users. However, the policy effectiveness depends on the value that people give to their trips (fare elasticity), as we saw in the previous section. As Hörcher and Tirachini (2021) argue, a better understanding of the political processes behind transport policies is necessary, in order to bring academic findings closer to social/political acceptance and actual implementation.

6. CONCLUSIONS

This paper presents the impacts of an alternative public transport subsidy policy consisting of transport vouchers in Bogotá. This policy was implemented as a direct cash transfer to smart travel cards. This paper has focused on the effects of the vouchers on the overall ridership, and they are evaluated from a policy perspective by using an equivalent fare-discount policy as a baseline. Controlled field experiments are a useful tool that can help transport planners and decision-makers generate robust evidence concerning the actual effects of a transport policy. The findings from this experimental study in a developing city context provide novel evidence of subsidies' impact on ridership and welfare gains. By using the proposed experimental method, we are able to avoid identification issues that may affect other types of research designs, indicating that our results are causal effects. The proposed methodology controls time dynamics and differences in personal characteristics in public transport usage using fixed effects, which further improve the precision of the estimation. We also use an economic welfare approach to determine the benefits that the users experience due to the increase in public transport use. Using this approach, it is shown that the vouchers are an improvement over the current fare discount scheme since the voucher scheme reaches higher levels of welfare and is effective from a city-policy perspective. However, the policy effectiveness depends on the particular level of the price elasticity of public transport trips. This effectiveness is higher for low elasticity levels (values close to zero).

In short, access to public transport vouchers leads to a ridership increase, which is entirely explained by an increase in weekday and peak-hour trips. This causes welfare gains for the participants and also improves the affordability of the public transport system. The results show that the 7.5 USD and 5.6 USD voucher values increase the weekly travel demand by between 8.7% and 8.0% compared with the control group. Contrary to the current literature, no evidence was found that the additional trips correspond to non-mandatory trips because in this case, the additional trips are concentrated within work days and peak hours. We find strong evidence that the vouchers cause increases in the social welfare per participant (per month) of 5.7 USD and 5.1 USD, for the treatment A and treatment B groups, respectively, as well as an improvement in affordability between 18 and 26%.

If Bogotá wants to implement a voucher scheme on a large scale, it is highly recommended that first an investigation of the operating costs of the operator companies should be conducted, rather than reviewing the operating costs reported by the companies. Perhaps this way, even more benefits can be obtained. The results have also suggested that free fares may deprive cities of resources essential for public transport development. Therefore, from this perspective, which has been considered by some city politicians, fare abolition is not viable in large public transport systems in which ticketing revenue is a very important source of revenue. We strongly believe that it is necessary to carefully consider these subsidies and to recognize the need for a common understanding that a high-quality and affordable public transport system is not only a viable and sustainable alternative to private vehicles but is also an incentive to make more efficient use of the urban space, promoting other forms of mobility and accessibility.

Finally, the findings concerning the impact of the voucher on travel behavior contribute to understanding these policies' broader effects. While the effects on poverty alleviation, employment, and funding are well documented, there are too few causal estimations of travel behavior, particularly in large public transport systems. This research is not free from limitations. The results observed here are limited to frequent users who mostly have low incomes. It is necessary to do more research to understand the effects of vouchers on other vulnerable people, such as those who do not use the transport system or cannot afford to pay the fare. Further analyses of the data will focus on the evaluation of heterogeneity in the results due to the socioeconomic characteristics and travel preferences of the participants.

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CONFLICT OF INTEREST STATEMENT

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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