Title: The compounding value of public transit for college students: Evidence from a multi-year randomized experiment on the impacts of free public transit in the Bay Area

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Motivation Public transit ridership in many metropolitan areas significantly declined during the COVID-19 pandemic, and has still not recovered to pre-pandemic levels. In spite of substantial government funding to preserve service frequencies and cover fare revenue shortfalls, talk of "death spirals" in public transit ridership persists.

Against this backdrop, public transit agencies across the United States have been exploring product offerings that might draw riders back to public transit systems and put public transit on a more sustainable footing. For instance, 35 municipal agencies—including Denver, Tucson, and Raleigh's—have made public transit fare-free across their systems, while Boston and New York City are trialing fare-free bus services.[1]

The agencies making these policies often cite secondary objectives, such as mitigating congestion, pollution, and socioeconomic inequities, as additional sources of motivation. However, the extent to which these product offerings are actually effective in increasing ridership—or cost-effective in terms of the welfare impact of taxpayer dollars—is an empirical question. If underlying demand for travel on public transit is inelastic, the social benefits that might accrue from greater public transit use are unlikely to offset losses of fare revenue.

Prior work has studied fare-free and heavily subsidized flat fee public transit, for example in Mexico (Davis 2021), Germany (Andor et al. 2023), and the United States (Brough, Freedman, and Phillips 2023). In each of these cases, however, fares were suspended for at most six months, precluding measurement of medium-term price responses. Furthermore, when the policy environment has allowed for longer-term measurement such as in Cats, Susilo, and Reimal (2017), prior work has largely studied small populations (of a thousand or so people), making it harder both to characterize heterogeneity in responses and to infer the equilibrium effects of scaling product offerings.

Research Context For the past 1.5 years, we[2] have been partnering with the Bay Area Rapid Transit (BART) and the Metropolitan Transportation Commission (MTC) authorities to evaluate the impact of a fare-free travel pass (a "Clipper BayPass") for public transit on students at public universities in the Bay Area. Through funding provided by BART and the MTC, we have been running a multi-year randomized control trial (RCT) since Fall 2022 involving a total of 106,000 students at three universities: the University of California Berkeley, San Francisco State University, and San Jose State University. At each of these, one third of the student population was randomly selected to receive the BayPass, while the remaining student population continued to receive existing student transit passes. As the analysis team responsible for reporting on the experimental results to BART/MTC, we

[1] https://www.cnn.com/2023/07/08/business/free-buses-us-public-transit/index.html

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have access to the complete public transit travel histories of study participants, as well as a representative sample of (regular, paid) transit pass holders throughout the Bay Area. In addition, we have access to a limited amount of administrative data about study participants (from the universities) as well as results from a series of four surveys (that we designed).

Research Questions The scale and duration of our experiment provides a unique vantage point into the short- and medium-run impacts that free transit access may have on college students and the urban areas that house them. Specifically, we are interested in the following four sets of questions:

1. What is the short-term elasticity of demand for travel by public transit among students, both on the intensive margin of trips (e.g. switching from another mode of travel for a trip that would be taken in any case) and on the extensive margin (e.g. taking additional trips that would not have been taken all else held fixed)? How do these elasticities vary across different students, and what do they imply for the potential welfare gains from providing free (or cheaper) access to public transit more broadly?

2. What, if any, are the medium-term mechanisms by which public transit use changes among treated students? Specifically, does free public transit access affect where students choose to live?

3. What, if any, are the medium-term impacts of free public transit access on students' educational attainment? Specifically, does free public transit access impact the probability of graduating within 4 years? On average GPA?

4. Given the short- and medium-run elasticities demonstrated by our experiment and the distribution of car ownership among students, what is the largest number of cars that might be taken off of the streets if a free (or reduced-fare) public transit pass for students were made permanent? What are the implications for carbon emissions and congestion?

Methodological Approach Our methodology combines experimental design, reduced form causal inference for heterogeneous dynamic treatment effects, and modeling for structural estimation and simulation.

Experimental Design: Our experimental design was aimed at detecting impacts on transit use and downstream factors affecting welfare across a representative population of students. To this end, a randomly selected subset of students who were enrolled at each university in Fall 2022 were allocated into treatment or control groups. Eligibility for participating in the experiment was not predicated on applying, and all students had access to a university-affiliated transit pass by default (in two universities, the pass was part of the university ID; in the third, students in the control group were invited to pick a pass up). As such, we are able to observe the transit behavior of students in both the treatment and control group.[3] Students who were enrolled in the experiment

[3]Control students (and all students enrolled in these universities) had access to default subsidies for the local transit modes closest to their universities and so there was a baseline incentive for students to use their university affiliated passes, reducing the concern for data censorship.

in the Fall of 2022 continue to be part of the experiment until its conclusion or their departure (e.g. from graduation) from the university. As such, we are able to observe outcomes over the course of multiple years for most students, as well as graduation and attrition events. Our surveys complement the administrative data that we observe through the transit passes and universities, by asking about housing moves, access to different modes of mobility (e.g. car ownership) and typical travel destinations (e.g. through a travel diary) among both treatment and control groups. We are also eliciting willingness to pay using canonical experimental methods (Becker, Degroot, and Marschak 1964).

Causal Inference: Our RCT design allows us to estimate average treatment effects over the course of the experiment with simple methods. At the most aggregate level, we can do this with differences in means. For an event study, we can do this with standard difference-in-differences designs (Callaway and Sant'Anna 2021; Borusyak, Jaravel, and Spiess 2024), leveraging public transit travel histories and repeated survey responses. Since we will be examining multiple outcomes (e.g. multiple time periods and different dimensions of intensive/extensive margin responses), we will compute confidence intervals via a Bayesian bootstrap with family-wise error rate correction (Romano, Shaikh, and Wolf 2010). Additionally, to examine heterogeneity across the different dimensions that may be relevant to the elasticity of demand for public transit—and to the impacts of free public transit access on residential choice, educational attainment, and driving habits—we plan to apply the "Sorted Effects" method (Chernozhukov, Fernández-Val, and Luo 2018).

Modeling: Our reduced form treatment effect estimates allow us to gauge the scope for increasing public transit use (and its downstream impacts) through a free transit program akin to our experimental treatment. However, in order to address our final set of questions, we need a modeling approach that can predict students' propensity to take different modes of transportation (e.g. driving or public transit) as a function of observable characteristics (e.g. their home location and class times). To achieve this, we will estimate a discrete choice model of mode choice for frequent individual trips in our data. Our model will seek to explain the extent to which students with different observable types are more or less likely to travel by public transit as a function of the price, travel time and frequency/reliability of public transit relative to driving or walking/biking/etc. In estimating our model, we will obtain estimates of the value of travel and wait time, as well as students' willingness to pay based on revealed travel preferences (which we can compare to the values elicited in our survey). The identification strategy for the mode choice model will parallel the reduced form: our model will trace differences in the levels of substitution to public transit between the treatment and control groups across students with commutes characterized by different costs/travel times/etc. Once the model is estimated, we will be able to extrapolate to counterfactual simulations by reweighting our population of students to match the full student population at each university and predicting the share of switches from driving to public transit under universal free or discounted transit passes. If our reduced form evidence on housing choice shows variation on this dimension as well, we will aim to

incorporate an additional medium-run choice of housing that modifies the later choices of transit choice, although this part of our modeling framework is less developed at this point. As we are only studying travel by students at the moment, our baseline approach intends to treat road speeds and public transit availability as exogenous in partial equilibrium. However, we intend to explore whether this is a reasonable assumption, and to consider modeling equilibrium congestion effects if necessary.

Preliminary Evidence Though our experiment is still ongoing, preliminary results can already speak to the (short- and medium-term) price elasticities of demand for public transit and the impact of free public transit access on educational attainment. In particular, observing the public transit travel histories of experiment participants at all three universities in our sample, we find large and statistically significant effects of free public transit access (treatment) on the number of public transit trips taken, at both peak and off-peak times, and across public transit operators and travel modes (see Fig. 1).

	Dependent variable:								
	Number of trips	Number of trips during peak hours	Number of trips during non-peak hours	Proportion of trips during peak hours	Proportion of trips during non-peak hours	Number of trips with top 5 operators	Number of trips with non-top 5 operators	Proportion of trips with top 5 operators	Proportion of trips with non-top 5 operators
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Treatment	18.342***	7.976***	10.366***	0.034***	0.055***	17.329***	1.012***	0.079***	0.010***
	(0.642)	(0.308)	(0.368)	(0.002)	(0.002)	(0.634)	(0.045)	(0.003)	(0.0004)
Constant	49.801***	21.409***	28.392***	0.206***	0.318***	49.437***	0.364***	0.519***	0.006***
	(0.454)	(0.218)	(0.260)	(0.001)	(0.001)	(0.448)	(0.032)	(0.002)	(0.0003)
Observations	106,104	106,104	106,104	106,104	106,104	106,104	106,104	106,104	106,104
R^2	0.008	0.006	0.007	0.005	0.007	0.007	0.005	0.006	0.005
Note:									*p<0.1; **p<0.05; ***p<0.01

Figure 1: (Preliminary) treatment effects of free public transit access on various public transit travel outcomes.

Administrative data from our partner universities also indicates reduced rates of dropout among students with free public transit access (relative to students with the default university-affiliated transit pass). At San Jose State University, for instance, we observe an approximately 2 percentage point lower year-to-year dropout rate, and at San Francisco State University we observe an approximately 4 percentage point lower dropout rate. Although these results are preliminary, our RCT design and large sample size suggests that these differences in drop-out propensities may be causally attributable to our experimental treatment.

Relevance for DOT Public transit is commonly cited as a key alternative to driving for the purpose of congestion and emissions reduction. This study aims to provide evidence on the feasibility and value of shifting travel onto public transit using fare subsidies for an especially price-sensitive population, under the constraint of the existing transit network in a populous US region with heavy vehicle traffic (e.g. not NYC). In addition, we aim to contribute to the evidence base on the importance of transportation for educational outcomes, complementing existing work on school age children (e.g. Herskovic 2020; Edwards 2022) with our study of college students.

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