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Getting a Lift: The Impact of Aerial Cable Cars in La Paz, Bolivia

RESEARCH

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ABSTRACT

This paper studies the effects of aerial cable cars on mode of transport, time use, and employment in the metropolitan area of La Paz, Bolivia. Using an instrumental variables approach, we estimate local average treatment effects of cable car use for residents who use the system due to proximity to a cable car station. Results suggest that cable car users substitute private transport in favor of public transit and experience large savings in commute time, which is reallocated toward educational activities. Users also increase self-employment activities, potentially reflecting improved access to local labor markets. The positive effects of the cable car are driven by residents of El Alto, a city with a high concentration of poor and indigenous households on the high plateau bordering La Paz. The economic benefits of the cable car outweigh the costs by a ratio of 1.05 to 2.16.

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1 INTRODUCTION

The capital city of La Paz, Bolivia, is situated in a canyon on the edge of the Andean highlands, approximately 3,650 meters above sea level. The metropolitan area has a population of roughly 1.8 million people, just over half of whom live in the city of El Alto at 4,100 meters above sea level (INE, 2018). The commute between La Paz and El Alto involves either navigating a single (toll) freeway or braving the narrow side streets that zigzag up and down the steep mountainous terrain separating the two cities. At peak commute hours, roads are congested with mini-buses, taxis, and private vehicles, with average travel times for commuters in the metro area estimated at 40 minutes (Suarez Aleman and Serebrisky 2017). Starting in 2014, an alternative approach to mass transit was introduced with the installation of the Mi Teleférico (MT) aerial cable car system, ferrying passengers between the edge of El Alto and downtown La Paz in as little as 10 minutes.

In this paper, we take a micro-econometric approach to studying the effects of MT using data from a representative sample of 3,575 households in La Paz and El Alto collected in 2016, approximately 2 years after the opening of the first MT line.[1] We estimate local average treatment effects (LATE) of MT on mode of transport, time allocation decisions, employment outcomes, and income. We find that users of the cable car system experienced important shifts in their preferred mode of transportation, substituting expenditures on private transport for public alternatives. Consistent with the existing literature, we find significant travel time savings for MT riders, though our LATE estimates suggest substantively larger time savings for the subset of riders who use MT because of their home's proximity to a station. The time saved appears to have been reallocated to educational and recreational activities for certain types of households. Finally, we find increased self-employment and some evidence of increased self-employment income from the use of MT, which likely reflect increased access to labor market opportunities. Our cost-benefit analysis suggests that, under most reasonable scenarios, the benefits produced by MT outweigh its costs by a ratio of 1.05 to 2.16.

This paper contributes to an increasing, but still limited, literature on the microeconomic effects of urban transport systems and an even smaller subset of studies looking at the impacts of cable cars. Few studies in this area respond to the complexities inherent to constructing credible counterfactual scenarios, particularly in settings where large transport investments may affect the entire transport network, with general-equilibrium effects and leaving little room for identifying pure control groups.[2] In addition, even in a partial equilibrium context, an individual's choice to use the cable car is likely a function of multiple unobserved determinants. Without exogenous variation in cable car use, comparing the outcomes of riders versus non-riders will confound those unobserved variables with cable car usage, resulting in biased estimates.

To overcome these challenges, we implement an instrumental variables (IV) approach using distance from households to the nearest MT station as an arguably exogenous determinant of cable car ridership. We show that baseline levels of economic activity are not correlated with the location of MT stations. Our regression models also control for a rich set of demographic and socio-economic covariates, as well as baseline public transport alternatives near the household. Given the topography of La Paz, with steep terrain and pronounced variations in altitude within the same city, the regression models control for ease of access as measured by the variation in slope between a household and its nearest MT station. Under certain conditions, the resulting LATE estimates will be unbiased, but are unlikely to reflect the average treatment effects for the entire population of La Paz and El Alto. Thus, it is important to emphasize that our estimates are LATEs at the outset. Unobservable differences that are not time varying could be controlled by a difference-in-differences (DID) approach á la Baum-Snow and Kahn (2000); however, given the cross-sectional nature of our dataset, we cannot reconstruct the baseline scenario. Moreover, our study sample is confined to a subset of households in the La Paz and El Alto metropolitan areas, and as such will not capture generalized effects.

1 This paper studies the impact of the first three MT lines (Red, Green, and Yellow lines) between 2014 and 2016. The system has since expanded to 10 lines as of February 2022.

2 For example, Gonzalez-Navarro and Turner (2018) find that subways lead to more decentralized cities, and Duranton and Turner (2012) and Garcia-López et al. (2013) find that highways led to population growth in the United States and Spain, respectively.

The key (endogenous) treatment variable in our analysis is cable car ridership, defined as 1 if a household declared using MT in the month prior to the interview and 0 otherwise. With a binary treatment variable, we implement an estimation method based on a three-stage IV approach proposed by Wooldridge (2002), which is more efficient in contexts with dichotomous endogenous variables when compared to the traditional two-step IV approach. In the absence of endogenous sorting of the population around stations, the distance of a residence to the nearest station is a strong predictor of cable car usage that is uncorrelated with unobserved variables, allowing us to identify consistent LATEs of cable car ridership. The absence of endogenous sorting, i.e., people moving to live closer to MT stations, is a critical assumption underlying our analysis. The relatively short time frame under consideration and our focus on the effects of the first three cable car lines (between the system's inauguration in 2014 and the survey data collected in 2016) make this assumption more plausible. While we do not have data to control explicitly for baseline residence status, we present multiple robustness checks, including an estimation of effects on the sub-sample of households that are property owners and may thus be less mobile in the short-run.

In addition to the methodological challenges, the lack of causal studies in urban transport is also explained by the limited number of transport-specific household-level surveys that would capture broader socioeconomic impacts, while also capturing transport behaviors. Traditionally, the transport sector has based investment decisions on engineering models or projections of travel time savings using origin-destination surveys and simulation exercises. Ex-post empirical studies computing actual travel time savings and looking at socio-economic effects are still relatively scarce (Yañez Pagans et al. 2019). The available causal studies have mostly focused on the impacts of subways and light rails in developed economies. Studies show important effects on housing prices (Baum-Snow and Kahn 2000; Billings 2011; Gibbons and Machin 2005), impacts on accessibility to employment (Holzer et al. 2003; Tyndall 2017), and the ability of these systems to have a transformative effect on cities and to encourage employment growth (Gonzalez-Navarro and Turner 2018).

Another strand of the literature has looked at the effects of Bus Rapid Transit (BRT) Systems, finding modest effects on housing prices and employment, which some authors hypothesize might be due to their perceived lower level of permanence when compared to subways or light rails (Rodríguez and Targa 2004; Vuchic 2002). In terms of aerial cable cars, the most closely related paper by Suarez Aleman and Serebrisky (2017) compares travel times between trips with the same origin-destination pair taken with the MT in La Paz versus trips completed with alternative transport modalities. They find that MT reduces travel times by 22% on average. Outside of the Bolivian context, the case of Medellín (Metrocable) is probably the most widely studied. Qualitative evidence suggests that it led to improvements in urban integration and modernization of neighborhoods (Brand and Dávila 2011; Goodship 2015), accessibility and improved citizen security (Heinrichs and Bernet 2014), improved quality of life (Roldan and Zapata 2013), increased employment opportunities for the poor (Bocarejo et al. 2014), and improved perceptions of pollution (Dávila and Daste 2012). In terms of causal studies, Bocarejo et al. (2014) implement a DID strategy to quantify the impacts of the Metrocable on rent, transport, and public utilities costs, finding no significant effects. Finally, Cerdá et al. (2012) and Canavire-Bacarreza et al. (2016) use DID methods to estimate effects on crime and homicides, finding significant declines in neighborhoods served by the cable car relative to comparable neighborhoods not connected to the cable car.

Our paper makes at least two contributions to the literature. First, we contribute to the limited evidence on the impacts of cable cars as mass transit alternatives. Historically, cable cars have mainly been touristic attractions in high income countries. Yet, in densely populated and complex topographical settings, cable cars offer multiple advantages over subways or light rail systems. They can be built in a shorter amount of time, they do not require the displacement of large groups of people, and they are more suitable for cities with mountainous geographies (The Economist 2017). However, some systems have been heavily subsidized, and cable cars lack the same capacity as other mass transport alternatives. In addition to La Paz and Medellin, cable car systems have been implemented in Caracas (Venezuela), Cali (Colombia), Mexico City (Mexico), and Rio de Janeiro (Brazil). As cable cars are being considered as viable transport alternatives in other contexts, our study contributes to the thin evidence base available to help guide urban transport policy in the region. Second, we explore a set of outcomes that have not been studied in the urban transport causal literature before, including time allocation decisions. By looking beyond the traditional outcomes expected from transport investments, such as travel time savings, we contribute to a more comprehensive understanding of the potential welfare impacts and cost-benefit balance resulting from these investments.

The remainder of the paper is structured as follows. Section 2 describes the MT cable car intervention and context. In Section 3, we describe the data used for the analysis, and section 4 describes our empirical strategy. Section 5 presents the primary results and discusses robustness tests. Section 6 conducts a simple cost-benefit analysis, Section 7 discusses the main methodological limitations of the paper, and Section 8 concludes.

2 Mi TELEFÉRICO

Mi Teleférico is an aerial cable car system serving the metropolitan area of La Paz and El Alto, located in the Andes mountains in Bolivia, and is currently the longest cable car system in the world (Suarez Aleman and Serebrisky 2017). The neighboring cities of La Paz and El Alto are the second and third most populous cities in Bolivia (INE 2018) and are an economically integrated metropolitan area. For example, the international airport serving the entire metropolitan area is in El Alto and many residents commute between the two cities for work. La Paz, the government's administrative center, is in a canyon on the Choqueyapu River, with much of the city built on steep inclinations and hillsides. El Alto is a fast-growing and majority indigenous city made up largely of bedroom communities and industrial areas. El Alto is located on the relatively flat and open Altiplano plateau above the city of La Paz. Despite their proximity, travel between the two cities has always been a challenge due to a difference in elevation of about 400 meters (1,300 ft.) and the treacherous terrain of the slopes that descend into La Paz (see Figure 1).

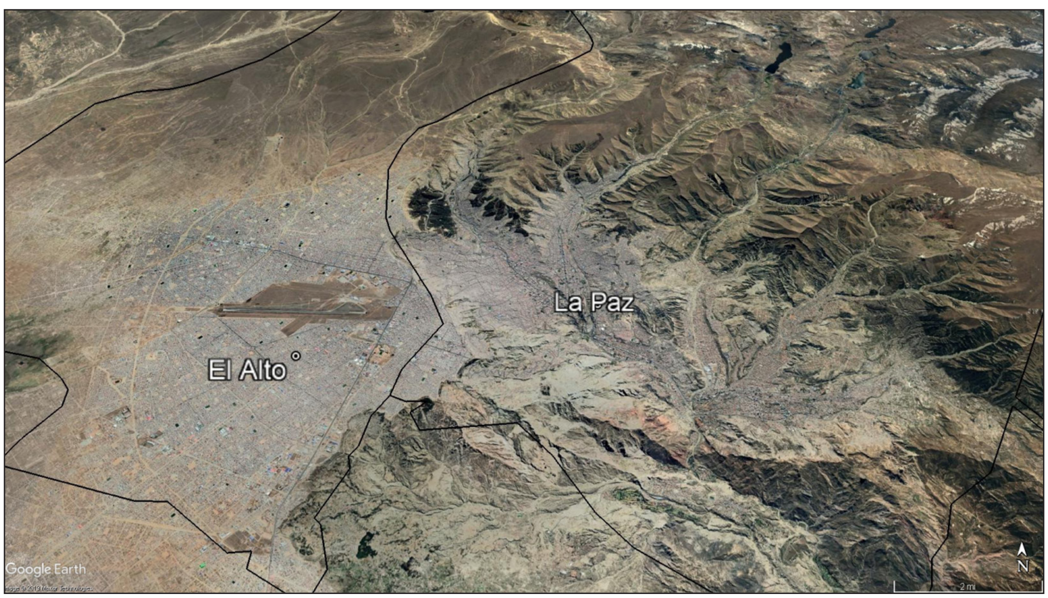

Figure 1 Topography of La Paz metropolitan area.

Before the construction of the cable car, public transportation options between La Paz and El Alto were limited to taxis, buses, and minibuses that were heavily crowded during rush hours. Commuters navigated winding streets with poor road safety and heavy traffic at peak hours. To address this situation, the idea of connecting the two cities with a cable car was proposed as early as the 1970s. In 2011, the Municipal Government of La Paz revived the cable car proposal and carried out a ridership demand study to guide the possible design of a cable car system, which could adapt well to the geographic conditions of the metropolitan area (Mi Teleférico 2016). The study found that the city handles 1.7 million trips per day, including 350,000 trips between La

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Paz and El Alto. In 2012, Bolivian President Evo Morales drafted a bill for the construction of the cable car and sent it to the Plurinational Legislative Assembly, asking mayors from both cities to participate in the project. The project cost for the first phase was US$234 million and was financed by the country's National Treasury with a loan from the Central Bank of Bolivia (Mi Teleférico 2018; Stewart 2017).[3] Phase I of the system consisted of three lines (red, yellow, and green) and was completed in May of 2014. Upon completion, the 10 kilometer (6.2 mile) system was the longest aerial cable car system in the world (see Figure 2).

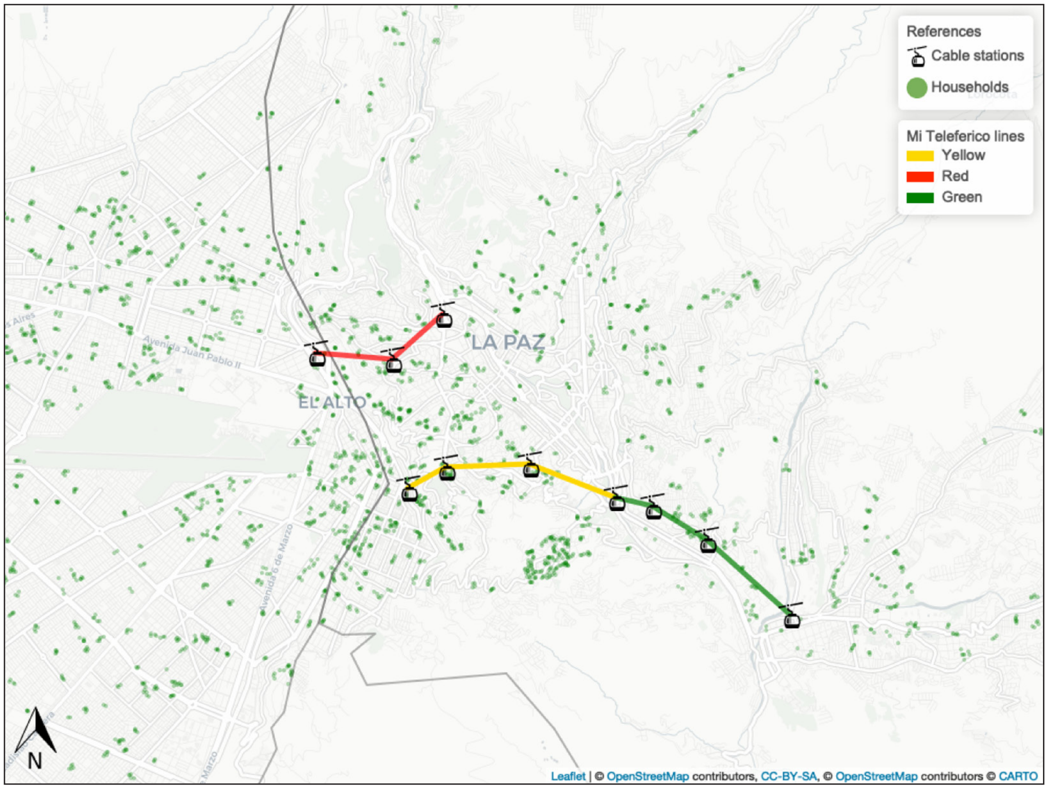

Figure 2 Map of Mi Teleferico lines (2014–2016) and spatial distribution of the survey sample.

In 2015, a law approving the construction of Phase II was passed, increasing the number of new lines to six and committing US$450 million to the project.[4] A seventh line was announced in February 2016, and an eighth was announced in July 2016 (Mi Teleférico 2018).[5] Based on its master plan, the completed system will reach a length of 33.8 kilometers (21 miles) with 11 lines and 39 stations. As of February 2022, 10 lines are already operating. Over the years, the system has received multiple awards and recognition for being one of the most innovative transport systems in the Latin American region.[6] It also entered in the Guinness World Record in 2018 for being the largest cable car network in the world.

MT is the first urban transit network to use cable cars as the backbone of the public transportation network (Neuman 2017). At 3 Bolivianos (approx. US$0.40) per ride (2023), prices have been set to be as competitive as possible with the local bus system. However, given the important reductions in travel time and the improved quality of the service compared to other modes of transportation, trip fares are above those of traditional transportation modes, particularly for longer trips. According to recent data, the trip fare of MT is 1.5 times the fare of other transport modes for short trips and could be up to 2.6 times for longer trips when compared to the cheapest

3 The project was constructed by the Austrian company Doppelmayr and it is operated by a government-owned enterprise called "Mi Teleférico" and created in 2014 (Mi Teleférico 2018).

4 Phase II of the project includes the lines blue, orange, white, light blue, violet, and brown lines.

5 Phase III includes the construction of silver and gold lines, plus an extension of the brown line.

6 For example, in 2016 it received the award from the Smart City Business America Congress and Expo and in 2018 the system received the Latam Smart City Award, under the category of Sustainable Urban Development and Mobility, which is the most important award in the Latin American region for urban projects (Mi Teleférico 2018).

alternative. Table C in the Appendix shows the trip fare comparisons per mode. Each line can transport up to 6,000 people per hour, with cabins leaving every 12 seconds and seating up to 10 people. The system is open between 6:30 AM and 11:30 PM Monday-Saturday and 7:00 AM to 9:00 PM on Sunday and Holidays. According to company statistics, the system transported up to a total of 84,830 passengers per day in 2018, and almost 100 million passengers since its first opening in 2014 until 2017 (Mi Teleférico 2018). Estimates indicate that the cable cars have cut commute times by up to 50% from end-to-end stations.[7] Each cable car is equipped with solar panels to power the doors, lights, and Wi-Fi. The aerial transport network has not only proved popular among locals and tourists but is also praised as a symbol of efforts to close the geographic and economic gap between Bolivia's indigenous and poor population in El Alto with the mestizo, the middle class population in La Paz (The Guardian 2016).

3 DATA

We use a purpose-specific household survey collected in 2016 to study the impact of Phase I of the cable car system. The survey covers a representative sample of households in the cities of La Paz and El Alto. Sampling was conducted at different distances from three main areas: i) currently operating MT stations (Phase I); ii) stations under construction (Phase II); or iii) future stations (Phase III). The unit of analysis was the household, defined as the set of people who live in the same home and share expenses on food and basic services (water, sanitation, and electricity). Households were selected for the application of the survey based on whether at least one member of the household of 12 or older had made a trip using any form of ground transportation in the past day. For each sampled household, the survey captured socio-demographic information for all household members, including the head of household and spouse. To complete the transport modules, the survey randomly selected one household member over 12 years old who had completed at least one trip in the day before the interview. The total sample size was 3,575 households distributed across 882 blocks. Figure 2 shows the geographic dispersion of the sample and the MT lines available in 2016.

The survey collected a rich set of household demographic and socio-economic characteristics and included a transport module with trip details from the previous day as well as GPS coordinates for each household. As outcomes of interest, we focus on four sets of variables: (i) transport-related expenses, (ii) time allocation decisions for different activities, (iii) employment outcomes, and (iv) income outcomes. Types of transport-related expenses include expenses for public transportation services, such as urban public transport (bus, minibus, taxi). Private transport expenses correspond to expenses for fuel and lubricants for cars and/or motorcycles, as well as vehicle repairs and maintenance. The survey also collected information about expenses on transport to educational centers, including colleges, universities, institutes, etc. Time allocation decisions focused on how much time the person dedicated the day before the interview to activities such as working, studying, household chores, transportation, eating, sleeping, recreation, and others. Employment outcomes are constructed from a labor module that asks if during the previous week the interviewee looked for a job, if he or she worked at least one hour, and if he or she is an independent employee. Income outcomes refer to the total amount (in Bolivianos) that the individual receives in terms of salary, in kind, as an independent employee, and his or her total income. We also compute total per capita household income. For the MT treatment variable, we consider a household to be a user of the system if they report having used MT at least once a month.[8] We conduct robustness checks using other definitions of the variable, including weekly and yearly use.

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7 These estimates are based on comparisons of the average travel times reported by Google Maps during rush hour from end-to-end stations for each of the three lines (red, yellow, and green) with private car versus those with MT. For example, an end-to-end trip on the red line lasts 10 minutes, while a private car commute would take approximately 24 minutes. These calculations do not consider that private cars might be faster that other modes of public transportation, therefore, time savings from end-to-end stations could be even larger.

8 Note that transport modes are reported only by the individual who answers the transportation module. We extrapolate use of MT for all household members based on this information.

In addition to the 2016 household survey, we add baseline geocoded information on alternative public transport modes in La Paz and El Alto, including minibus,[9] micro,[10] trufi,[11] and Puma Katari.[12] This information was extracted online from the Mayor's Office of Planning for Development (OMPD) of the Autonomous Municipal Government of La Paz, in 2013. We use this information to construct a variable that measures a household's pre-MT level of accessibility to public transportation. The variable computes the number of lines for each type of public transportation at a walking distance of 250 meters from the dwelling. We also use geocoded baseline information on the location of markets and banks in La Paz and El Alto to construct a measure of intensity of economic activity around MT stations. This information was extracted from the GeoBolivia portal, a central government initiative to provide access to geographic information (GeoBolivia 2022). Finally, as a robustness check, we add night light luminosity data (Visible and Infrared Imaging Suite, VIIRS, Day Night Band, Elvidge et al. 2013) to control for the approximation of baseline economic activity in the area of influence of the project (see Section 5.3 for further references).

4 EMPIRICAL STRATEGY

In a general setting, the decision to use transportation or to use a certain mode of transportation derives from an optimization problem where individual *i* chooses transportation mode *j* to optimize (maximize or minimize) its objective function (T_{ij}).[13] The objective function is dependent on characteristics of the individual *i* (X_i) and characteristics of the transportation mode and the environment (W_j), such as transport specific characteristics, safety or travel time, or the existence of other alternative modes of transportation.

$$T_{ij} = F(X_i, W_j) \tag{1}$$

Assuming that the objective function is random, it can be divided in two parts. The first one is deterministic ($V_{ij}(X_i, W_j)$) and the second one is random (ϵ_{ij}). The random term of the objective function (ϵ_{ij}) reflects the unobservable behavior of individuals. This means that two individuals with the same observed characteristics and faced with the same choice can make different decisions. This reflects the probabilistic nature of discrete choice models.

$$T_{ij} = V_{ij}(X_i, W_j) + \epsilon_{ij} \tag{2}$$

Assuming a simple linear form, the decision of individual (*i*) to use transportation mode (*j*) can be expressed in the following reduced-form model:

$$T_{ij} = \alpha_0 + \alpha_1 X_i + \alpha_2 W_j + \epsilon_{ij} \tag{3}$$

Where T_{ij} is a binary variable that takes the value of 1 if the individual *i* uses transportation mode *j* and 0 otherwise. X_i and W_j are vectors of observable characteristics or covariates of the individual and the environment, respectively, and ϵ_{ij} is the random error term. This model confirms that an individual's decision or propensity to adopt the MT as a transport mode is driven by multiple factors. Not only personal characteristics, such as age, education, and income status, among others, will influence this decision, but there are transport and location-varying characteristics

9 Minibus routes are displayed on a sign that hangs from the windshield. The minibuses are characterized by the presence of a "voceador," who is the person in charge of collecting the fares (between US$0.16 and 0.23) and to announce (shouting through the window) the route and destination of each minibus. They do not have an established schedule.

10 Micro is the traditional bus service that has an established route, but not assigned stops or schedules. Usually the buses that operate in this category are old and are part of a specific transport union.

11 The trufi is a collective taxi that fits up to 5 passengers and has a predetermined route (written on a sign that hangs from the windshield). It costs about US$0.33.

12 Puma Katari is a relatively new bus service, launched by the local government in La Paz. Buses have an established route, designated stops, and an organized schedule.

13 We present here a simple model to show how our estimated equations are derived from discrete choice models. This is inspired by work such as McFadden (1978), and more recently Ben-Akiva and Lerman (1985) and Bierlaire (1998), among others.

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that may drive this behavior. For instance, individuals who live further away from the new MT stations might also be located in less central areas in general with fewer transportation options, which would impact their propensity to adopt the MT in an endogenous way. These observable differences in location will be accounted for in our models by controlling for a rich set of covariates, including the availability of alternative transport options at baseline as well as variables to approximate economic activity around the dwelling.

Considering the discrete choice explained above, in this paper we seek to estimate the causal effects of the use of MT on multiple outcomes of interest, such as transportation expenditures, time allocation decisions, and employment outcomes. In an ideal scenario, one would like to compare a population randomly assigned to use the cable car against a population with no access to the system. In the absence of such an assignment, a naïve approach might compare outcomes of populations that use the system to those who do not. The estimation would be as follows:

$$Y_{ij} = \beta_0 + \beta_{use} T_{ij} + \lambda V_{ij} + \epsilon_{ij} \tag{4}$$

Where Y_{ij} is the outcome of interest for household *i* living in area *j*. T_{ij} is a binary variable that takes the value of 1 for users of MT and 0 otherwise, and V_{ij} are covariates that affect the outcome variable, which include variables considered in the vectors (X_i and W_j).

The main concern with the above approach is that MT users might be inherently different from non-users and, while we could control for multiple observable variables, any unobservable characteristics driving these differences that simultaneously affect the outcome variable could lead to an inconsistent parameter estimation. In other words, the error term (ϵ_i) could be correlated both with T_{ij} and Y_{ij}. To overcome this endogeneity concern, we propose an instrumental variables (IV) approach to generate exogenous variation in the treatment variable. We use the distance of individual *i* to the nearest MT station that was in operation in 2016 (the year of the survey) as an instrument for the actual use of the system. The minimum distance to an MT station is constructed using GPS coordinates for sample dwellings and MT stations. Rather than using a straight line to compute the distance we use the shortest distance of a walking path that considers the real street configuration and therefore incorporates the differences in topography in the city. For example, Figure 3 shows the ten possible paths to the existing MT stations for household *i*.[14] The instrument Z_{ij} is the walking distance in kilometers between individual *i*'s home and the nearest station (in this case the Sopocachi station, transportation mode *j*). We argue that it is plausible that the instrument (Z_{ij}) satisfies two important conditions. First, a shorter distance to the MT system facilitates access, leading households to use or more frequently use the MT. Thus, our prior is that T_{ij} and Z_{ij} would be strongly correlated in a "first stage." Second, it is plausible that the distance to a MT station will satisfy the exclusion restriction, only affecting the outcome variables through MT usage, under certain conditions. Further discussions around the potential methodological limitations is presented in Section 7.

The literature has commonly used the location of historical routes (Baum-Snow 2007; Duranton and Turner 2012) or least-cost paths (Faber 2014) as instruments to solve for the non-random location of transport infrastructure projects. The first instrument assumes that the location of routes in the past should predict the placement of current infrastructure but should not directly affect current levels of economic activity or population growth. For the second one, authors have used engineering estimates for the cost of building transport on different types of land to estimate the least-cost paths to connect relevant city points (see, for example, Tsivanidis 2019). Given that MT is an aerial transportation mode, which does not occupy physical space on the ground, the location decisions take different considerations that may not be as correlated with the location of the routes or the costs to build on different types of land. Therefore, the traditional IV used in the literature may not be applicable in this case.

14 Our analysis includes all stations of the first three lines of Phase I, including: 16 de Julio, Cementerio, Central, Parque Mirador, Buenos Aires, Sopocachi, Del Libertador, Alto Obrajes, Obrajes 17, and Irpavi.

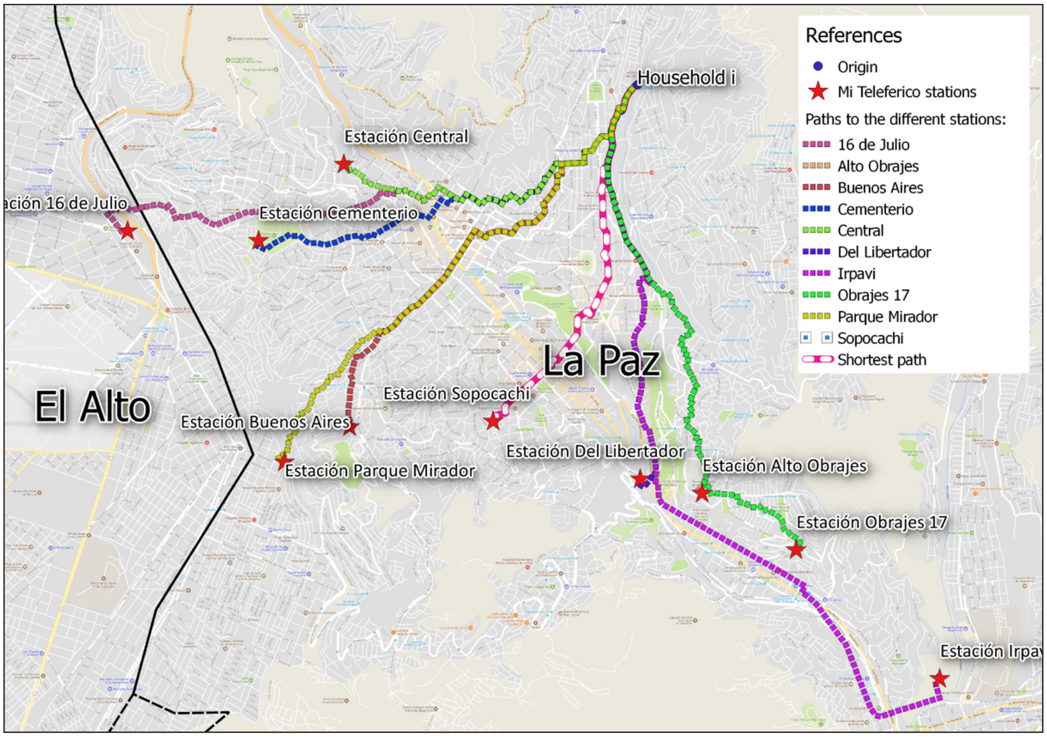

Figure 3 Construction of the instrument.

In this paper, we argue that the location of MT stations was largely an ad-hoc process based primarily on the availability of space to build a station on the ground. Thus, stations were not always located in the most desirable commercial centers or the most central areas, and their placement was akin to an exogenous shock for residents in the vicinity. To support this idea, we look at the correlation between baseline economic activity and the locations of MT and use of the system in the future. Using data on the location of markets and banks in 2013, we create a map showing baseline economic activity in the cities of La Paz and El Alto.[15] We then compute the minimum distance (for each household in the sample) to the closest market, bank, or both. Figure D1 in Appendix D visually confirms that most MT stations were not located in areas with high intensity of economic activity at baseline. In addition, Table D1 shows that the correlation between baseline economic activity and the use of MT is not statistically significant across different definitions of economic activity.

Another important point to consider is whether households change their location in response to where MT stations were built over time. This would invalidate our empirical approach, since households living closer to the stations would be composed of individuals that value living near a station and may have different work and commute patterns that would directly affect our outcomes of interest. Our data set does not include the duration of residence in the current location; however, as a robustness check, we estimate models only on the sample of households that are property owners and thus are likely to have higher transaction costs to relocate, and the results hold. Thus, at least in the short run context analyzed here, we argue that endogenous sorting is not likely a major threat to our identification. In addition, Table A2 shows (although with contemporaneous variables) that households living very close to an MT station are overall not statistically different to those living farther away (500 to 1,500 mts).[16]

A common procedure to estimate IV models is through a two-stage least squares model (2SLS, Cameron and Trivedi 2005), by which in a first step the use of MT or treatment variable (T_{ij}) is regressed on a set of covariates V_{ij}, including the instrument Z_{ij}. Then, the predicted value of the treatment variable $\hat{T}_{ij}$ is used as the main covariate of interest in a second step. Given that we have

15 Information was extracted from the GeoBolivia portal (GeoBolivia 2022).

16 Figure 4 shows the kernel density of the distribution of households according to the distance to their closest MT station and their use of the cable car system.

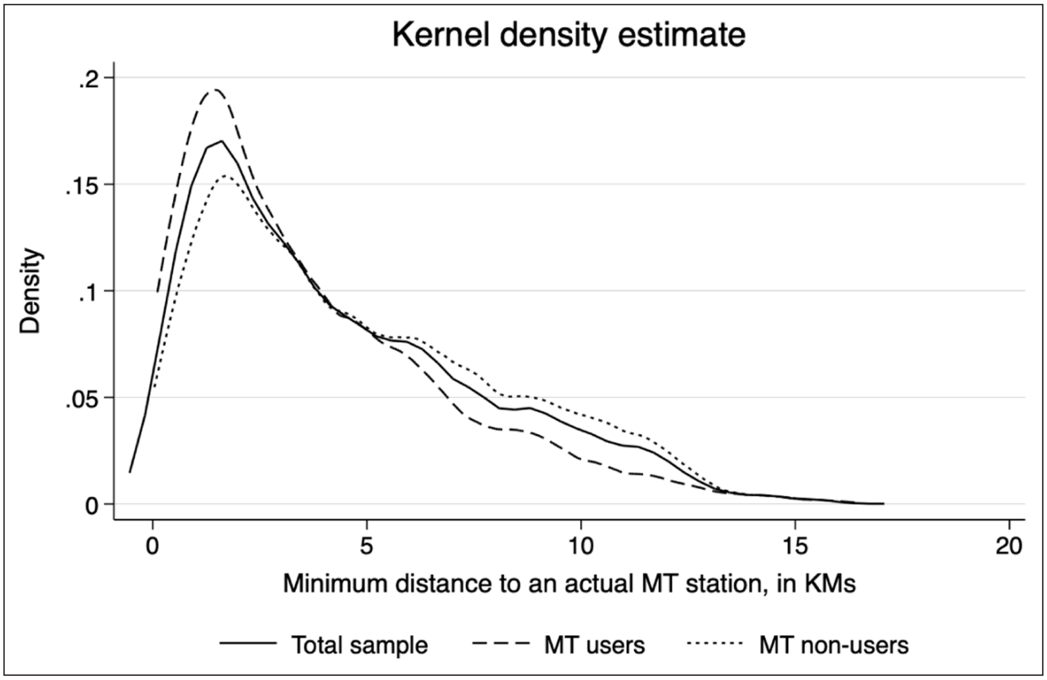

Figure 4 Kernel estimated for users and non users of MT and the minimum distance to the closest MT station.

an endogenous dummy variable model, Heckman (1978) and Wooldridge (2002) propose a more efficient IV estimation process that follows a three-stage procedure and considers a non-linear functional form.[17] Therefore, following this method we estimate a binary model (Probit) in a first stage, regressing the use of MT (T_{ij}) on other covariates V_{ij}, which include the different observable personal and location-specific characteristics that may affect the decision to use the aerial cable car system, including the instrument Z_{ij}:[18]

$$T_{ij} = \gamma_0 + \gamma_{distance} Z_{ij} + \eta V_{ij} + u_{ij} \tag{5}$$

From the first stage, we obtain the predicted value of treatment $\hat{T}_{ij}$. In a second stage, we estimate a linear model, which would be the first stage of the traditional 2SLS model, using $\hat{T}_{ij}$ as the instrument for the treatment:

$$T_{ij} = \alpha_0 + \alpha_{use} \hat{T}_{ij} + \delta V_{ij} + e_{ij} \tag{6}$$

From this second stage, we obtain a new predicted value of the treatment $\hat{\hat{T}}_{ij}$ that we then use to estimate the final and third stage to compute the impact:

$$Y_{ij} = \beta_0 + \beta_{use} \hat{\hat{T}}_{ij} + \lambda V_{ij} + \epsilon_{ij} \tag{7}$$

The coefficient of interest is β_{use} and measures the impact of the use of MT on the outcomes of interest. Besides the efficiency gains from this procedure, the usual 2SLS standard error and test statistics are asymptotically valid. Also, it does not require the Probit model in the first stage to be correctly specified as long as the instrument is correlated with the treatment variable. The estimated treatment effect is interpreted as a LATE, which in this context can be thought of as the effect of cable car ridership for those users who are induced to use the system thanks to the geographical proximity of their residence to an MT station. We report cluster robust standard errors, where the cluster unit is the area code, which is the smallest geographical unit that can be identified in the survey.[19]

17 For more details, please review Procedure 18.1 reported on page 623 of Wooldridge (2002). This methodology has also been implemented by Adams et al. (2009), Tan (2010), and Niimi (2016).

18 For clarity and simplicity, we separate the instrumental variable Z_{ij} from the rest of the covariates contained in vector V_{ij} but maintain the same notation or name for vector V_{ij}, so it follows the presentation of the model explained in equations (1) to (4).

19 There are a total of 29 area codes in the survey sample.

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5 RESULTS

5.1 DESCRIPTIVE STATISTICS

Table 1 presents descriptive statistics of the sample. In terms of the geographic distribution, 57% of the sample comes from El Alto, while 43% comes from La Paz. Most household heads are men (77%), 57% report to be indigenous, 25% have completed university studies or more, 67% are property owners, and the average household size is four. With respect to the use of MT, 36% of respondents report having used the cable car system at least once per month.[20] The average minimum distance to a MT station is 4 km, but there is large variation, with the closest households being less than 500 meters away and the farthest more than 16 kilometers away.

Table 1 Summary statistics.

Notes: Monetary figures, such as expenses on transportation and income, are expressed in Bolivianos.

	ALL SAMPLE		LA PAZ (1)		EL ALTO (2)		MEAN DIFFERENECE p-VALUE
	MEAN	SD	MEAN	SD	MEAN	SD	(1)–(2)
Covariates							
Male	0.77	0.42	0.74	0.44	0.79	0.40	0.00
Age	47.71	14.80	50.60	14.99	45.49	14.27	0.00
Single	0.10	0.30	0.12	0.32	0.09	0.29	0.01
Married/cohabiting	0.73	0.44	0.70	0.46	0.76	0.43	0.00
Separated/divorced	0.08	0.26	0.09	0.28	0.07	0.25	0.01
Widow	0.09	0.29	0.09	0.29	0.09	0.28	0.53
Indigenous	0.57	0.49	0.29	0.45	0.79	0.41	0.00
Less than secondary	0.23	0.42	0.13	0.33	0.30	0.46	0.00
Complete secondary and technical	0.41	0.49	0.42	0.49	0.40	0.49	0.24
Incomplete and complete university	0.22	0.41	0.32	0.46	0.14	0.35	0.00
Masters and PhD	0.02	0.16	0.05	0.21	0.01	0.10	0.00
Disable	0.03	0.18	0.03	0.18	0.03	0.17	0.46
Asset index	–0.00	1.87	0.78	2.16	–0.60	1.32	0.00
Own automobile	0.21	0.41	0.28	0.45	0.16	0.37	0.00
Owner of the property	0.66	0.47	0.69	0.46	0.63	0.48	0.00
*N*º of household members	4.00	1.75	3.88	1.70	4.09	1.78	0.00
Standard deviation of elevation	0.04	0.03	0.05	0.04	0.03	0.01	0.00
*N*º of lines of public transport	10.73	14.09	16.12	17.78	6.58	8.27	0.00
Remittances/transfers	0.19	0.39	0.22	0.42	0.16	0.36	0.00
Expenses on transportation during last month (per capita)							
Public	88.63	83.35	99.47	88.89	80.29	77.82	0.00
Private	25.47	97.25	33.34	101.81	19.41	93.17	0.00
For education	8.66	34.31	9.21	36.30	8.24	32.71	0.40
Total	122.76	135.18	142.02	135.92	107.94	132.75	0.00

(Contd.)

20 For a representative sample of households in La Paz and El Alto, Suarez Aleman and Serebrisky (2017), find that the model share of MT in 2015 was 2% of trips, equivalent to the modal share of taxi rides. Minibuses (57%), walking (19%), private car (6%), buses (5%), and trufis (5%) were the other primary modes of transport reported for trips within the metropolitan area (4% reported other). These numbers compare to the modal share reported in the evaluation survey used in this paper where MT represents 3.24% of trips taxis (2.11%), minibuses (76.7%), walking (2.5%), private car (3.28%), buses (4.02%) and trufis (4.95%).

	ALL SAMPLE		LA PAZ (1)		EL ALTO (2)		MEAN DIFFERENECE p-VALUE
	MEAN	SD	MEAN	SD	MEAN	SD	(1)–(2)
Time dedicated to (in minutes)							
Working	250.98	252.54	233.55	252.42	264.40	251.87	0.00
Studying	83.19	158.40	98.48	173.52	71.42	144.65	0.00
Household	291.20	175.76	302.47	179.75	282.53	172.18	0.00
Transport	87.00	51.74	84.70	49.04	88.78	53.66	0.02
Lunch break and meals	105.69	40.94	104.02	39.72	106.99	41.82	0.03
Sleeping	435.02	65.44	443.45	64.32	428.52	65.58	0.00
Recreation	47.74	70.95	47.86	71.93	47.65	70.20	0.93
Other	139.17	128.52	125.47	124.13	149.71	130.85	0.00
Income							
Salary	1,110.29	2,274.26	1,212.33	2,761.43	1,031.74	1,809.04	0.02
In kind	14.62	136.25	12.16	113.21	16.52	151.61	0.34
Self-employment	1,834.19	4,631.02	1,617.31	4,369.04	2,001.13	4,817.41	0.01
Total income	2,959.10	4,751.39	2,841.80	4,778.30	3,049.39	4,729.79	0.20
Per capita income	1,376.44	1,707.37	1,410.08	1,935.67	1,350.54	1,508.29	0.30
Work							
Looked for job?	0.01	0.09	0.01	0.10	0.01	0.07	0.07
Worked ≥ 1 hr last week	0.82	0.38	0.77	0.42	0.86	0.34	0.00
Self-employed	0.44	0.50	0.37	0.48	0.48	0.50	0.00
Endogenous variables							
Use Mi Teleférico (month)	0.36	0.48	0.38	0.48	0.34	0.48	0.04
Instrument							
Minimum distance to station (in *km*)	4.39	3.30	2.38	1.74	5.93	3.39	0.00
Sample size	3,566		1,551		2,015		

With respect to the outcome variables, we see that on average, total household per capita expenditure on transport per month is around 123 Bolivianos (approx. US$18), representing almost 7% of the minimum wage in the country.[21] In terms of time allocation decisions, for household members over 12 years old, transport time consumes on average 1.4 hours per day, while time devoted to educational activities is 1.3 hours (72% of respondents reported zero hours of study). Finally, regarding employment outcomes, 82% of household heads report having worked at least one hour in the past week. The average per capita household income is around 1,300 Bolivianos (approx. US$188), and those working independently earn more than those working as employees (1,800 vs. 1,100 Bolivianos, respectively).

We also explore the profile of MT users in more detail, considering how frequently they use the system, and compare them with non-users. Table A1 in the Appendix shows that a large proportion of the more frequent users (i.e., daily, weekly, or monthly) are located in La Paz versus less frequent users (i.e., bimonthly to annually), 46% vs. 39%, respectively. More frequent users also have higher incomes, higher levels of education, and a lower proportion of them are indigenous people. This seems consistent with the fact that trip fares are higher when compared to other

21 For 2016, the minimum wage in the country was 1,805 Bolivianos, which is equivalent to US$262.

modes of transportation. Less frequent users are located at larger distances to MT stations when compared to frequent travelers, thus suggesting that the instrument of distance might be relevant to predict the use of this transport system. Regarding non-users, the descriptive statistics reported in Table A1 suggest that they are older than frequent users, have lower levels of incomes, and seem to be more dependent on private modes of transportation. They also devote more time to household chores and a larger proportion of them are unemployed or worked less than 1 hour in the past week. In terms of distance, interestingly, they are not located at larger distances to MT stations than those who use the system more frequently, which suggests that although distance seems to be an important predictor of frequency of use of MT, there might be other personal and household-level characteristics influencing the demand for this service. We control for these differences in characteristics (to the extent possible) in the regression analysis.

5.2 MAIN RESULTS

Table 2 reports the estimation of the first two stages of the model specified in equations 5 and 6. These first two stages are common for all of the outcome variables that will be analyzed in this section. The estimated coefficient $\gamma_{distance}$ refers to the effect of distance to the nearest station on the use of MT, obtained from the Probit model regressing the use of MT on covariates V_{ij} and the instrument Z_{ij}. The results confirm that living further away from the nearest station reduces the probability of using MT both for the total sample as well as for the sub-samples of the cities of La Paz and El Alto (rows 2 and 3 of Table 2, respectively). Moreover, α_{use} refers to the effect of the predicted probability of using MT ($\hat{T}_{ij}$, from the previous step) on T_{ij}. Because this step is similar to the first stage of a traditional instrumental variables approach, and given that we have clustered standard errors, we report the Kleibergen-Paap statistic associated to the model (Kleibergen and Paap 2006).[22] The baseline specification includes the covariates for city,[23] gender of household head (male), age, marital status, indigenous, educational level,[24] physical condition (disabled), household asset index, owns a car, property of the residence, number of household members, variation of the slope along the way from the household to the closest MT station,[25] the number of available lines of public transportation (transport accessibility measure) prior to the existence of MT, and reception of non-labor income, such as remittances and transfers from social programs. The reported standard errors are cluster robust at the minimum geographical level available (in this case, it corresponds to the area code).

Table 2 Estimation of the first two stages of preferred specification.

Instrument: Dwelling distance to actual MT stations.

Covariates V_{ij} include: La Paz, gender of household head (male), marital status, indigenous, educational level, physical condition (disable), household asset index, owns car, property of residence, number of household members, altitude variation between dwelling and closest MT station, accessibility to public transportation at baseline, and received non-labor income such as remittances and transfers.

$\gamma_{distance}$ refers to the effect of distance to the nearest station (Z_{ij}) on the use of MT (T_{ij}), obtained from the binary model (Probit) on covariates V_{ij} (equation 5).

α_{use} corresponds to the effect of the predicted probability of using MT ($\hat{T}_{ij}$, from the previous step) on T_{ij}, according to equation (6).

Cluster robust standard errors in parentheses.

KP-test refers to the Kleibergen-Paap robust rk Wald F statistic obtained with `ivreg2` package in `Stata`.

	1st STAGE	**2nd STAGE**		**Obs.**
	$\gamma_{distance}$	α_{use}	***KP-TEST***	
Total sample	–0.074***	1.000***	24.601	3,566
	(0.014)	(0.202)		
La Paz	–0.107***	0.986***	9.577	1,551
	(0.031)	(0.318)		
El Alto	–0.055***	0.996***	12.047	2,015
	(0.014)	(0.287)		

22 See `Stata` package `ivreg2` for a discussion on the equivalence of Kleibergen-Paap robust rk Wald F statistic and the F-test from the first-stage regression in the case of a single endogenous regressor. To analyze for weak instruments, a test of joint significance of the instruments' coefficients via the *F-test* is used. The rule of thumb is that an *F*-statistic bigger than 10 (see Stock and Yogo 2002). In our estimated models the *KP-F* statistic is equal to 24.60, indicating that the IV estimation is strong.

23 We also estimate the model without covariates and all main results presented in this section remain significant. These results can be observed in Tables F7 and F8.

24 The survey only asked for the highest level of education completed and not for total years of schooling; therefore we are not able to include a continuous and possibly more simple control for educational attainment.

25 Given the mountainous terrain of the city and pronounced changes in altitude, particularly in La Paz, the slope between a house and an MT station is included as a proxy measure for the ease of access to a MT station. We construct the slope variable as the standard deviation of the altitudes calculated every 50 meters along the road between the dwelling and the MT station.

Table 3 presents the estimation results for household transport per capita expenditures. The survey asked households to provide information on how they distributed their transport expenditures across different transport modes (private versus public) and according to the motive of use (in particular, they asked about transport expenditures for educational purposes). The information is reported in monthly Bolivianos. We observe that OLS estimates report small but statistically significant effects on total expenditures for public or private transportation of approximately the same dimension but of opposite signs. For instance, those who use MT spend on average 10.11 Bolivianos more on public transport, and they spend 9.27 Bolivianos less on private transportation. As discussed before, OLS estimates may be subject to endogeneity. Implementing the three-stages approach (IV-3 stages) discussed in section 4, we find a significant increase in public transport expenditures of 62.46 Bolivianos. The magnitude of this effect seems relevant as it represents 70% of the average per capita expenditure in public transportation for all the sample (88.63 Bolivianos).[26] In addition, we estimate a reduction in private transport expenditures of 50.66 Bolivianos, which is almost twice the average for the sample (25.47 Bolivianos).[27] Overall, these results suggest that MT promoted a shift in transport mode, leading individuals to adopt more public transportation and to use private vehicles less. This modal change is quite important from the perspective of urban mobility and is usually one of the main objectives of urban transport interventions. Our results also show a marginally significant increase, of around 16 Bolivianos (sample average of 8.661 Bolivianos), in transport expenditures for educational purposes. This could be related to the improved accessibility to educational centers that the MT brings.[28]

	β_{use}				Obs.
	PUBLIC	**PRIVATE**	**EDUCATION**	**TOTAL**	
OLS	10.114***	–9.268***	1.926	2.772	3,566
	(3.635)	(2.855)	(1.664)	(5.445)	
IV-3 Stages Estimation					
Total sample	62.461***	–50.663***	15.878*	27.676	3,566
	(26.250)	(18.761)	(9.220)	(26.736)	
La Paz	–56.039	–29.075	–11.460	–96.575	1,551
	(44.792)	(39.272)	(18.405)	(73.400)	
El Alto	62.926	–81.094**	16.204	–1.964	2,015
	(60.198)	(37.953)	(11.101)	(43.010)	
Average value of outcome variables					
Total sample	88.631	25.470	8.661	122.762	3,566
La Paz	99.472	33.342	9.208	142.023	1,551
El Alto	80.287	19.410	8.240	107.937	2,015

Table 3 Household per capita expenditure in transport (Bolivianos per month).

Covariates V_{ij} include: La Paz, gender of household head (male), marital status, indigenous, educational level, physical condition (disable), household asset index, owns car, property of residence, number of household members, altitude variation between dwelling and closest MT station, accessibility to public transportation at baseline, and received non-labor income such as remittances and transfers.

β_{use} coefficient corresponds to the estimation of equation (4) obtained by Ordinary Least Squares (OLS) and equation (7) from process 18.1 proposed by Wooldridge, 2002 (IV-3 stages).

Monetary figures are expressed in Bolivianos.

Cluster robust standard errors in parentheses.

We are also interested in capturing any heterogenous effects across the cities of La Paz and El Alto, given the very different transport and socio-economic characteristics of these two cities. La Paz is the center of government activities in the country and concentrates most of the employment in the metropolitan area. El Alto is a city that has experienced large increases in population, mainly migrants from rural areas. It is composed of lower income populations and

26 Table 3, and all the results tables that follow, include the average of the outcome variables in the analyzed sample to understand the magnitude of the estimated effects.

27 The fact that the average is relatively low compared to the effect size suggests that impacts could be concentrated in certain populations that have large private transport expenditures.

28 Most educational centers, particularly advanced ones, are located in La Paz rather than El Alto, and MT facilitates access from El Alto to La Paz, which helps to explain this result.

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has fewer infrastructure services relative to La Paz. With the opening of MT, the residents of El Alto gained improved access to La Paz. The results in Table 3 disaggregated by city of residence confirm this hypothesis. Residents of El Alto experience considerable increases in expenditure on public transportation (although not precisely estimated) which is offset by statistically significant decreases in private transport because of MT, whereas estimated changes for residents of La Paz are not statistically different from zero. In the case of educational transport expenditures, the direction of impacts is positive for El Alto and negative for La Paz, but they are not precisely estimated.

Table 4 presents results related to time allocation decisions for a randomly selected household member above 12 years old, measured in number of minutes per day that are devoted to different types of activities. On average, cable car users report spending 70 fewer minutes per day on transportation (considering an average of 87 minutes). In the context of La Paz and El Alto, average travel times are 84.7 to 88 minutes, respectively, with commuters in the top quintile of travel time distribution (not including MT users), averaging 181.4 to 186.9 minutes daily. Thus, while the LATE coefficient on travel time appears large for the average commuter in the sample, it represents a reduction of approximately 47% (in both cases) for those individuals with longer commutes. We speculate that "compliers" who are induced to use MT because of their dwelling's proximity to a station may be precisely those with most to gain in terms of time savings.[29] We also observe statistically significant reductions in the time devoted to lunch breaks, approximately 52 minutes of savings. In Bolivia, it is customary for workers to return home for the mid-day meal, which is the primary meal of the day. We believe that to the extent that MT is allowing people to travel longer distances, people may decide to not return home for lunch and therefore spend less time eating.[30] Freeing up time that was previously devoted to transportation allows individuals to allocate this extra time to other activities. Consistent with this fact, we observe increases in the amount of time that the household head devoted to recreational activities (increase of 32 minutes per day, even though not statistically significant) and to educational activities (increase of 120 minutes per day). The results also confirm that the benefits of MT use accrue mostly to the inhabitants of El Alto, who report a 95 minute-reduction per day in transportation time. If we also consider the 68 minutes they save on lunch breaks, total time savings for residents of El Alto who use MT due to geographic proximity to an station is over two and a half hours per day, time that is reallocated primarily to study.

Table 4 Time allocation decisions (Minutes per day—for any household member age 12 or above).

Covariates V_{ij} include: La Paz, gender of household head (male), marital status, indigenous, educational level, physical condition (disable), household asset index, owns car, property of residence, number of household members, altitude variation between dwelling and closest MT station, accessibility to public transportation at baseline, and received non-labor income such as remittances and transfers.

β_{use} coefficient corresponds to the estimation of equation (4) obtained by Ordinary Least Squares (OLS) and equation (7) from process 18.1 proposed by Wooldridge, 2002 (IV-3 stages).

For the outcome variables related to time allocation, we use the transport module. In this case, people aged 12 or over (either present or not at the time of the interview) were randomly selected to answer the questions.

Cluster robust standard errors in parentheses.

	β_{use}								Obs.
	WORKING	**STUDYING**	**HOUSEHOLD**	**TRANSPORTATION**	**LUNCH BREAK**	**SLEEPING**	**RECREATION**	**OTHERS**	
OLS	3.869	25.448***	–15.247**	12.111***	–2.752	–2.804	0.037	–20.662***	3,566
	(9.015)	(9.000)	(6.621)	(2.074)	(1.728)	(2.396)	(2.681)	(5.522)	
IV-3 Stages Estimation									
Total Sample	–34.694	120.027*	–2.363	–70.573*	–52.252**	20.827	32.466	–13.438	3,566
	(92.487)	(62.680)	(49.008)	(28.092)	(25.402)	(22.385)	(32.389)	(64.995)	
La Paz	134.375	–37.748	98.226	–9.209	–67.860*	–27.327	–3.691	–86.766	1,551
	(177.960)	(146.366)	(176.028)	(42.810)	(41.190)	(51.069)	(45.891)	(96.022)	
El Alto	–35.213	141.406	–30.387	–95.874*	–68.677***	20.361	32.988	35.396	2,015
	(221.190)	(93.004)	(95.089)	(53.717)	(31.446)	(54.410)	(59.661)	(143.093)	

(Contd.)

29 Also note that time use data are noisy, and the 95% confidence interval for the IV estimate of travel time is 34.6 to 106 minutes. The OLS estimate on transportation time of –12 minutes may be closer to the expected treatment effect on an average user (vis-à-vis the LATE for compliers), and is much more consistent with the 9 minute average travel time savings reported by Suarez Aleman and Serebrisky (2017).

30 Question A16 of the questionnaire asks, "Please indicate how much time you spent YESTERDAY on the following activities", and the options are: Sports/recreation, fun; Sleep; Eat; Transport; Home and family; Study; To work; Others.

	β_{use}								Obs.
	WORKING	STUDYING	HOUSEHOLD	TRANSPORTATION	LUNCH BREAK	SLEEPING	RECREATION	OTHERS	
Average value of outcome variables									
Total sample	250.982	83.191	291.204	87.004	105.695	435.015	47.740	139.168	3,566
La Paz	233.549	98.485	302.473	84.698	104.019	443.453	47.856	125.467	1,551
El Alto	264.401	71.419	282.531	88.779	106.985	428.521	47.650	149.713	2,015

We next explore whether MT usage leads to changes in employment outcomes for the head of the household. As reported in Table 5, we do not observe any changes in employment search for unemployed individuals, either for the whole sample or in La Paz and/or El Alto. This is probably due to the high levels of informal employment in the country and the fact that most heads of household were already employed in some type of activity. For individuals who are employed, we see that MT increases the rate of those who work more than one hour per day by 15%, and also, there are strongly significant increases (48%) in the rate of those who work in independent employment. As with previous outcomes, the probability of being self-employed increases significantly in El Alto (almost 80%), compared to La Paz (which is not significant). Given impacts on self-employment, we evaluate whether these changes led to increased household income. Results are reported in Table 6. Even though coefficients are not precisely estimated in levels and are not significant, we observe positive coefficients in the income reported from independent work sources by households, with an estimated LATE of 3,052 Bolivianos (approximately US$434) from independent labor (at an average of 1,834.19 Bolivianos), and on total income (2,443.29 Bolivianos, given an average of 2,959.10 Bolivianos).

Table 5 Employment outcomes (household head).

Covariates V_{ij} include: La Paz, gender of household head (male), marital status, indigenous, educational level, physical condition (disable), household asset index, owns car, property of residence, number of household members, altitude variation between dwelling and closest MT station, accessibility to public transportation at baseline, and received non-labor income such as remittances and transfers.

β_{use} coefficient corresponds to the estimation of equation (4) obtained by Ordinary Least Squares (OLS) and equation (7) from process 18.1 proposed by Wooldridge, 2002 (IV-3 stages).

Cluster robust standard errors in parentheses.

	β_{use}			Obs.
	LOOKED FOR JOB	WORKED ≥ 1 HOUR	SELF-EMPLOYED	
OLS	0.003	–0.001	–0.015	3,566
	(0.004)	(0.010)	(0.025)	
IV-3 Stages Estimation				
Total Sample	0.031	0.151***	0.483***	3,566
	(0.028)	(0.058)	(0.182)	
La Paz	0.053	0.031	0.204	1,551
	(0.051)	(0.147)	(0.323)	
El Alto	0.045	0.067	0.798**	2,015
	(0.044)	(0.123)	(0.340)	
Average value of outcome variables				
Total sample	0.008	0.820	0.436	3,566
La Paz	0.011	0.765	0.375	1,551
El Alto	0.005	0.863	0.483	2,015

To help the interpretation of the estimation results, we apply the inverse hyperbolic sine transformation to our outcome variables. It should be noted that, in this transformation, the first two stages of the estimation (included in B1) are similar to the general estimated specification included in Table 2. Table B2 in the Appendix presents results from a specification in logs showing large positive and statistically significant results in income from independent

	β_{use}					Obs.
	SALARY	**IN KIND**	**INDEPENDENT**	**TOTAL**	**INCOME PER CAPITA**	
OLS	–90.790	3.893	111.359	24.462	63.867	3,566
	(86.097)	(5.800)	(205.917)	(202.508)	(68.291)	
IV-3 Stages Estimation						
Total Sample	–601.211	–7.770	3052.270	2,443.289	409.065	3,566
	(763.441)	(37.368)	(2,336.183)	(2,025.734)	(549.276)	
La Paz	–2,665.083	–54.336	2,076.682	–642.737	–728.083	1,551
	(2,179.343)	(46.799)	(2,002.074)	(2,305.002)	(1,226.046)	
El Alto	–847.449	–12.919	6,180.968	5,320.600	667.825	2,015
	(1,301.051)	(67.870)	(5,840.404)	(5,404.758)	(1,151.426)	
Average value of outcome variables						
Total sample	1,110.287	14.624	1,834.192	2,959.103	1,376.438	3,566
La Paz	1,212.331	12.159	1,617.314	2,841.804	1,410.080	1,551
El Alto	1,031.741	16.521	2,001.130	3,049.392	1,350.543	2,015

Table 6 Head of household income and household per capita income.

Covariates V_{ij} include: La Paz, gender of household head (male), marital status, indigenous, educational level, physical condition (disable), household asset index, owns car, property of residence, number of household members, altitude variation between dwelling and closest MT station, accessibility to public transportation at baseline, and received non-labor income such as remittances and transfers.

β_{use} coefficient corresponds to the estimation of equation (4) obtained by Ordinary Least Squares (OLS) and equation (7) from process 18.1 proposed by Wooldridge, 2002 (IV-3 stages).

Monetary figures are expressed in Bolivianos.

Cluster robust standard errors in parentheses.

work both for the total sample and the sample of El Alto.[31] Taken together, these results suggest that increased access to labor markets facilitated by the MT allow individuals to gain new employment opportunities and potentially increase income, particularly in the informal sector. While estimates are noisy and some lack statistical significance when we divide the sample by city, the magnitude of the coefficients again suggests that gains accrue most strongly to residents of El Alto.

Given that the city of El Alto has a higher concentration of poor and indigenous populations, it could be inferred from the previous results that MT created more benefits for lower income households, and this may eventually have a positive effect in reducing inequality. To complement this analysis, we run separate regressions for two groups of households: those in the bottom 25% of the asset index distribution and those above this threshold.[32] We see that impacts observed are driven mostly by the sample of households above the 25th percentile of the asset index distribution. Almost no significant results are observed in the lowest income households regressions, but coefficients are in the right direction and we may lack power to precisely estimate effects in this case. Since we do not have baseline information on income or assets, and income/wealth may be endogenous at end line, we argue that these results need to be taken with caution. The geographic stratification of the sample (La Paz vs. El Alto) seems to be the best alternative under the assumption that household location is exogenous.

Finally, one open question is whether there are any heterogeneous effects across gender. For this, we separate the sample of households with male and female heads. The first stage estimation results are generally consistent with the full specification model (see table E3 in the Appendix). At the outcome level, the results presented in Table E4 of the Appendix show that the findings using the male head of household sample are very close to those observed in our main specifications. This is probably due to the fact that the full sample is concentrated among households with male heads. There are a total of 2,751 observations with a male household head in a full sample of 3,566 households. For female-headed households, interestingly, the impacts of increased time

31 In this case we apply the inverse hyperbolic sine (IHS) transformation to minimize the influence of outliers while also avoiding the problem that the logarithm of zero is undefined. The IHS transformation of y_i is equal to $y_i^* = \log\left(y_i + (y_i^2+1)^{\frac{1}{2}}\right)$. It is defined at zero and has a similar interpretation to a logarithm specification. See Burbidge et al. (1988) for details.

32 Tables E1 and E2 show the estimation results of the lower 25% according to the asset index and for those above this threshold.

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for educational activities are more significant as well as the impacts on increased time devoted to recreational activities. While we observe a significant reduction in private transport expenditure, we do not observe significant effects for public expenditure, but given the reduced sample size, we are not able to estimate this precisely.

5.3 ROBUSTNESS TESTS

We conducted several robustness checks, which are reported in the Appendix. First, we divide the sample between households that are property owners and those that are not. This serves to reduce concerns about endogenous location decisions, by which households could be choosing their location in response to the location of MT stations. If this were to occur, our estimated LATEs would be biased by endogenous sorting, potentially capturing more highly skilled individuals or those prone to use the transport system more often. By focusing on property owners, we use a sample of households that have an arguably higher cost for relocating relative to households that rent. Results from this analysis are reported in Tables F1 (first stage of the proposed method, Panel A) and F2 (estimation of results on the relevant variables, Panel A). Results on the sub-sample of owners are consistent with our main findings. The only exception is that we do not see significant impacts for property owners on increases in the time devoted to recreational activities, although this may be explained by reduced statistical power. For non-owners, we see statistically significant results showing reductions in transport time and lunch break. We also see consistent positive signs in transport expenditures and reductions in private transport expenditure, but these coefficients are not significant which could be due again to the smaller sample sizes.

The second robustness check uses an alternative definition of the treatment variable. In the base specification we defined whether a household was a user of MT if they reported that they used the system at least once in a month. Alternatively, we construct two other treatment variables considering whether they report using the system weekly or yearly. The results, reported in Tables F1 and F2 Panel B, show that estimates are robust to both definitions of treatment. We also analyze the results of a traditional two-stage IV estimation. The results included in Tables F3 and F4 confirm the stability of the results regardless of the IV estimation approach used and some are even more statistically significant in the two-stage model. In addition, we include square quadratic terms of the instrumental variable as additional instruments in the regression model showing that all main conclusions do not change (see Tables F5 and F6).

Given that we are estimating models with multiple stages, we also use a bootstrap procedure to get more reliable estimates of the standard errors and confidence intervals. Table G1 shows the first stage results and Table G2 shows the results for the main outcome variables under the preferred specification. Both confirm that conclusions remain unchanged with bootstrapped standard errors.

To reduce concerns of having an unbalanced sample by including households that are too far away from MT stations and living in the periphery of the cities, we run one alternative specification restricting the sample to households living less than 1,500 meters from a station. We observe that the power of the estimation results is affected, particularly as there are only 160 observations from El Alto. Based on the full sample results, we see that the increase in time devoted to educational activities continues to be significant. For the rest of the outcomes, we cannot precisely estimate them due to the loss of sample.[33] We also estimate a model where treatment and control group are constructed based on those households that are close (less than 0.5 KM, see Table H1) to actual or future MT stations, respectively. However the sample size is restricted and we lose statistical power.

In the absence of baseline household data, we conducted an additional robustness test, controlling for the initial characteristics of the locations using satellite images. These covariates control for the initial characteristics and help alleviate concerns of potential endogeneity in the location of MT stations. The location characteristics are based on night light data from satellite images. The data

33 Results are reported in Table F9 and Table F10. Results become more stable when we consider a sample of households located, at most, 5,000 meters from a station.

was obtained from the Visible and Infrared Imaging Suite (VIIRS) Day Night Band (DNB), Elvidge et al. (2013), and was available on a monthly basis between April 2012 and December 2013 in segments of an image resolution of 15 arc second (~500 m at the Equator) kilometers. Radiance values of the DNB composite vary between approximately 25 to 280 nanowatts/cm2/sr.[34] For each household in our data set, we assign the average luminosity in the baseline period, and use this variable as a control in our regressions (represented by $\beta_{\overline{NL}}$).

In Table I1, we conduct the first two stages of our estimation, including the average luminosity. In general, adding the DNB composite variable to our main specification does not affect the power of the first two stages of our estimation. Furthermore, the magnitude of this new control is close to zero and is not statistically significant ($\beta_{\overline{NL}}$) (the base model estimates are included in Table 2). Next, we analyze the effect of MT on our outcomes of interest controlling for baseline characteristics as given by the DNB composite variable. Results presented in Table I2 show that, with some loss of precision, five out of six estimated impacts increase in magnitude relative to our preferred specification.

5.4 MODAL CHANGE ANALYSIS

One of the questions that remains after implementing a new transportation system is the degree to which the beneficiaries stop using the previously available means of public transportation. To answer this question and given that we only have information from one round of data, we add two interaction terms to our original model. The first one captures the use of public transport, which is approximated by baseline information (i.e., 2013) on the number of available lines of other modes of public transportation within a radius of 250 meters around the household location. The second interaction considers whether the household owns a private vehicle. The coefficient of the treatment variable (β) gives the effect of MT with respect to those that did not have good access to public transportation or did not have a car. The main effects of "availability of public transport" or "private car ownership" estimate the effect on the outcome variable of each additional line of public transportation that is available to a household within a 250 meter buffer or of having a vehicle. Finally, the interaction term reports the marginal or differential effect of MT between those who already had access to other means of public transportation or have a private vehicle versus those that do not. The total treatment effect for those that are well-connected or have a car is computed as the sum between the main treatment effect (β) and the interaction term. For the case of the availability of public transport lines we evaluate this total effect at the median of the distribution and at the 90th percentile. The results of this exercise are included in Appendix Tables J1 and J2. Table J1 shows that the effect of MT on expenses on public transport for those who do not have access to public transportation is equal to 78.64 Bolivianos, which is larger than the average effect found in previous models, suggesting that impacts are larger for those who were not well-connected to public transportation at baseline. Each additional line of trufi, bus or minibus increases the expenditures on public transportation in 0.88 Bolivianos. The interaction term is negative, significant, and equal to –2.29 Bolivianos, suggesting that impacts are smaller for those that were better connected to public transport versus those that were not. The effect of MT on public transportation expenditure for the median value of the distribution of availability of public transport lines is 64.27 Bolivianos and the effect for the 90th percentile is just 41.90 Bolivianos. In all the outcomes analyzed (Tables J1), we observe similar results. The interaction term is always in the opposite direction of the treatment effect but coefficients are relatively small. Point estimates at the median and the 90th percentile of the distribution are significant but of smaller magnitude. Overall, these findings suggest that MT users are substituting the usage of other means of public transportation for the cable car.

Table J2 reports the results for those that own a private vehicle. The estimated interactions in this case also go in the opposite direction of the main treatment effect, but coefficients are much larger in magnitude. For example, we can see that for those who do not own a car the average treatment effect on public transportation expenditure is equal to 70.35 Bolivianos. In addition, owning a

34 Source: https://eogdata.mines.edu/nighttime_light/monthly/v10/2012/.

car significantly increases the expenditures reported on private transport (107.23 Bolivianos per month). The interaction term indicates that the treatment effect on public transportation expenditures for those who own a private vehicle is smaller in magnitude compared to those who do not own a car by 55.91 Bolivianos. When we look at the treatment effect for those who own a vehicle we see a significant and positive effect of MT on public transport expenditure, but the point estimate is small and reports an increase of only 14.43 Bolivianos per month. Given the magnitude of the coefficients, these results suggest that substitutability from private vehicle to MT is small and that most of the gains reported previously are coming from households that do not have a private vehicle.

6 COST-BENEFIT ANALYSIS

This Section reports multiple cost-benefit ratios (CBRs) of MT based on the impact estimates obtained in Section 5. More formally, the cost-benefit ratios are calculated using the following equation:

$$CBR = \frac{B_t}{C_t} \tag{8}$$

According to equation 8, the CBR is obtained as the relation between the total benefit per trip (B_t) and the total cost per trip (C_t). In general, the total benefit per trip represents the monetary value of the total amount of time that the MT users "save" by using this means of transport. Also, the costs are associated with the monetary value of the provision of the service.[35]

To calculate these ratios, we construct two different models that vary across the definition of benefits. In the first model, time savings are the main benefit considered, while in the second model, we add transport expenditure savings.[36] In both models, costs correspond to those of providing the service (obtained from the Operational Report Mi Teleférico 2016).[37] It is important to mention that costs of providing the service include the debt service; therefore, no project investment costs are included. For both models, we construct multiple sensitivity scenarios that vary some of the assumptions taken to construct the baseline scenario. Overall, results suggest that the economic benefits of MT outweigh the costs. Of course, the major caveat of this analysis is that the estimated benefits are LATEs affecting a specific segment of the population.

The baseline scenario (Panel A in Table 7) monetizes time savings with the average labor income reported by the heads of households in the survey sample. This includes data from wages or self-employed income. In addition, we assume that the average number of trips per person per day is two. Finally, we use the average effect estimated for time savings in transportation, which is equivalent to 70 minutes per day (a lower bound estimate if we ignore time saved on the lunch break). Taking all this information into account, the CBRs presented in Table 7 indicate that benefits are almost 2.16 times the project costs. Changing the number of trips to 4 (Scenario #1, Panel B of Table 7), while keeping the rest constant, puts the CBRs between 1.08 and 0.99. A second scenario (Panel C of Table 7) considers the country's minimum wage for 2016, which is lower than the average labor income of the sample.[38] In this case, ratios are around 1.00, on average. A third sensitivity analysis (Panel D, Table 7) assumes travel time savings are 50% lower than the estimated values (45 minutes) and report CBRs between 1.08 and 0.99. In general, results are lower than the baseline scenario but do not vary widely across the scenarios.

35 In this case, we compute the average total cost per trip as the total amount of the service provision in 2016 divided by the total number of trips in the same year.

36 The two models are represented by the columns CBR_1 and CBR_2 in Table 7.

37 Based on the findings, and given the transport mode change, transport expenditures increase rather than decrease. This is because the MT is more expensive relative to other modes of public transportation. Additional information about the construction of these scenarios can be found in Appendix K.

38 This information was obtained from the Decreto Supremo 2748, approved on May 1st, 2016. The minimum wage for 2016 was Bs. 1,805, the sample average is Bs. 2,470.

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SENSITIVITY SCENARIOS	MODEL 1 (CBR_1) (TIME SAVINGS)/(SERVICES PROVISION COSTS)	MODEL 2 (CBR_2) (TIME SAVINGS + TRANSPORT EXPENDITURE SAVINGS)/SERVICE PROVISION COSTS)
Panel A: Baseline scenario		
Wage = Sample average Trips/day = 2 Time savings = 70 min	2.16	2.06
Panel B: Scenario 1		
Wage = Sample average Trips/day = 4 Time savings = 70 min	1.08	0.99
Panel C: Scenario 2		
Wage = Country's minimum wage Trips/day = 2 Time savings = 70 min	1.05	0.96
Panel D: Scenario 3		
Wage = Sample average Trips/day = 2 Time savings = 35 min	1.08	0.99
Panel E: Most negative Scenario		
Wage = Country's minimum wage Trips/day = 4 Time savings = 70 min	0.52	0.43
Panel F: Most positive Scenario		
Wage = Sample average El Alto Trips/day = 2 Time savings = 94 min	2.63	2.54

Table 7 Cost-Benefit Ratios.

Summary table of the exercise conducted in Appendix K.

Finally, we construct two additional scenarios to show the most positive and negative settings under reasonable albeit conservative assumptions. For the worst case scenario (Panel E, Table 7), we assume 4 trips per day plus the minimum wage and obtain results below 1. We argue that this is a highly unusual scenario given that 97% of survey respondents indicate that they made two trips or fewer the day prior to the interview. The most positive scenario (Panel F, Table 7) calculates CBRs considering the travel time savings estimated for the populations with the largest gains in accessibility (El Alto) and also adjusts the values of labor income for this population, considering that average incomes reported for El Alto households are lower than for La Paz. The results show that benefits in this case are more than 2.63 times the size of project costs.

7 METHODOLOGICAL LIMITATIONS

This paper quantifies the impacts of the MT cable car transit system exploiting variation across households in their distance to a MT station. The main argument behind the validity of our empirical strategy is that MT stations were not always located in the most desirable commercial centers or the most central areas, and their placement was akin to an exogenous shock for residents in the vicinity. Therefore, distance to the closest MT station should affect the probability that a household uses the aerial cable car system but should not directly affect the outcomes of interest. In this section we summarize and discuss some of the potential methodological limitations of the paper and the different approaches taken throughout the analysis to overcome them.

A first concern is that there may be pre-existing sorting patterns relative to the MT station location. More specifically, there may be initial differences between households that are close and not so close to the MT stations and that have an influence on final outcomes of interest. If this were to occur, our estimated LATEs would be biased by endogenous sorting, potentially capturing more highly skilled individuals or those prone to use the transport system more often, which could lead to an upward bias in some of the estimated coefficients, such as those related to expenditures and time allocated to study or the decision to be self-employed, as well as income generated from these activities. In other cases, such as outcomes related to expenditures on public versus private transport or the time allocated to recreational activities, the direction of the bias is not straightforward and could go in both directions.

Given that we are limited by cross-sectional data in our analysis, we cannot fully analyze whether there were baseline differences across households located at different distances from a MT station, plus we cannot run difference-in-difference specifications, which would allow us to control (at least) for time-invariant unobserved heterogeneity. To reduce some of these concerns, all estimated models include a rich set of contemporaneous controls to capture heterogeneity in household and individual-level characteristics that may directly influence outcomes. In addition, we construct a set of baseline covariates, based on available information, to capture characteristics of the areas prior to the opening of the MT stations. For instance, one could argue that households that are located further away from the MT stations might also have fewer transportation options which would impact their propensity to adopt MT in an endogenous way. For this, we construct a measure of available transportation options close to each dwelling at baseline and include this variable as a control in all estimated regressions. Moreover, we use satellite data on nightlight luminosity, which has been shown to be a good proxy of economic activity (Henderson et al. 2012), and include robustness checks controlling for this in the regressions. Finally, we also construct variables of density of economic activity around MT stations using the location of markets and banks at baseline and show that measures of economic activity around stations is not significantly different from activity further away.

While MT stations do not seem to be located in very distinctive areas, households could also change their location in response to where MT stations were built over time. As mentioned before and given that we only have cross-sectional data for a period after the opening of the MT system we cannot check whether household characteristics were different at baseline. In light of this limitation, we run robustness checks restricting the sample of households to those that are property owners and thus are likely to have higher transaction costs to relocate. The first MT station opened in 2014 and the household survey we use was collected in 2016; therefore, our assumption is that, at least in the short run, these households were not very likely to have moved. As shown in Section 5.3, almost all results are maintained for this sample of households, which confirms that, at least in the short run context analyzed here, endogenous sorting is not likely a major threat to our identification.

8 DISCUSSION

Urban transport problems are prevalent in many Latin American and Caribbean (LAC) cities. With approximately 80% of its population living in cities, LAC is the most urbanized region in the world (Saliez et al. 2012). While infrastructure investments in urban areas have been increasing in recent years (Infralatam 2018), the supply of high-quality public transport systems has not kept pace with the growth in transport demand. Low investments, together with limited urban and transport planning, has led to high rates of informality in passenger transport systems and an aging vehicle fleet that result in high levels of congestion, reduced traffic safety, and increased air quality problems (Yañez Pagans et al. 2019).[39] In addition, the average one-way commute time reached up to two hours in some cities, imposing considerable time and monetary costs to both freight

39 The region has an average of around 90 vehicles per 1,000 people that exceeds that of Africa, Asia, and the Middle East (de la Torre et al., 2009). In addition, in 2010, LAC reported an average rate of 25.3 fatalities per 100,000 inhabitants, compared to 16.1 deaths per 100,000 inhabitants for high-income countries in North America (Scholl et al., 2013).

and passenger transport (Saliez et al. 2012). Finally, according to the Clean Air Institute (Clear Air Institute 2013), air pollution levels in many LAC cities exceed WHO guidelines for major pollutants creating risks to human health, life expectancy, and productivity.

According to CAF (2010), a significant share (43%) of passenger travel in LAC cities is still conducted by public transportation. Interventions that seek to improve transportation and accessibility provide an opportunity to promote social equity and reduce urban poverty. Given financing gaps and the need to improve operational and managerial efficiency in the transport sector, the role of both public and private actors is essential to respond to the current challenges. Among the possible set of urban transport interventions, aerial cable cars are an innovative alternative for certain cities in the region, allowing improved transport links for low-income and mountainous areas on the outskirts of economic activity. Cable cars are cheaper to build than subway lines and less invasive than other surface transportation systems. They tend to be more energy efficient and environmentally friendly. Given the panoramic views they offer, they can also become tourist attractions. Despite these advantages, questions remain about their economic viability given high subsidies and limited capacity relative to other mass transport systems.

This paper quantifies the socioeconomic impacts of La Paz and El Alto's aerial cable car transit system, MT. While other cities have implemented cable cars as complementary transport modes, La Paz is the first to use cable cars as one of the primary pillars of the urban transit system. With its steep hillside neighborhoods, where alternative modes of mass transit such as subterranean metros, light rail, or dedicated bus ways would be technically unfeasible or too costly, cable cars seem better suited.

Using household survey data and distance to the nearest MT station as an arguably exogenous explanatory factor for cable car ridership, we implement an instrumental variables estimation to quantify impacts on transport costs, time allocation decisions, employment, and labor income. Results indicate that the use of MT has significantly reduced the time that people spend in transit, freeing up time for leisure and educational activities across different types of households. These results can provide insights about the value of travel time and how transport interventions might lead to longer-term development impact by promoting a more educated population or influencing the health and happiness status of the population thanks to increased leisure time.

Estimated impacts suggest that there has been a shift in people's mode of transportation, as we identify increases in public transport expenditures and decreases in private transport expenditures. As the MT system continues to expand in the future and the population values the time savings and quality of its service, these effects may have important implications for traffic congestion in the city and thus for air quality and traffic safety. Findings also indicate that improved accessibility has translated into more employment opportunities, including more self-employed occupations and higher incomes. Since we do not observe changes in the time devoted to work or increases in the probability of working, we interpret these results as a substitution effect, by which people switch to more lucrative self- employed work when granted increased accessibility to labor markets.

Given that some parts of the metropolitan area have gained more in terms of accessibility thanks to MT, compared to their baseline situation, we test for heterogeneous effects across the populations of La Paz and El Alto. Results show that the benefits of MT accrue most clearly to the residents of El Alto who, until the opening of MT in 2014, endured a lengthy and arduous commute into la Paz. Increased accessibility to La Paz is important for El Alto residents as most employment opportunities and economic activity center in La Paz, and it also has a wider range of leisure and entertainment activities. In addition, a substitution analysis suggests that users might be substituting other public transportation modes with MT, but the substitution effects for those with private vehicles is small. The results of our cost-benefit analysis indicate that benefits are between 1.05 and 2.16 times the costs of providing the service.

Moving forward, there are additional areas of research that are promising in this field and that will be useful to improve the operation of cable car systems. In particular, generating evidence on how tariffs could be accommodated to maximize demand considering peak and non-peak hours would allow operators to increase efficiency in the use of a system with essentially fixed supply. In addition, from the social mobility perspective, how these systems contribute to the integration of neighborhoods and reduce segregation is a relevant question. Finally, this analysis could be extended as data becomes available after the opening of additional MT lines, using panel data methods to estimate longer run impacts of MT and measuring alternative outcomes such as changes in property prices.

ADDITIONAL FILE

The additional file for this article can be found as follows:

- **Appendices.** Appendix A to K. DOI: https://doi.org/10.31389/eco.439.s1

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COMPETING INTERESTS

The authors were employees of the Inter-American Development Bank at the time the study was conducted. The authors have no competing interests to declare.

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