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

Sebastián Martínez
Raúl Sánchez
Patricia Yañez-Pagans[1]

This document, led by specialists from the Inter-American Development Bank, is meant to show the design of a case study to request feedback to improve the study.

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Sebastian Martinez[i]
Raúl Sánchez[ii]
Patricia Yañez-Pagans[iii]

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i. The Office of Strategic Planning and Development Effectiveness at the Inter-American Development Bank, smartinez@iadb.org
ii. The Office of Strategic Planning and Development Effectiveness at the Inter-American Development Bank, rsanchez@iadb.org
iii. The Strategy, Development Effectiveness, and Programming Department at IDB Invest, patriciaya@iadb.org

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Study Proposal

Sebastian Martinez **Raúl Sanchez** **Patricia Yañez-Pagans**[1]

Abstract: We propose studying the effects of aerial cable cars on mode of transport, time use and employment in the city of La Paz, Bolivia. Using an instrumental variables approach, we will estimate local average treatment effects of cable car use for residents close to a cable car station.

Key Words: Cable Car, *Mi Teleférico*, Mass Transit, Travel Time, Employment

JEL Codes: L92, O18, R41

[1] Authors: Sebastian Martinez (smartinez@iadb.org), Raul Sanchez (rsanchez@iadb.org), Patricia Yañez-Pegans (patriciaya@iadb.org): Inter-American Development Bank, 1300 New York Avenue, NW, Washington, DC 20577.

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 inhabitants, and just over half live in the city of El Alto at 4,100 meters above sea level (INE, 2018). The daily commute from El Alto to La Paz and back involves navigating the single highway connecting the two cities or braving the narrow side streets that zigzag the steep mountainous terrain separating the two cities. At commute hours, roads are congested with mini-buses, taxis and private vehicles transporting workers to and from the city. Starting in 2014, the *Mi Teleférico* (MT) mass-transit areal cable car system opened, ferrying passengers from El Alto to the downtown and back in as little as 10 minutes from end to end stations. Using a purpose specific representative sample of 3,575 households in La Paz and El Alto, we propose evaluating the impacts of MT on mode of transport, time allocation decisions, employment outcomes, and income. [2]

To identify the effects of MT we will implement an instrumental variables (IV) approach that uses distance from each residence in the sample to the nearest MT station as an instrument for cable car ridership, allowing for the identification of a "local average treatment effect" (LATE) parameter for individuals who use the MT system because of better access (Imbens and Angrist, 1994). Given the potentially endogenous nature of transport modality, we implement an instrumental variables estimation method using distance to the nearest MT station as an arguably exogenous explanatory factor for cable car ridership. With a binary endogenous model for the use of the cable car, we implement an efficient estimation method based on a three-stage IV approach, proposed by Wooldridge (2002). 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 local average treatment effects of cable car ridership. The absence of endogenous sorting, i.e. moving of residence because of MT, is a critical assumption underlying our analysis. The relatively short timeframe for our analysis, focusing on the effects of the first three cable car lines between 2014 and 2016, make this assumption more plausible. While we cannot control explicitly for baseline residence, we propose multiple robustness checks, including estimation of effects on households that are property owners and were we expect to see lower mobility over time because of higher transaction costs

There is a rich literature exploring the impacts of urban transport systems, however, given empirical identification challenges there are still few causal evaluations quantifying these effects, and even fewer exploring the impacts of cable car interventions (Yañez-Pagans et al. 2018). One of the most studies cable car interventions is the *Metrocable* in the city of Medellin, Colombia. Evidence suggests that it led to improvements in urban integration and modernization of neighborhoods (Brand and Davila, 2011; Goodship, 2015), accessibility and improved security (Heinrichs and Bernet; 2014), quality of life (Roldan and Zapata; 2013), employment opportunities for the poor (Bocarejo et al., 2014) and perceived pollution (Dávila and Daste, 2012). In terms of

[2] This paper studies the impact of the first three lines of MT (Red, Green and Yellow lines) between 2014 and 2016. The system has since expanded to 7 lines as of June 2018 with 4 more in planning and is the longest aerial cable car system in the world.

causal studies, for the case of Metrocable, Bocarejo et al. (2014) exploits a difference-in-differences (DID) models to quantify impacts on rent, transport, and public utilities costs but finds no statistically significant evidence. Cerdá et al. (2013) uses DID and matching methods and exploits homicide reports and household surveys to show that neighborhoods close to the cable car exhibit less violence when compared to similar ones that are further away.

For the case of MT in La Paz, the only other attempt to quantify potential effects, to our knowledge, is a study by Serebrinsky and Suarez (2017) who focus on a quantitative estimation of travel time savings arising from MT. They use individual-level origin and destination surveys and compare travel times between trips, with the same origin-destination pair, that are done with MT versus those that are done with alternative transport systems. Their findings suggest that, on average, Mi Teleférico reduces travel times by 22%.

2. Mi Teleferico Aerial Cable Car

MT, also known as Teleférico La Paz–El Alto, is an aerial cable car system serving the La Paz–El Alto metropolitan area in Bolivia. The neighboring cities of El Alto and La Paz are the second and third most populous cities in Bolivia. Despite their proximity, travel between the two has always been a challenge, due to a difference in elevation of about 400 meters (1,300 ft) between them. La Paz, the government's center of the country, is in a canyon on the Choqueyapu River, while El Alto, a poorer but growing city with a majority indigenous population, is located above La Paz on the Altiplano plateau.

Before the construction of the cable car, travel between La Paz and El Alto had to be done only in buses and minibuses, that were heavily crowded during rush hours, had to go through winding streets reducing road safety, and were usually stack in traffic. To alleviate this situation, the idea of connecting the two cities with a cable car was proposed. The original idea of a cable car connecting the two cities emerged in the 1970s, but the work was stalled due to several controversial aspects, such as the fare, which could be above other transport systems, the low passenger capacity, the negative effects on minibus drivers' main source of income, and the details of tower placement that could affect the historical Basilica of San Francisco.

In 2011, the Municipal Government of La Paz brought back to the political conversation the possibility of conducting this project and carried out a study on potential ridership demand. The study found that the city handles 1.7 million trips per day, including 350,000 trips between La 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 was US$ 280 million and was financed by the country's National Treasury with an internal loan from the Central Bank of Bolivia.

The Phase I of the system consisted of the three lines, the Red Line, Yellow Line, and Green Line (Figure 1) and the cost was around US$ 280 million (Stewart, 2017). Upon the completion of the 10-kilometers (6.2 mi) of phase I in May 2014, the system was the longest aerial cable car system in the world. Based on its master plan, the completed system will reach a length of 33.8 kilometers

(21.0 mi) with 11 lines and 39 stations. While other urban transit cable cars like Medellín's Metrocable complement existing rapid transit systems, MT is the first urban transit network to use cable cars as the backbone of the public transportation network (Neuman, 2014). In 2015, a law approving the construction of Phase II was passed, increasing the number of new lines to six and committing US $506 million to the project. A seventh line was announced in February 2016, and an eighth was announced in July 2016.

At 3 bolivianos (approx. US$ 0.40) per ride, prices have been set to be competitive with the local bus system. 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 am and 11 pm daily. Estimations indicate that the cable cars have cut commute times down from 1 hour to just 10 minutes between La Paz and El Alto. Each cable car is equipped with solar panels to power the doors, lights, and Wi-Fi, (Watts, 2016). The aerial transport network has not only proved popular among locals and tourists but is also praised to be a symbol of efforts to close the geographic and economic gap between Bolivia's indigenous and poor in El Alto with mestizo and the middle class in L Paz (Watts, 2016).

3. Data

We will use a purpose-specific household survey commissioned by MT in 2016, covering a representative sample of households in both Laz Paz and El Alto. The area of study was delimited in 6 impact areas following a two-step process. In the first step, 3 areas were identified, based on geographic proximity to: i) currently operating MT stations (Phase I); ii) stations under construction (Phase II); or iii) future stations (Phase III). Based on these areas, buffers or areas of influence were constructed considering the geographic distance to either existing or future stations. In La Paz, 3 buffers were defined as follows: i) 0 km - 0.5 km from stations in Phase I and Phase II; ii) 0.5 km - 1km from stations in Phase I and Phase II; and iii) within 1 km of stations in Phase III; (iv) more than 1 km from the rest. For El Alto, buffers were defined as follows: i) 0 km - 1 km from stations in Phase I and Phase II; ii) 1 km – 2 km from stations in Phase I and Phase II; and iii) within 2 km of stations in Phase III; (iv) more than 2 km from rest. The difference in the size of the buffers for La Paz and El Alto considers the walking distance time and the fact that El Alto is a flat city that greatly facilitates walking when compared to the mountainous city of La Paz.

The sampling frame uses the Population Census of 2012. Primary sampling units were defined as the 6 impact areas and buffers, the secondary sampling units were the blocks and within each block residences were randomly selected. In sampled residences, enumerators surveyed the head of the household or the most informed person older than 18 years old. Only households were one of these people had used some form of transit one day before the interview entered in the sample. The total sample size is 3575 households distributed across 882 blocks.

The survey collected a rich set of household demographic and socio-economic characteristics and included a transport module with detailed trip details from the last day. As outcomes of interest, we will focus in four sets of variables: (i) different types of transport-related expenses; (ii) time allocation decisions for different activities; (iii) employment outcomes; and (iv) income outcomes.

4. Empirical Strategy

To estimate the impacts of MT one immediate approach would be to compare outcomes of interest between populations that use the system and those that do not. In this case, the baseline estimation would be:

$$Y_i = \alpha + \beta T_i + \lambda X_i + u_i$$

Where Y_i is the outcome of interest for household i. T_i is a binary variable that takes the value of 1 for users of MT and 0 otherwise (treatment variable), and X_i are all other covariates that affect the outcome of interest. Under this specification, β would be the coefficient of interest or impact estimator. For the treatment variable, we consider a household to be user of the system if they report having used the MT at least once a month. We will conduct robustness checks using other definitions of the treatment variable, namely weekly and yearly use. The yearly use is not included as part of our main specification as probably the population using it yearly use it more for recreational purposes. We also will not include the weekly definition in the main specification as the sample of users was relatively small compared to the rest of the sample under this definition.

The main concern with the previous approach is that MT users might be inherently different from non-users and any unobservable characteristics driving these differences and that simultaneously affect the outcome variable could lead to inconsistent parameter estimation. This means the error term (u_i) could be correlated both with T_i and Y_i. Thus, to estimate the causal effects of MT we use an instrumental variables (IV) approach, which allows us to generate exogenous variation in the treatment variable and overcome the endogeneity problem mentioned above. More specifically, we propose distance to the nearest MT station, that was in operation in 2016 (the year of the survey), as an instrument for the use of the system.

We argue that this instrument (Z_i) satisfies two important conditions. First, a shorter distance to the system facilitates the access to this service, probably encouraging households to use or more frequently use the MT. Therefore, we expect a strong correlation between T_i and Z_i. Second, the distance to a MT station should only affect the outcome variables using the system, but not directly. If households can change their location easily in response to where MT stations where placed this would invalid our empirical approach, given that households living closer to the stations would probably be composed by individuals that value living at a centrally located address and that work more or commute more, which would directly affect our outcomes. To reduce any concerns about the validity of the instrument, there are two aspects worth highlighting of the context. First, the location of MT stations has been an ad hoc process based mostly on the availability of space, as this are not underground systems, therefore many of the stations are not necessarily located in the centers of the city. Second, although the data are not available to condition on baseline residency status, as part of the robustness check, we focus only on the sample of households that are property owners given that for the decision to reallocate might be more restricted.

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_i) is regressed on a set of covariates X_i, including the instrument Z_i . Then, the predicted value of the treatment variable $\widehat{T}_i$ is used as the main covariate of interest in a second step. Given that we have a dummy endogenous variable model (Heckman, 1978), Wooldridge (2002)[3] proposes a more efficient IV estimation procedure that follows a 3-stage procedure and that considers the non-linear functional form. Then, following this method we will estimate in a first stage a binary model (Probit) regressing the use of MT (T_i) on other covariates X_i, including the instrument Z_i:

$$T_i = \beta_0 + \beta_1 X_i + \beta_2 Z_i + u_i$$

From this first stage we will obtain the predicted value of treatment $\hat{T}_i$. In a second stage, we propose estimating what would be the first stage of the traditional 2SLS model, using $\hat{T}_i$ as the instrument for the treatment:

$$T_i = \alpha_0 + \alpha_1 \hat{T}_i + \alpha_2 X_i + e_i$$

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

$$T_i = \gamma_0 + \gamma_1 \hat{\hat{T}}_i + \gamma_2 X_i + \epsilon_i$$

The coefficient of interest is γ_1 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 local average treatment effect (LATE), which in this context can be thought of the effect of cable car ridership for those users who are induced to using the system thanks to the geographical proximity of their residence to a MT station.

5. Analysis

Analysis will include 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 Bolivians. A second set of results are related to time allocation decisions, measured in number of minutes per day that are devoted to different types of activities. We will focus on the time allocation decisions reported by the head of the household and observe positive and significant effects on travel time savings. Given that accessibility to the city center and other centers of employment is improved thanks to the cable car, we will also explore whether there are changes in employment outcomes, focusing on employment variables related to the head of the household and household income.

As a robustness check, we propose dividing 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 setting of MT stations. If this is true, any impacts observed could not be attributed to the intervention as they could be capturing that households that live closer to cable car stations are those that value more a well-connected location and are probably more employed or use the transport system more

[3] For more details please review Procedure 18.1 reported in page 623 of Woolridge (2002).

often. By focusing on property owners, we will use a sample of households that has an arguably higher cost for relocating relative to households that rent. The second robustness check is related to way the treatment variable is defined. In the baseline specification we will define whether a household was user of MT if they reported that they used the system at least once in a month. Alternatively, we can construct two treatment variables considering whether they report using the system weekly or yearly.

Finally, travel time savings and accessibility gains could be different across different areas of the city, depending on their location and baseline mobility situation. We are interested in capturing whether there are heterogenous effects across the cities of La Paz and El Alto, both part of the department of La Paz and both served by MT. These two cities are contiguous to each other, and jointly could be the entire metropolitan area, but they also have very different transport and socio-economic characteristics. La Paz is the center of government activities in the country and concentrates most of the employment centers in the metropolitan area. El Alto is a city that has experienced large increases in population, mainly migrants from rural areas, therefore it is composed by lower income populations, fewer infrastructure services, and thus mobility problems are more noticeable. With the opening of MT, residents of El Alto gained increased access to the center of La Paz. For example, during rush hour an average trip from El Alto to the center of La Paz in a minibus (the most common way of transportation) can take approximately 45 to 60 minutes.

6. Discussion

Over the past forty years, the share of urban population in Latin America and the Caribbean (LAC) has increased from 50% of the population in 1970 to 80% by 2013 (United Nations, 2011), being the most urbanized region in the world. This unprecedent growth of cities has brought important opportunities and challenges. One the one hand, the concentration of the population around urban areas facilitates the provision of basic, and more sophisticated, services to the population. On the other hand, increased population density is associated with increased problems of transportation capacity, urban sprawl that comes with informal housing development, and reduced citizen security, among others.

While infrastructure investments in urban areas of LAC have been increasing (Infralatam, 2018), the supply of high quality public transport systems has not kept pace with the growth in transport demand. This, in combination with a growing middle class and certain policies encouraging new car purchases, has generated a surge in motorization rates. the region has an average of around 90 vehicles per 1,000 people that exceeds those of Africa, Asia, and the Middle East (de la Torre et al., 2009). Limited investments, together with partial urban and transport planning, has led to high rates of informality in passenger transport systems and an aging vehicle fleet that result in important levels of congestion and air quality problems. This, in turn, generates health impacts and increases traffic fatality rates (Yañez-Pagans et al. 2018). To give some statistics about the magnitude of urban transport problems in LAC, 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 (IDB, 2013). 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 and passenger transport (UN-Habitat, 2012). Finally, according to the Clean Air Institute

(CAI, 2013), air pollution levels in many LAC cities exceed WHO guidelines for major pollutants posing significant adverse costs to human health, life expectancy, and productivity.

As a significant share (43%) of passenger travel in LAC cities is still conducted by public transit (CAF-OMU, 2007), improving transportation and mobility provides an important opportunity for policy makers to improve social equity and reduce poverty. Among the set of public transport policies available, cable cars have been a vital alternative for certain cities. Cable cars are mainly touristic attractions in rich Western countries, but in LAC cities they have been implemented as transport systems to connect isolated low-income neighborhoods with the city center. Cable cars offer multiple advantages over subways or light-rails systems. They can be built in a shorter amount of time, do not require the displacement of large groups of people, and seem more suited for cities with mountainous geographies (The Economist, 2017). However, these systems can also be heavily subsidized and do not have the same capacity as other massive transport systems. The first cable car designed as a transport system in LAC opened in Medellín, Colombia, in 2004. Since then, Caracas (Venezuela), Cali (Colombia), Mexico City (Mexico), Rio de Janeiro (Brazil), and La Paz (Bolivia), have built similar systems.

This proposal will study the impact of La Paz's aerial cable car mass transit system using an instrumental variables approach. While other cities have implemented cable cars as complementary transport modes to bus and rail, the MT system in La Paz is the first to use cable cars as one of the primary backbones of an urban transit system. Cable cars seem to be well suited to the topographic context of La Paz, with its steep hillside neighborhoods where alternative modes of mass transit such as subterranean metros, light rail or dedicated busways would be technically infeasible or prohibitively costly. We expect that the contributions of our study will be two-fold. First, it will contribute to the limited causal evidence available on cable cars, both in the region and worldwide. As these systems are being considered as interesting alternatives in other countries, it is important to provide more evidence about their impacts and in different context to build a robust based of causal evidence. Second, we will explore a set of outcomes that have not been studies in the literature before, which are those related to time allocation decisions and employment outcomes. Although the non-causal literature suggests there might be important impacts on employment accessibility, this has not been quantified empirically in an impact evaluation.

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1. Figures

Figure 1. Map of Mi Teleferico lines (2014-2016)