# Making the links between ride-hailing and public transit ridership: impacts in medium and large Colombian cities

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## Abstract

As transit ridership continues to fall in many cities across the globe, key policy debates continue around whether Uber and other ride-hailing services contribute to this trend. This research explores the effects of ride-hailing to Colombian cities on public transportation ridership using Uber's timeline as a case study. We test the hypothesis that ride-hailing may substitute or compete with public transit, particularly in cities with significant transit service gaps in coverage or quality. Our analysis builds on historic transit ridership data from national authorities and uses a staggered difference-in-difference model that accounts for fixed effects, seasonality, socioeconomic controls, and the presence of integrated transport systems. Despite significant reductions in transit ridership in most cities, our results suggest that Uber is not statistically associated with the observed drop in ridership. Moreover, consistent with evidence from previous research, public transit reforms implemented between 2007 and 2015 throughout Colombian cities appear to have contributed substantially to the declines in transit ridership observed across the country. Findings in this paper inform policy-targeted insights and contribute to current debates of the links between ride-hailing and public transit in Latin American cities.



**Keywords:** Impact evaluation, Transportation Network Companies (TNCs), ride-hailing, public transit, Latin America.

## 1. Introduction

Ride-hailing services, defined as on-demand mobility services with seamless payment options, offer advantages for users such as relative ease of use, security features, and service in hours and places lacking public transit and traditional taxi services. They offer several advantages to consumers compared to traditional taxi (Hu et al., 2022) and other transport companies, many of which are associated with system features such as newer vehicles, route optimization, and surge pricing (Jiao, 2018), enabling them to gain market share rapidly. Ride-hailing's flexible work schedules for drivers (Ashkrof et al., 2020) and more competitive pricing are argued to have increased its market advantage over traditional taxis (Zgheib et al., 2020). Ride-hailing has increasingly penetrated Latin American markets in recent years. Uber, which first entered the market in 2011 in San Francisco, currently operates in more than 300 cities, out of which 47 are in the Latin American and Caribbean (LAC) region, including its biggest market outside the US (Sao Paulo) and other densely urbanized areas (Bogotá, México D.F) (Moed, 2018). Research has shown that main users of on-demand mobility services are well-educated and tech savvy young people often living in urban areas (Alemi et al., 2018; Malik et al., 2021; Sabogal-Cardona et al., 2021; Tirachini, 2020).

Companies offering ride-hailing and other app-based mobility services are known as Transportation Network Companies (TNCs). While market shares of TNCs have steadily grown, policymakers have raised concerns about their potential impacts on congestion, traffic accidents, and their competition with public transit, arguing that they not only have the potential to compete with taxi services but with public transit (Oviedo et al., 2020). As public transit agencies often struggle under the financial constraints of declining passenger revenue, this has raised concerns about the viability of public transit services to maintain high-quality services, and the implications for populations who depend upon them, who tend to be lower-income households with lower access to private forms of mobility.

While several recent studies have assessed the impacts of Uber and other ride-hailing on transit ridership (Hall et al., 2018), traffic accidents (Dills and Mulholland, 2018; Oliveira et al., 2019), and the use of health services (Moskatel and Slusky, 2019; Oliveira et al., 2019), few studies on ride-hailing exist in the international context and in particular for LAC cities. Using data on public transit ridership and the timing of Uber entrance, we estimate the effects of ride-hailing services on transit ridership in Colombian cities by employing a set of difference-in-difference models. Moreover, most related studies have looked at this question using aggregate survey data; for instance, (Smith, 2016) found that public transit use is correlated with Uber use in the U.S., with 56% of those who use Uber weekly taking public transit each week; and (Murphy and Feigon, 2016) reported that 15% of those who use ridesharing now also use more often public transit. However, this approach does not identify a causal relationship, nor consider a differentiated effect by public transport mode. We follow the approach of (Hall et al., 2018) and analyze data at the transportation mode level, which allows a better understanding of transit ridership and control for potential confounders at this level. Our results coincide with those in the US on a negative effect of Uber presence on transit ridership; however, in the context of LAC the effect loss statistical relevance as we go through a battery of robustness checks. To the authors' knowledge, this is the first causal study on the potential impacts of ride hailing on public transit in the LAC context. This research has significance for the study of transportation business and management as it provides an evidence examination of the interactions between historical market disruptions brought about by the introduction of app-based ride-hailing services, which can become a challenge for public transport planning, policy and management in cities in the global south.

This paper is structured as follows. Section two review the literature on the impacts of ride-hailing on public transit and the debates surrounding urban transport systems, followed by the specific Colombian case description. Section three presents the data sources and methodology and shows the historical behavior of transit ridership in Colombian cities. In section four, we assess the exogeneity of Uber entrance in the Colombian cities and formally present the staggered difference-in-difference model. Next, we move to the results section, where we offer evidence of the parallel trends assumptions and evaluate different effects across time. We close with a reflection on the policy implications and suggestions for further research.

## 2. Literature review and background

### 2.1 Literature review

Whether ride-hailing services compete with or complement public transit has been the topic of several academic debates, with theories regarding the net impacts being ambiguous (Diab et al., 2020; Hall et al., 2017; Tirachini, 2019). On the one hand, ride-hailing services may compete with transit by providing fast, affordable, and on-demand, door-to-door trips and, in many cases, reducing uncertainty around travel times. In this case, ride-hailing services may serve trips that would have otherwise been taken in a collective mode. On the other hand, ride-hailing trips can potentially increase the catchment area of mass transit systems by providing first, and last-mile connections from origins to or destinations from transit stop (Mallett, 2019; Oviedo et al., 2020; Tirachini and del Río, 2019a), or may provide mobility in areas underserved by public transit. A work in Wanneroo (Western Australia) found that people using shared mobility services expressed that they are willing to use these services to reach rail transit stations as well as for travelling from the rail transit station (Jie et al., 2021). Additionally, app-based services could potentially complement public transit where the access or return portion of a round trip would occur in hours not served by transit. For example, with ride-hailing options available, travelers may be able to attend evening events arriving by public transit but returning home late in the night in ride-hailing when transit may not be available (Sabogal-Cardona et al., 2021). In this way, ride-hailing enables trips that were previously more restrictive given the schedule constraints of transit operation and induces transit trips that would not have been taken otherwise (Hall et al., 2018).

These relationships have been approached in previous literature using a myriad of methods and data that we have grouped in the following paragraphs, differentiating those using more descriptive analysis and those applying econometric methods. Research that has been based on descriptive analysis suggests that ride-hailing may compete with public transit. For example, a study in New York found that ride-hailing passenger trips outpaced the growth of subway and bus ridership in the city during 2015 and 2016 (Bruce Schaller, 2018; Schaller Consulting, 2017). Clewlow and Mishra (2017) collected survey data and reported that shared mobility in major US cities could be transporting six percent of previous bus users and three percent from light rail passengers, but increased rail ridership by three percent. Also, (Schaller Consulting, 2017) explored the 2016-17 National Household Travel Survey (NHTS) to find that 60% of overall ride-hailing trips in the largest and most dense cities of the US could have been made in public transportation (between 15% and 55%), by walking or biking (between 2% and 22%), or would not be able to be completed if ride-hailing had not been available (40%). Finally, in Toronto, Young et al. (Young et al., 2020) studied the travel time differences between ride-hailing and transit options applying ordinary least squares and ordered logistic regressions through survey data. This work finds that 30% of the ride-hailing trips could have been taken by public transit with similar travel times, while 27% would take 30 minutes longer. As ride-hailing trips become more attractive with the same or less travel time than public transportation, authors suggest imposing an additional tax upon ride-hailing trips with available transit alternatives and very similar duration.

Another strand of literature has emerged that employs econometrics methods to make causal inferences of ride-hailing on public transit. For example, (Hall et al., 2018) used the National Transit Database (NTD) reporting monthly ridership information by transit mode in the US from 2004 to 2005 and used difference-in-differences to analyze the impact of Uber on public transit. Controlling for Uber entry dates and several city variables (e. g., fare, unemployment), the study finds that Uber decreases transit ridership in small cities by 5.9% but brings 0.8% more passengers in larger cities. Moreover, there is a slow positive effect on transit ridership as Uber becomes popular and a trend towards increased rail ridership but decreased bus ridership. The authors hypothesize that these results could rise because, in small cities, users circumvent transit with Uber. On the other hand, in larger cities, people with high income tend to use rail and can afford Uber, while low-income groups rely more on the bus and cannot afford Uber. A study focusing only on San Francisco and using longitudinal data (from 2010 to 2015) concluded that ride-hailing is responsible for around a 10% decline in bus ridership and that there was no effect on light rail ridership (Erhardt et al., 2022).

Following the econometric tradition and based on longitudinal data, a study in Canada found that the impact of Uber on transit ridership is positive and small for large transit agencies but negative for small agencies (Diab et al., 2020). The study in Canada also found that transit ridership is associated with many variables (such as revenue vehicle hours, transit fares or number of business/recreation facilities) and that bike-sharing might have a negative effect. A study widening the scope to Toronto found that ride-hailing has a positive effect on subway station ridership, mainly during the midday and early evening, but a negative effect on the ridership of surface transit services (Li et al., 2022)

Malalgoda et al. (Malalgoda and Lim, 2019) used similar data to the reported in Hall et al. (Hall et al., 2018) to examine if the decline in transit ridership across the US was related to either internal transit performance factors or a modal shift towards Uber. Using a data envelopment analysis (DEA) approach, results from the study indicate that ride-hailing has no positive or negative effect on bus transit, suggesting that ride-hailing is neither complementing nor a substituting bus transit. Nevertheless, and similar to Hall et al. (Hall et al., 2018), they found some evidence of increased ridership in the major metropolitan areas (excluding New York).

In South America, Tirachini et al. (Tirachini and del Río, 2019) examined the impacts of ride-hailing on public transit in Santiago de Chile (Chile). Implementing a survey on knowledge and use of ride-hailing platforms in Santiago, they find that ride-hailing is not replacing public transport altogether. The reported ride-hailing trips were occasional trips made mainly by affluent and young people, with a rate of one trip per week in the 70% of surveyed people (on average), and only 3% of users stated that ride-hailing was their primary transport mode. This result suggests that regular public transit users before the ride-hailing entrance remained regular public transit users, but now a small share of transit users make one or two rides in ride-hailing every month. Despite not taking regular passengers from public transit, the authors find that ride-hailing substitutes specific trips from public transit and regular taxis without generating complementarity.

Furthermore, the authors mention that for every public transit user who complements public transit with occasional ride-hailing trips, 11 riders completely replaced public transport trips with ride-hailing. Finally, using generalized ordinal logit models to estimate the probability and frequency of ride-hailing usage, the authors show that high-income individuals are less likely to share a ride-hailing service with other passengers. Nevertheless, leisure trips are more likely to be shared regardless of income level. An interesting finding is that car ownership is not significant in explaining the frequency of ride-hailing, which is not consistent with other studies in North America.

Particularly concerning car usage, also by using survey data, (Tirachini and Gomez-Lobo, 2020) conducted Monte Carlo simulations to find that unless ride-hailing applications substantially increase the average occupancy rate of trips and become shared or pooled ride-hailing, the impact is an increase in VKT. Finally, (Diao et al., 2021) examined the impacts of TNCs on road congestion, transit ridership, and private vehicle ownership in the United States; the results suggest increases in road congestion in terms of both intensity and duration, and the highest effect is a decline in transit ridership although with insignificant changes in vehicle ownership.

## 2.2 Background on public transit systems and ride-hailing in Colombian cities

In 2013, when Uber became the first ride-hailing company to start operations in Colombia, many cities were coming out of a period of significant transformations in the configurations of urban transit systems across the country, which had been mainly implemented by 2012 (Gómez-Lobo, 2020a). Since the introduction of Transmilenio, Bogotá's Bus Rapid Transit (BRT) system, similar systems have been implemented across large urban agglomerations with different levels of success under the guise of Integrated Mass Transit Systems (SITM in Spanish) (Gilbert, 2008; Hidalgo and Huizenga, 2013). Since 2000, SITMs have been implemented in Bogotá (2000), Pereira (2006), Cali (2009), Bucaramanga (2010), Barranquilla (2010) and Medellin (2012) (Toro-González et al., 2020). Medellín is the only city with a public train system (metro), and it was also the first Colombian city to invest in aerial cable cars as public transit solution, a model later adopted in other three Colombian cities.

According to the National Statistics Department (DANE, in its Spanish acronym for Departamento Administrativo Nacional de Estadística), the largest six cities, where SITMs have been implemented, concentrate over thirty percent of the country's urban population and over 65% of the national GDP. Alongside investments in sizeable public transit infrastructure, Colombian authorities have developed regulations and have promoted initiatives to integrate semi-formal buses and minibuses into fully integrated systems to increase access, affordability, and service quality (Rodriguez et al., 2017). However, such transitions have required an overhaul of operations and a reorganization of incumbent owners and operators into cooperatives or unions to guarantee their participation after strong tensions and demonstrations by transport providers (Hidalgo and Díaz, 2014; Rodriguez et al., 2017).

Research on Colombian cities has unearthed inequalities in the ability of citizens to access job opportunities and afford public transport across major urban areas, despite significant efforts for strengthening public transit. Various studies suggest that while higher-income residents of cities such as Bogotá, Cali, Barranquilla, and Medellín enjoy convenient access to private motorized travel choices, access to public transit, and proximity to centers of economic activities, lower-income groups tend to be relegated to the urban peripheries, with lower access to public transit and higher dependency on semi-formal buses (Bocarejo et al., 2014; Calvo and Ferrer, 2018; Guzman et al., 2017; Jaramillo et al., n.d.). Estimations by (Hidalgo and Díaz, 2014) suggest that while average urban residents in Colombia spend 11% of their income on transport, the poorest quintile can spend up to 19%. Other research has found even larger percentages among the poorest segments of the population, reaching up to 24% in cities such as Bogotá and Barranquilla (Calvo and Ferrer, 2018; Guzman and Oviedo, 2018).

Disparities in urban mobility in the country can be partly linked with the limited success experienced by many integrated buses systems. According to data reported by (Gómez-Lobo, 2020), when comparing ex-ante projections of demand for integrated buses systems with their actual demand in 2015, systems such those in Barranquilla and Bucaramanga only achieved around 35% of their expected level, while Medellín achieved nearly 75%. In Cartagena, the effective demand was less than 22% of initially projected, suggesting a significantly limited capture of demand from traditional public transport offered by formal and informal incumbent owners and operators. In many of these cities, the limited success of public transit reforms has entailed uncertain effects concerning affordability, sustainability, and the ability of local and national governments to curb the increase in the use of private modes.

The landscape of urban transport demand in Colombian cities when Uber and other TNCs entered the national urban market suggests that public and nonmotorized transport modes still shared the most significant proportion of the total urban trips. However, as Hidalgo and Díaz (2014) reported, tendencies across the country pointed at a general decline in the use of public transport with increasing private modes. Other research has estimated that the increase in private motorization has been marked by growth in motorcycle use. The number of motorcycles increased 212% between 2000 and 2010. Estimations suggest that in Colombia, the number of households with motorcycles more than doubled between 2003 and 2013 (Gómez-Gélvez and Obando, 2013). While demand for public and private motorized transport has changed across the years, it is notable that different studies in cities across the country have reported a stable percentage of demand for taxi services (Ortiz et al., 2017; Toro-González et al., 2020).

These trends bring relevant challenges in transport externalities mitigation such as congestion and air and noise pollution. For instance, in Bogotá, congestion was estimated to result in seven million lost hours a year, while an extrapolation by the same research suggests that losses accumulated in urban congestion across the country can represent over 2% of the national GDP (Hidalgo and Díaz, 2014). Recent estimates suggest that road congestion in Bogotá costs 335 million hours in 2019, reaching 0.9% of the city's GDP (Calatayud et al., 2021). Moreover, (Sánchez González et al., 2021) estimated the causal link between road congestion and traffic accidents and argued that a 10% reduction in road congestion predicted the avoidance of around 11,000 events in 2019. Although ride-hailing could play a determinant role in these trends and externalities, globally, there is still a poor regulatory framework to address them.

In many cases, as argued by (Shaheen, 2018), the standards that regulatory frameworks seek to codify have already been put in place by ride-hailing firms. These, however, set no standards or rules regarding service fares or fleet sizes. Other authors have argued that via features such as real-time matching of consumers and drivers, rating systems, built-in pricing functions and payment alternatives, and competition between multiple rider sourcing companies, these platforms have shifted commonplace conceptions about pricing, interactions between users and suppliers, fare control and abuse, and competition (Koopman et al., 2014). It may explain the recent surge of dedicated technological platforms for traditional hailing services such as Cabify and Tappsi, among many others, which have allowed the conventional taxi to close the gap with ride-hailing services. In fact, according to a recent survey by (Rodriguez-Valencia et al., 2020), 46% of conventional taxi drivers in Bogotá used a smartphone or tablet with mobile internet access in their daily operation, and the two most popular taxi apps (Tappsi and EasyTaxi) were used by 73% and 66% of Taxi drivers with a smartphone or tablet (Rodriguez-Valencia et al., 2020b). The development of such platforms may enable traditional taxi companies to respond to the constraints mentioned above and criticisms within regulatory frameworks already in place if concessions can be reached around employment and operation features deeply ingrained in traditional models of taxi services.

The lack of a clear regulatory framework and the rapid increase in information and communication technology in mobility operations has led to tensions between different branches of government responsible for transport and technology agendas. In Colombia, for example, recent regulation changes have pitted transportation and information technology authorities at the national and local levels against each other in a battle to define Uber's legal and formality status. While Colombian law protects the right to operate the platform and web-based businesses, pressure from special interest groups —namely taxis— and an agenda of reducing informal supply in urban transportation nationwide has led the Transport Ministry to declare ride-hailing services illegal. This has implications beyond the Colombian context. It reflects the disruptions associated with policies seeking to foster technological innovation in Global South contexts and the resistance from traditional sectors of the economy that might see their operating models threatened by new competitors outside of mainstream regulations.

Uber in Colombia has become an example of the tensions between TNCs and other special interest groups, which is best reflected by Colombia becoming the first country where the company ceased operations in Latin America. After a lawsuit by incumbent taxi operators, a local regulatory body declared the company's services illegal and ordered Uber to cease all passenger transport operations by 31 January 2020. However, only 20 days later, Uber launched a new model of operation of "car rental with a driver" under a variety of service categories that mimics its different options for ride-hailing, effectively enabling it to "circumvent the court's decision and operate within existing regulations […], opening a new debate in relation to the operation of the ride-sourcing platform and its role in the city's urban mobility and renewed resistance from conventional taxi operators in the country" (Oviedo et al., 2020).

## 3. Data and methods

We use monthly data on transit ridership from the Urban Transport Passengers Survey published by DANE. The dataset includes monthly transit ridership for every formal urban public transport mode from January 2005 to March 2018 and is available for 23 cities (including eight metropolitan areas, see Table 1) and 19 transit modes. We aggregate modes into five categories: bus, feeder[1], BRT, metro, and cable car for this analysis. We also rely on administrative data retrieved from DANE, including monthly population and unemployment rates for each city or metropolitan area. Based on the OECD (2019) definition[2], Colombian cities are classified into large, medium, or small (Table 1).

We code each city-month as either treated or control based upon the timing of Uber's entrance reported in Table 1. In cities where Uber operates at some point, the treatment period is defined from the entrance month. We built on information published in newspapers and blogs announcing the entrance of Uber to identify, for every city, the moment when Uber started operation and distinguish the pre-treatment and treatment periods. In addition, we include a

[1] In this research feeder refers to trips that start in buses operating outside the trunk system of the BRT and that can feed the trunk system. On the other hand, BRT refers only to trips that start in the trunk system via one of the stations.
[2] All the details about this classification for city size can be consulted at http://www.oecd.org/cfe/regional-policy/Colombia.pdf.

control variable for the introduction of SITM reforms. Table 1 lists the 23 cities in the study, and presents both the date when Uber began operating in every city and the date when SITM reform took place if it applies.

The final dataset contains 8,699 treated and 3,565 untreated observations. Table 2 shows monthly transit ridership, population, and unemployment rates during the entire analysis timeframe for treated and untreated groups. The difference and related p-value confirm that groups are not balanced and therefore systematic differences between them must be accounted for in the methodological approach. The before-after treatment descriptive statistics in Table 2 suggest that ridership and unemployment rates in untreated cities decreased after the intervention period, but the population increased. In treated cities, the same trend is observed in population and unemployment, but the opposite happened in the level of ridership. The following section describes the econometric approach to statistically test whether Uber beginning to operate determined these trends in ridership.

**TABLE 1 Cities included in the sample (2005-2018)**

| Cities | Metropolitan Area Classification | Population (Millions) | Monthly ridership (Millions) | | Uber Date | SITM Date |
|---|---|---|---|---|---|---|
| | | | Mean | S.D. | | |
| Barranquilla | Large | 1,75 | 0,84 | 0,38 | Feb-15 | May-10 |
| Bogotá | Large | 7,42 | 4,61 | 5,62 | Dec-13 | Dec-12 |
| Cali | Large | 2,34 | 20,61 | 14,59 | Dec-13 | Mar-09 |
| Medellín | Large | 3,46 | 2,05 | 1,90 | Dec-13 | Jan-12 |
| Bucaramanga | Medium | 1,03 | 4,17 | 3,46 | Dec-15 | Jan-10 |
| Cartagena | Medium | 0,9 | 2,10 | 2,18 | Dec-15 | Dec-15 |
| Cúcuta | Medium | 0,77 | 2,74 | 3,55 | Jan-16 | --- |
| Ibagué | Medium | 0,5 | 0,22 | 0,12 | Jan-16 | --- |
| Manizales | Medium | 0,41 | 1,51 | 1,89 | --- | --- |
| Pereira | Medium | 0,6 | 1,46 | 1,21 | May-16 | Sep-06 |
| Armenia | Small | 0,28 | 6,44 | 5,55 | --- | --- |
| Florencia | Small | 0,14 | 0,59 | 0,28 | --- | --- |
| Montería | Small | 0,32 | 1,21 | 1,22 | Feb-16 | --- |
| Neiva | Small | 0,32 | 1,06 | 0,47 | --- | --- |
| Pasto | Small | 0,35 | 2,48 | 2,09 | --- | --- |
| Popayán | Small | 0,24 | 1,21 | 0,77 | Mar-16 | --- |
| Quibdó | Small | 0,11 | 0,31 | 0,32 | --- | --- |
| Riohacha | Small | 0,19 | 0,13 | 0,07 | --- | --- |
| Santa Marta | Small | 0,44 | 3,44 | 3,55 | --- | --- |
| Sincelejo | Small | 0,25 | 0,44 | 0,32 | --- | --- |
| Tunja | Small | 0,17 | 0,99 | 0,56 | --- | --- |
| Valledupar | Small | 0,36 | 0,36 | 0,31 | Apr-16 | --- |
| Villavicencio | Small | 0,42 | 2,28 | 0,71 | --- | --- |

**TABLE 2 Descriptive statistics for treated and untreated cities**

| Variable | Treated (City-months with Uber) | | Untreated (City-month without Uber) | | Diff | P-Value |
|---|---|---|---|---|---|---|
| **All Periods** | **N** | **Mean** | **N** | **Mean** | | |
| Transit Ridership (millions) | 8,699 | 5.47 | 3,565 | 1.30 | 4.17 | 0.0 |
| Population (millions) | 8,699 | 2.30 | 3,565 | 0.31 | 1.99 | 0.0 |
| Unemployment rate (%) | 8,699 | 0.12 | 3,565 | 0.13 | -0.01 | 0.0 |
| **Before treatment** | | | | | | |
| Transit Ridership (millions) | 6,551 | 5.23 | 2,291 | 1.34 | 3.89 | 0.0 |
| Population (millions) | 6,551 | 2.03 | 2,291 | 0.31 | 1.72 | 0.0 |
| Unemployment rate (%) | 6,551 | 0.13 | 2,291 | 0.14 | -0.01 | 0.0 |
| **After treatment** | | | | | | |
| Transit Ridership (millions) | 2,148 | 6.19 | 1,274 | 1.23 | 4.95 | 0.0 |
| Population (millions) | 2,148 | 3.12 | 1,274 | 0.33 | 2.79 | 0.0 |
| Unemployment rate (%) | 2,148 | 0.10 | 1,274 | 0.11 | -0.01 | 0.0 |

## 3.1 Model specification

We use a staggered difference-in-differences (DID) approach to estimate the effect of Uber operations on public transit ridership. Treated months and cities are those where Uber has announced its entrance and continued operating over time without any interruptions, and comparison months and cities are those where Uber either never entered or periods in cities before the company's entrance. We compare monthly transit ridership in metropolitan areas in months beginning when Uber announces operations, compared to monthly ridership in cities where Uber has not entered yet or has never entered, controlling for factors that could affect transit ridership such as integrated transport systems reforms, unemployment rates, and seasonality. In addition, we include city and transit fixed effects to control for potential time-invariant unobserved heterogeneity at the city level. Finally, we control for seasonal impacts by including a dummy variable per semester. Critical to the assumptions in our analysis, Uber was the first TNC to start operating in Colombia, and there were no other TNCs that entered in the following two years[3].

We estimate total monthly ridership in each of the five transit modes for each city/metropolitan area in the DID equation form:

$$Y_{ijt} = \alpha + \theta_i + \rho_j + \tau_t + \beta_1 \partial_{m(t)} + \beta_2 \gamma_{s(t)} I_i + \beta_3 T_{c(i)t} + X_{jt}\eta + \epsilon_{it} \quad (1)$$

Where $Y_{ijt}$ is the log of total monthly public transit passengers of mode *i* in metropolitan area *j* in month *t*; $\theta_i$, $\rho_j$, and $\tau_t$ represent mode, metropolitan area, and time fixed effects, respectively. The term $\partial_{m(t)}$ is a vector composed by a calendar month fixed effect, and a time trend; $\gamma_{s(t)} I_i$ is a calendar semester fixed effect by city; we expect that this battery of fixed effects and time trends capture any confounding variation caused by unobserved historical trends in motorization rates and specific economic events in Colombian cities, considering the context and literature reviewed in previous sections. $T_{c(i)t}$ is the treatment variable which takes the value of 1

[3] The dataset and the coding can be shared upon request for reproducibility of the results.

if Uber is active in the Colombian metropolitan area *c(i)* at time *t*; and $X_{jt}$ is a vector of controls, which includes the total population and unemployment rate in the city *j* during month *t*.

As reforms to public transit systems in Colombia sharply reduced the supply of informal transit operators in many cities (Gómez-Lobo, 2020b), we include specifications that consider a dummy variable for the year when SITM reforms. Finally, we test for potential heterogeneous impacts of Uber's entrance by transit mode using a triple difference specification, including interactions of our treatment variable (Uber presence) with each of the five transit mode dummies as follows:

$$Y_{ijt} = \alpha + \theta_i + \rho_j + \tau_t + \beta_1 \partial_{m(t)} + \beta_2 \gamma_{s(t)} I_i + \beta_3 T_{c(i)t} + \sum_k \beta_k M_{ikt} + X_{jt}\eta + \epsilon_{it} \quad (2)$$

Where k dummies ($M_{ikt}$) are equal to one for each treated transit mode and zero otherwise, and $\beta_3 + \beta_k$ measure the average effects of Uber on each mode. Following the arguments of (Athey and Imbens, 2018), the fundamental identifying assumption is the parallel trends in public transit ridership between treated and untreated cities. In other words, we are assuming that notwithstanding systematic baseline differences in the cities and their transport systems, that the overall trends in per capita public transit ridership are parallel between the cities with Uber and the rest of the cities in the study. The following specifications include a battery of dummy variables for ten years before as a robustness check on the parallel trend assumption. Also, previous specifications do not account for the possibility of an effect several months after Uber's entrance into the Colombian market. Thus, we also test the coefficient three years ahead to look for an effect in the long run. This specification is presented in equation (3) as follows:

$$Y_{ijt} = \alpha + \theta_i + \rho_j + \tau_t + \beta_1 \partial_{m(t)} + \beta_2 \gamma_{s(t)} I_i + \sum_{r=-10}^{R=3} \rho_r \tau_{c(i)a+r} + X_{it}\eta + \epsilon_{it} \quad (3)$$

Where $\alpha$ represents the year when Uber started operating, and $\tau$ is a dummy variable that takes the value of one in the corresponding previous or following years. The rest of the specification remains the same. Next, we include a group of monthly dummy variables to look for evidence closer to the treatment date. In equation (4), $\omega$ represents the previous or following month of Uber's entrance. Here we look for any monthly effect two years before and after the treatment.

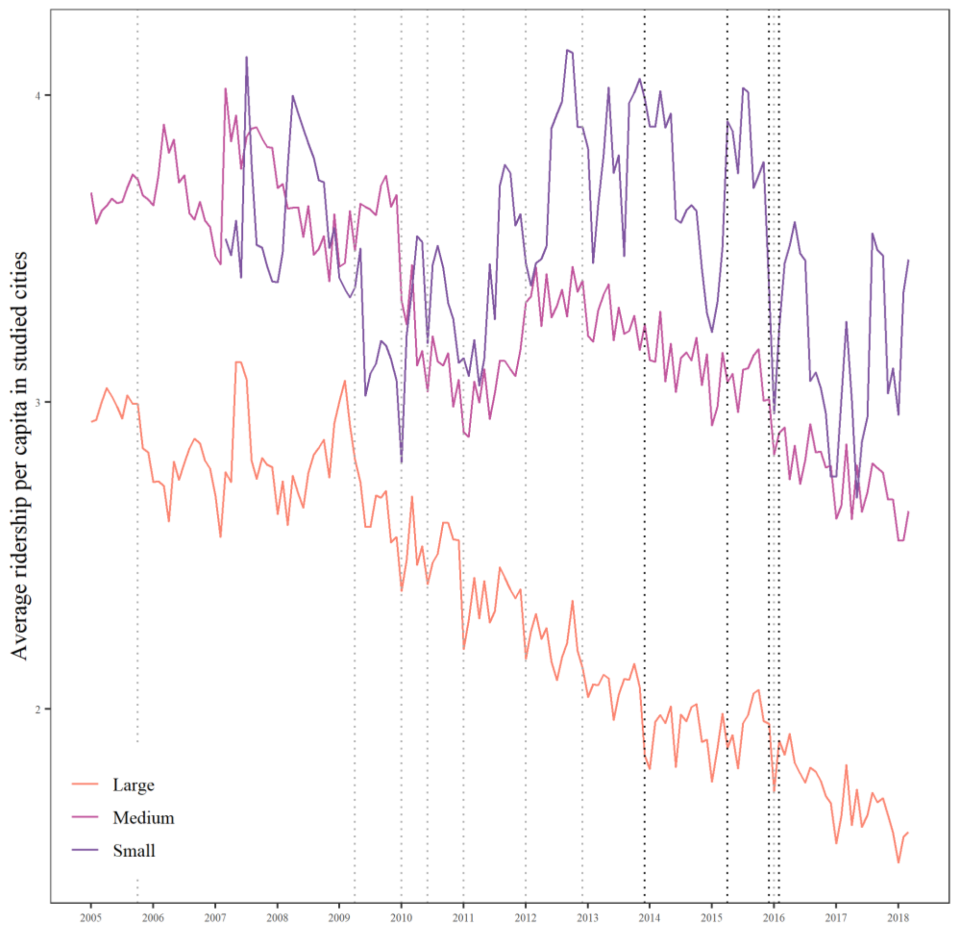
$$Y_{ijt} = \alpha + \theta_i + \rho_j + \tau_t + \beta_1 \partial_{m(t)} + \beta_2 \gamma_{s(t)} I_i + \sum_{r=-24}^{R=24} \vartheta_r \omega_{c(i)a+r} + X_{it}\eta + \epsilon_{it} \quad (4)$$

### 3.2 Summary Statistics

As shown in Figure 2, there has been a systematic decrease in public transit ridership since 2005. Between the date of the first Uber operation in Colombia (December 2013) and the last month in the dataset (March 2018), monthly transit ridership fell on average by 14%. Table 3 reports the summary statistics for the sample dividing treated and untreated cities before and after the date Uber started operating and showing systematic differences in observables variables between both groups.

**TABLE 3 Transit ridership per capita by transportation mode (millions)**

| Mode | All periods | | Before Uber | | After Uber | |
|---|---|---|---|---|---|---|
| | **Mean** | **S.D.** | **Mean** | **S.D.** | **Mean** | **S.D.** |
| BRT | 1.96 | 1.87 | 2.12 | 1.63 | 1.77 | 2.11 |
| Bus | 3.19 | 3.46 | 3.35 | 3.58 | 2.01 | 2.03 |
| Cable | 0.25 | 0.05 | 0.22 | 0.04 | 0.30 | 0.03 |
| Feeder | 1.67 | 1.21 | 1.48 | 0.85 | 1.94 | 1.55 |
| Metro | 4.08 | 0.51 | 3.78 | 0.33 | 4.59 | 0.32 |
| All | 2.95 | 3.25 | 3.16 | 3.42 | 1.97 | 1.99 |




**Note:** Own elaboration with data from DANE. The gray dotted vertical lines represent the dates on which SITM reforms took place in the main Colombian cities. The black dotted vertical lines represent the dates when Uber started operating in the cities. Only one line is plotted for Popayán, Valledupar, and Pereira.

**FIGURE 2 Monthly average ridership per capita between 2005 and 2018 in large, medium, and small Colombian cities**

## 3.3 Evidence on the exogeneity of Uber entrance

The critical assumption in this difference-in-difference estimation is that the intervention (Uber's entrance) is uncorrelated with the error term. We estimate a logistic regression that predicts the treatment (Uber entrance) as a function of population, average ridership, the SITM reform, and the ratio of kilometers covered by BRT over total kilometers covered by regular bus as a proxy for the quality of public transportation service (Table 4). We find that none of these variables predict the entrance of Uber in the Colombian market and hypothesize that Uber's entrance is not statistically significantly related to trends in transit ridership.

**TABLE 4 Prediction of Uber presence in Colombian metropolitan areas**

| Variable | Dependent variable: Presence of Uber (dummy) |
|---|---|
| Population (mill.) | 27.09* |
| | (15.36) |
| Average monthly transit ridership (mill.) | -0.02 |
| | (0.01) |
| SITM reform (dummy) | 21.01 |
| | (93.92) |
| Average unemployment rate | 46.30 |
| | (45.47) |
| Ratio kilometer BRT/BUS | -110.30 |
| | (160.74) |
| Intercept | -12.52 |
| | (7.97) |
| N | 23 |
| Log-Likelihood | -6.003 |

**Notes: *p<0.1, **p<0.05, ***p<0.01.**

## 4. Results

### 4.1 Evidence on parallel trends

Figure 3 presents the average transit ridership per capita in treated and untreated cities. Although differences in levels are substantial between groups over time, both groups follow on average the same trend before the entrance of Uber, with the dates when the SITM reform took reporting reductions for the two groups. However, the cases of metro and cable cars are extraordinary in the Colombian context, only the city of Medellín has a metro system, which is integrated with the cable cars network, feeder buses, BRT, and tram. The city has developed a successful model around this system and enhanced accessibility to marginalized areas. Its level of daily ridership has even allowed it to be a financially sustainable and profitable company. Therefore, such exceptional cases and the observed nonparallel ridership trend, relative to other modes, make it necessary to isolate it from the overall results. This is reported tested in models 3 to 4b, and these transit modes are also excluded in models 5 and 5b.

To test the robustness of the results, we further present different models accounting for city and mode fixed effects. In the Appendix (Figure A1), we present graphical evidence by transportation mode.

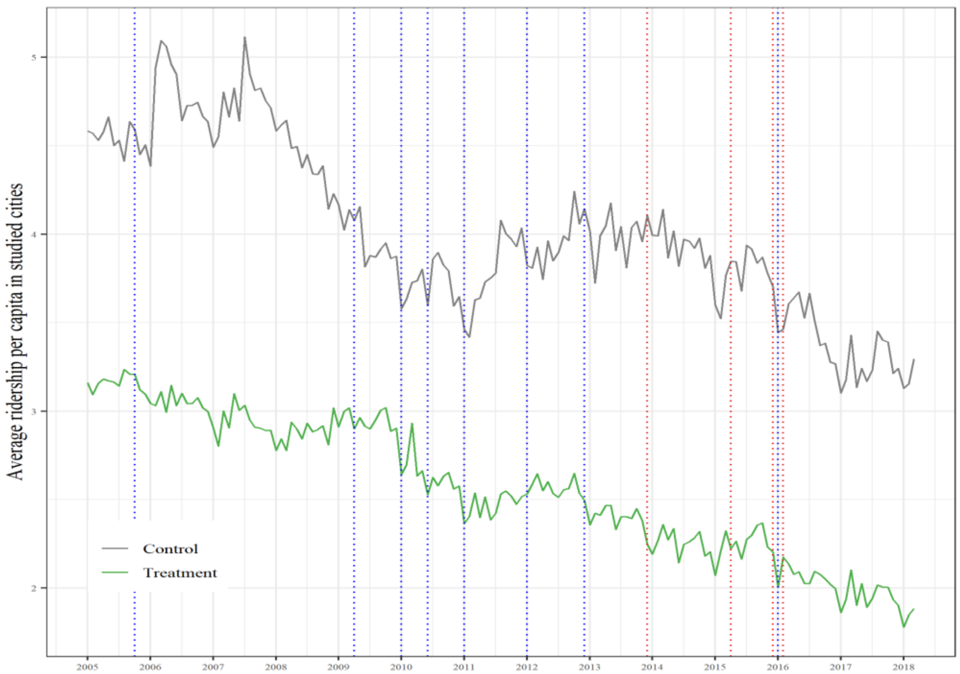



**FIGURE 3 Average ridership per capita in treated and untreated cities**

## 4.2 Impact of Uber on ridership

Table 5 summarizes the results from the difference in difference analysis. We tested different specifications to explore if the estimations changed when controlling for additional variables. The first eight models use the whole sample, and in models 4 and 4b we excluded the larger metropolitan areas (Bogotá, Medellín, Cali, and Barranquilla) to consider impacts for medium- and small- cities only. In the last two columns, model 5 and 5b, we conducted to different approaches to capture the role of city size: model 5 filters by small cities, which means that the only three treated cities are Montería, Popayán y Valledupar; model 5b includes city size effects as control variables, as well as the interaction of city size to the DID variable.

Although the coefficient estimate of the effect of Uber's entrance suggests a negative relationship of around 2% (Model 0) in monthly ridership after Uber entered the Colombian cities, this relationship is not statistically different from zero after controlling for the SITM reform (Model 0b). Also, when we control for time fixed effects (Model 1), seasonality (Model 1b), and city-mode fixed effects (1c), the effect of Uber remains not significant. Model 2 considers all the prior mentioned variables yielding a very low and not significant estimate. In models 3 and 3b, we examine the regressions that test heterogeneous effects by transit mode. We find a positive and significant effect of Uber entrance in the monthly ridership of metro or cable cars compared to the monthly ridership of buses. However, as both transportation modes followed a positive trend before Uber entered the Colombian market, the observed effects may be spurious correlations. Therefore, we do not consider these meaningful findings. The following models exclude these modes from the estimation, but the conclusion concerning the impact of Uber entrance into the market remains unaltered, i.e., there is not enough evidence to support an overall effect after the intervention event.

Regarding the last model (5b), there is a positive and statical significant effect when we interact the DID variable with the city fixed effects. In this case, the baseline category is large cities. In other words, we find evidence that the impact is heterogenous per city size. The result suggests that, in comparison to large cities, the beginning of Uber operation is associated with an increase in the level of public transit; furthermore, the increase is also identified comparing the level of ridership in small cities with large cities. These are novel finding from previous literature looking at developed contexts.

We also observe a strong negative effect that comes with the SITM reform is statistically significant at the 5% level in all estimates consistent with findings of Gómez-Lobo (Gómez-Lobo, 2020a). As robustness, we exclude all large metropolitan areas to explore a possible heterogeneous effect when only considering the treated small and middle metropolitan areas. Although the ridership in BRT and feeders seems to increase compared to bus ridership, the estimates are not precise enough to gather any conclusion.

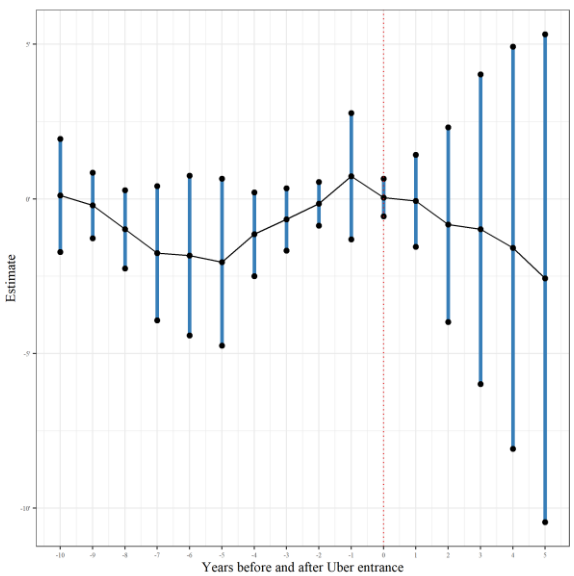
## TABLE 5 Effect of Uber entrance on public transit ridership in Colombian cities

| Variable | All cities | | | | | | | | Medium and small cities | | Small cities - interaction | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Model 0 | Model 0b | Model 1 | Model 1b | Model 1c | Model 2 | Model 3 | Model 3b | Model 4 | Model 4b | Model 5 | Model 5b |
| Uber | -0.023** | -0.012 | -0.084 | -0,099 | -0,099 | 0,003 | -0,029 | -0,078 | 0.448 | 0.449 | -0.143 | -0.215 |
| | (0.013) | (0.136) | (0.132) | (0.169) | (0.169) | (0.170) | (0.225) | (0.218) | (0.279) | (0.278) | (0.489) | (0.22) |
| SITM Reform | --- | -0.023** | --- | --- | --- | -0.671** | -0.707*** | -0.498*** | -0.425 | -0.423 | --- | -0.798*** |
| | | (0.011) | | | | (0.176) | (0.185) | (0.174) | (0.251) | (0.262) | | (0.15) |
| Uber*BRT | --- | --- | --- | --- | --- | --- | -0,135 | 0,344 | -0,276 | -0,297 | --- | --- |
| | | | | | | | (0.382) | (0.229) | (0.196) | (0.206) | | |
| Uber*Cable | --- | --- | --- | --- | --- | --- | 0.906*** | 0.792*** | --- | --- | --- | --- |
| | | | | | | | (0.230) | (0.219) | | | | |
| Uber*Feeder | --- | --- | --- | --- | --- | --- | 0,335 | 0,392 | -0.527* | -0,241 | --- | --- |
| | | | | | | | (0.329) | (0.308) | (0.296) | (0.198) | | |
| Uber*Metro | --- | --- | --- | --- | --- | --- | 0.789*** | 0.675*** | --- | --- | --- | --- |
| | | | | | | | (0.230) | (0.219) | | | | |
| Population (logged) | x | x | x | x | x | x | x | x | x | x | x | x |
| Unemployment | x | x | x | x | x | x | x | x | x | x | x | x |
| Time fixed effects | | | x | x | x | x | x | x | x | x | x | x |
| Time trend | | | | x | x | x | x | x | x | x | x | x |
| Mode fixed effects | x | x | x | x | x | x | x | | x | | | |
| City fixed effects | x | x | x | x | x | x | x | | x | | x | x |
| Mode*Seasonality | | | | | x | x | x | x | x | x | | |
| City-Mode Fixed Effects | | | | | | | | x | | x | | |
| City Size Effects | | | | | | | | | | | | x |
| DID*City Size Effects | | | | | | | | | | | | x |
| N | 12264 | 12264 | 11954 | 11954 | 11954 | 11954 | 11954 | 11954 | 7779 | 7779 | 1279 | 10759 |
| Cities | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 19 | 19 | 13 | 22 |
| R2 - Adj. | 0,525 | 0,538 | 0,391 | 0.393 | 0.382 | 0,389 | 0,391 | 0,415 | 0,249 | 0,249 | 0,36 | 0,39 |

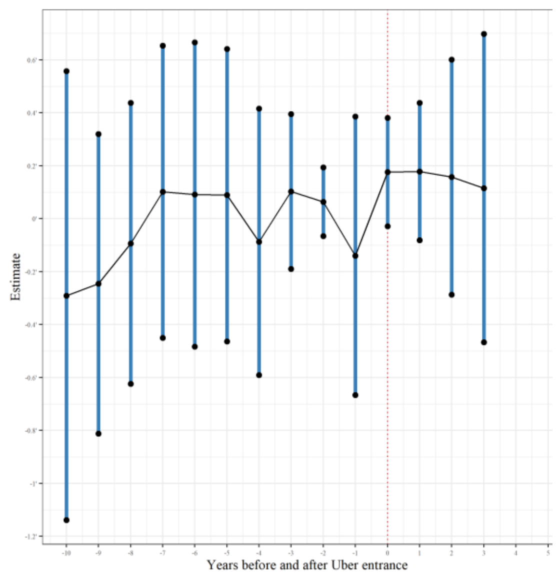
Notes: The table presen the estimates of the Diff-in-diff regression. Errors clustered at the City-mode Level. *p<0.1, **p<0.05, ***p<0.01.
The Large MA are Bogotá, Medellin, Cali, and Barranquilla. The triple difference takes Bus as the comparison category.

### 4.3 Evidence on lagged effects on transit ridership

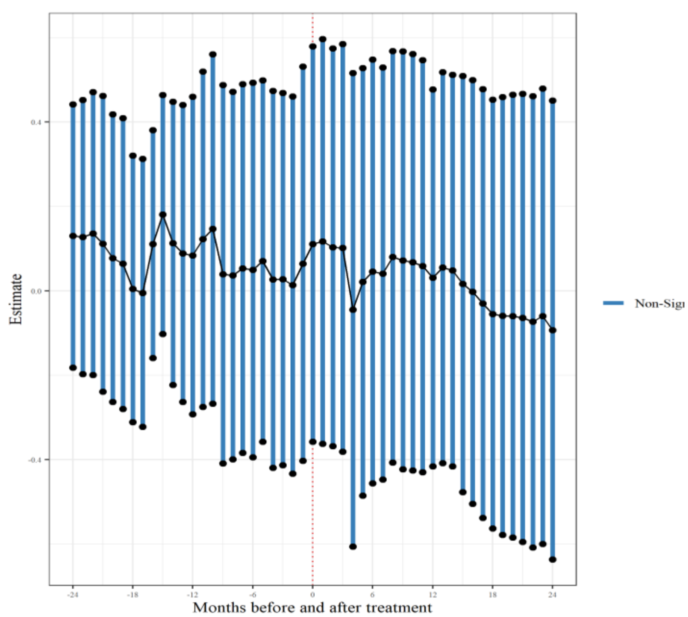
As shown in Figure 4, the results of the year lagged dummies suggest a negative response of transit ridership after the entrance of Uber and onward, and it is positive when excluding the large metropolitan areas, but the estimates have large confidence intervals in both cases. In other words, there is no evidence of any effect of the entrance of Uber in the long run of public transit ridership in Colombia.




(a) Complete sample




(b) Small and medium cities




(c) Complete sample. Monthly effect.

**Figure 4 Changes in transit ridership before and after Uber began operating in Colombia**

Following (Gómez-Lobo, 2020), we also explore whether the effect of the SITM reforms in the following years' public transit ridership. Figure A2 presents the main specification estimates with the lagged dummies battery for the corresponding SITM indicator. Interestingly, the observed negative effect remains for two years when considering all the metropolitan areas in the study. Moreover, when Medellín is excluded, the effect persists two years more, which could be related to the quality and saturation of the service at the time these reforms took place. The coefficients in Table 5 represent the average aggregated effect of the SITM reforms in public transit ridership during the number of years identified by Figure A2.

## 5. Discussion and concluding remarks

Findings in this paper contribute to a body of literature exploring the various urban and transportation effects ride-hailing has on rapidly growing cities in Latin America. Urban Colombia is a relevant setting because of its advances in public transit since the beginning of the 2000s. The implementation of BRT and aerial cable cars for public transportation has been recognized in the international literature as good practices in transport planning and development (Hidalgo and Huizenga, 2013). This paper takes a broader perspective on urban public transport in the country, both by interrogating the links between changing demand for transit and ride-hailing and stepping away from positive narratives that have emphasized the experiences only in larger cities such as Bogotá and Medellín (Hidalgo and Díaz, 2014; Hidalgo and Huizenga, 2013; Levy and Dávila, 2017) . In this line, this work builds on recent research that has taken a more critical stance concerning the effectiveness of transit reforms in intermediate cities, where both regulations and implementation of infrastructure such as BRT have shown mixed effects on transit quality and demand. We analyzed noticeable reductions in the number of transit users over time made visible by previous research, expanding on factors such as declining quality of public transport and increases in the uptake of private motorization (Gómez-Lobo, 2020a; Toro-González et al., 2020) by incorporating the effect of the introduction of ride-hailing as a potential additional explanatory factor in such trends. By considering ride-hailing in the analysis of drivers of public transit demand declines, the paper addresses a frequent question in ride-hailing research: whether on-demand transport competes with public transport.

Earlier research in other urban contexts, particularly in the Global North, has found diverse relationships between on-demand transport and public transit. From complementarity and competition, the links between public transit and ride-hailing are highly context-dependent and can be amplified by governance and regulatory arrangements (Hall et al., 2018; Wang and Ross, 2019). Such research suggests a distinction in the effect ride-hailing has depended on the size of the city, its density, the functional configuration of the land-use and transport systems, and levels of car adoption, among other factors. This analysis in this paper suggests that such factors are also relevant in the context of urban Colombia, with observable differences in the trends of public transit ridership between large metropolitan areas and smaller cities. Our analysis indicates that both the introduction of transit reforms and the start of operations of Uber may have influenced aggregated ridership. This is reflected by trends' evidence, which suggests reductions in ridership in cities across the country following the Uber entrance dates. Such tendencies are stronger for medium and small cities. By contrast, data trends for large metropolitan areas point at no influence of the introduction of Uber. From a descriptive perspective, this suggests that Uber's start of operations might have had a lower impact on transit ridership in cities with a more consolidated public transit system structured around mass transit lines (e.g., BRT or metro) and greater demand for regular travel. Research in intermediate cities in the country supports this finding. Overall, the disruptive effect expected from the introduction of Uber in Colombian cities of different sizes was less than expected, suggesting more general insights associated with the maturity of public transport services and the role of reforms in consolidating already ongoing trends as findings potentially relevant outside the Colombian context, which can be tested using a similar methodology to the one suggested in this research.

Despite such observed trends, the analysis did not find sufficient evidence of a statistically significant effect of Uber on ridership demand. Furthermore, the various regression results and robustness checks show no significance in introducing ride-hailing on transit demand. Nevertheless, in Medellin, our findings suggest that Uber and other forms of ride-hailing may play a role in expanding access to some forms of public transport, suggesting a potential area of future research around complementarity between public transit and on-demand ride-hailing.

One of this paper's limitations is the availability of detailed information on the intensity of ride-hailing use and other characteristics of this mode demand. More disaggregated data is necessary to understand ride-hailing's role as a substitute or a complement to public transit and other modes in varying contexts and scales. Further areas for inquiry include, for example, the relationships between ride-hailing and private vehicle use. Ride-hailing ridership can act as a substitute for car ownership, it can enable a more multimodal lifestyle where public transit serves as the primary mode, and it also has the potential to serve an under-supplied demand at times of the day when public transit is unavailable or where feeder services are unavailable to access mass transit hubs (with ride-hailing serving as a first or last-mile service). Findings in this paper can inform the design of future instruments for data collection that consider some of the factors we have suggested are relevant for the relationship between transit and ride-hailing. The paper proves the need for purpose-built datasets to analyse a changing mobility ecosystem as a result of the introduction of new on-demand travel alternatives. Evolving frameworks and approaches such as those adopted in this, and previous similar studies improve our understanding of the influence of new modes of transport on travel demand and inform decision-making in policy and practice for a more sustainable and inclusive urban mobility.

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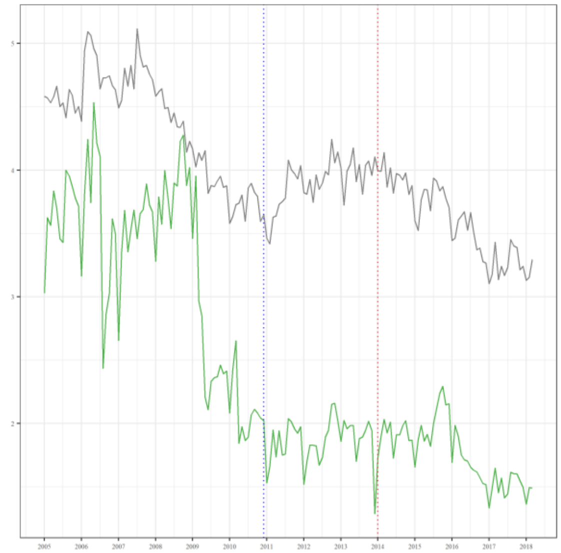
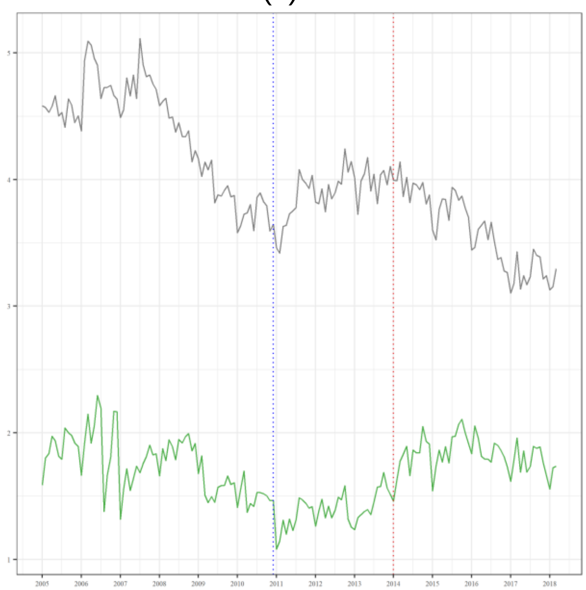
## Annex


(a) Bus

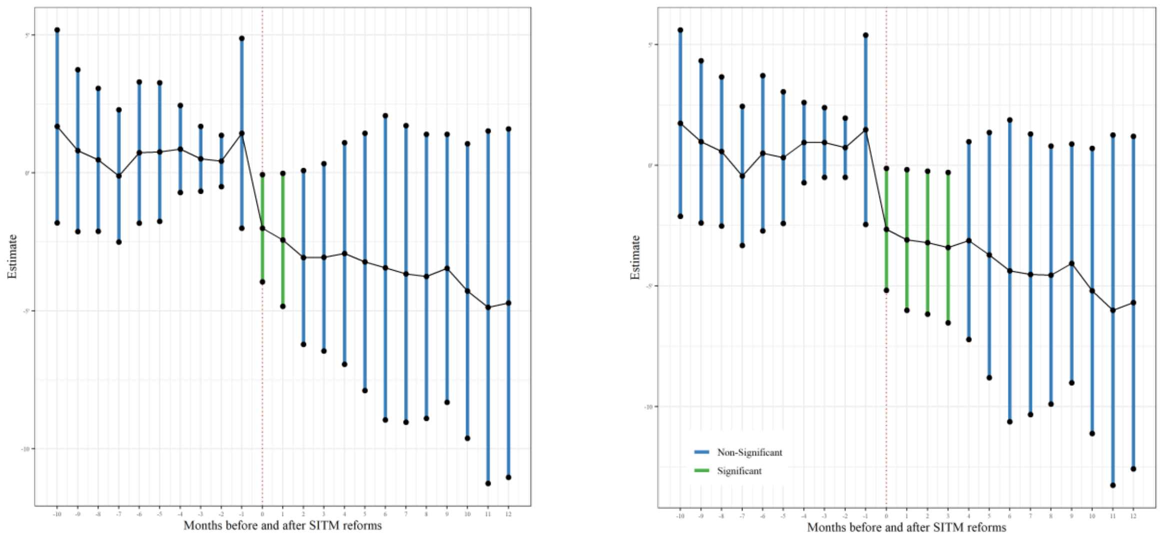


(b) BRT



(c) Feeder

**FIGURE A1 Average ridership per capita by mode in treated cities in comparison to untreated cities**




(a) Complete sample (b) Excluding Medellín

**FIGURE A2 evidence of changes in transit ridership years before and after the date of the SITM reform**