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Taxi devastation fallacy, technology, and other issues: the case of Bogotá, Colombia

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Abstract

The appearance of small groups of on-demand transportation alternatives has exacerbated taxi industry. Given that in the past 20 years technology has evolved and thereby taxis operation has changed, an interest on the effects it had on taxi industry has emerged. Is really taxi industry devastated? Have taxis taken advantage of communication technologies as their competitors did? Researchers at Universidad de los Andes Bogotá, found a robust methodological way to answer these question. A before-after study was conducted based on a drivers' survey from 2009. So, in 2017, we repeated the same survey to a representative sample of taxi drivers in Bogotá (Colombia) from, using the same sampling method. Currently 47% of drivers have a mobile device with e- hailing applications. Results have shown that taxi operation has change between 2009 and 2017, being nowadays more efficient. On the money's in- and outflow we did not find statistical significance on the gross income of drivers in Bogota, correcting for the change in value of money in time. Although these findings are valid just for Bogotá, the results provide conclusive and robust evidence of the taxi devastation fallacy.

Keywords: taxi; ridesourcing; technology; e-hailing; TNCs

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1. Introduction

Recent information and telecommunication technology (ICT) developments have revolutionized taxi industry in different ways. On the one hand, these developments facilitated private competition to taxis based on “sharing economies” principles. ICTs allow pairing drivers in private vehicles with users seeking flexible on-demand transportation services. On the other hand, technology also benefitted taxi industry; higher handling capacity, shorter user’s waiting time, enhanced personal safety, improved traffic safety, and efficiency are among the most common advantages brought by technology. According to Bostrom (2007), information technology (among other technology developments), is likely to have transforming impacts on human society, and perhaps on human nature itself in the twenty-first century.

The appearance of Transportation Network Companies (TNCs) that pair passengers with drivers who provide transportation services (ridesourcing) using their personal, non-commercial vehicles, has exacerbated taxi industry. Among many other complaints, taxi industry claims unfair competition, since these new ride-sharing and ride-sourcing services operate without medallion, with lower insurance requirements, and have less barriers to enter the market. In addition, traditional taxi telecommunication companies based on radiophones, got their technology and infrastructure obsolete. Taxi owners got heavily affected in cities with fleet entry control, where the price of the rights-to-operate (e.g. medallion) fell down dramatically in recent years. There is a fear of taxis of losing a large share of the market they served for centuries, by a service that offers attractive prices, enhanced personal safety, and other quality features. Therefore, protests, demonstrations and strikes of taxi owners, drivers and companies have become frequent and recurrent topic of our daily news worldwide.

Given that technological revolutions have such profound effects in society, public policy development and analysis reclaim relevance. As mentioned by Crow and Sarewitz (2000) , the key to face this situation relies in knowledge upon which to base action, a capacity to learn from experience, close attention to observe the present, and healthy and resilient institutions that can effectively respond or adapt to change in a timely manner. There are few studies that provide unbiased, valid evidence to inform and enlighten policymakers and regulators on this regard. When the transportation paradigm changed to a sustainable transportation one, new challenges and requirements were set when defining policies and regulations. The role of academia in this process is to provide evidence to enrich the discussion and to contribute to develop the most convenient policies for society.

Is really taxi industry devastated after the emergence of TNCs and ridesourcing companies? Have taxis also taken advantage of communication technologies as their competitors did? A research project financed by Universidad de los Andes Bogotá found a robust methodological way to answer these question. A before-after study was conducted based on a drivers’ survey from 2009. So, in 2017, we repeated the same survey to a representative sample of taxi drivers in Bogotá, using the same sampling method and added some more questions about their use of new communication technologies. In this study, we compare results using hypothesis testing. Such differences are identified through the analysis of operational variables regarding working preferences, income and vehicles, among others.

2. Context

The taxi is an important actor of Bogotá’s transportation system. It is in continuous operation throughout the day and night and it explains 7.00% of motorized trips and 4.08% of all trips in Bogotá in year 2016 (Alcaldía Mayor de Bogotá - Secretaría Distrital de Movilidad and Secretaría Distrital de Movilidad, 2015). The people of Bogotá use it mostly for going to work, going back home and for medical purposes and the average trip time is 47 minutes.

In Bogotá, the taxi industry is formed by (1) users, (2) vehicles, owners and drivers, (3) the Transport Authority and a Transport Company and (4) a radio dispatch company. (1) The user interacts with the driver, the vehicle and a radio dispatch company. (2) In most cases the vehicle is leased to a driver who pays the owner a daily rent. (3) Each taxi must be affiliated to a taxi (transportation) company (Ministerio de Transporte, 2001), which acts as intermediary to request the yearly permission to the city transportation authority. Currently there are nearly 62 taxi companies in Bogotá, almost 15 more than in 2009 (Movilidad, 2017). (4) Discretionarily, drivers or owners could affiliate to radio dispatch companies, which were in most of the cases part of a taxi (transportation) company. However, in recent years radio dispatch companies have been displaced by E-hailing companies for taxis (e.g. Tappsi, Taxis Libres, Easy Taxi) and for private vehicles (e.g. uber, cabify). A scheme of the taxi industry is presented in Fig. 1.

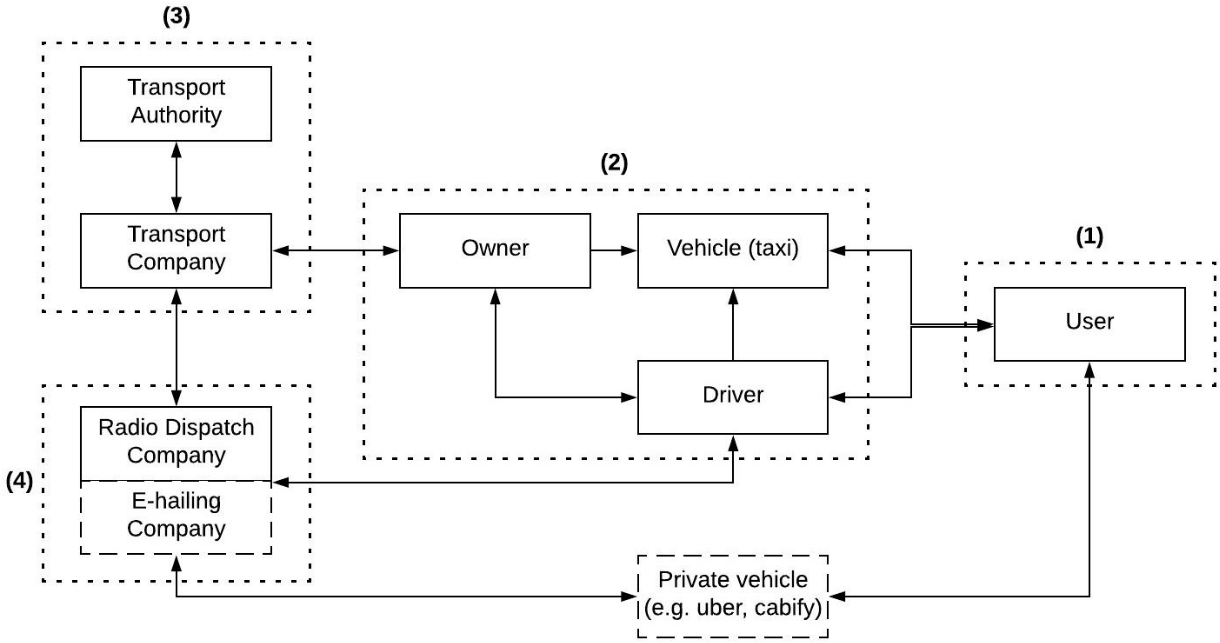

Fig. 1. Taxi industry scheme

Some studies conducted before the new telecommunication technologies arose, provide insightful information about how taxi industry was in 2009. For example (Rodriguez-Valencia, 2014, 2013; Rodríguez Valencia and Acevedo Bohórquez, 2012), argue that radio-dispatch, the affiliation system, and the open market for medallions generate perverse incentives that have led to a horrible perceived taxi service and bad road safety indicators. In the studies the authors also describe the operation and the effects taxi have on the city mobility.

In the past few years, along with ridesourcing mobile applications (herafter referred as apps), multiple taxi e-hailing apps, based on collaborative economy and independent from the taxi transport companies, entered the market in Bogotá to request taxi service. This last, made the taxi industry angry but offered users another way to get a taxi, as in the past the only two options were calling a taxi dispatch company or getting it on the street. Also, this apps allowed the user to know the rate, the information and the real time position of the driver who is going to arrive. However, even though they allowed the service to be efficient and to be rated by users, they didn't completely solve the service quality problem, as users still make complaints regarding the service quality. This, given that while users` rating could force taxi drivers to be suspended from an app for a while, the existence of multiple e-hailing apps meant that they could continue working for other apps in the meantime and that service quality did not improve.

As a result of this, disrupting transportation modes such as Uber, which entered the market in 2013, were positively accepted within taxi users. An example of the above are findings by Cala and Lecompte (2016) who show that 45% of taxi users also use Uber. Such positive acceptance lead to constant complaints among the taxi industry, as drivers argue that Uber has a direct effect on the amount of services they provide per day and thereby on their daily profit.

Consequently, the taxi industry has held multiple protests against Uber and demanded that the government prohibits it. This phenomenon is not exclusive to Bogotá, drivers around the world have also protested against TNCs. For example, "in the summer of 2014, four thousand London taxis brought the center of London to a standstill following similar protests that had taken place in Paris, Madrid, Rome, Milan, and Berlin (Fleisher 2014). However, for some, it became an opportunity for the taxi industry to re-think its business and implement technologies that bring efficiency to service provision. As mentioned by Bostrom (2007), even though this type of developments create problems, they also bring opportunities, so turning back is neither feasible nor desirable.

3. Literature review

Technology has been historically linked with taxi operation. In most cities, the taxi industry still utilizes technologies developed in the 1940s (Cramer et al., 2015), like radiophones. Effects of technology revolutions have been present in the past. Taxi operation changed 20 years ago with the introduction of satellite-based dispatch systems and GPS on-board devices which came to replace the traditional phone-based system. These systems or any derivation were easily adapted and well received by the telecommunication industry associated with taxi companies, since the intermediary was required in the dispatch: either an operator or a machine received the users' requirements and assigned them to the closest cab (Graeme Mcleod, 1972).

Also, Mason and Deakin (2001) and Daud et al. (2015) mention that information technology allows transportation systems to be "smart" given the amount of data that can be collected and processed to enhance the operation. Compared to the previously phone-based system, satellite-based dispatch and GPS on board systems enable higher handling capacity as service reservations can be processed with the same accuracy and in a shorter period.

However, regarding satellite-based dispatch systems a research of the taxi market in Suzhou, that interviewed 132 taxi drivers, finds that service providers do not benefit from the use of these systems but that most passengers express positive interest in them as they do well in improving travel experience (Feng, 2015).

Also in a literature review on the impact of app base taxi services, (Liao, 2001) outlines that technologies such as GPS cannot fully solve problems such as: i) mismatching in the demand for supply of taxi services, ii) job segregation based on location proximity from a service, iii) noise generated by radio-paging systems and iv) empty cruising while waiting confirmation of a taxi. On the contrary, (Daud et al., 2015) argues that the implementation of GPS based systems in large cities like London, New York and Singapore has improved the way taxi operators manage their businesses.

TNCs (also called ridesourcing services) are part of a recent technological development called e-hailing apps. These last have been designed to order transportation services via a computer or a mobile device, and have caused a disruption on the industry. TNCs differ with other e-hailing apps, such as DiDi (taxi app in china), in the fact that they connect users with private car owners.

According to the Transportation license section and State of California public utilities commission (2015), a TNC is defined as "a company or organization that provides transportation services using an online-enabled platform to connect passengers with drivers using their personal vehicles". Also, Zha et al. (2016) refers to ridesourcing as an emerging urban mobility service in which private car owners drive their own vehicles to provide a service through an app. Some of the most common TNCs services nowadays are Uber, Lyft and Sidecar. These TNCs appeared in the urban transportation scene, providing a perfect substitute for taxi services whose quality has decreased in the last years (Cala et al., 2016).

Authors like (Daud et al., 2015; Liao, 2001; Veloso et al., 2011) evidence that these new systems reduce waiting time and improve accuracy and efficiency, as drivers can provide the service without having to drive around searching for the next customer, which therefore reduces daily operating cost. This last given that the systems analyze and optimize the demand and supply by using algorithms which permit real-time response. Also, Daud et al. (2015), argue that this recent technology revolution allows direct contact between users (demand) and service providers (supply) as they only need a mobile device and are able to see the vehicle and driver´s information. This service quality and positively affects drivers' productivity whether they are taxi, TNCs or ride-sourcing drivers.

Regarding the TNC Uber, which is the most known around the world (and the most popular in Bogotá) Rogers (2015), argues that it model of business has basically eradicated search costs given that users can hail a car from indoors and watch its progress toward their location rather than calling a dispatcher and waiting, or standing on the street. Drivers also cannot poach one another's pre-committed fares, which in some cities is one of the main complaints. However, as mentioned before, this services benefit all markets, referring to the taxi industry, Nie (2017) and Asmi et al. (2016) argue that e-hailing helps lift the capacity utilization rate of taxis.

Even though TNCs brought multiple benefits to users, their arrival disturbed taxi industry as they entered the market for free, without fulfilling the requirements of regulated markets. This generated several consequences, like the reduction on the medallion prices and the substitution of radio dispatch technology, which ended the oligopolistic market of communication services. Also, Nie (2017) argues that taxi Industry in Shenzhen, as in New York City, experienced a reduction in its ridership, however in Shenzhen taxi service managed to compete more effectively given that it had used an e- haling app (Didi) long before the arrival of ridesourcing. Regarding what cities gain or lose in terms of sustainability, Henao and Marshal (2015) argue that there remain unsolved questions, such as VMT and carbon emissions, among others.

As a result of these new services, the taxi industry made multiple protests around the world and demanded the governments to ban or regulate these types of technologies, arguing that such services affected their jobs and that they were at a disadvantage. However, Uber not only produced negative consequences on the taxi industry, but also became an opportunity for it to change and adapt to the users' needs. As presented in Kingdom´s multiple stream approach, some issues, in this case Uber and taxis, move onto the governments agenda while others do not (Kingdon, 2003). Considering Kingdoms three streams: problem, policy and politics streams, the arrival of Uber made the taxi industry identify their problems and apply new policies and politics to improve their service.

4. Methodology

For this research, we conducted an uncontrolled before-after technique, based on a taxi drivers' survey held in 2009. Before-after studies are powerful research tools to evaluate the effect of changes in time. Since we were not able to trace the same drivers of the 2009 survey, a longitudinal time series method was not possible. Uncontrolled before–after studies deal with observing and systematically measuring the situations before and after the implementation of an intervention or the appearance of a phenomenon, without having an untreated control group. Being frequent in science in controlled environments, these methods contribute to associate causality to the treatment. We replicated the survey in 2017 and through statistical techniques we analyze how the appearance of ITC and other measures might have affected taxi drivers, taxi operation, and in general, taxi industry in Bogota.

Since the 2009 survey was too general in terms of taxi operation in Bogota, it was necessary to add some new questions about TNCs and perceptions in the 2017 one. Some other questions, specific to the 2009 research, were dismissed to make the questionnaire short (see Table 1). Similarly, as in the initial survey, 400 surveys were applied in person in January 2016 using a multistage sampling method to random taxi drivers. This sampling approach ensures that all individuals have the same probability of belonging to the sample, and allows an unbiased estimation by eliminating self-selection bias. For multistage sampling, we selected the same locations to administer the survey, including Bogotá bus terminals and airport, car washes, malls, designated taxi stands in different zones, drivers' restaurants, etc.

Pilot surveys were tried to some experts and drivers in order to identify potential mistakes before applying the final version and to train the surveyors' team. The final questionnaire has the following structure:

1. The first section collected information about the survey: location, date, hour, interviewer
2. The second allowed the gathering of socio demographic information regarding taxi drivers: age, sex, highest educational degree attained, income levels, etc.
3. The third section requested information regarding taxis operation: vehicle type, daily income, daily expenses, operation scheme and covered distances.
4. The fourth inquired about the use of applications: tele-communication equipment ownership and expenses
5. The fifth and last section allowed the knowledge of drivers' perception regarding alternative individual transport modes such as motorcycle taxis, bicycle taxis, Uber black, UberX, hotel taxis and illegal taxis.

Table 1. Groups of variables applied on the 2009 and 2017 surveys.

Variable	Description	Range
Drivers' Context Variables		
gender	Gender. 0: female, 1: male	0-1
start year	Taxi Driving initialization year	1960-2016
work experience	Number of days driving taxi	Number
age	Age of the driver in years	17-80
taxi type	1: own, 2: hired, 3: familiar, 4: partnership	1-4
daily rent	Daily expenditure for hiring a taxi in thousand COP	40-120
back up	The driver leaves savings for hired taxi type in thousand COP. 0: No, 1: Yes	0-1
back up value	Savings daily amount for hired taxi type in thousand COP	1-120

Variable	Description	Range
education level	Completed highest educational achievement: 1: Primary school, 2: Secondary school, 3: Technical, 4: Bachelor, 5: Masters, 6: Other	1-6
socio-economic level	Colombian ordinal scale (1 to 6) attached to residences to compute utility fares according to the income. 1: lowest, 6: highest	1-6
EPS	Affiliated to a social health program. 0: No, 1: Yes	0-1
pension	Affiliated to a pension program. 0: No, 1: Yes	0-1
expenses_EPS_pension	EPS and pension payment in thousand COP	20-110
cost responsible	Person responsible for the spending's of those programs. 1: Driver, 2: Company, 3: Split, 4: Other	1-4
back pain	During work time driver have pain on the back. 0: No, 1: Yes	0-1
narcotic use	During work time driver uses any kind of narcotic. 0: No, 1: Yes	0-1
Vehicles' context variable		
trunk	The vehicle has trunk. 0: No, 1: Yes	0-1
car brand	Brand of the taxi. 1: Hyundai, 2: Chevrolet, 3: Daewoo, 4: Kia, 5: Other	1-5
car reference	Reference of the taxi	Text
car model	Model of the taxi (year)	2000-2017
Operations' Context Variables		
shift modality	1: Short day, 2: Short night, 3: Long, 4: Variable, 5: Rotating	1-5
work days during week	Taxi doesn't work for every day of the week. 0: No, 1: Yes	0-1
schedule Mon-Thurs	Taxi schedule during this days in military format	0-24
schedule Friday-Saturday	Taxi schedule during this days in military format	0-24
schedule Sunday	Taxi schedule during this days in military format	0-24
company affiliation	Name of the company affiliation	1-6
radio equipment	Radio communication equipment ownership. 0: no equipment, 1: one radio, 2: two radios	0-2
type of radio	Type of equipment. 0: Local, 1: Normal, 2: Satellite	0-2
frequent client	Taxi has a frequent client. 0: No, 1: Yes	0-1
daily traveled km	Distance per shift in kilometers	70-450
num. drivers per taxi	Number of drivers in the vehicle. 1: One, 2: Two	1-2
good work	Taxi driving is a good work. 0: No, 1: Yes	0-1
bad work days	Bad working days for everyday of the week. 0: No, 1: Yes	0-1
fuel expenditure	Fuel spending during each day in thousand COP	12-75
daily gross income	Gross income during each day in thousand COP	35-450
daily profit	Free income during each day in thousand COP	5-280
Unable to pay rent	Taxi driver can't pay the daily share. 1: Very frequently, 2: Frequently, 3: Sometimes, 4: Never	1-4
car wash	Taxi driver is responsible for daily car wash. 0: No, 1: Yes	0-1
car wash spending	Spending of the car wash	0-22
Technologies Usage Variables		
smart phone use	Taxi driver uses Smartphones or Tablets. 0: No, 1: Yes	0-1
easy taxi app	Taxi driver uses Easy Taxi app. 0: No, 1: Yes	0-1
tappsi app	Taxi driver uses Tappsi app. 0: No, 1: Yes	0-1
smart app	Taxi driver uses Smart app. 0: No, 1: Yes	0-1
libres app	Taxi driver uses Libres app. 0: No, 1: Yes	0-1
OK app	Taxi driver uses OK app. 0: No, 1: Yes	0-1
schedule app	Schedule in which taxi driver uses the app (s) in military format	0-24
app spending	App spending for its usage in thousand COP	10-310
app legal	Taxi driver considerations about legality of the taxi APPs. 0: No, 1: Yes	0-1
use of apps	Why do drivers use apps	Text
rating by clients	Clients rating motivates to improve service. 0: No, 1: Yes	0-1
Other Individual Public Transportation Service Variables		
feelings Uber	Feelings when thinking about Uber	Text
bicycle-taxi	This service has negative effects on taxi service. 0: No, 1: Yes	0-1
Uberblack	This service has negative effects on taxi service. 0: No, 1: Yes	0-1
Uber x	This service has negative effects on taxi service. 0: No, 1: Yes	0-1
moto-taxi	This service has negative effects on taxi service. 0: No, 1: Yes	0-1
hotel transport	This service has negative effects on taxi service. 0: No, 1: Yes	0-1
informal taxi	This service has negative effects on taxi service. 0: No, 1: Yes	0-1
switch bicycle taxi	Consideration of switching taxi service for this service. 0: No, 1: Yes	0-1
switch Uber	Consideration of switching taxi service for this service. 0: No, 1: Yes	0-1
switch Uber x	Consideration of switching taxi service for this service. 0: No, 1: Yes	0-1
switch motorcycle-taxi	Consideration of switching taxi service for this service. 0: No, 1: Yes	0-1
switch hotel transport	Consideration of switching taxi service for this service. 0: No, 1: Yes	0-1
switch informal taxi	Consideration of switching taxi service for this service. 0: No, 1: Yes	0-1

The selected technique to analyze the data is the statistical hypothesis testing of the means of different variables in 2009 and 2017 (mean differences), The 2009 information comes from the published book "Taxi! The forgotten transportation mode in Bogota" (written in English) (CITA), and two peer-reviewed papers "" (cITA)and "" (CITA) the technology effect in taxi drivers, we made some more mean differences analysis only with the 2017 drivers to see differences between users and non-users of e-hailing apps and users and non-users of mobile radiotelephone. We also used the binomial logistic regression, to determine the variables affecting the decision of using both e-hailing apps and radiotelephone.

Some secondary information was provided by the Bogotá Transportation Authority (Secretaría Distrital de Movilidad), and was used to compare variables from the survey to corroborate the quality of the results. These databases contained information on brands and models of vehicles and taxi operating companies.

5. Results

The taxi industry experienced important changes between 2009 and 2017 in terms of drivers, operation, and fleet (see Table 2). Nowadays, drivers are 2.1 years older on average, are significantly more experienced, however, 25.9% of them consider their job as temporary compared to 21.8% in 2009 (Rodríguez Valencia and Acevedo Bohórquez, 2012). Fleet has also shown important ageing; as vehicles in Bogota are on average 1.54 years older than they were in 2009 (see Table 3). The average engine size remained the same in the period, as taxis in Bogotá nowadays taxis still have very small engines (1126 cc).

In terms of taxi operation, the most remarkable result is the reduction in the average activity factor per taxi, which was significantly reduced from 255 km per day to 218km. This reduction represents a reduction of approximately 390 tons of CO_2 and 1.2 million VKT per day. Furthermore, in terms of shift modalities, remain unchanged -long and short shift modalities- (Rodríguez Valencia and Acevedo Bohórquez, 2012). However, table 2 shows a substantial reduction of daily traveled distance without a significant change on working time.

Another finding was the increase in 2% of taxis that operate in long shifts, this means that 2% of the taxis that used to have 2 drives now only have one. While in 2009 each cab had 1.38 drivers on average, in 2017 the number was reduced to 1.33 drivers per cab. This shows that the total number of jobs in the capped taxi system in Bogotá was affected as in the 7 years period, around 1000 less drivers are employed by taxis.

Table 2. Average hours worked, kilometers traveled, age of drivers according to operation mode

Shift worked	Proportion of taxis		Working time (h)		Daily distance (km)		Age (years)	
	2009	2017	2009	2017	2009	2017	2009	2017
Short day	16.3%	16.5%	12.1	11.48	242.5	182.93	43	43
Short night	16.3%	16.5%	12.1	11.79	231.9	203.97	37	42
Long	65.3%	67.0%	14.7	15.37	270.1	234.42	43	44

In terms of drivers' money in and outflows, this study found that the gross daily income of a taxi driver in Bogotá in 2017 is statistically the same as in 2009, after correcting for changes in the value of money in time. On the outflow side, drivers reported having significantly less daily expenses for fuel (-20.7%), approximately -8,904 COP (2017) or 2.95 US$ (see Fig. 2). For drivers renting the vehicle for exploitation, the daily average fee charged by the owners remained statistically constant. Finally, the reported daily net income of a driver at the end of the day had great variability, but is still significantly constant. However, by analyzing only the night shift, findings show that drivers gross daily income is statistically lower that in 2009, as it is approximately –66,380 COP (2017) or 21.99 US$.

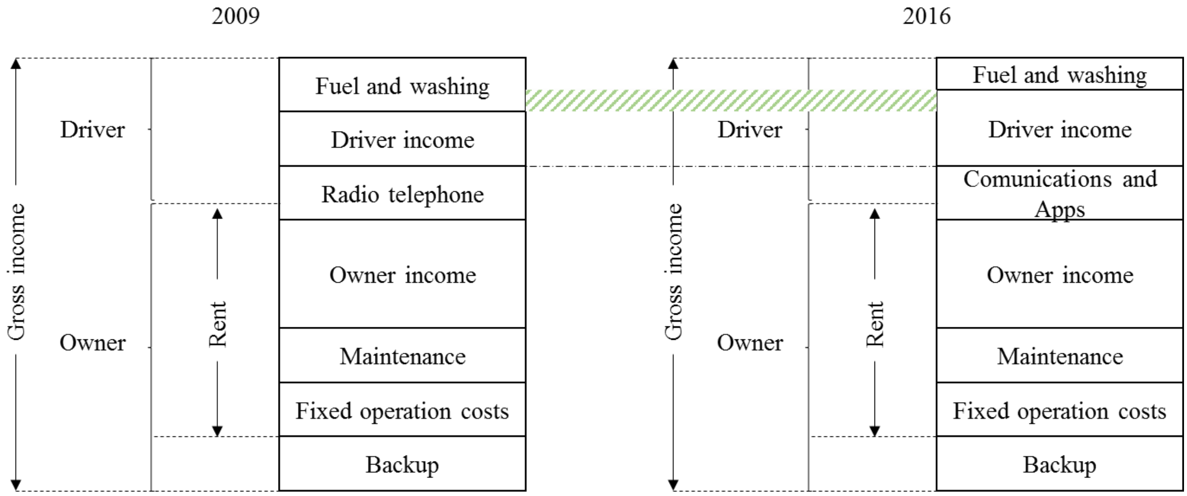

Fig. 2 Costs of operation in 2009 and 2017

As in other countries in the world, communications have played and important role for the dispatch demand segment in Bogotá. In the recent years, communication technologies had a strong transformation. While in 2009, 3 out of 4 taxis had at least one radiophone device, today barely 28% still uses this technology. Conversely, almost half (46%) of the drivers have mobile devices connected to e-hailing applications. On the contrary, daily time devoted by drivers has remained constant at approximately 14 hours per day on average.

Table 3. Comparison of taxi operation between 2009 and 2017

	2009			2017			Difference	Z	p-value	
	n	Mean	StD	n	Mean	StD				
Work experience (years)	386	9.21	8.25	394	12.22	10.50	3.01	4.457	0.0000	***
Age (years)	386	41.48	11.30	394	43.58	12.67	2.10	2.445	0.0145	*
Vehicle age (years)	386	4.16	3.29	394	5.70	3.99	1.54	5.876	0.0000	***
Num. radiotelephones per taxi	386	0.77	0.78	394	0.28	0.51	-0.48	-10.213	0.0000	***
Daily traveled km	386	255.09	50.11	394	218.36	49.41	-36.73	-10.305	0.0000	***
Num. drivers per taxi	386	1.38	0.51	394	1.33	0.22	-0.05	-1.720	0.0854	
Fuel expenditure (2017 COP)	386	$ 43,067	$ 8,803	394	$ 34,162	$ 9,141	-$ 8,904	-13.859	0.0000	***
Daily gross income (2017 COP)	334	$ 193,221	$ 34,812	394	$ 193.561	$ 46.647	$ 340	0.112	0.9105	
Daily profit (2017 COP)	371	$ 97,005	$ 56,197	382	$ 90,507	$ 40,465	-$ 6,498	-1.816	0.0693	
Daily hours worked	386	13.66	2.13	394	13.95	2.26	0.29	1.852	0.0641	

Note: ***, **, *, and · = significance at 0.1%, 1%, 5%,

By statistically testing differences in the means of variables of taxi drivers that use and do not use e-hailing apps, we found substantial differences in operation (only 2017 database). First, the drivers that use these applications are significantly younger (6.62 years) than their counterparts that do not use them. Second, drivers that use apps have a significantly greater daily gross income and daily profit than those that do not, when working the same number of hours (see Table 4). Some other differences were that both number of drivers per taxi and daily traveled km increased with the use of e-hailing apps.

Table 4. Comparison between drivers with and without apps in 2017

	Without Apps			With Apps			Difference	Z	p-value	
	n	Mean	StD	n	Mean	StD				
Work experience (years)	213	13.01	11.73	179	11.41	8.86	-1.60	-1.540	0.1235	
Age (years)	213	46.62	12.92	179	40.01	11.44	-6.62	-5.377	0.0000	***
Daily rent (2017 COP)	147	$ 80,288	$ 10,414	116	$ 81,926	$ 9,699	$ 1,637	1.316	0.1883	
Vehicle age (years)	213	6.00	3.97	179	5.30	3.99	-0.71	-1.747	0.0806	
Num. radiotelephones per taxi	213	0.15	0.37	179	0.44	0.60	0.30	5.840	0.0000	***
Daily traveled km	213	211.14	47.14	179	227.09	49.91	15.95	3.233	0.0012	**
Num. Drivers per taxi	213	1.31	0.24	179	1.35	0.18	0.05	2.133	0.0329	*
Fuel expenditure (2017 COP)	213	$ 33,841	$ 9,412	179	$ 34,715	$ 8,904	$ 874	0.944	0.3454	
Daily gross income (2017 COP)	213	$ 184,984	$ 42,366	179	$ 204,910	$ 47,424	$ 19,926	4.349	0.0000	***
Daily profit (2017 COP)	213	$ 84,737	$ 37	179	$ 97,765	$ 44	$ 13,029	3156.811	0.0000	***
Daily hours worked	213	13.96	2.26	178	13.97	2.29	0.01	0.051	0.9593	

*Note: ***, **, *, and · = significance at 0.1%, 1%, 5%,*

6. Analysis

Between 2009 and 2017 many social, economical, and technological changes occurred that might have affected the taxi industry in Bogotá, Colombia. As mentioned in the context section, ride-sourcing, e-haling, TNCs, and other technology-based transportation options arose in Bogotá during such period. However, other important events took place during that time. First, international oil prices fell dramatically and therefore so did fuel prices in Colombia. Second, taxi fleet finally reached a plateau (51,600 cabs), despite being capped in 36,000 taxis in 1993. After inexplicably growing by around 1.000 taxis per year until 2010, fleet size stagnated at its current level. These three external factors simultaneously acting might blur the explanation of many of the changes presented in previous section.

Drivers and fleet ageing is an interesting phenomena that can be explained by the fleet growth stagnation. In a capped system, in principle, the average age of drivers should be stable in time, since retired drivers are compensated with newer ones. However, having 1,000 new taxis per year, each with 1.33 drivers per vehicle, implies lowering the average age of both. However, even though the emergence of TNCs in Bogotá might also discourage fleet renewal and drivers perception on whether the job is permanent or not, its effects cannot be unveiled through the presented statistical analysis.

To better understand the in and outflow monetary results, we analyzed the evolution in time of the gasoline prices, the fare, and the medallion price (see Fig. 3). Correcting for the value of money in time, the amount of money drivers can charge for a kilometer is 4.9% lower than in 2009. The authority defines the fare setting based on the operational costs of taxis. If fuel is 11.42% cheaper now than in 2009, then the lower fare allowance is justified. This provides more arguments to reject the hypothesis that the taxi industry has suffered a strong decline in their gross and net income. If the income seems to remain the same after corrections for value of money in time, results show that taxi operation changed in order to keep the income conditions.

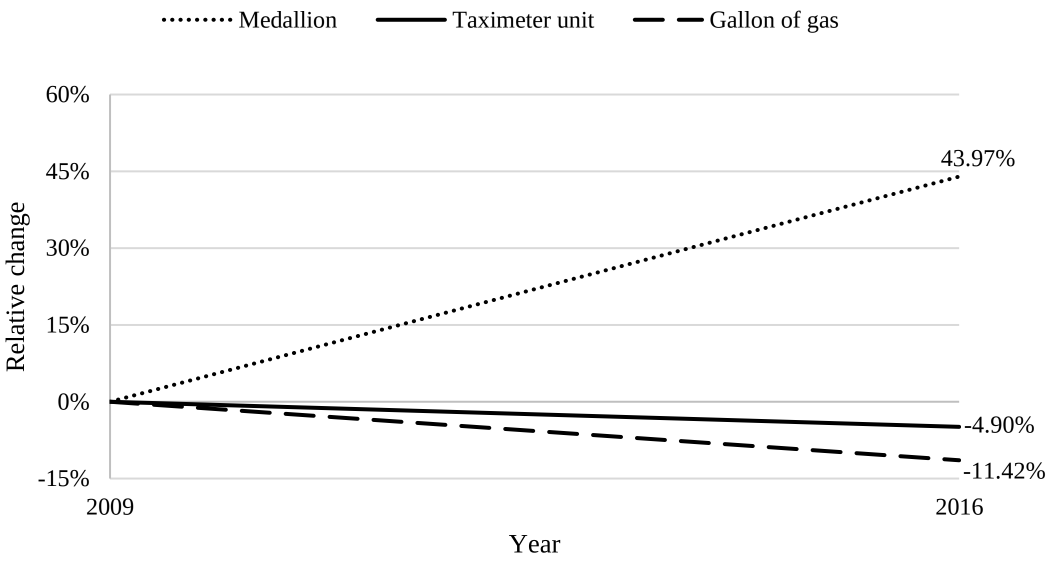

Fig. 3 Relative change in prices

One more actor, not frequently mentioned in the literature that also suffered a negative effect produced by new ICTs is the telecommunication industry attached to the taxi industry. Two binomial logistic regression models were estimated with the purpose of determining what variables can influence the probability of using smartphones or radiophones (see Table 5). For both cases, age and experience are significant factors in the probability of using both communication technologies. The fact that both models have the same significant variables and the same coefficient signs on them, imply a direct substitution of technologies (both target the same population).

By analyzing the data obtained regarding working hours and daily distance per shift, we found an increase in efficiency, understood as the input output relation. The reason to state that is that (a) drivers are working more in the long shift, (b) drivers are working in average the same amount of hours, and (c) they are driving less kilometers per shift. Simplifying the big idea, drivers are getting the same income, driving less kilometers, but with the same efforts. Less distance is to be traveled in the same period of time, possibly due to drivers not having to empty cruise while waiting for a service. Recall that radiophone drivers travel in average 25 km more than the other. Then, the reduction can be accounted on the new mobile communication technologies.

Table 4 shows that taxi drivers that use this technology, have a more efficient operation, since they are increasing their gross income and daily profit, without having to work more hours. This may be related to the probability of use of e-hailing apps, as drivers who use them are generally more educated than the ones who do not (see Table 5).

Table 5. Logit regressions

	Tablet or smartphone (N=394)					Radiotelephone (N=394)			
Variable	Estimate	Std. Error	z value	Pr(>|z|)		Estimate	Std. Error	z value	Pr(>|z|)
(Intercept)	1.2390	0.5837	2.1230	0.0337	*	-0.7085	0.6434	-1.1010	0.2708
Age	-0.0613	0.0112	-5.4530	0.0000	***	-0.0237	0.0120	-1.9680	0.0490
Experience (days)	0.0001	0.0000	1.7140	0.0865	.	0.0001	0.0000	1.9170	0.0552
Educational degree	0.2370	0.1405	1.6870	0.0916	.	0.0912	0.1565	0.5830	0.5602
Socioeconomic level	0.1337	0.1804	0.7410	0.4586		0.0787	0.19	0.4020	0.6879

	Tablet or smartphone (N=394)				Radiotelephone (N=394)			
Variable	Estimate	Std. Error	z value	Pr(>|z|)	Estimate	Std. Error	z value	Pr(>|z|)
						59		
Day-Night operation (Night=1, Day=0)	0.2141	0.3596	0.5950	0.5516	0.3679	0.3702	0.9940	0.3204
Rented (Rented=0, Owned=1)	0.4000	0.2337	1.7110	0.0870 .	-0.4012	0.2650	-1.5140	0.1300

Note: ***, **, *, and · = significance at 0.1%, 1%, 5%, and 10% levels, respectively. Pseudo R^2:0.1085 and 0.0334 respectively

Qualitatively speaking, the substitution in communication technology, from radio-based to internet-based, might have had a positive effect on service quality, personal safety and road safety for users (and drivers), as a matter of fact. In the book *Taxi! The forgotten mode of transportation in Bogotá* the authors highlight the negative issues of radio dispatch. Open competition among drivers to be the first to arrive at a location to pick up a ride, generated reckless driving. Constant oral announcement of rides by the operator to a group of drivers caused noise and discomfort for users. Finally, sometimes in Bogotá, indecorous taxi drivers, listening illegally to taxi frequencies, picked up users. This situation generated constant discomfort to users, because of the lack of certainty of the identity of the driver.

With current dispatch technology for taxis in Bogotá, although not all three problems are solved, some positive outcomes come by with the change. Recall that taxi companies oversaw receiving users' complaints and grievances, making them be both the judge and interested party, thus generating a perverse incentive to provide low sanction rates, impunity and low service. With the mobile internet-based taxi dispatch apps, this situation improved dramatically due to the two-sided rating system. However, as mentioned in the context, there is still the issue of multiple e-hailing apps that can be simultaneously used by taxi drivers. Furthermore, another advantage brought by the new technology is the possibility of offering a surcharge to drivers during peak periods, to generate incentives for them to provide a service therefore facilitating users' access to taxis.

The self-adduced devastation of the taxi industry due to unregulated operation of ridesourcing, ridesharing, and other TNCs in Bogotá is not completely true. While we have analyzed that there are some groups that have been negatively affected, there are other that have been better off. On the one hand, the night shift drivers, the radiophone industry, and "cupo" owners have been certainly damaged at some point, but on the other hand, day shift and long-shift drivers have kept their income and profit, in spite of ridesourcing. Taxi companies also have kept their income, as long as the number of taxis in Bogota has remain constant, and each taxi must be affiliated to a single company. Even some of the radiophone companies (attached to taxi companies) stared developing e-hailing apps, which are also profitable activities.

The devastation of taxis after ridesourcing, would have shown other different symptoms in the system. In terms of economics, taxis is an atomistic market, in which service providers act in zero profit. Whenever the business is not enough to pay the expenses (including the salary of the driver and the capital costs of the owner), people would simply quit to other labor markets. That happened indeed in the night-shit drivers in Bogotá, whose demand was extremely reduced by the unregulated lower prices of Uber. Many of the owners, just changed the scheme from two 12-hour shifts to long shifts, reducing the supply during the night until the equilibrium. Conversely, day and long shift drivers keep working continuously throughout the day

Technological revolution produced disruption in taxi industry. A set of unexpected situations arose that require the development of policies. In the case of taxi industry, we already mentioned some of these situations. According to the multiple stream theory, "when simultaneously a problem is recognized, a solution is available, and the political climate is positive for change, a window of opportunity, a policy window, opens which facilitate policy change" (Guldbrandsson and Fossum, 2009, p. 435). But for policy makers to act, a key factor is knowledge (Crow and Sarewitz, 2000).

The lack of knowledge produced uniformed public debate, which at the end turned in many cases into the dilemma between taxi versus Uber. However, the societal interest goes beyond this dichotomous fallacy, rooted in industry interests and moral rhetoric. The questions associated to this overarching social interest to produce this required knowledge can address the effect of technology on the urban transportation systems; e.g. changes in VMT, congestion, users waiting time, users' satisfaction, transportation system efficiency, etc. In such turbulent environment, academia might have tried to provide evidence to enrich the discussion and to contribute to develop the most convenient policies.

7. Conclusion

This research has found conclusive and robust evidence to state that taxi industry operation in general has not suffered the devastation reported by drivers and taxi industry leaders, due to the emergence of TNCs in Bogotá. In terms of gross income, the industry is receiving statistically the same amount of money as it was in year 2009 even though the maximum fare permitted charge declined 4,9% (later correcting for money value in time). In terms of the net income, we also did not find a significant change between 2009 and 2017, but the changes in the cost of several other expenses, like fuel, makes difficult to make detailed inferences about the internal compensations.

A second conclusion is that new individual mobile communication technologies have had improved operation efficiency of taxis, reducing their average daily traveled distance, while keeping constant working time and income. This implies an important effect for congestion (less VKT) and for the environment (less CO2 resealed). Also, as mentioned previously in the literature review, e-hailing apps produce positive consequences on users' perception, as it is easier to get a taxi and users can see drivers distance from the pickup point, vehicles and drivers' information thereby perception of safety improves.

While the public debate has focused on the false dilemma whether taxi or uber is better, academia might have tried to provide evidence to enrich the discussion and to contribute to develop the most convenient policies. Regarding this debate, the Mobility Authority is now implementing e-hailing app of mandatory use to improve the quality and efficiency of the service.

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