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Was household internet adoption driven by the reform? Evaluation of the 2013 telecommunication reform in Mexico

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ABSTRACT

In 2013 the Mexican Telecommunications and Broadcasting Reform was launched with the goal of promoting competition and access in the telecommunications sector. The aim of this paper is to evaluate whether the 2013 reform had an impact on household fixed internet adoption and to what extent Mexican households, classified into ten wealth groups, had adopted internet. For the assessment, after a revision of supply and demand Reform's measures to reduce the digital divide, data from the 2010 Census and 2015 Intercensal Survey were used to create adoption indexes using Poisson estimations. The results were analyzed by ten wealth groups, constructed on principal components based on household characteristics (type of dwelling, electricity availability, availability of drinking water, sewer system, internet and ICT devices: computer, telephone, cell phone and internet). Additionally, the impact of both indexes was validated by a difference in differences method. The results suggest a 66% overall increase in internet adoption between 2010 and 2015. The decile analysis showed considerable internet adoption in the low and middle wealth groups (deciles 2–8), while in the highest wealth groups (deciles 9–10) the impact of internet adoption has been relatively moderate. It is worth noting that internet adoption is unequally distributed, as less than 1% of households in deciles 1 to 6 had adopted internet in 2015, while nearly all of the wealthiest ten percent of households have internet access. Nevertheless the increment in internet adoption was not only the result of the reform but the combination of the broadband penetration trend and the reform together.

1. Introduction

Developing countries face a major challenge of digital inclusion. The problem is even greater if the telecommunication market has to cope with regulatory failures, combined with challenging geography and extremely variable population densities. This is the case of Mexico, situated in 51st place in the most recent global competitiveness index, but 71st in the 9th pillar, technological readiness (World Economic Forum, 2017). Despite having leapt forward in recent years, Mexico is far below Chile, the Latin American leader, which is in 38th place in the technological readiness pillar. The WEF report notes Mexico's most significant problems in technological readiness: adoption and use of information technologies by the general population.

In the recent past, Mexico's urgent need for regulatory changes in the telecommunications sector has been pointed out repeatedly (Aceves, 2013; Noll, 2013; OECD., 2012; Ten Kate, 2014). The Mexican telecommunications market has been characterized by high

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concentration, which results in low levels of competition, as well as a lack of facilities and low broadband penetration rates. This was the state of the market when the 2013 Telecommunications and Broadcasting Reform (the Reform) was enacted (SEGOB., 2013). Access to information and communications technologies (ICT) was recognized as a fundamental right by means of a constitutional amendment. Additionally, in the same year, the National Regulatory Authority, Comisión Federal de Telecomunicaciones (COFETEL for its acronym in Spanish), was replaced by a new agency, the Instituto Federal de Telecomunicaciones (IFT for its acronym in Spanish). The new autonomous regulator is in charge of promoting competition and ICT access. Thus far, international agencies (OECD., 2017b) and scholars (Ayala, Chapa, García, & Hibert, 2017; Cave, Martin, Mariscal, 2017; Gamboa, 2017) have examined certain policy decisions by the IFT, such as the creation of the figure of preponderance (a significant market power operator), and imposition of asymmetrical regulation.

On the demand side, the Mexican ICT market possesses certain socio-economic characteristics that may serve as barriers to the adoption of internet, such as high poverty rates and unequal access to social services in terms of education, healthcare, housing and culture (CONEVAL., 2016a). In this regard, it may be noted that according to data from the National Survey on the Availability and Use of Information Technologies in Households (INEGI, 2016b),[1] the main reasons by far for not adopting internet are the lack of economic resources (55.2%). 16.3% of the respondents reported “other” (none of the reasons listed in the questionnaire) as the main reason for not adopting internet access services, followed in third place by lack of internet access services (15.7%) and lack of digital literacy skills (10.8%). Not having an internet-capable device was reported by only 2%. These results are consistent with a previous assessment in Mexico, where poverty is identified as the main reason for technological exclusion (Casanueva-Reguart & Pita, 2010). Unfortunately, the Reform has only been centered on the supply side, as it has not been complemented by digital skills programs (Mecinas, 2016).

Given these facts, and as the impact of the Reform on household fixed internet adoption remains unexplored, the aim of this paper is to evaluate whether the 2013 Telecommunications and Broadcasting Reform had an impact on household internet adoption, and to what extent Mexican households, classified into ten wealth groups, have adopted internet. For the assessment, data from the 2010 Census and 2015 Intercensal Survey are used to create adoption indexes through Poisson estimations. Both census surveys provide detailed information on *household income*, household condition and assets (*such as type of dwelling, electricity availability, availability of drinking water and sewer system, internet and ICT device availability*). As household assets provide a significant contribution to explaining welfare (Torche & Spilerman, 2009), internet adoption is analyzed by constructing ten wealth groups using principal components. Additionally, the impact of both indexes is validated by a difference in differences method.

The paper is structured as follows. Section 2 describes the telecommunication industry in Mexico. It is divided into three subsections; 2.1 explains the Reform, 2.2 describes the evolution of the market, 2.3 presents a compilation of government and private entity digital inclusion programs and 2.4 highlights notable academic works about the Reform. Section 3 presents the methodology, beginning with the research framework. In Section 4 the results are explained and discussed. In Section 5, the main conclusions are presented.

2. The telecommunications industry in Mexico

2.1. The telecommunications reform

In 1990 the Mexican state telephone company was privatized, and Carlos Slim's Grupo Carso bought 51% of its shares. In the following year the group gained total control of the company. For seven years it held a monopoly on long distance and domestic telecommunications in Mexico. It was not until 1995 that the Federal Telecommunications Law was established to provide a regulatory structure to the recently liberalized Mexican telecommunications market (Aceves, 2013). It is important to note that in 1993 the Foreign Investment Act permitted foreign investment up to 49% (Álvarez, 2014). The National Regulatory Agency (NRA), the COFETEL, was created in 1996, with very limited power (Noll, 2013; Suarez, 2016). This limitation is reflected in the fact that the incumbent telecommunications operators took advantage of appeals as a way of delaying their compliance with NRA resolutions. They filed objections against COFETEL decisions to engage in anti-competitive practices, delaying interconnection and access to prevent the entry of new players (Alvarez, 2006). The regulatory agency did not have economic independence either, as it was dependent for its budget on the Ministry of Communications and Transportation.

The document entitled ‘Pact for Mexico,’ published in 2012, one day after Peña Nieto was inaugurated as president, set the first precedent for the telecommunications reforms initiated shortly afterwards, in 2013. The Telecommunications Reform aimed to extend the benefits of competitive markets to the Mexican telecommunications sector, which had long suffered from a quasi-monopoly market structure, as well as to ensure equitable access to telecommunication services (PactoporMéxico, 2012).

On June 11, 2013, the Diario Oficial de la Federación (DOF for its acronym in Spanish), the federal institution responsible in Mexico for publishing up-to-date information on reforms and modifications to laws and regulations, as well as new laws and regulations, announced the reforms (additions) to the Constitution in the field of telecommunications. The decree established that the State would guarantee or promote that provision of services be carried out under conditions of competition, quality, plurality, universal coverage, interconnection, convergence, and continuity, and without arbitrary interference. The reform included, among

[1] The Instituto Nacional de Estadística y Geografía (INEGI for its acronym in Spanish) is the National Agency who regulates and coordinates the National System of Statistical and Geographical Information in Mexico. The INEGI is the Agency who performs: national census and prepare national indexes and others statistical projects.

other points, (Álvarez, 2017): i) constitutionally recognizing several fundamental rights (right of access to ICTs, rights of audiences and users of telecommunications); ii) establishing the IFT as the telecommunications regulatory body; iii) that for the first time, the only legal challenge to a regulation, act or omission of the IFT would be through a special judicial review (indirect amparo proceedings) and injunctions would be prohibited; iv) the creation of special courts and judges specialized in broadcasting, telecommunications and economic competition to provide more certainty in this highly litigated field; v) defining the figure of preponderance (market dominance); vi) making the limits on foreign investment more flexible (100% in telecommunications and 49% in broadcasting); vii) building a public wholesale shared mobile network; viii) mandating the establishment of a public broadcaster; and ix) deeming telecommunications and broadcasting services to be public services of general interest.

The IFT was created in September 2013 as a constitutionally autonomous entity. The new NRA conducted a market analysis and imposed asymmetrical regulation. The IFT determined the preponderant carriers to be telecom and broadcast groups that had more than 50% Mexican ownership, and these were deemed to be Preponderant Economic Agents (PEA) based on the number of users, audience, network traffic or capacity. Special obligations were imposed on the PEA in order to limit their market power (Álvarez, 2014).

In the telecommunications sector, Telcel and Telmex, Grupo America Movil's mobile and fixed operators respectively, were designated Preponderant Agents. The obligations imposed on the incumbent telecommunications company can be summarized as follows: i) to provide new entrants with access to all elements that may be necessary for the provision of service to the company's end users; ii) to allow commercialization and resale of their network services and capacity to Mobile Network Operators (MNO) in the technologies available in its system, and for all the telecommunication services that the PEA offers to its users. Network neutrality, not discriminating between content, applications, and traffic of different services and providers, must be guaranteed; iii) to allow concessionaires of public telecommunications networks to access and use the passive infrastructure that they hold under any legal title; iv) elimination of roaming charges (national); v) asymmetric interconnection rates; vi) a price cap to end users of fixed communications; among others (IFT, 2014). As can be seen, the most significant and immediate measures affecting end users were on mobile telephony.

2.2. Evolution of the market

Mexico has a population of 112.34 million distributed in 31.8 million households (INEGI, 2010). The country is characterized by a significantly unequal distribution of household income. According to the OECD, the richest 10% of the population in Mexico earns 20 times more than the poorest 10% (OECD., 2017a). For the present analysis, it is important to note that in mid-2010, 22.2 million inhabitants could not afford the basic monthly basket (extreme poverty) and 59.6 million lived below the welfare threshold.[2] In 2010, the basic monthly basket of goods per person was 970 MXN, and the welfare threshold was 2107 MXN (CONEVAL., 2016a). Unfortunately, there is no information for 2015, but in 2016, 21.4 million Mexicans were reported to be living in extreme poverty, and 62 million below the welfare threshold. It can be inferred that almost 2 deciles of the Mexican population; 19.4% in 2010 and 17.5% in 2016, live in extreme poverty and can not afford internet service (Avgerou, 2010).

During the first quarter of 2017, the telecommunications industry accounted for a 3.4% share of the GDP, approximately USD 35.56 billion (IFT, 2017b). Despite the large size of the telecommunications market, only 60 out of 100 households are fixed-line telephone subscribers, and only 49 out of 100 households are fixed-line broadband subscribers (IFT, 2017b). As outlined above, the telecommunication market is highly concentrated. Before the Reform, America Movil's Telmex had 71% of the total subscribers in fixed telephony and 60.2% of the fixed data share. In the mobile segment, America Movil's Telcel had 69% of subscribers in telephony and 68.6% in mobile data. At the same time, Grupo Televisa had 60.1% of pay TV subscribers and 70% of the free-to-air TV market (Álvarez, 2015).

Fig. 1 shows the behavior of total fixed telephone line growth in Mexico from 2010 to the first quarter of 2017. The data show two trends: positive annual growth from 2011 to 2013, when maximum growth was achieved, and negative annual growth rate subsequently. This effect may be due to the fixed–mobile substitution as suggested by the literature (e.g. Srinuan, Srinuan, & Bohlin, 2012; Suárez & García-Mariñoso, 2013; Vogelsang, 2010; Ward & Zheng, 2012).

Fig. 2 shows the revenues of fixed telecommunication services per operator in 2013 and 2016. The graph shows that the preponderant operator recorded a loss of almost ten percent. Despite data inconsistency due to the change of the NRA, the data suggest that the loss was not absorbed by other operators.

At the same time, fixed-line and broadband penetration (subscriptions per 100 persons) has maintained a consistently positive pattern of growth since 2014 (Table 1). It is important to note that fixed broadband increased by 20% from 2014 to 2017.

Fig. 3 shows market share evolution from 2014 to the first quarter of 2017. Overall, there has not been any substantial change; America Movil continues to dominate the fixed telephony market. The market power of the incumbent company has dropped by only 1%, while the rest of the operators maintained their market share, except Megacable and Others. Megacable showed the highest growth during the period, increasing from 4% to 7%. 'Others' recorded the largest decrease, falling from 12% to 9%.

The fixed broadband market (Fig. 4) was more dynamic than the fixed-line telephone market. Despite maintaining preponderance, America Movil lost 8% of the fixed broadband market from 2014 to 2017. Two operators have strengthened; Grupo

[2] The welfare threshold is equal to the total value of the basic basket and non-basic basket per person per month. The latter includes public transport, cleaning and care of the house, personal care, education, culture and recreation, communications and services for vehicles, household and conservation services, clothing, footwear, and accessories, glassware, and household utensils, healthcare, household appliances and house maintenance, recreation articles and other expenses (CONEVAL., 2016b).

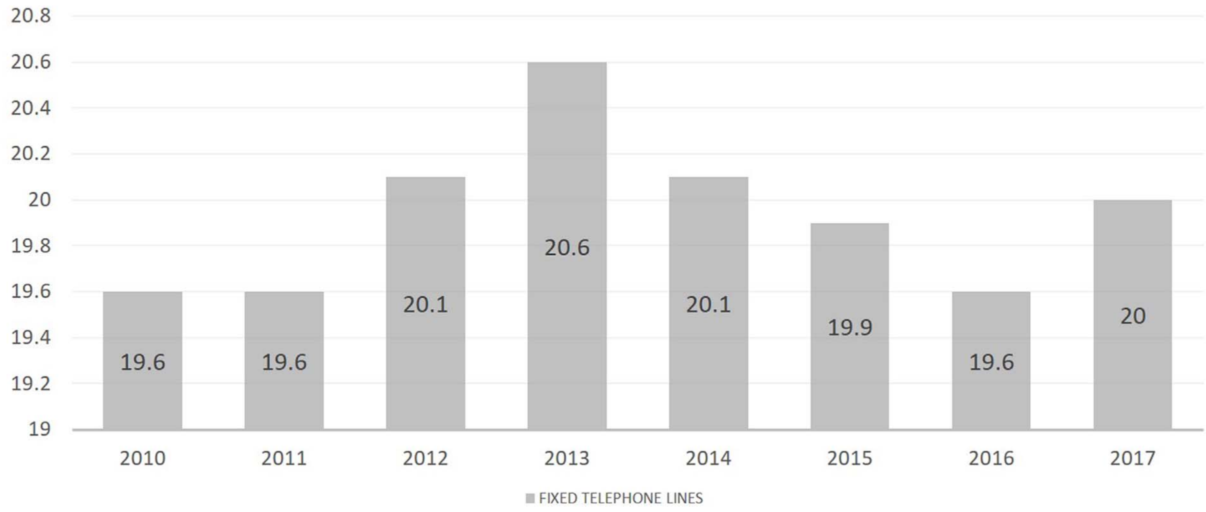

Fig. 1. Fixed telephone lines. COFETEL (2010, 2011, 2012) and IFT (2017a).

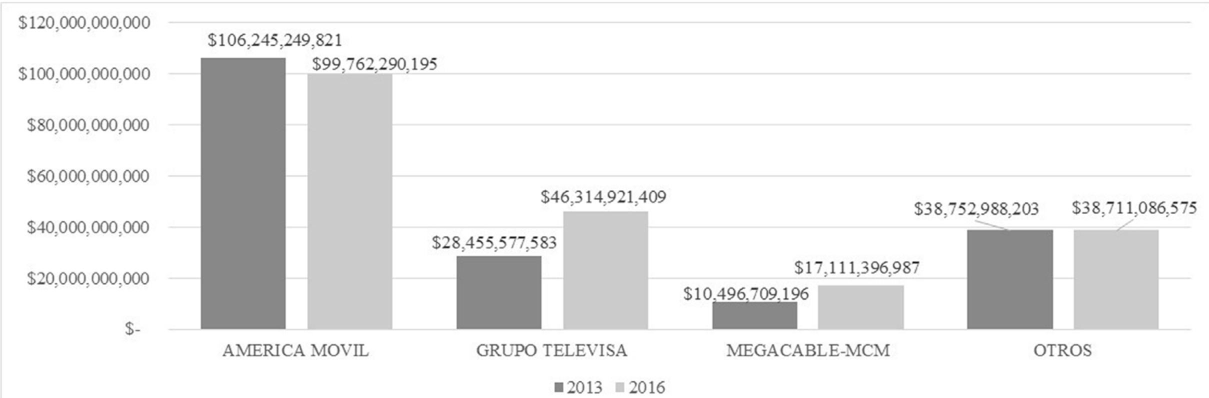

Fig. 2. Revenue per operator (2013–2016). IFT (2017a).

Table 1
Evolution of fixed telecommunications.
Source: IFT (2016, 2017b).

Concept	Fixed telecommunications			
	2014	2015	2016	2017
Fixed-line subscriptions (millions)	18.60	19.30	19.60	20.03
Fixed-line penetration (subscriptions per 100 persons)	58	59	59	60
Fixed broadband subscriptions (millions)	13.00	14.80	16.10	16.21
Fixed broadband penetration (subscriptions per 100 persons)	41	45	48	49

Note: 2017 data first quarter only.

Televisa, achieving 20% of the market, and Megacable, with a 5% increase from its original market share.

Prices of telecommunication services have been decreasing since the Reform. It is notable that mobile telephony is the service that has dropped the most in price, because of the imposition of asymmetric access charges, such as mobile termination rates which were reduced to zero in the case of the preponderant agent. The price index for internet service has remained stable, but the volume of data offered to users has increased (IFT, 2017a). Fig. 5 shows the behavior of the price indexes of communications and fixed internet during the study period.

2.3. Government and private entity digital inclusion programs

After revising all the Reform measures to reduce the market efficiency barrier, it is necessary to explore the actions implemented

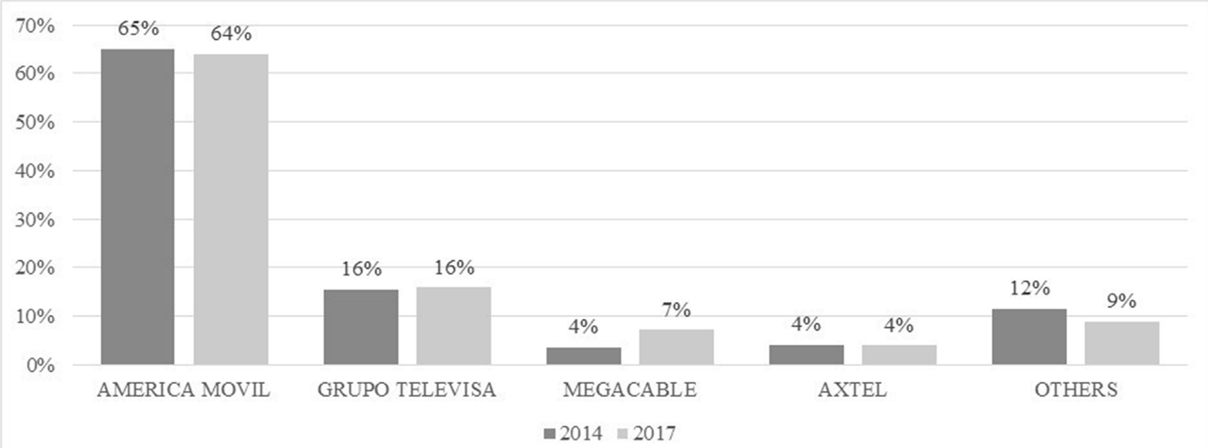

Fig. 3. Distribution of fixed telephone lines by operator. IFT (2017a).

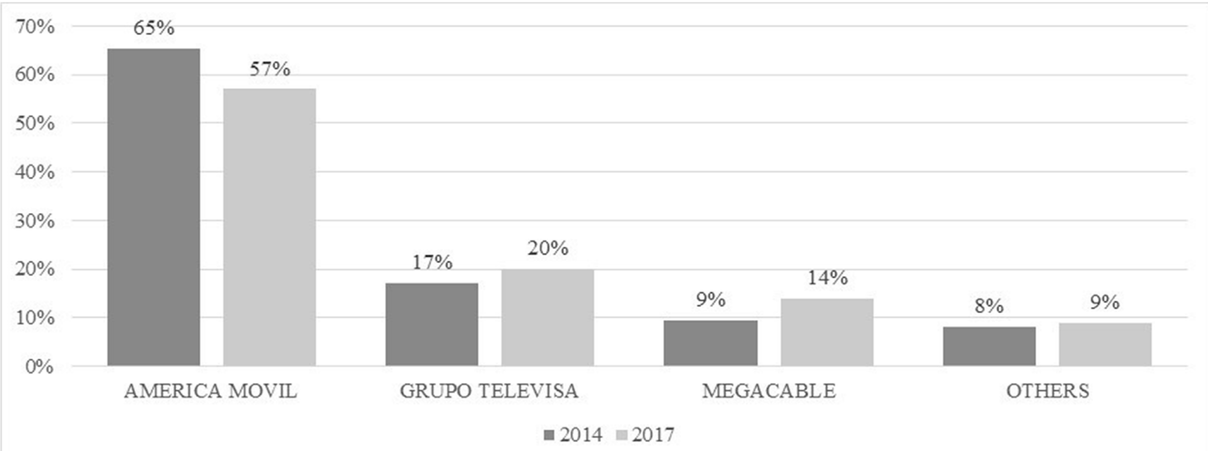

Fig. 4. Distribution of broadband by number of accesses. IFT (2017a).

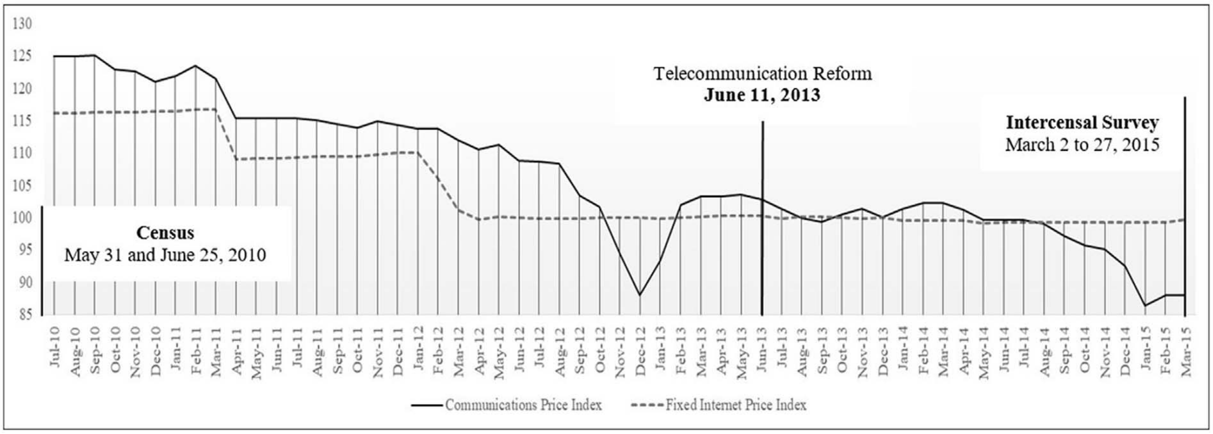

Fig. 5. Behavior of the price indexes of communications and fixed internet. IFT (2017a,b).

to reduce digital exclusion. Table 2 shows a summary of the public and private programs with national wide coverage, since the introduction of broadband in the National Social Coverage Fund in 2002 (Casanueva-Reguart, 2018). It is worth mentioning that private foundations, such as Telmex Foundation or Intel, had developed (few) computer centers with internet access. However, those centers were only rolled-out in Mexico City, Coahuila City and Durango City, which implies no or very limited impact to the total

Table 2
Government and private entity national wide connectivity programs.
Source: Prepared by the authors.

Program	Description	Results
National system e-Mexico -Digital Communitary Centers (DCC)	Since 2002 the Mexican Communications and Transportation Ministry launched digital centers, a pool of computers having access to the internet, in order to provide access. Educational, health, economic and government digital content was available on those computers. (Casanueva-Reguart, 2018).	By 2010, 3000 DCCs were reported to be in service, however this program impact was very limited and focused on specific groups (students, health and government workers) (Pérez Salazar & Carabaza, 2011).
Bill & Melinda Gates Foundation: “Program of Access to Digital Services in Public Libraries”	This program provided computers in 8000 public libraries throughout the country. The program was also intended to provide internet access (Pérez Salazar & Carabaza, 2011).	The program faced serious connectivity problems and was only focused on elementary school students (Santos, Maria, and De Gortari, 2009).
e-Digital Agenda	In 2010 e-Mexico (new DCCs deployment) program was relaunched to connect remote and marginalized areas.	Results were not published (Quintanilla, 2016).
National Digital Strategy “México Conectado” (Connected Mexico)	Since 2012, more than 65,000 public buildings (schools, clinics, town halls, parks and libraries) offer free Wi-Fi. The government committed to provide 250,000 Wi-Fi hotspots by the end of 2018.(Quintanilla, 2016)	Current program, there are not impact result yet.
National network of training and digital education community centers	Since 2015, 32 (one per state) Digital centers are operating in Mexico (Communications and transportation Ministry, 2015).	Current program, there are not impact result yet.
Pilot program for Digital Inclusion	During 2013–2016 the government implemented a pilot program with reduced coverage of digital skills and provided gadgets to elementary school students (Presidency of the Republic, 2016).	Limited, it was almost centered in providing gadgets (Mecinas Montiel, 2016).

Mexican Population (Pérez Salazar & Carabaza, 2011). Additionally, they were other public programs on schools and in other public spaces without national wide coverage that were not considered in this study.

Despite most digital centers counted with some king of digital skills programs, they were focused on specific groups (e.g. elementary school students, government workers, health workers, etc.), therefore overall population had not benefitted from these programs. Finally, it can be concluded that most of the initiatives have been focused on providing access, while a national wide digital skills program is lacking.

2.4. Related work

Since the Reform was as recent as 2013, there are not a large number of articles related to policy evaluation. However, the IFT issued a working paper by Cave, Martin, and Mariscal (2017), about the impact of asymmetric mobile regulation on less well-off Mexican households, using a descriptive approach. The analysis focuses on evaluating the elimination of termination rates on the network of the preponderant mobile telephone provider. This paper uses more detailed data about household spending on mobile telephony, provided by comparing the 2014 and 2016 National Survey of Household Income and Expenditure. The article concludes that lower income households benefited the most (Cave, Martin, and Mariscal (2017)). This valuable article is the closest to the present study; however, there are significant differences. Cave, Martin, and Mariscal (2017) focused their assessment on only one of the Reform measures and only on mobile telephony service.

Another similar assessment was carried out some years earlier by Barrantes and Galperin (2008), in which the cost of mobile telephony is evaluated in several Latin American countries. The study found that affordability is the most significant barrier to extending the reach of mobile service, which is the reason that Latin American countries are lagging behind in mobile telephony penetration (Barrantes & Galperin, 2008). Casanueva and Bacilio (2014, 2015) also studied the relationship between the impact of telecommunications and poverty. The impact of national broadband plans in Latin American countries have been studied by Galperin, Mariscal, and Viecens (2013) and Katz (2015).

Ayala et al. (2017) have recently published a study on the welfare effect of the Reform through a general equilibrium model for the Mexican economy. Their results suggest that the drop in telephone prices is the main driver of the welfare effect, but benefiting mainly the highest income households (Ayala et al., 2017). Unlike the approach proposed here, where demand conditions affecting internet adoption are assessed, the paper focuses only on consumer welfare and income distribution. None of these studies have examined the impact of the 2013 Mexican Telecommunications Reform on internet adoption through a wealth approach.

3. Methodology

The aim of the paper is to assess whether the 2013 Telecommunications Reform in Mexico led to an increase in fixed internet adoption and to compare internet adoption behavior in households of different wealth groups. Fig. 6 shows the general framework of the study.

The research framework includes a review of two statistical reports published by INEGI. The first is the 2010 Population and

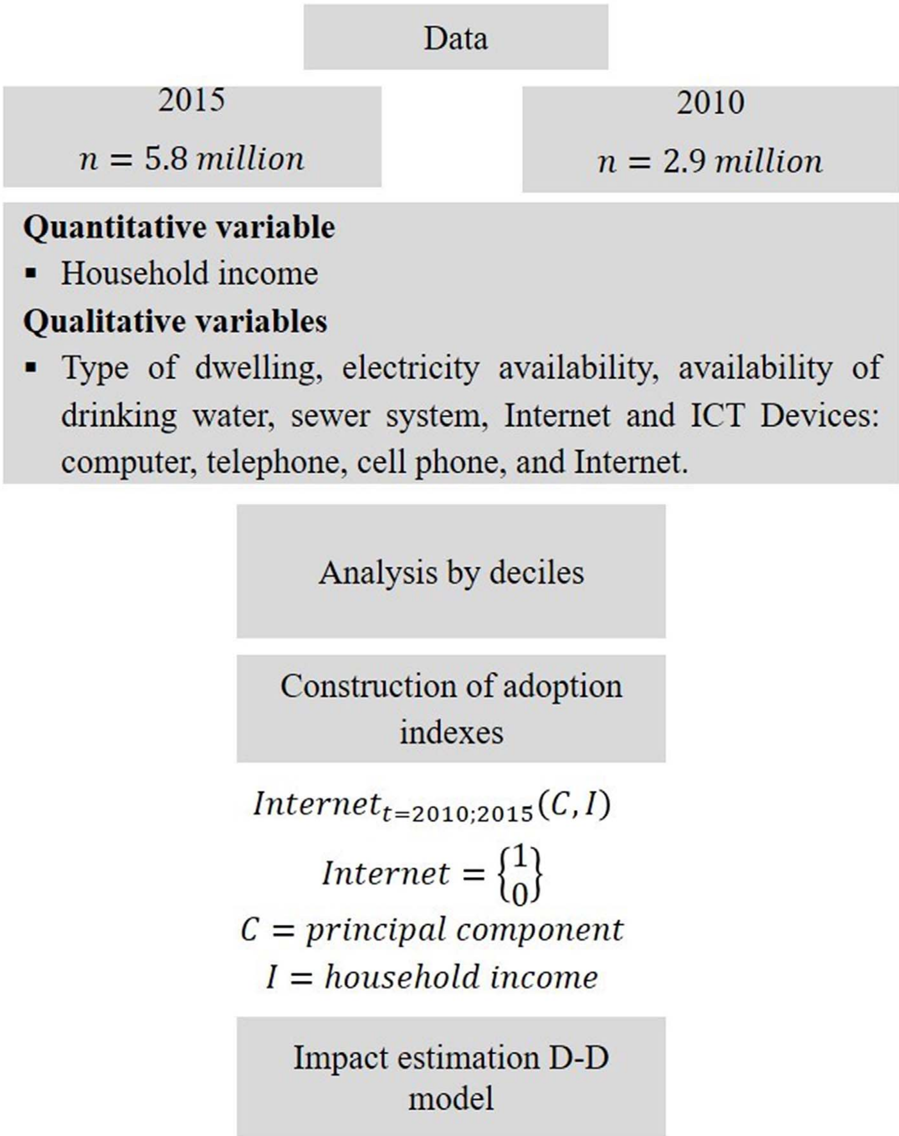

Fig. 6. Research framework.

Household Census and the second is the 2015 Intercensal Survey. For the purposes of this analysis, the household is defined as "a unit formed by one or more persons, related or not, who customarily reside in the same private dwelling" (INEGI, 2017). Both documents provide sociodemographic information that can help define or reorient Mexican economic public policy.

Both statistical surveys were based on probability samples. For the 2010 survey, the sample consisted of 2.9 million households, and data were collected May 31 to June 25, 2010 (INEGI, 2010). In 2015, the sample was made up of 5.8 million households, and data were collected March 2 to 27, 2015 (INEGI, 2015). Despite having different characteristics, the two documents are historically comparable (INEGI, 2015). It is important to mention that there are other statistical surveys generated by INEGI, such as the National Survey on Availability and Use of Information Technologies in Households – ENDUTIH, for its acronym in Spanish (INEGI, 2016b), which includes more detailed information on the availability and use of information technologies and communications in households; and the National Survey of Household Income and Expenditure – ENIGH, for its acronym in Spanish (INEGI, 2014, 2016a). These surveys have more detailed information about the use and cost of ICTs; however, the number of observations are much lower, and they weren't available at the beginning of the research. Furthermore, at the time this project was initiated, the published editions of ENDUTIH and ENIGH did not have national and state level representativity. In spite of not having very detailed data, the 2010 Census and the 2015 Intercensal Survey provide consistent information on internet availability and household income. In addition, they also report a large set of relevant data that is useful for the construction of wealth groups using principal component analysis (Abdi & Williams, 2010). This approach has been used in similar studies (Córdova, 2009). It is important to note that this analysis had previously been done using quartiles and quintiles, however, due to high income concentration, a decile analysis was chosen to

Table 3
2010 Descriptive statistics.
Source: Prepared by the authors.

Variable	Obs	Mean	Std. Dev.	Min	Max
Type of dwelling	2,903,640	1.09896	0.7030896	1	9
Electricity availability	2,885,227	0.9545589	0.2082697	0	1
Availability of drinking water	2,626,692	0.4987726	0.4999986	0	1
Sewer system	2,874,519	0.5051245	0.4999738	0	1
Internet and ICT Device: computer	2,882,847	0.172374	0.3777053	0	1
Internet and ICT Device: telephone	2,882,380	0.2896794	0.4536136	0	1
Internet and ICT Device: cell phone	2,883,058	0.4670458	0.4989129	0	1
Internet and ICT Device: internet	2,882,004	0.1124513	0.3159209	0	1
Household income	2,310,550	6380.41	12947.82	0	999998

monitor adoption effects in the less well-off households.

The database constructed for analysis purposes contains microdata on eleven variables related to household condition, and internet and ICT device use by geographic unit, following other recognized reports (e.g. Nam, Huang, & Sherraden, 2008). The variables can be grouped into four dimensions. The first relates to the geographic location of the households: *state and municipality levels*. The second corresponds to dwelling and household characteristics: *type of dwelling* (for example detached house, apartment or mobile home), *electricity availability, availability of drinking water and sewer system*. The third dimension relates to *internet and ICT devices: computer, telephone, cell phone, internet*. The fourth dimension is referred to as *household income*. The variables related to dwelling and household characteristics and internet and ICT devices are dichotomous, where zero represents absence and one represents presence (Tables 3 and 4).

A Poisson distribution is proposed for the analysis of the variable *Internet Access*. This variable has a large number of zeros because of its categorical nature. The Poisson estimation method is one of the most useful models for the study of discrete variables (Greene, 2008) and in internet diffusion studies (Dinterman & Renkow, 2017; Srinuan, Srinuan, & Bohlin, 2014; Stern, Adams, and Elsasser, 2009; Yamin et al., 2011). It also eliminates correlation between the error term and the explanatory variables, since it assumes a maximum likelihood function with $E[\,x\,|u\,] = 1$ as its multiplicative form. The advantages of using a Poisson distribution are the ability to accurately adjust the dependent variable to the data, the fact that the distribution has a strictly positive domain, and the construction of a nonlinear index. The Poisson model is defined by:

$$Prob(Y = y_i|x) = \frac{e^{-\lambda}\lambda_i^{y_i}}{y_i!} \quad y_i = 0,1,2, \dots \tag{1}$$

where

$\lambda_i > 0$ is a parameter of the distribution.

$Y =$ is the dependent variable(*Access to the Internet*).

$X =$ is the vector of independent variables (initial conditions of the household – *type of dwelling, electricity availability, availability of drinking water, sewer system, Internet and ICT Device: computer, telephone, cell phone and Internet, and income levels of the household).*

The purpose is to estimate the probability that $Y = y$ for each observation, where λ_i takes a value for each observation. The most common formulation for λ_i is the loglinear model. Taking the logarithm of both sides of (1), we have:

$$ln\lambda_i = x_i^{'}B \tag{2}$$

where

B is the vector of coefficients to be estimated.

Table 4
2015 Descriptive statistics.
Source: Prepared by the authors.

Variable	Obs	Mean	Std. Dev.	Min	Max
Type of dwelling	5,854,392	2.8544	12.24134	1	99
Electricity availability	5,826,321	0.976645	0.1510284	0	1
Availability of drinking water	5,514,675	0.5313702	0.499015	0	1
Sewer system	5,805,232	0.5737342	0.4945334	0	1
Internet and ICT Device: computer	5,813,807	0.2005739	0.4004298	0	1
Internet and ICT Device: telephone	5,812,499	0.2425862	0.4286469	0	1
Internet and ICT Device: cell phone	5,814,455	0.6620424	0.473014	0	1
Internet and ICT Device: internet	5,811,062	0.1855642	0.3887546	0	1
Household income	4,284,582	7527.84	12833.16	0	999998

Therefore, the expected number of events per period is given by:

$$\frac{dE[y_i|x_i]}{dx_i} = \lambda_i B \tag{3}$$

With the parameter estimates in hand, the desired vectors are calculated. With the Poisson model, it is much easier to estimate the parameters than with maximum likelihood techniques, so the log-likelihood function is:

$$ln \ \ L = \sum_{i=1}^{n} [-\lambda_i + y_i x_i' B - ln \ \ y_i!] \tag{4}$$

The likelihood equations are:

$$\frac{d \ \ In \ L}{d \ \ X} = \sum_{i=1}^{n} (y_i - \ \lambda_i) X_i = 0 \tag{5}$$

where the parameter λ_i is known.

Introducing the error term to capture the heterogeneity of observations, we have:

$$ln \ \ \mu_i = x_i' B + \xi_i = ln \ \ \lambda_i + ln \ \ u_i \tag{6}$$

where $E(\text{In } u_i|\text{x}') = 0$

In multiplicative form this can be expressed as:

$$f(y_i|x_i, u_i) = \frac{e^{-\lambda u_i} u_i^{y_i} \lambda_i^{y_i}}{y_i!} \tag{7}$$

The indexes are estimated using the Poisson method, according to the following equations:

$$y_{i2010} = \alpha_0 + \alpha_1 C_{i2010} + \alpha_2 I_{i2010} + u_{i2010} \tag{8}$$

$$y_{i2015} = \sigma_0 + \sigma_1 C_{i2015} + \sigma_2 I_{i2015} + \varepsilon_{i2015} \tag{9}$$

where C_{i2010} and C_{i2015} are the first principal components (Abdi & Williams, 2010) of the initial household characteristics *(type of dwelling, electricity availability, availability of drinking water, sewer system, internet and ICT device: computer, telephone, cell phone and internet)*.

y_{i2010} and y_{i2015} take the value 1 when there is access to the internet, and 0 when there is not.

I_{i2010} and I_{i2015} are the monthly *income levels of the household*.

Hence, for every i we have:

$$\widehat{y_t} = Adoption \ \ Index \ \ by \ \ Household \tag{10}$$

The difference in differences method (D-D), introduced by Ashenfelter and Card (1985), is used to evaluate public policies (Khandker, Koolwal, & Samad, 2010). In this particular case, the model evaluates the result of the implementation of policies over time for the control group (t = 2010) and treatment group (t = 2015). The most general specification is:

$$\widehat{y_t} = \delta_0 + \delta_1 t + \delta_2 T + \delta_3 tT + \theta \tag{11}$$

where:

δ_0 is the intercept of the equation
δ_1 is the time effect for $t_{2010;2015}$
δ_2 is the adoption effect in the Treatment Group (T)
δ_3 is the D-D effect (interaction between T and t)
As there are only two years of analysis, due to multicollinearity the model is reduced to:

$$\widehat{y_t} = \delta_0 + \delta_3 t \ \ T + \theta \tag{12}$$

After Equation (9) is estimated by ordinary least squares (OLS), we have

$$\hat{y} = \widehat{\delta_0} + \widehat{\delta_3} t \ \ Internet \tag{13}$$

In order to eliminate the adoption trend, (13) is estimated without the intercept (Khandker et al., 2010); resulting in:

$$\hat{y} = \widehat{\delta_3} t \ \ Internet \tag{14}$$

4. Results and discussion

4.1. Results

To analyze the effects of the 2013 Telecommunications Reform on internet adoption, two adoption indexes were constructed, for

Table 5
Descriptive statistics.
Source: Prepared by the authors.

Adoption Index	N	Mean	Standard deviation	Min	Max
Adoption Index 2010	2,088,838	0.1332629	0.2723592	0.0001439	5.396808
Adoption Index 2015	4,064,939	0.2210554	0.3138913	0.0025979	4.410047

the years 2010 and 2015 as shown in Table 5. It can be seen that in 2010, the mean index of households with internet access was 13.33%, and in 2015 it was 22.11%, which represents a 66% increase.

Table 6 suggests that *Wealth* and *Household Income* have a positive and statistically significant effect on internet adoption. It can be seen that the *Wealth* effect is greater in 2010 than in 2015. This result could be the consequence of the Reform, even though the Reform led to increased internet adoption. The estimators of *Household Income* show a zero effect on internet adoption. This result is a consequence of the scale (Mexican pesos).

The *pseudo* R^2 (maximum likelihood version of the coefficient of determination) indicates the percentage of variability explained by *Household Income* and *Wealth* on internet adoption. It is observed that the *pseudo* R^2 is bigger for 2010 than for 2015. This could be the consequence of the lower influence of both variables (*Wealth* and *Household Income)* on 2015 *Wealth* on internet adoption derived from other factors, such as the effectiveness of the Reform.

Table 7 displays endogeneity and omitted variables test for the year 2010 and 2015. Results shows that Poisson method is appropriate for the analysis, as Table 7 illustrates that there are no determined endogenously regressors, hence it is not necessary an instrumental variables estimation.

Tables 8 and 9 show other relevant statistical data, confirming the proper models specifications.

Tables 10 and 11 show household income distribution for 2010 and 2015 by decile. It can be observed that the first decile did not report any income in 2010, and that the first three deciles in 2010 and the first two deciles in 2015 are below the welfare threshold. Although the household income census data is not as robust as ENIGH, the unequal income distribution and wealth concentration in Mexican households can be observed. It is important to note that the differences between the observations of the samples and the observations of the analysis (approximately 0.6 million and 1.6 million households respectively) are because not all respondents reported income. Tables 6 and 7 show the effect of adoption per decile.

The analysis of *Adoption Index* by deciles is shown in Table 12. Although the adoption effect is unequally distributed in the wealth groups, it is worth noting that there is a positive effect in all deciles. In absolute terms, it can be observed that deciles 9 and 10 have a very high value of *Adoption Index*. Decile 10 in particular has almost reached maximum adoption, implying that nearly all of the wealthiest households (those in the tenth decile) have internet. In contrast, in deciles 1 to 5, the groups with the lowest incomes, the adoption level is much lower. It may be noted that despite a 300% increase in internet adoption between 2010 and 2015, adoption in decile 1 only reached 0.04%. This outcome is not surprising, as internet adoption decreases as household income decreases.

Fig. 7 (deciles 1 to 5) and Fig. 8 (deciles 6 to 10), present a comparison of the increase in adoption from 2010 to 2015. The two groups of deciles are presented separately in order to give a more detailed view, as adoption levels vary greatly. Surprisingly, the results shows that deciles 2 to 8 (poor and middle-income households) were the greatest beneficiaries.

All the deciles in this range showed adoption increases above 100% in the study period. It may be noted that households in decile 2 benefited the most. Despite being below the poverty line, decile 2 showed a 1900% adoption increase from 2010 to 2015. It may also be noted that middle income households in decile 8 also experienced a very sizeable adoption increase of 1363%.

Finally, Table 13 shows the estimates of four D-D model specifications (see equation (13) and (14)). These OLS estimated models were applied in order to show alternative ways to measure the impact of the public policy on the internet adoption index. For the first two models, estimated *Adoption Index* (Poisson method) was used. Models 3 and 4 use the logarithm of *Adoption Index* to increase the variation of the observations. Furthermore, the use of the natural logarithm allows a better adjusting to estimates OLS (normality assumption) coefficients (Wooldridge, 2008).

Eliminating the *Intercept* in models 2 and 4 is intended to eliminate the trend and temporary effect on *Internet Adoption* in D-D

Table 6
Results of internet adoption estimates.
Source: Prepared by the authors.

	2010	2015
Wealth	1.492	0.963
	(0.003)**	(0.001)**
Household income	0.000	0.000
	(0.000)**	(0.000)**
Intercept	−4.443	−2.621
	(0.007)**	(0.002)**
Pseudo R^2	0.4470	0.3018
N	2,087,407	4,060,980

*$p < 0.05$; **$p < 0.01$.

Table 7
Test for continuous endogenous covariates.
Source: Prepared by the authors.

	2010		2015	
	Additive	Multiplicative	Additive	Multiplicative
Chi2 (2)	4.30E+05	29037.4	1.60E+06	1.20E+05
P-Value	0.000	0.000	0.000	0.000

Note [1]. GMM Regression (Generalized Method of Moments Estimator.

Table 8
Year 2010 Poisson specification Statistics.
Source: Prepared by the authors.

Goddness of Fit	Deviance	Pearson
Chi2(2087398)	371359	1967777
P-Value	1.000	1.000
LR Test of Overdispersion		
Chibar (01)	0.000	
P-Value	1.000	
Log-Lik Intercep Only	−838811.712	
Log-Lik Full Model	−463852.509	

Table 9
Year 2015 Poisson specification Statistics.
Source: Prepared by the authors.

Goddness of Fit	Deviance	Pearson
Chi2 (4060979)	1350143	2773981
P-Value	1.000	1.000
LR Test of Overdispersion		
Chibar(01)	0.000	
P-Value	1.000	
Log-Lik Intercep Only	−2253000.000	
Log-Lik Full Model	−1573000.000	

Table 10
Household income distribution in 2010.
Source: Prepared by the authors.

Decile	Observ.	Freq	Cum. Freq.	Mean (pesos)	Mean (USD)	STD.	Min	Max
1	379,362	16.42	16.42	0	0.0000	0	0	0
2	108,605	4.70	21.12	546.671	30.3710	264.2424	1	857
3	271,430	11.75	32.87	1673.564	92.9760	392.4095	858	2143
4	207,960	9.00	41.87	2724.789	151.3770	233.0139	2144	3000
5	209,833	9.08	50.95	3588.550	199.3640	273.1618	3001	4000
6	261,162	11.30	62.25	4645.437	258.0800	383.7783	4001	5143
7	185,123	8.01	70.26	6020.696	334.4830	374.6563	5144	6429
8	234,248	10.14	80.40	7832.772	435.1540	720.0213	6430	9000
9	227,785	9.86	90.26	11306.200	628.1220	1402.5350	9001	14000
10	225,042	9.74	100.00	27421.600	1523.4220	33371.0900	14001	999998
Total	2,310,550		100.00					

Note: Exchange rate 18 pesos per USD.

Models. This enables the effects of the Reform on internet adoption to be isolated and analyzed.

The results of the first two models suggest a positive and significative impact of public policy on internet adoption from 2010 to 2015. However, the most interesting results can be observed in models 3 and 4. Model 3 shows a positive effect on *Internet Adoption*, while model 4 shows a negative effect. It should be noted that the coefficient of determination (R^2) is considerably higher in model 4 than any of the previous models, showing that when the trend is eliminated, all possible effects of the reform fade or fall considerably. This result implies that the Reform is not necessarily a determining factor in the increase in internet adoption from 2010 to 2015. This outcome suggests that the internet penetration trend, rather than the Reform itself, could be the most potent trigger of the increase in internet adoption.

Table 11
Household income distribution in 2015.
Source: Prepared by the authors.

Decile	Observ.	Freq	Cum. Freq.	Mean (pesos)	Mean (USD)	STD.	Min	Max
1	429,554	10.03	10.03	215.9389	11.9966	337.3148	0	1000
2	450,669	10.52	20.54	1750.3850	97.2436	371.6874	1001	2143
3	405,179	9.46	30.00	2759.2590	153.2921	234.1813	2144	3167
4	431,193	10.06	40.06	3648.8910	202.7161	268.9231	3168	4200
5	567,765	13.25	53.32	4677.3570	259.8531	383.5851	4201	5143
6	405,448	9.46	62.78	6053.2570	336.2920	358.3978	5144	6429
7	318,344	7.43	70.21	7383.4970	410.1942	448.4860	6430	8000
8	419,559	9.79	80.00	9175.2870	509.7381	707.6659	8001	10501
9	428,744	10.01	90.01	12704.1300	705.7850	1422.5140	10503	15571
10	428,127	9.99	100.00	27851.2400	1547.2911	32618.5900	15572	999998
Total	4,284,582		100.00					

Note: Exchange rate 18 pesos per USD.

Table 12
Adoption Index results (%) by decile.
Source: Prepared by the authors.

Year	Internet Access	1	2	3	4	5	6	7	8	9	10	Total
2010	No	10.39	9.70	9.86	10.06	9.88	10.08	9.66	9.33	6.13	1.58	86.67
	Yes	**0.01**	**0.01**	**0.03**	**0.03**	**0.06**	**0.14**	**0.08**	**0.67**	**3.87**	**8.42**	**13.33**
	Total	10.40	9.71	9.89	10.09	9.94	10.22	9.75	10.00	10.00	10.00	100.00
2015	No	10.02	9.96	9.61	9.69	9.41	9.22	8.84	6.41	4.14	0.59	77.89
	Yes	**0.04**	**0.20**	**0.18**	**0.30**	**0.59**	**0.79**	**1.17**	**3.59**	**5.94**	**9.32**	**22.11**
	Total	10.06	10.16	9.79	10.00	9.99	10.01	10.01	10.00	10.09	9.91	100.00

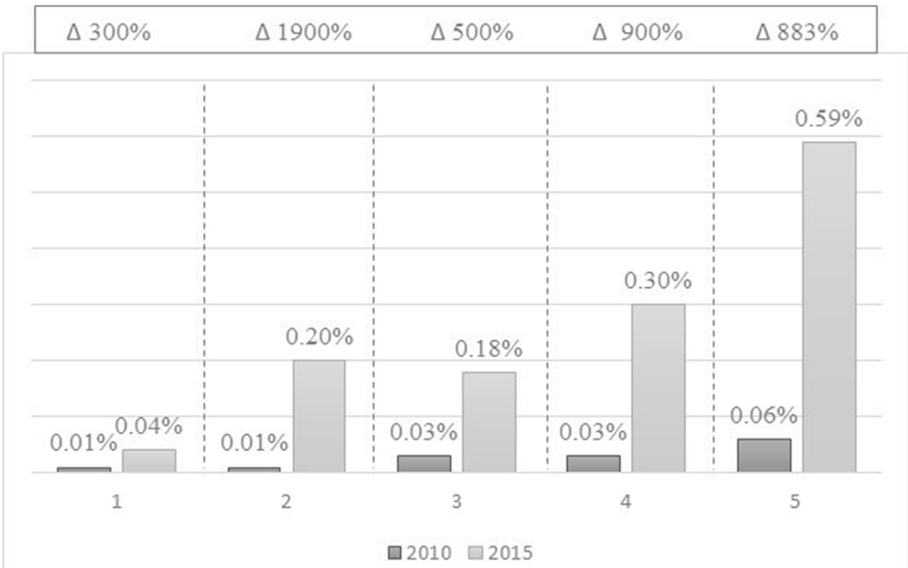

Fig. 7. *Internet Adoption Index* comparison, deciles 1–5.

4.2. Discussion

After conducting the decile analysis and the econometric approach to assessing the Reform, we can conclude the following. The decile analysis showed a considerable increase in internet adoption in the low and middle wealth groups (deciles 2–8), while in the highest wealth groups (deciles 9–10) the impact on internet adoption has been relatively moderate. The econometric analysis (D-D model) reinforces this result in three models, where the internet penetration trend and the adjusted discrete effects from the Poisson estimation are included. However, by separating the indirect effects from the Reform by means of a logarithmic transformation and elimination of the intercept, the results appear to contradict the decile analysis. Nevertheless, this is not entirely accurate, because both the Reform and the internet penetration trend have contributed to the increase in internet adoption. While it is true that the

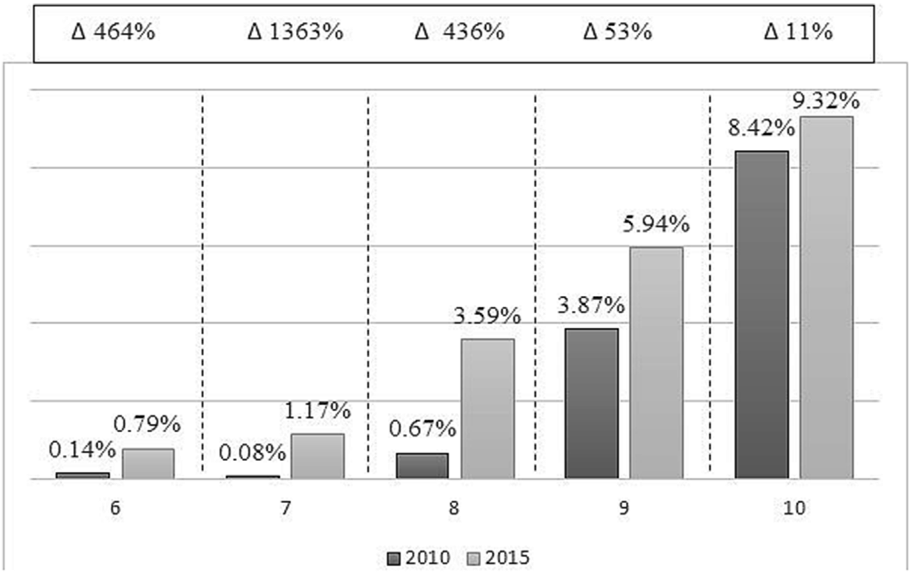

Fig. 8. *Internet Adoption Index* comparison, deciles 6–10.

Table 13
D-D Models.
Source: Prepared by the authors.

Variable	Model 1: Adoption Index	Model 2: Adoption Index	Model 3: ln(Adoption Index)	Model 4: ln(Adoption Index)
2015	0.088	0.221	1.859	−2.457
	(343.25)**	(1436.27)**	(1202.25)**	(1596.70)**
Intercept	0.133		−4.316	
	(641.07)**		(3433.79)**	
R^2	0.02	0.25	0.19	0.29
N	6,153,777	6,153,777	6,153,777	6,153,777
*p < 0.05; **p < 0.01				
Total effect	**0.221**	**0.221**	**−2.457**	**−2.457**

internet penetration trend is highly relevant to explaining the adoption increase, the trend is influenced by the potential number of consumers adopting internet by taking prices and other market characteristics established by the Reform. Furthermore, as most of the Reform's regulatory interventions were centered in improving market's efficiency and a national wide digital inclusion plan is lacking, it is not surprise that the Reform had a limited effect on household fixed internet adoption. Finally, the results obtained in this empirical paper suggest that the internet penetration trend and, to a lesser extent, the Reform are significant factors for the increase in internet adoption.

5. Conclusion

The aim of this paper is to evaluate whether the 2013 Telecommunications and Broadcasting Reform had an impact on household fixed internet adoption and to what extent Mexican households, classified into ten wealth groups, adopted internet services. For the assessment, after a revision of supply and demand Reform's measures to reduce the digital divide, the 2010 Census and 2015 Intercensal Survey data were used to create adoption indexes through Poisson estimations. The results were analyzed by ten wealth groups, constructed on principal components based on household conditions (*type of dwelling, electricity availability, availability of drinking water, sewer system, Internet and ICT Device: computer, telephone, cell phone and internet*). Additionally, the impact of both indexes was validated by a difference in differences method.

Although it is too early to establish a definitive position on the telecommunication Reform, the results suggest that overall the Reform increased internet adoption between 2010 and 2015. This impact is demonstrated by an overall adoption increase of 66%. Furthermore, though the adoption effect is unequally distributed, there is a positive effect in all deciles. However it is worth noting that fewer than 1% of households in deciles 1 to 6 have adopted internet, while nearly all of the wealthiest ten percent of households have internet access. Nevertheless, in relative terms, deciles 2 to 8 (poor and middle-income households) were the Reform's major beneficiaries, as they had adoption increases above 100% in the study period. Surprisingly, decile 2 which is below the poverty line, was the most benefited, as it recorded a 1900% increase in adoption. Conversely, the Reform's impact on the wealthiest groups (deciles 9–10) has been relatively moderate.

In conclusion, the econometric analysis (D-D model) reinforces the decile analysis results in three of the four models. However, when the indirect effects on internet adoption are separated, the results seem to be contradictory. The internet penetration trend has proved to be a determining factor in internet adoption. Finally, the results obtained in this empirical paper suggest that the internet penetration trend and, to a lesser extent, the Reform are significant factors for the increase in internet adoption.

For the time being, the Reform has been centered on providing access, promoting competition and reducing telecommunications prices, but demand stimulus programs, such as a national digital skills program, are lacking. For bridging the digital divide, especially for the most vulnerable population, the literature suggests that better results are obtained when supply and demand side policies are combined (e.g. Mecinas, 2016; OECD., 2017b; Ovando, Pérez, & Moral, 2015; Townsend, Sathiaseelan, Fairhurst, & Wallace, 2013). It is hoped that this article will contribute to providing information on the early results of the Mexican Telecommunications Reform and to the development of specific digital strategies for the poorest socioeconomic groups.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at http://dx.doi.org/10.1016/j.telpol.2018.03.005.

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