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Subsidies, Speed and Switching? Impacts of an Internet Subsidy in Colombia

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Abstract

Inequality in access to health, education, and employment opportunities is exacerbated in developing nations due to the uneven distribution of access to high-speed internet connections. In Colombia, the government enacted a policy (in 2012) to subsidize internet fees for low-income households so as to bridge the digital divide. The reductions were not granted to all plans and thus created incentives for consumers to switch between plans. We estimate a structural model of demand for internet connection plans, which we use to quantify the importance of switching behavior. We estimate the model using data on plans that are offered by all internet service providers to households in all socioeconomic (SES) groups across Colombia. Our results indicate that the subsidy caused a non-negligible fraction of low-SES households to switch internet plans - the majority of which switched to plans with lower speeds, not higher speeds. Furthermore, the more wealthy households (of the lower SES groups) were twice as likely to switch plans than were those in the lowest SES group. Our findings suggest that the effect– not only on internet adoption but also on switching behavior– should be taken into account when formulating subsidies that are designed to bridge the digital divide.

Keywords Digital divide · Internet access · Developing countries · Covid-19 · Limited choice sets · Consumer switching behavior

JEL Classification L15 · L51 · L86 · D12 · D31

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1 Introduction

Access to a fast, stable internet connection is commonplace in households in developed nations: This is instrumental to how we conduct our day-to-day lives. As such, it is not surprising that roughly 80% of Americans recently reported having a high-speed broadband internet connection (Pew Research Center, 2022).

Unfortunately, this picture looks drastically different for households in developing nations, where fewer than 35% have a fast connection.[1] Many developing nations, such as Colombia, have pursued policies to close this digital gap using a variety of tools that range from subsidizing plans, to providing education on information technology, to installing computers with high-speed connections in public kiosks.

As part of a larger agenda to decrease the digital divide, the Colombian Ministry of Information and Telecommunication Technologies (MinTIC) enacted a policy in 2012, that subsidized the internet connection fees of low-income households.[2] In Hidalgo and Sovinsky (2023), we examined the effect of this subsidy on internet adoption, where we found that the subsidy was effective in increasing adoption, which in turn decreased the digital divide that was prevalent among low socioeconomic groups. However, the benefits were not distributed evenly among the group: The subsidy was most beneficial for the “wealthier" of the low-income consumers. Interestingly, the form of the subsidy affected the characteristics of the plans that were available to consumers (as well as the price).

The resulting change in the sets of cheaper plans may have caused already-connected consumers to switch plans. This is consistent with findings from a survey by the US Federal Communications Commission, where participants stated that the main reasons for broadband switching were either to switch to a superior service or alternatively a cheaper service (49% and 47%, respectively) see (FCC, 2010). In this paper, we examine the switching behavior of consumers after the subsidy was implemented. In the Colombian context, this is particularly salient as internet service providers (ISPs) often do not offer the faster (more expensive) broadband plans to all socioeconomic groups within the same geographic region. As a result, consumers who previously subscribed to narrowband plans may have moved to (subsidized) faster broadband plans or consumers may have moved from faster connections to slower (now less expensive) broadband plans. Understanding the extent to which the subsidy caused consumers to switch plans is important to determine the effect of the subsidy on bridging the digital divide. Faster speeds allow for more opportunities from the connection (e.g., online courses, medical downloads, job applications, etc.)– which is of first-order importance for improving labor, health, and educational outcomes, particularly in developing nations.

To determine the effect on switching behavior, we estimate a model of consumer demand for plans (with different connection speeds and prices). We take the model to data from ISPs, which include the speed of the plans and the choice of plans that

[1] World Bank. Connecting for Inclusion: Broadband Access for All. World Bank Brief. Available at: https://www.worldbank.org/en/topic/digitaldevelopment/brief/connecting-for-inclusion-broadband-access-for-all. Accessed June 29, 2022.

[2] Section 2 of article 58 of the Act 1450 of 2011.

were available to each socioeconomic group across Colombia. We use the estimates to evaluate counterfactual policies where the subsidy was not in place, to determine the prevalence and direction of switching behavior post subsidy.

Not surprisingly, our results indicate that consumers value faster connection speeds and that they are heterogeneous in their price sensitivity across socioeconomic strata. Perhaps more surprising is that we find that the subsidy caused a non-negligible fraction of households– about 13%– to switch internet plans. Furthermore, individuals in the more wealthy of the lower socioeconomic groups were twice as likely to switch plans than were individuals in the lowest socioeconomic group. In addition, we find that switching is more likely in markets that have a more advanced internet infrastructure and in markets that offer a broader array of providers and plans.

We also find that, on average, subscribers who switched moved to plans with lower speeds– not higher speeds– which thus eroded the benefits of the subsidy in terms of increasing digital quality connections. In fact, our counterfactual findings show that the vast majority of switchers arise from the top two speed groups (84%). This result has relevant implications for the quality and performance of internet services, and should be taken into account when designing such demand-side interventions.

There is a large body of work that examines residential internet adoption policies (e.g., Cardona et al. (2009); Hausman et al. (2001); Rappoport et al. (2003); Ida and Kuroda (2006); Goolsbee and Klenow (2006); Nevo et al. (2016); Rosston et al. (2010); Dutz et al. (2009); Varian (2002); Goldfarb and Prince (2008); Greenstein and McDevitt (2011); Hidalgo and Sovinsky (2023)), where our work is specifically related to the literature on consumer switching behavior (e.g., Giulietti et al. (2005); Krafft and Salies (2008); Wilson and Price (2010); Genakos et al. (2023)). We examine this issue in the context of a developing nation, and thereby add to the literature that includes studies of OECD countries (Belloc et al., 2012), Latin American (Jordán et al., 2013) and Caribbean countries (Galperin and Ruzzier, 2013), and African countries (Hjort and Poulsen, 2019) and Chinn and Fairlie (2010). For Colombia: Hidalgo and Oviedo (2014) provide some descriptive analysis of the impact of standards on download speed on the market for internet provision; Vélez-Velásquez (2019) examines the impact of mergers in telecommunication on the provision of broadband; and Vélez-Velásquez (2024) studies the implications of price discrimination on telecommunication services. Our work is most closely related to Hidalgo and Sovinsky (2023), who examine the effect of the Colombian subsidy policy on consumer internet adoption, but who do not address switching behavior.

We examine the effect of governmental programs in the context of low-socioeconomic groups. There is a growing literature that studies the digital exclusion of low-income populations: including, Powell et al. (2010); Prieger (2013); Salemink et al. (2017); Savage and Waldman (2009); Greenstein and Prince (2007); Ackerberg et al. (2014). Finally, we apply structural industrial organization tools to examine these issues in developing nations, and hence our work is related to the literature that uses tools from structural industrial organization to examine issues in developing nations (Chaudhuri et al., 2006; Walsh, 2023).

In the next Section, we discuss the data. We present the empirical model and estimation methodology in Sects. 3 and 4. In Sect. 5 we discuss our estimates, which are used to conduct counterfactual results that inform the impact of the subsidy policy on the consumer switching behavior in Sect. 6. We conclude in Sect. 7.

2 Data

We use data that were provided by the Colombian Comisión de Regulación de Comunicaciones (CRC) on plans that were offered by all ISPs between 2013:1 to 2014:4.[3] The data include: (i) transmission speeds (i.e., download speed); (ii) monthly service fee; (iii) type of Internet access technology; (iv) municipality and socioeconomic group to which the service was offered; (v) number of subscribers; and (vi) the ISP that offered the service. We define a plan as a combination of ISP, download speed, upload speed, and technology.

In 2012, the Colombian government subsidized plans with broadband connections for eligible households. Households in Colombia are divided into six socioeconomic strata that depend on the characteristics of the neighborhood– the amenities that surround the dwellings– within each municipality. The strata are highly correlated with income, as richer individuals tend to live in areas with more amenities. The subsidy was available to households who were in the most vulnerable stratas 1 and 2.[4]

Households in stratas 1 and 2 paid a discounted price for qualified plans, where the amount of the discount depended only on where in the country– state or the metropolitan area– the household resided.[5] More specifically, the government (MinTic) determined the subsidy based on the cost of the last-mile connection: The higher was the cost, the larger was the subsidy. Qualified plans included those with download speeds of greater or equal to approximately 1 Mbps and upload speed greater or equal to 0.5 Mbps (CRC resolution 2352 of 2010). Across all states and metropolitan areas, the potential monthly discount was on average $4 US dollars– ranging from $2 to $7 US dollars– which is about 21% of the average monthly tariff. The observed discount, however, varies depending on the location where the internet service is offered and whether the ISPs choose to subsidize qualified plans in that particular location.

We have information on all of the plans that were offered– non-subsidized and subsidized– for about 90% of the population. We restrict our focus to individuals in

[3] The CRC is the Colombian analog of the US Federal Communications Commission.

[4] According to the Gran Encuesta Integrada de Hogares (GEIH) Survey, which is a survey of selected households from about 13 major cities and metropolitan areas, monthly income averages around 262US$ for those in strata 1 and around 316US$ for those in strata 2.

[5] All municipalities have households in stratas 1 and 2. Municipalities are grouped into 32 states and metropolitan areas. A metropolitan area (MA) is a geographical region that consists of one or more neighboring municipalities that are located around a core (large city). Medellin MA includes the municipalities Medellin; Caldas; La Estrella; Sabaneta; Itagui; Envigado; Bello; Girardota; Copacabana; and Barbosa. Barranquilla MA includes the municipalities Barranquilla y Soledad. Manizales MA includes the municipalities Manizales and Villa Maria. Cucuta MA includes the municipalities Cucuta; Villas del Rosario; Los Patios; and El Zulia. Pereira MA includes the municipalities Pereira; Dos Quebradas; and La Virginia. Bucaramanga MA includes the municipalities Bucaramanga; Giron Piedecuesta; and Floridablanca. Cali MA includes the municipalities Cali and Yumbo.

Table 1 Summary statistics (Strata 1 and 2)

	Download speed group				
	All	< 1	$1 - 1.9$	$2 - 3.9$	> 44]]>
Market price	22.0	17.4	18.0	23.1	26.4
	[9.9]	[8.3]	[8.1]	[10.3]	[9.3]
Price with subsidy	21.0	17.4	16.0	21.7	25.7
	[10.2]	[8.3]	[8.8]	[10.9]	[9.3]
Speed	3.9	0.5	1.1	2.5	8.4
	[6.1]	[0.2]	[0.2]	[0.5]	[8.6]
Tech: Cable	0.2	0.2	0.2	0.2	0.3
	[0.4]	[0.4]	[0.4]	[0.4]	[0.5]
Tech: xDSL	0.5	0.6	0.4	0.4	0.5
	[0.5]	[0.5]	[0.5]	[0.5]	[0.5]
ISP Seniority	13.0	13.7	12.6	11.6	13.8
	[5.2]	[3.9]	[5.1]	[5.7]	[5.3]
# Plans	446	96	87	107	156
# ISP	35	20	29	29	23

The unit of observation is the Internet plan. Means are reported for each variable and the corresponding standard deviations are in square brackets. Real prices (base 2008) are in US dollars. ISP seniority denotes the number of quarters that the ISP has been operating in the municipality since 2010:1

Strata 1 and 2, where our final sample consists of 44,518 observations.[6] Given that the ISPs can identify strata, they offer different plans across municipalities and strata. Therefore, we define a market as a municipality-strata combination. Finally, we use data from the 2018 Census on the number of households in the strata-municipality as the number of potential subscribers: the market size.[7]

The ISPs are required to report technical, commercial, and financial data to the Telecommunications Information System. However, disaggregated information is not always required; consequently, the information that was provided by each ISP is limited during many years - including missing information on the monthly fee for a plan. One of the major components that drives adoption decisions is the price (and it is what the subsidy is focused on); consequently, we focus our analysis on the consecutive period 2013:1–2014:4 for which we have information on the plan prices.

Table 1 provides the summary statistics of the internet plans that were offered to households in stratas 1 and 2 between 2013:1 to 2014:4. The first column shows the statistics for plans of all download speed levels. This shows, for example, that an average plan with a download speed of 3.9 Mbps is offered at a price of \$22 which, in turn, is reduced by \$1 due to the subsidy.

Table 1 also presents the statistics by download speed group. The monthly internet fees vary substantially across speed groups. Note that the fees are positively correlated with the connection speed: The higher is the speed, the higher is the price of the service. In all speed groups– except the narrowband group (< 1 Mbps)– the price is reduced via subsidies. The average reduction ranges from \$0.7 in the very-high-speed

[6] We drop plans that are: misclassified as residential; have download speed less than 64kbps; or are below the 5th price percentile or above the 98th price percentile. The price of plans below the 5th percentile is less than 8\$US, whereas the top percentile contains prices above 200\$US, which is approximately two-thirds of the average income.

[7] The census provides projections of the population from 2018 to 2050. Based on these projections, we determine the population size in each period by linear interpolation.

group, to \$1.4 in the 2–3.9 Mbps group, and up to \$2 in the group that just complies with the subsidy requirements (1–1.9 Mbps).

As for the average speed, group 1–1.9 shows the lowest variation, as measured by the coefficient of variation. When contrasted with the average speed, this low variation indicates a bunching of internet plans around the policy threshold (1 Mbps). This aspect is relevant for the economic analysis of the switching behavior as internet plans around the policy thresholds are the ones that received, on average, the highest fee reduction– and are likely the ones that drew more consumers from other speed groups.

Finally, the latter rows of Table 1 indicate that there is little variation in connections delivered via cable or xDSL across speed groups. However, ISPs that have been in operation longer (ISP seniority) are more likely to offer connections at the ends of the speed spectrum (narrowband or $>$ 44]]> Mbps) on average. We will explore this more in the counterfactuals.

3 Model

Consumer *i* chooses from a set of plans of differing speeds that are offered in her municipality-strata (i.e., market). Following the literature [e.g., Berry et al. (1995)], we model the indirect utility that she obtains from plan *j* that is offered in her market *m* in quarter *t* as

$$u_{ijmt} = \delta_{jmt} + \mu_{ijmt} + \epsilon_{ijmt}. \tag{1}$$

Every consumer derives mean utility δ_{jmt} from subscribing to plan *j* at time *t*. Heterogeneity around this mean is captured in $\mu_{ijmt} + \epsilon_{ijmt}$,[8] where a mean zero stochastic term– ϵ_{ijmt}– is i.i.d. type I extreme value across products and consumers. For ease of exposition, we suppress the time index.

The mean utility is given by

$$\delta_{jm} = \alpha(p_{jm} - d_{jm}) + \lambda c_{jm} + \beta x_{jm} + \gamma G_m + \xi_{jm}, \tag{2}$$

where p_{jm} is the monthly subscription fee and d_{jm} is a discount on the monthly price due to the subsidy (which may be equal to zero). Each plan is composed of connection speed attributes c_{jm}, and non-price non-speed observed attributes x_{jm}. The latter includes the internet access technology that is used to deliver the connection and whether the plan is offered by an established ISP. The G_m term includes market variables that may affect services, which are captured by a set of: municipality fixed effects (which account for time-invariant geographic characteristics); firm (ISP) fixed effects; and socioeconomic-strata fixed effects. The attributes of the plan that matter to the consumer, but are unobserved to the researcher are given by ξ_{jm}. The parameter α captures price sensitivity; λ captures the importance of connection speed

[8] Choices of an individual are invariant to that multiplication of utility by a person-specific constant, so we fix the standard deviation of the ϵ_{ijmt}.

(which we allow to vary across strata); and β and γ capture the value that is placed on other plan attributes.

Consumers may vary (along unobserved dimensions) in their price sensitivity, as captured by

$$\mu_{ijm} = (p_{jm} - d_{jm})\sigma_v \nu_i \qquad \nu_i \sim N(0, 1), \tag{3}$$

which allows for interactions between unobserved (to the econometrician) consumer tastes (ν_i) and service fees ($p_{jm} - d_{jm}$), where σ_v is a scaler. Finally, consumers may decide not to purchase an internet plan. When we normalize the service fees to zero, the indirect utility from the outside option of no-purchase is

$$u_{i0m} = \xi_{0m} + \epsilon_{i0m}.$$

We also normalize ξ_{0m} to zero, because we cannot identify relative utility levels.

As we discussed in the previous section, not all plans are offered in all markets. We model the limited choice set following previous literature (e.g., Sovinsky Goeree (2008)). However, unlike Sovinsky Goeree (2008), we observe the choice set of the consumer. In addition, there are not many plans in each market, so we follow Hidalgo and Sovinsky (2023) and assume that consumers are aware of the plans that are offered in their market. The (conditional) probability that consumer *i* subscribes to plan *j* is

$$s_{ijm} = \frac{\exp\{\delta_j + \mu_{ij}\}}{1 + \sum_{r \in \mathrm{J}_m} \exp\{\delta_r + \mu_{ir}\}} \mid j \in \mathrm{J}_m, \tag{4}$$

where the summand is over plans that are offered in consumer *i*'s market.

We assume that a consumer purchases at most one plan per period: the plan that provides the highest utility– *U*– among all of the plans that are available to her. Let $R_{jm} \equiv \{v_i : U(v, p_{jm}, c_{jm}, x_{jm}, \xi_{jm}, \epsilon_{ijm}) \geq U(v, p_{rm}, c_{jm}, x_{rm}, \xi_{rm}, \epsilon_{irm})$ $\forall r, j \in \mathrm{J}_m, r \neq j\}$ define the set of variables that results in the purchase of *j* given the parameters of the model. The market share of plan *j* in market *m* is

$$s_{jm} = \int_{R_{jm}, j \in \mathrm{J}_m} dF(\nu, \epsilon) = \int s_{ijm} dF_\nu(\nu) \tag{5}$$

where $F(\cdot)$ denotes the respective distribution functions, and the second equality follows from independence assumptions. Demand for plan *j* in market *m* at time *t* is

$$\mathcal{M}_{mt} s_{jmt}, \tag{6}$$

where $\mathcal{M}_{mt}$ is the number of households by strata and municipality.

4 Estimation

Following the literature [e.g., Berry et al. (1995)], we restrict the model predictions for *j*'s market share to match the observed shares and solve for $\delta(S,\theta)$ that is the implicit solution to

$$S_t^{obs} - s_t(\delta,\theta) = 0, \tag{7}$$

where S_t^{obs} represents the vector of observed shares and s_t is the vector of predicted shares.[9] The moment that is unobservable is

$$\xi_{jmt} = \delta_{jmt}(S,\theta) - \alpha(p_{jmt} - d_{jmt}) - \lambda c_{jm} - \beta x_{jm} - \gamma G_m.$$

The ξ_{jm} are unobserved to the researcher but known to market participants, and hence are taken into account by consumers when they decide in which plan to enroll. However, these unobserved quality attributes are likely to be correlated with price. This leads to an endogeneity problem between price and unobserved attributes.

Following the literature, if we assume that the demand unobservables– which are evaluated at the true value of the parameters $\Theta_0 = (\theta_0)$– are mean independent of a vector of observable product characteristics (c, x) :

$$E\left[\xi_j(\Theta_0) \mid (c,x)\right] = 0, \tag{8}$$

we can use variables that shift costs to account for the endogeneity of prices. We use the monthly cost (per Mbps) to an ISP of a network internet connection and its interaction with the connection speed as instruments that shift the price of the connection but are not correlated with unobserved quality.[10]

The variation of the cost-shifter comes from the highly fragmented telecom network and the respective interconnection charges. The telecommunications fixed network in Colombia consists of multiple geographical segments that are owned by different (private) operators. To offer Internet services in a particular market, a provider must pay an interconnection charge to the incumbent operator.[11] The interconnect pricing rule is based on the network capacity (in Mbps) and the location of the local market. Accordingly, our main cost-shifter exhibits substantial variation across municipalities (location of the market) and internet providers (variation in network capacity).

[9] We use the contraction mapping that is suggested by BLP to compute $\delta(S,\theta)$: We use SQUAREM (Varadhan and Roland, 2008), which is an algorithm that uses information from multiple iterations to accelerate the fixed-point convergence.

[10] The source of this information is the telecommunications competition authority's Form 7. All operators that provide network interconnection fill out Form 7 to report information about the transaction: year; the ISP that is requesting interconnection; municipality; installed capacity; utilized capacity; fixed cost; and monthly interconnection charge. This information is available for the 2012-2019 period.

[11] In markets where the internet provider is the incumbent operator of the local fixed network, the interconnection fee is zero.

Note that each plan is associated with a mean utility, which is chosen to match observed and predicted market shares. If consumers were identical, then all variation in sales would be driven by variation in plan attributes. To identify the parameters of the mean utility we use variation in plan market shares that correspond to variation in the observable attributes of those plans (such as connection speed). The distribution of unobserved tastes– ν_i– is fixed over time, but ISPs change their plan offerings over time. To identify the σ_v we use the variation in sales patterns over time as the choice sets change.

We estimate the parameters by Simulated Generalized Method of Moments (GMM), which finds the parameter values that minimize the objective function, $\Lambda' Z A^{-1} Z' \Lambda$. The weighting matrix– A– is a consistent estimate of $E[Z' \Lambda \Lambda' Z]$, and Z are instruments that are orthogonal to the composite error term Λ: If Z_ε are the instruments for the demand unobservable, the sample moments are

$$Z'\Lambda = \frac{1}{J} \sum_j Z_{\xi,j} \xi_j(\delta, \alpha, \beta, \gamma, \lambda),$$

where $Z_{\xi,j}$ is column j of Z_ξ. If the parameters don't minimize the moments (according to some criteria), we make a new guess of the parameters. We repeat the estimation steps until the moments are close to zero.

We follow standard simulation techniques to simulate the market shares (which are given in Eq. 5), by sampling a set of "individuals", where each consists of taste parameters that are drawn from a normal distribution.[12] The parameters are simultaneously estimated with the use of two-step feasible GMM in pyBLP (Conlon and Gortmaker, 2020). We restrict the non-linear search to the standard deviation of the random coefficients.[13] The resulting estimator is consistent and asymptotically normal (Pakes and Pollard, 1989). As the number of pseudo-random draws that are used in simulation $R \to \infty$, the method of simulated moments covariance matrix approaches the method of moments covariance matrix. The (asymptotic) standard errors are derived from the inverse of the simulated information matrix, which allows for possible heteroskedasticity.[14]

5 Results

Table 2 provides estimates of the elements of demand that inform consumers' choices of residential internet services among the poorest households. All regressions include instruments for price, where the weak IV Kleibergen-Papp statistic indicates that the pricing instruments are not weak.[15]

[12] To reduce simulation error, we employ 500 Latin hypercube sampling draws. The market share simulator is then the average over individuals of the choice probabilities.

[13] The estimates are obtained using the pattern search optimization routine.

[14] The reported standard errors do not include additional variance that is due to simulation error.

[15] Appendix A contains details on the performance of the instruments.

Table 2 Demand estimates

	Logit IV		Random Coeff.	
	(1)	(2)	(3)	(4)
Price - subsidy	−0.302***	−0.301***	−0.442***	−0.466***
	(0.033)	(0.033)	(0.032)	(0.043)
Std. dev. Price - subsidy			0.108***	0.121***
			(0.003)	(0.007)
Tech: Cable	1.128***	1.14***	1.17***	1.19***
	(0.079)	(0.079)	(0.082)	(0.082)
Tech: xDSL	1.101***	1.112***	1.12***	1.133***
	(0.068)	(0.068)	(0.07)	(0.07)
Seniority	0.089***	0.089***	0.094***	0.096***
	(0.007)	(0.007)	(0.007)	(0.007)
Strata 2	1.326***	0.831***	−0.168***	−0.172***
	(0.029)	(0.075)	(0.017)	(0.018)
$\text{Speed}_{1-1.9}$	2.006***	1.667***	1.85***	1.592***
	(0.103)	(0.11)	(0.101)	(0.11)
$\text{Speed}_{2-3.9}$	2.3***	1.918***	2.293***	1.895***
	(0.079)	(0.089)	(0.081)	(0.09)
$\text{Speed}_{\geq 4}$	3.223***	2.869***	3.139***	2.615***
	(0.283)	(0.275)	(0.281)	(0.264)
$\text{Speed}_{1-1.9} \times \text{Strata 2}$		0.533***		0.346***
		(0.082)		(0.077)
$\text{Speed}_{2-3.9} \times \text{Strata 2}$		0.596***		0.616***
		(0.083)		(0.09)
$\text{Speed}_{\geq 4} \times \text{Strata 2}$		0.534***		0.787***
		(0.085)		(0.104)

Total number of observations is 44,518. The time period is 2013:1–2014:4. All specifications include a time trend, municipality fixed effects, and firm fixed effects. For Columns (1) and (2), the Kleibergen-Paap statistics are 48.6 and 48.5, respectively. Robust standard errors are reported in parentheses. $^{***}p<0.001$; $^{**}p<0.05$; $^{*}p<0.1$.

The results show that the higher is the price of the plan, the less likely is the consumer is to adopt it, which is not surprising. In addition, there is significant heterogeneity in price sensitivity across consumers. Consumers have a positive valuation for connections that are delivered via cable or xDSL, as well as those with providers that have been in operation longer (seniority). This latter finding could be a reflection of the reputation of established ISPs– which may convey positive information about services and encourage some consumers to subscribe. Consumers' marginal utility is increasing in the speed of the connection, and they value broadband connections more than narrowband (the excluded group). Finally, the valuation of speed differs across individuals in the two socioeconomic strata, with those in the more "wealthy" strata 2 having a higher valuation for speed.

In summary, our estimates reveal that consumers value faster connection speeds and that there is heterogeneity in price sensitivity. In addition, they show that there is variation across strata. These results suggest that the types of plans that are offered under the subsidy scheme may affect switching behavior.

Table 3 shows the price elasticities of demand for connection speed. The cells are the average percentage change in the market share of the row plan that is due to a one percentage change in the price of the column plan. For example, the market share

Table 3 Speed elasticities

	$\text{Speed}_{0-0.9}$	$\text{Speed}_{1-1.9}$	$\text{Speed}_{2-3.9}$	$\text{Speed}_{>4}$
$\text{Speed}_{0-0.9}$	−5.048	0.263	0.16	0.106
$\text{Speed}_{1-1.9}$	0.035	−3.965	0.125	0.092
$\text{Speed}_{2-3.9}$	0.049	0.233	−4.944	0.119
$\text{Speed}_{>4}$	0.047	0.204	0.204	−5.801

This table shows the mean elasticities by groups of speed based on the 4th specification of Table 2. The cell in row *j* and column *k* is the average percentage change in the market share of a product *j* with respect to a one percentage change in the price of product *k*. The means are computed across year-quarter-municipality-strata combinations

Table 4 Diversion ratios

	$\text{Speed}_{0-0.9}$	$\text{Speed}_{1-1.9}$	$\text{Speed}_{2-3.9}$	$\text{Speed}_{>4}$	Outside
$\text{Speed}_{0-0.9}$	–	0.065	0.031	0.015	0.617
$\text{Speed}_{1-1.9}$	0.004	–	0.024	0.013	0.742
$\text{Speed}_{2-3.9}$	0.006	0.065	–	0.019	0.633
$\text{Speed}_{>4}$	0.006	0.062	0.062	–	0.465

This table shows the mean diversion ratios by groups of speed based on specification 4 of Table 2. The cell in row *j* and column *k* is the average fraction of consumers of product *j* who would switch to product *k* due to a price increase of product *j*. The means are computed across year-quarter-municipality-strata combinations

for narrowband plans (speed below 1 Mbps) will drop by 5% with a 1% increase in narrowband prices.

The table shows that a price drop of 1% for the slowest broadband connections (speed between 1 and 1.9 Mbps) will result in a 0.26% decline in the market share for narrowband. Hence, if broadband connections were less expensive, consumers would move from narrowband to broadband. However, the last two rows of column 2 indicate that almost an equal market share would switch from a faster broadband connection to a slower one.

Table 4 presents diversion ratios, which allow us to quantify the impact of a price change. Column 2 shows that switchers to the slowest broadband from narrowband represent about 0.065 percent of consumers, whereas more than double $(0.065 + 0.062)$ would switch to a slower connection from a faster one.

Table 5 shows the diversion ratios for each strata. A comparison of the top and bottom panels reveals that the average rate of switching is not the same for both socioeconomic groups. Focusing again on Column 2, we see that the largest fraction of switchers is among households in strata 2. Given that the plans with the slowest broadband connection were the plans that were most affected by the subsidy, the results suggest that the subsidy could have had a significant impact on switching behavior - and that it might have had the opposite effect than was intended.

Table 5 Diversion Ratios by Strata

	$\text{Speed}_{0-0.9}$	$\text{Speed}_{1-1.9}$	$\text{Speed}_{2-3.9}$	$\text{Speed}_{>4}$	Outside
Strata 1					
$\text{Speed}_{0-0.9}$	–	0.041	0.022	0.009	0.778
$\text{Speed}_{1-1.9}$	0.003	–	0.017	0.009	0.846
$\text{Speed}_{2-3.9}$	0.005	0.046	–	0.013	0.76
$\text{Speed}_{\geq 4}$	0.007	0.048	0.048	–	0.615
Strata 2					
$\text{Speed}_{0-0.9}$	–	0.077	0.035	0.017	0.528
$\text{Speed}_{1-1.9}$	0.004	–	0.028	0.016	0.661
$\text{Speed}_{2-3.9}$	0.006	0.076	–	0.022	0.545
$\text{Speed}_{\geq 4}$	0.006	0.071	0.071	–	0.363

This table shows the mean diversion ratios by groups of speed based on specification 4 (Table 2). The cell in row *j* and column *k* is the average fraction of consumers of product *j* who would switch to product *k* due to a price increase of product *j*. The means are computed across year-quarter-municipality-strata combinations

6 Subsidy Policy Evaluation

We conduct a series of counterfactual analyses to explore the extent to which the price subsidy resulted in consumers' switching internet plans. We first provide details on how we predict pre-subsidy shares and the number of subscribers. Next we discuss how we identify switching behavior with the use of only data on market shares. We then present our results.

To predict the pre-subsidy market shares, we increase the price of the plan by the subsidized amount and predict the market shares according to Eq. 5. We compute the number of subscribed households that is implied by the predicted market shares according to Eq. 6. We note that the resulting change in pre- and post-subsidy market shares reflects both take-up of new consumers– changes on the extensive margin– as well as consumers who switched from other (potentially non-subsidized) plans: changes on the intensive margin. Ideally, we could focus on the intensive margin by examining the choices of those consumers who subscribe to Internet plans both prior to and after the subsidy. Unfortunately, we do not observe individual behavior; consequently, we cannot identify the individuals who always subscribe.

However, we note that it is less likely that a new consumer (who did not subscribe in the pre-subsidy world) chooses to subscribe to a non-subsidized plan in the post-subsidy world. This suggests that changes in the market shares (pre- to post-subsidy) of non-subsidized plans are more likely to result from plan switching of ′always subscribers' rather than takeup by new subscribers.

Specifically, changes in the market shares of non-subsidized plans can be used to identify the intensive margin under two mild assumptions: First, (pre-subsidy) subscribers to non-subsidized plans do not drop their internet connections post-subsidy or switch to another non-subsidized plan. Second, (pre-subsidy) subscribers to subsidized plans do not switch plans after the subsidies are granted. To the extent that the subsidy causes consumers to drop their internet connections, our measurement will overestimate the effect of the subsidy on switching behavior.

Table 6 Switching prevalence

	Predicted Pre-subsidy	Observed Post subsidy	Switchers Always subscribers	%
Total	1598.4	2077.4	207.7	13.0
Strata 1	253.7	394.9	18.3	7.2
Strata 2	1344.6	1682.6	189.4	14.1

The number of subscribers is in thousands

Table 6 reports the predicted number of subscribers both pre- and post-subsidy in the last quarter of our sample (2014:4). The first column presents the number of predicted subscribers in the predicted pre-subsidy market; whereas the second column provides the observed post-subsidy scenario. The difference between these two columns shows that roughly 479,000 households decided to subscribe to internet services due to the pricing subsidies.[16] However, the final columns of Table 6 indicate that the subsidy had a substantial effect on the intensive margin as well: Approximately 207,000 households– 13% of the pre-subsidy households– switched plans after the subsidies were granted. Furthermore, individuals in strata 2 were almost twice as likely to switch plans than were individuals in strata 1.

To understand what is driving switching prevalence, in addition to differences in socioeconomic status, we project the fraction of switchers on characteristics of the plans that were offered in their market: e.g., market concentration of ISP providers (HHI); speed of plans; the infrastructure.[17] Table 7 provides the results, where the first column indicates that consumers are less likely to switch plans in markets where the ISPs have greater market power (HHI). In addition, consumers are more likely to switch in markets where there is higher penetration of plans with higher speeds.

These estimates suggest that switching decisions are more likely to be found in competitive and technologically savvy markets. The second column confirms this finding: A greater prevalence of switching decisions is associated with markets with: (i) more advanced internet infrastructure (i.e. more available technologies); (ii) higher quality of the service (connection speeds); and (iii) a broader offer of providers and plans.

The economic relevance of switching decisions, in the context of internet services, is related to how consumers substitute between connection speeds: quality of the service. Due to the subsidy scheme, former narrowband– low-quality– subscribers might substitute to a (subsidized) broadband plan with a higher speed. In contrast, subscribers of very-high-speed plans might decide to switch to lower-speed subsidized broadband plans (which now are relatively cheaper). We conduct an analysis by speed groups to gain an understanding of the direction of the switching decisions and their implications.

Figure 1 shows the cumulative distribution of internet connections in 2014:4. The curves show the share of subscribers with a plan that has an internet speed below the corresponding value on the X-axis. The (lower) solid line represents the coun-

[16] We explore the effectiveness of the intervention and analysis of alternative policies on take-up in Hidalgo and Sovinsky (2023).

[17] To control for multiple fixed effects, we do this econometric analysis using the entire time period (2013:1–2014:4) and collapse the data at the market level.

Table 7 Switchers prevalence and market characteristics

	(1)	(2)
HHI	−4.439***	−3.456***
	(0.376)	(0.478)
$\text{Penetration}_{1.1-5}$	0.141	0.176
	(0.092)	(0.092)
$\text{Penetration}_{5.1-10}$	1.016***	1.044***
	(0.146)	(0.144)
$\text{Penetration}_{10.1-20}$	4.054***	4.028***
	(0.201)	(0.200)
$\text{Penetration}_{20-100}$	8.400***	8.141***
	(0.298)	(0.303)
Strata 2	0.965***	0.758***
	(0.081)	(0.084)
Avg. Speed		0.330***
		(0.053)
# Technology		0.315**
		(0.116)
# ISP		0.267*
		(0.125)
# Product		0.082***
		(0.020)
Constant	5.228***	2.265***
	(0.342)	(0.589)
R-squared	0.845	0.848

Total number of observations is 6528. The time period is 2013:1–2014:4. All specifications include municipality fixed effects and time (year and quarter) fixed effects. HHI denotes the Herfindhal–Hirschman concentration index among Internet providers. Robust standard errors are reported in parentheses. ***p <0.001; **p <0.05; *p <0.1

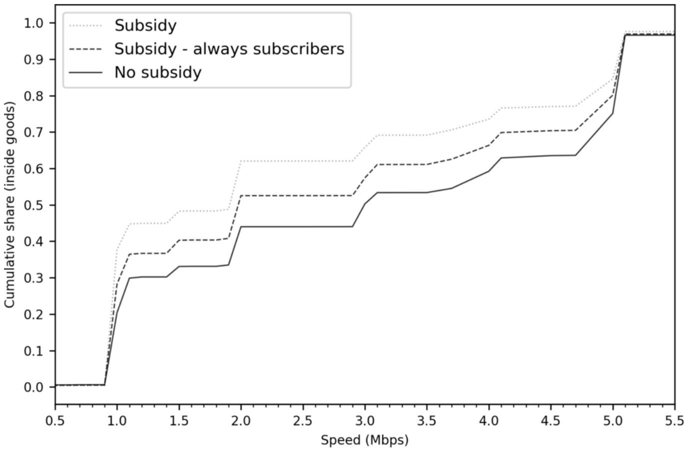
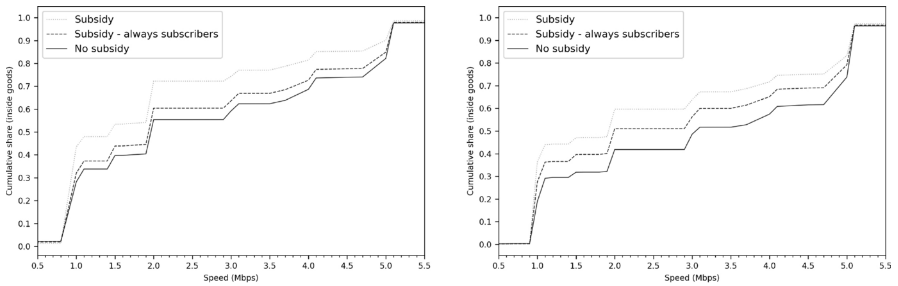


Fig. 1 Cumulative distribution of Internet connections



Strata 1 Strata 2

Fig. 2 Cumulative distribution by socioeconomic strata

terfactual scenario absent subsidies. The (top) light-dotted line depicts the observed cumulative distribution post-subsidy accounting both for switching behavior and new takeup. The (middle) dashed line shows the cumulative distribution post-subsidy for consumers who subscribed pre- and post-subsidy: the 'always subscribers'.[18] The difference between the bottom solid line and the middle dashed line shows the effect of switching in the market. The figure shows that the subsidy policy shifted the cumulative distribution curve upwards– at least for connection speeds that were greater than 1Mbps: On average subscribers switched to plans with lower speeds due to the pricing subsidies. For example, prior to the intervention, half of the subscribers had a connection below 3Mbps. This median point fell to 2Mbps after the subsidies were granted.

With regard to the comparison between socioeconomic groups, Figure 2 presents the cumulative distributions for stratas 1 and 2. In the pre-subsidy world, the advantage in terms of connection speed for strata 2 relative to strata 1 is evident. This is in line with the demand estimates shown in Table 2. This speed advantage, however, is substantially reduced as a result of the subsidies as there is little switching behavior in strata 1, and strata 2 subscribers switch to lower-speed internet plans.

To quantify better the switching decisions between speed groups, we conduct counterfactuals in which we grant subsidies to plans by speed groups. Table 8 shows the total number of subscribers (first column) for each speed group. The last columns

[18] Determining the middle dashed line in Fig. 1, requires us to compute the (post-subsidy) predicted plan shares taking into account only 'always subscribers.' We calculate the number of 'always subscribers' post-subsidy for each subsidized plan by subtracting the number of new consumers– consumers who choose to subscribe only after subsidies are granted– from the (observed) post-subsidy number of consumers. To compute the number of new consumers to subsidized plans, we calculate the proportion of (post-subsidy) consumers who would opt for the outside option in the absence of subsidies (by adjusting the diversion ratio). We remove the subsidies for all subsidized plans regardless of the speed range. For a subsidized plan, the diversion ratio to any other subsidized plan is set equal to zero. This follows the logic that (post-subsidy) consumers of subsidized plans either switch to a non-subsidized plan or drop their plan after all subsidies in the market are removed. The remaining non-zero diversion ratios are proportionally scaled such that they add up to one. We use the adjusted diversion ratio of the outside option to compute the number of new consumers post-subsidy. Due to the scaling, for some markets there may be small discrepancies between the market-level number of switchers and our procedure. In those cases, we distribute the difference among subsidized plans according to their post-subsidy market share.

Table 8 Switchers by speed groups

	Sub-scribers Pre-subsidy	Switchers counterfactual			
		< 1	1–1.9	2–3.9	4
Total	1598.38	207.7	216.54	180.63	213.99
		% of pre-subsidy subs			
$\text{Speed}_{<1}$	9.85	15.8	12.0	12.1	15.8
$\text{Speed}_{1-1.9}$	525.53	5.7	0	14.4	24.6
$\text{Speed}_{2-3.9}$	336.27	10.8	20.7	0	24.8
$\text{Speed}_{>4}$	726.73	19.2	20.0	14.3	0

The number of subscribers is in thousands. The last four columns show the fraction of always subscribers that decide to swtich after the subsidies are granted

of the bottom panel show the fraction of subscribers that switch to subsidized plans within each (counterfactual-subsidized) speed group.

With respect to the Colombian subsidy scheme– subsidies for any plan with a speed greater than 1Mbps– we see that over 15% of the narrowband and very-high-speed subscribers decide to switch to subsidized plans. In terms of switchers, these numbers imply that the vast majority of switchers arise from the top two speed groups (84%).

The third column of Table 8 provides the analysis for the counterfactual in which the subsidies are granted to all Internet plans with speeds between 1 and 1.9 Mbps. This alternative policy delivers similar conclusions to the benchmark policy: The subsidized plans draw consumers mainly from the high-end of internet plans. This result has relevant implications for the quality and performance of internet services, and should be taken into account when designing such demand-side interventions.

The last two columns of Table 8 simply show that one way to incentivize switching to high-speed plans is by reducing their prices. However, such a subsidy may affect the adoption of internet services. The assessment of this trade-off is beyond the scope of this paper.

7 Conclusions

We examine the effect that a broadband subsidy targeted at low-income consumers in Colombia had on consumer switching. In particular, we estimate a model of consumer demand for internet plans among low SES groups and use the estimates to evaluate counterfactual policies to determine whether the subsidy spurred switching behavior and to quantify the effect of the behavior on connection speeds.

We find that the internet subsidy had the (likely) unanticipated effect that a substantial number of already connected households moved to slower internet connections post-subsidy. Our counterfactual findings show that the vast majority of switchers arise from the top two speed groups (84%). In addition, these individuals were primarily from the richer of the lower income strata, as they were the ones who were more likely to have faster internet connections prior to the subsidy. Finally, we find that switching is more likely in markets that have a more advanced internet infrastructure and in those that offer a broader array of providers and plans.

In summary, we find that switching behavior that was motivated by the subsidy caused a decrease in connection speeds among households that were connected prior to the subsidy. Thus, the benefits of the subsidy in spurring adoption were eroded in terms of the speed of connections. Our findings suggest that the overall effect– not only on internet adoption, but also on switching behavior– should be taken into account when formulating subsidies that are designed to bridge the digital divide.

Appendix A: Instruments

See Tables 9 and 10.

Table 9 IV

	(1)	(2)	(3)	(4)
Price - subsidy	−0.253***	−0.361***	−0.302***	−0.301***
	(0.039)	(0.052)	(0.033)	(0.033)
Tech: Cable	1.615***	1.306***	1.128***	1.140***
	(0.080)	(0.121)	(0.079)	(0.079)
Tech: xDSL	1.667***	1.369***	1.101***	1.112***
	(0.060)	(0.103)	(0.068)	(0.068)
Seniority	0.076***	0.088***	0.089***	0.089***
	(0.007)	(0.009)	(0.007)	(0.007)
Trend	−0.099***	−0.167***	−0.141***	−0.141***
	(0.023)	(0.032)	(0.017)	(0.017)
Strata 2	1.209***	1.264***	1.326***	0.831***
	(0.029)	(0.036)	(0.029)	(0.075)
Speed	0.190*	0.561***		
	(0.074)	(0.131)		
Speed^2		−0.012***		
		(0.003)		
$\text{Speed}_{1-1.9}$			2.006***	1.667***
			(0.103)	(0.110)
$\text{Speed}_{2-3.9}$			2.300***	1.918***
			(0.079)	(0.089)
$\text{Speed}_{\geq 4}$			3.223***	2.869***
			(0.283)	(0.275)
$\text{Speed}_{1-1.9} \times \text{Strata 2}$				0.533***
				(0.082)
$\text{Speed}_{2-3.9} \times \text{Strata 2}$				0.596***
				(0.083)
$\text{Speed}_{\geq 4} \times \text{Strata 2}$				0.534***
				(0.085)
Weak IV	32.5	30.5	48.6	48.5

Total number of observations is 44,518. The time period is 2013:1–2014:4. All specifications include municipality fixed effects and firm fixed effects. The weak IV corresponds to the Kleibergen-Paap statistic. Robust standard errors are reported in parentheses. $***p < 0.001$; $**p < 0.05$; $*p < 0.1$

Table 10 OLS

	(1)	(2)	(3)	(4)
Price - subsidy	−0.091***	−0.091***	−0.091***	−0.091***
	(0.002)	(0.002)	(0.002)	(0.002)
Tech: Cable	1.839***	1.842***	1.410***	1.420***
	(0.055)	(0.055)	(0.059)	(0.059)
Tech: xDSL	1.803***	1.807***	1.291***	1.301***
	(0.040)	(0.040)	(0.047)	(0.047)
Seniority	0.061***	0.061***	0.085***	0.085***
	(0.006)	(0.006)	(0.006)	(0.006)
Trend	−0.007	−0.006	−0.046***	−0.047***
	(0.007)	(0.007)	(0.007)	(0.007)
Strata 2	1.122***	1.122***	1.201***	0.745***
	(0.019)	(0.019)	(0.018)	(0.057)
Speed	−0.119***	−0.122***		
	(0.006)	(0.010)		
Speed^2		0.000		
		(0.001)		
$\text{Speed}_{1-1.9}$			2.588***	2.219***
			(0.033)	(0.052)
$\text{Speed}_{2-3.9}$			1.867***	1.527***
			(0.034)	(0.053)
$\text{Speed}_{\geq 4}$			1.446***	1.164***
			(0.038)	(0.055)
$\text{Speed}_{1-1.9} \times \text{Strata 2}$				0.590***
				(0.065)
$\text{Speed}_{2-3.9} \times \text{Strata 2}$				0.533***
				(0.066)
$\text{Speed}_{\geq 4} \times \text{Strata 2}$				0.431***
				(0.064)

Total number of observations is 44,518. The time period is 2013:1–2014:4. All specifications include municipality fixed effects and firm fixed effects. The weak IV corresponds to the Kleibergen-Paap statistic. Robust standard errors are reported in parentheses. $***p < 0.001$; $**p < 0.05$; $*p < 0.1$

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Declarations

Conflict of interest The author declare that they have no conflict of interest.

Ethical Approval Not applicable.

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