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# THE IMPACT OF BROADBAND QUALITY STANDARDS ON INTERNET SERVICES MARKET STRUCTURE IN COLOMBIA

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# The impact of Broadband quality standards on Internet services market structure in Colombia

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**Abstract**

This paper develops a structural model which allows estimating the impact of regulatory decisions looking for the setting of download-speed standards on market structure and performance. We characterize a setting under which quality standards improve both service quality and availability. As to quality, we evaluate the impact of quality standards on the performance of local demand from a detailed database of broadband internet subscribers, discriminated by the main attributes of an internet subscription contract as location, supplier, monthly-fee, download- and upload-speed features. From these results, we are able to identify the effect of quality regulation on the behavior of internet providers in a differentiated product market approach. As a consequence, we are able to assert that the response of internet service providers to quality regulation is a more intense product differentiation that contributes to demand expansion and therefore to improve broadband penetration indicators.

**JEL-code:** L51, L96, L86
**Key words:** Regulation, Telecommunication, Information Services, Internet Economics.

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# 1 Introduction

This paper explores the issue of how the regulator's objective of guaranteeing adequate quality provision of Internet services to potential users, typically emphasized in reducing information asymmetry by setting download-speed standards, should affect the market structure and performance in the provision of Internet services. Such regulatory decisions have been on the stake in many countries in which the increasing demand of streaming music and video services means that currently online activities require a lot more bandwidth compared to even five years ago. Broadband-level speed, as a technical definition, was implemented by the FCC in 2009 as 4 megabits per second and currently the regulator is beginning to consider whether to raise the definition of broadband – a change that might have big implications for the way Internet services providers (ISPs from now on) are regulated.

In Colombia, such a regulatory decision has been implemented both in 2008 and 2010. Between January 2008 and July 2010, Broadband speed-level was defined as a download speed greater or equal to 512 kilobits per second, whereas since August 2010, the Broadband quality-label raised to 1024 kilobits per second. By the beginning of 2012, this measure could be considered as a success because the 95.33% of aggregate always-on Internet subscribers were connected to the net with a speed over the Broadband label[1].

However, OECD (2014a), in its recent review of telecommunication policy and regulation in Colombia, has stated that the growth in per capita broadband subscriptions has lagged relative to OECD countries and, although growth increased after 2006, it has been insufficient to close the gap with the OECD country with lowest penetration (Turkey). Moreover, OECD (2014a) affirms that Colombia's fixed broadband speed is in the lowest range of OECD countries, including Chile and Mexico, although in line with some Latin American peers such as Argentina and Brazil.[2]

Therefore, following these indicators, Colombia not only has a much lower broadband penetration rate than OECD average, as of 2012, but according to Akamai's speed test, which refers to actual speeds, most broadband subscriptions in Colombia (92%) belong to the lowest speed tier, i.e., connections with speeds lower than 4 megabits per second.

The purpose of this paper is to analyze the role that Broadband-level standards

[1] See appendix D for further details in subscriber distribution on Broadband-level standards

[2] These results are based on measurements by Akamai, a major content distribution network. Indeed, the broadband speed indicators published by Akamai are the result of user initiated tests, and as such, hold the caveat that they measure the speed from particular observation points.

may play in the structure and performance of Internet services markets, and once a relation is found, to provide a possible explanation to the current conditions of the market, recently highlighted by the OECD. Using the industry configuration for the fixed Internet market in Colombia, we develop a structural model which allows estimating the impact of regulatory decisions looking for the setting of Broadband download-speed standards on market structure and performance. First, we characterize a setting under which quality standards improve both service quality and availability. We then focus in the impact on service availability through a demand estimation of internet services under a framework of differentiated products. The analysis yields some insights on the role that regulatory standards may play as an instrument to improve both service penetration and contract diversity, but to hinder the provision of contracts of speed-levels significatively higher that the minimum broadband standard.

This paper is organized as follows. The next section presents the theoretical motivation of the paper. Section 3 describes the basic market configuration of the Colombian always-on fixed Internet market. Section 4 describes in detail the data set to develop our research. Section 5 develops the structural demand model to be estimated and the main results of the impact of Broadband speed standards are provided. Section 6 analyzes the effect of quality standards in variety provision, in a mixed horizontally and vertically differentiated product market. Finally, Section 7 summarizes our main results and contributions to the literature of fixed Broadband Internet markets regulation and the appendix gives the formal evidence of processes applied to the data.

# 2 Theoretical motivation

In terms of measuring the impact of a regulated Broadband quality label on market structure and performance, a clear definition of the product and geographic scope of the fixed Internet market should be assessed. In this line, the market for fixed Internet services can be defined as a differentiated products market in which an homogeneous good, namely, the access to Internet, is differentiated from the supply side by setting different quality attributes, mainly associated with download and upload speed levels. As to the geographic scope of the market, OECD (2014b) states that the retail dimension of this market is sub-national. More specifically, the Colombian telecommunications regulator (CRC from now on for its denomination in Spanish) since 2009, has characterized this market as a local one.

As far as product differentiation, an important strand of the theoretical literature deals with this issue and the choice of product quality. Since in the fixed Internet market products have a natural quality ordering, following download and upload speed, the frameworks established by Gabszewicz and Thisse (1979), and Shaked and Sutton (1982) are highly relevant to understand vertical product differentiation, where products are ordered by quality and consumers have different quality valuations.

From the empirical perspective, a number of important studies analyzing the choice of product quality using structural models, should be mentioned. The early structural literature led by Berry (1994) and Berry et al. (1995) treats product attributes as exogenous, but recent empirical models have portrayed firms as choosing product quality along with price. In the models of Crawford et al. (2011) and Fan (2011), firms choose the levels of continuous measures of product quality (for cable television and newspapers, respectively), while firms in Draganska et al. (2009) choose which product varieties to offer. In each case, the empirical exercise yields estimates of taste and cost parameters, which are used in the latter two papers to simulate the effects of mergers on product quality or variety.

By contrast, the main objective of this paper is to measure the impact of Broadband quality labeling on product adoption and variety, and hence there is not currently an interest to identify underlying utility and production parameters, which are intermixed in the structural demand estimation.[3] Therefore, we follow the traditional structural demand estimation of discrete choice models with exogenous product attributes, in line with Berry et al. (1995).

Regarding the impact of Broadband quality standards on product differentiation, there is a rich literature since the use of quality standards (i.e. minimum quality standards, MQS, or product labeling) has become increasingly common in several industries where consumers are willing to pay higher prices for higher qualities and the government judges the qualities supplied in the unregulated market as too low. Such quality standards aim at increasing social welfare through a reduction of the price/quality ratio prevailing in the market.

From the theoretical perspective, the regulation of an imperfectly competitive market with vertically differentiated products has been introduced in the economic literature by Spence (1975) and Sheshinski (1976). More particularly, the examination of the consequences of the adoption of MQS in oligopolistic markets where each firm supplies at least one variety has been addressed by Besanko et al. (1987) and (1988), Ronnen (1991) and Crampes and Hollander (1995). In the work of

[3]Our research agenda is addressing this issue under a framework similar to Fan (2011) and Draganska et al. (2009). Results are forthcoming.

Ronnen (1991) a duopoly model with Bertrand competition and quality dependent fixed costs is studied. He shows that the introduction of a MQS (that marginally increases the quality offered by the low quality firm) increases the substitutability of the two products, making the competition stronger. The high quality firm increase its quality (qualities are strategic complements), in order to restore partially the product differentiation and to soften the degree of price competition. With fiercer competition (and therefore lower prices) and higher qualities, consumers' surplus increases. Profits of the high quality firm decrease since it has to incur higher fixed costs for quality, while the low quality firm's profits increase because the MQS imposes a commitment to quality and the market pays for it.

Similarly, Crampes and Hollander (1995) study a duopolistic market with single-product firms. The introduction of the minimum quality standard is then analyzed as an exogenous constraint on the low quality firm to increase its quality level. The introduction of the standard gives a strategic advantage and higher profits to the low quality firm and reduces the degree of differentiation in the market. Although the standard exerts a positive welfare effect, its consequences, as far as consumers' surplus is concerned, are quite different depending on the cost functions of firms.

Since in the framework, which will be described in detail in the next section, Internet provision in Colombia not only features vertical differentiation, by means of alternative quality levels linked to download and upload speeds, but also horizontal differentiation through the provision of several 'varieties' by each ISP, it is important to foresee the impact of quality standards in the provision of horizontally differentiated products. This kind of product differentiation, where products have no natural quality ordering, is usually analyzed in a spatial-competition setting in the Hotelling tradition, with important contributions by d'Aspremont et al. (1979) and Salop (1979).

Economides (1993) develops a framework under which the circular model of variety-differentiated products is expanded to introduce quality differentiation. In this scenario, Economides obtains that the level of quality and the number of varieties provided by the market are substitutes, and thus, setting a MQS, as a quality floor, reduces the number of varieties at equilibrium. This result, together with the fact that the number of firms at the free-entry equilibrium in this model is larger than in the case of pure horizontal differentiation, suggests the possibility that setting a MQS may be welfare improving.

Following, Economides (1993) our paper looks for the impact of setting a Broadband quality label, which is less stringent than a MQS, since the provision of narrowband Internet services is not forbidden, by means of a market proxy variable which measures the average supply of varieties in the local market, by means of averaging the diversity of fixed Internet contracts supplied in a given municipality of Colombia.

# 3 Colombian market for always-on Internet services

It is widely recognized that Information and Communications Technology (ICT) plays a crucial role in economic growth across all sectors - energy, transportation, health, and many others. Adequate ICT infrastructure is now a prerequisite for other forms of investment. Moreover, international trade and investment in the sector unlocks the potential for other services and manufacturing trade and investment. Yet, a variety of challenges prevent countries from realizing this potential. Problems to be addressed include, among others, the provision of broader access in poorer areas; the supply of sophisticated connectivity needed for commerce in the 21st century; and the maximization of the impact of ICT in addressing developing countries' macroeconomic and social goals.

Colombia, has been a leader in the implementation of ICT policies to meet those challenges. Since 2006, the Colombian ICT sector has seen an astonishing expansion. This has primarily been driven by new disruptive technologies which were effectively exploited by new business models and enabled by policy and regulatory reforms. Convergence constitutes the main technological force that is already remaking the Colombian ICT sector and aligning it with the global trend. Colombia has led the way in the mobile revolution in Latin America, and this has had a dramatic impact on access in rural and remote areas, ensuring whole coverage of all Colombian municipalities.

As a measure of the dynamism of the ICT sector, it is more dynamic that the aggregate economy in terms of GDP growth since 2005. This evolution has implied a fast growth in mobile subscriber rate and broadband connections, the widespread emergence of bundles of services and applications, a price-shrinking trend of ICT services,and the dynamic performance of infrastructure investment, both public and private, in telecommunications networks. Thus, Colombia is paving the road of successful economies that have based their development model on the ICT sector and its related services.

The enactment of Law 1341 of 2009 (hereafter named the ICT Law) represents a major turning point in Colombia's telecommunication policy and regulation, following the liberalization of telecommunication services in 1994. Oviedo and Guerra

(2010) affirm that the ICT Law provides a converged framework to foster the development of ICTs in Colombia through four main axes: (i) Principle-based: certain degree of stability to allow mean- and long-term planning by both the policy-maker and the industry; (ii) Institutional Convergence, in order to facilitate the developments associated with technological and market convergence; (iii) Flexibility: to face the requirements arising from technological development; and (iv) Global perspective: to constantly gather input from the industry.

In the provision of fixed Internet services, the government has performed three leading roles in the policy and regulatory perspective. First, the universal service fund (FonTIC for its denomination in Spanish) has continuously provided enough resources to finance the Internet provision in geographic areas under which the market itself would not be profitable. Second, the Colombian government has adapted its legal and regulatory framework in order to reduce barriers to entry and to foster competition, and making it compatible with private incentives to investment. Third, protecting the rights of ICT users, the regulatory body has set a Broadband quality standard since 2007. Between January 2008 and July 2010, Broadband speed-level was defined as a download speed greater or equal to 512 kilobits per second, whereas since August 2010, the Broadband quality-label raised to 1024 kilobits per second.[4] By the beginning of 2012, this measure could be considered as a success because the 95.33% of aggregate always-on Internet subscribers were connected to the net with a speed over the Broadband label. See Figure 1.

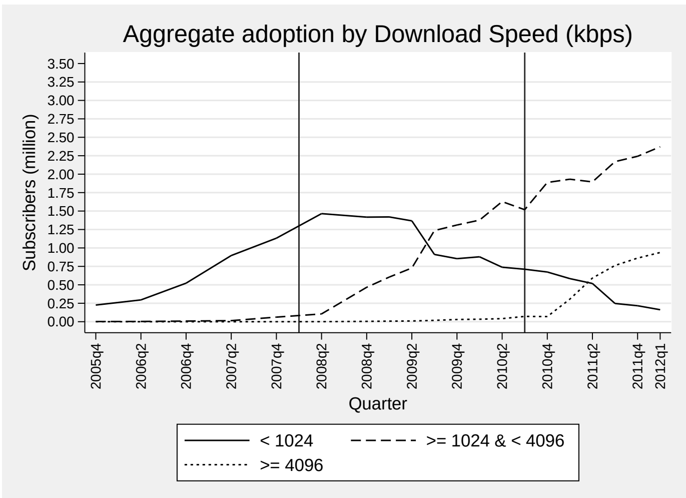


**Figure 1:** Aggregate always-on Internet subscribers by download speed

From Figure 1 it can be inferred that since the implementation of the 2008 Broadband label (hereafter named $08-BL$) there was a breakpoint of fixed Internet

[4]See CRC Orders 1740 of 2007 and 2352 of 2010, respectively, for each Broadband label.

subscribers with download speed over 1024 kbps which was indeed the anticipated 2010 Broadband level (hereafter named $10-BL$).[5] This is seen from the contraction of subscriptions under 1024 kbps together with the acceleration in the subscription rate of contracts which feature $10-BL$. Moreover, since the implementation of the standard $10-BL$, there is a continuous trend in subscriptions over 1024 kbps accompanied with a relevant breaking point over 4096 kbps, the current Broadband speed-level defined by the FCC in the United States.

Despite the dynamic growth rate, OECD (2014a), in its recent review of telecommunication policy and regulation in Colombia, has stated that the growth in per capita broadband subscriptions has lagged relative to OECD countries and, although growth increased after 2006, it has been insufficient to close the gap with the OECD country with lowest penetration (Turkey). Moreover, OECD (2014a) affirms that Colombia's fixed broadband speed is in the lowest range of OECD countries, including Chile and Mexico, although in line with some Latin American peers such as Argentina and Brazil. Therefore, following these indicators, Colombia not only has a much lower broadband penetration rate than OECD average, as of 2012, but also concentrates all Broadband connections with speeds lower than 4 megabits per second. See Figure 2.

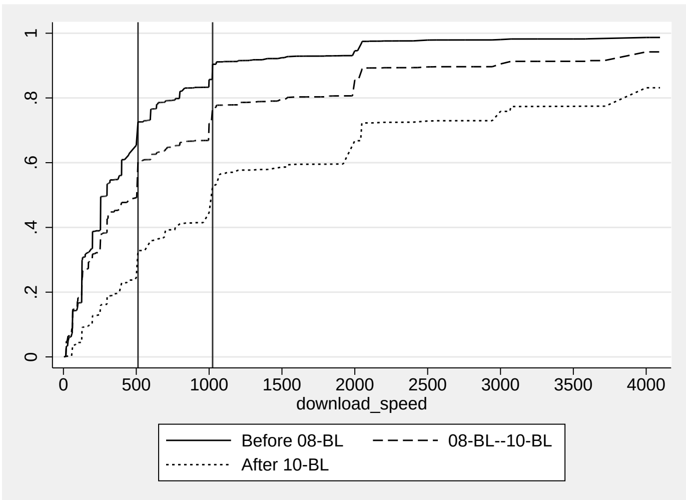


**Figure 2:** Cumulative distribution function of Internet connections

From Figure 2, we observe that before the setting of $08-BL$, approximately, the 70% of fixed Internet contracts offered by ISPs lied under the 512 kbps label. This concentration measure decreased sequentially to 50% and 20%, respectively, for the period after $08-BL$ setting and before $10-BL$, and afterwards. Similarly, we observe that before the setting of $10-BL$, approximately, the 70% of fixed Internet

[5] See the regulatory background document of the Colombian telecommunications regulator CRT (2007).

contracts, supplied by ISPs, lied under the 1024 kbps label. Again, this concentration measure decreased to 50% since the setting of the last standard. However, from Figure 2, we infer that even after the settlement of $10 - BL$ standard, 85% of the contracts supplied by ISPs in Colombia feature a download speed under 4096 kbps. This represents just a decrease from almost 100% and 95% displayed before the setting of $08 - BL$ and in-between both labels, respectively.

Therefore, there exists preliminary evidence that quality standards have allowed to promote fixed Internet adoption in the Colombian ICT market, but unfortunately, some stickiness is observed since a significative fraction of the contracts supplied by ISPs lie under the current FCC-Broadband standar of 4 megabits per second. Hence, there is a need to study the role that Broadband-level standards may play in the structure and performance of Internet services markets, and once a relation is found, to provide a possible explanation to the current conditions of the market, recently highlighted by the OECD and ratified by available data.

# 4 Data

The Colombian telecommunications regulator, currently CRC, has implemented, since 2006 a rigorous information disclosure regime for fixed Internet services providers. Indeed, every ISP is mandated to provide, initially biannually and afterwards quarterly, information about all the offers, namely contracts, available to be chosen by potential subscribers in every municipality of Colombia.

More specifically, since the end of 2005 and the end of 2008 every ISP in the country had to report, on a biannually basis, for every advertised offer, all details related to: (i) the municipality at which the contract is available; (ii) the segment for which the offer is designed to (residential or business offer); (iii) the technology by means of the service is supplied; (iv) the download and upload speeds; (v) the monthly fee; and (vi) effective subscribers to the respective contract.[6] Since the first quarter of 2009 and nowadays, the information above is disclosed on a quarterly basis. The database available for our purposes covers the period between the last quarter of 2005 and the first quarter of 2012.

Summary descriptive statistics reflect that for the period of study, 32.7% of the available contracts correspond to residential varieties, whereas the remaining 67.3% is linked to business varieties.[7] Alternatively, when measured through subscriptions,

[6]Upload speed is only available since the second quarter of 2008.

[7]The Colombian fixed Internet database also includes public institutions and social connections financed through the universal service fund, FonTIC, which were excluded so as to control for

the average composition of the Colombian fixed Internet market corresponds to 87.1% of residential subscribers and 12.9% of business users.

Concerning the technological profile, fixed Internet connections classified by the provision-technology imply that the 49.2% of the varieties are served through xDSL technology, the 14.4% of the varieties by satellite, the 9.6% by cable, and the remaining 26.7% of varieties were supplied by other technologies. When the analysis is made in terms of subscriptions, 63.5% of fixed Internet connections are done by xDSL technology, 33.8% correspond to cable connections, and 0.1% to satellite Internet.

For this study we have compiled a new data set for the Colombian fixed Internet market. Provided that the relevant market for fixed Internet is of local scope, we aggregate the detailed information of varieties in a representative contract for every municipality of the country so as to display aggregate information on quantities (i.e., aggregate subscribers per local inhabitant or local penetration rate, $penetration_{i,t}$) and weighted average information on prices (i.e., weighted average monthly fee in USD, $p_{i,t}$) for every local market of the country.[8]

The data set also contains information of fixed Internet quality attributes in every local market, which for the purpose of the present paper, are restricted to the weighted average download speed (measured in kilobits per second) of the representative contract or variety in the municipality, which we will call $s_{i,t}$. Moreover, an average measure of contract diversity is built, in order to reflect the average number of varieties (contracts) per ISP in each local market, which is referred as $d_{i,t}$. In this line, a technology diversity indicator is constructed for every municipality, which amounts to add-up the different technologies which are used to cover the local market, namely, $tec_{i,t}$.

Three structural indicators of the supply-side of every local market were obtained. First, we construct a concentration measure, from the family of Herfindahl-Hirschman indices, to evaluate the distribution of contracts or varieties among ISPs in every local market, which we name as $hhi_{1,i,t}$. In this line, $hhi_{1,i,t}$ allows us to evaluate the level of concentration of varieties among ISPs and hence, to identify

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private supply of fixed Internet in our study.

[8] Two methodological issues in the consolidation of the data set should be highlighted. First, for the observations of years 2011 and 2012 residential contract varieties were also discriminated by socioeconomic strata, which for the Colombian case lies between 1 to 6, from the poorest to the richest households. Since this disaggregation was not available for the period 2005 to 2010, we simply averaged the monthly fee of contract varieties which display the same ISP, technology, download speed, and upload speed. Second, due to severe inconsistencies in the tariff information reported by the ISP TELMEX S.A. in the third quarter of 2010 and 2011, the simple average of the monthly fee of every contract variety of this ISP of the second and fourth quarter of the respective years was employed.

if a given provider is hoarding or not the diversity of contracts in the municipality. Second, we measure the distribution of subscribers along varieties in every municipality by the construction of the indicator $hhi_{2,i,t}$. Third, we build the standard distribution of subscribers among ISPs in every local market, and we call it $hhi_{3,i,t}$.

Complementarily, to allow the possibility of income effects in our analysis, we build a per capita income *proxy* using fiscal income information for every Colombian municipality, on a yearly basis for the period 2005-2012, published by the Ministry of Planning of Colombia (DNP for its name in Spanish).[9]

Table 1 presents the descriptive statistics for the main variables of our database. Missing and zero data on monthly fees per contract lead to the deletion of all these varieties before aggregating or weighting at every local market [10]. This implied that aggregate information reported for the Colombian fixed Internet market for the first and third quarter of 2008 was ignored due to the unavailability of information linked to monthly fees.

| Variables | Obs. | Mean | Std. Dev | Min | Max |
|---|---|---|---|---|---|
| *Demand Expansion* | | | | | |
| Subscribers | 14435 | 2809.59 | 31250.47 | 1.000 | 1097475 |
| Penetration | 14435 | 0.01 | 0.02 | 0.000 | 0.25 |
| *Internet Service Attributes** | | | | | |
| Download Speed | 14435 | 1534.52 | 674.81 | 4.000 | 16640 |
| Monthly-fee | 14435 | 40.68 | 25.39 | 0.005 | 4187 |
| *Municipality market attributes** | | | | | |
| Contracts | 14435 | 194.68 | 117.23 | 1.000 | 376 |
| Internet Service Providers (ISP) | 14435 | 12.91 | 5.51 | 1.000 | 23 |
| Contracts/ISP | 14435 | 13.79 | 4.67 | 1.000 | 25 |
| Available technologies | 14435 | 7.55 | 1.77 | 1.000 | 10 |
| $hhi^1$ | 14435 | 0.21 | 0.15 | 0.064 | 1 |
| $hhi^2$ | 14435 | 0.52 | 0.22 | 0.180 | 1 |
| $hhi^3$ | 14435 | 0.16 | 0.09 | 0.058 | 1 |
| *Municipality additional variable* | | | | | |
| log(pc income) | 14189 | -2.70 | 0.97 | -10.693 | 3 |

*Note:* *Weighted average by municipality total subscribers.

**Table 1:** Market Represantive Summary Statistics 2005q4-2012q1

[9] For detailed information on this variable visit the webpage: *https://www.dnp.gov.co/Programas/DesarrolloTerritorial/Evaluaci%C3%B3nySeguimientodela Descentralizaci%C3%B3n/Desempe%C3%B1oFiscal.aspx*

[10] See appendix A for a descriptive presentation of data set consolidation.

From Table 1, we see that, weighting by subscribers in every local market,the average municipality in Colombia for the period 2005-2012 had an average download speed of 1534 kbps with an average monthly fee of USD 41. In the same terms, the average number of varieties supplied in a municipality were 194.68 contracts supplied by 12.91 ISPs by means of 7.55 technologies. Additionally, from Table 1 we infer that the average municipality in Colombia has a Herfindahl measure $hhi_1$ of 2100 which implies that contract varieties are hypothetically distributed among, approximately, five ISPs. Observing the average value of $hhi_2$ we see that in the representative local market of the country, approximately two contracts cover the fixed Internet penetration of the municipality. Similarly, from the average value of $hhi_3$, we obtain that the average Colombian municipality is served by six ISP during the period of analysis.

In addition to the main descriptive statistics of the full data set, it is important to evaluate the aggregate performance along time of the main variables related to price, $p_{i,t}$, quality, $s_{i,t}$, and contract diversity, $d_{i,t}$. Table 2 shows the evolution of the country average indicators of those variables on a yearly basis.[11]

| Year | Municipalities | Download Speed ($\bar{s}$) | Monthly-fee ($\bar{p}$) | Contracts/ ISP ($\bar{d}$) |
|---|---|---|---|---|
| 2005 | 54 | 290.71 | 56.00 | 8.25 |
| 2006 | 509 | 327.74 | 50.16 | 9.57 |
| 2007 | 675 | 424.51 | 46.21 | 11.90 |
| 2008 | 902 | 940.44 | 43.38 | 13.06 |
| 2009 | 1014 | 1376.15 | 45.97 | 13.49 |
| 2010 | 753 | 1665.66 | 40.27 | 14.27 |
| 2011 | 710 | 2181.60 | 38.56 | 14.84 |
| 2012 | 732 | 2218.34 | 36.80 | 14.76 |

**Table 2:** Always-on fixed Internet Acces Data set

From Table 2 we infer that the average monthly fee of a fixed Internet connection in Colombia decreased from USD 56.00 in 2005 to USD 36.80 in 2012, which represents a continuous weighted average yearly decrease of $-5.82\%$. As far as the weighted average download speed, it passed from 290.71 kbps in 2005 to 2218.34 kbps in 2012, which amounts to an average yearly increase of 33.68%. In the same line, the average value of contract diversity in the representative local market in 2005 was 8.25 varieties per ISP, whereas this indicator for 2012 expanded to 14.76, showing an average yearly increase of 8.67%. This performance provides preliminary

[11] See appendix A for the evolution of the country average indicators on a quarterly basis.

evidence of the prevalence of quality and variety, instead of price, competition in the Colombian fixed Internet market.

# 5 The structural demand model

We follow the traditional structural demand estimation of discrete choice models with exogenous product attributes, more specifically the vertical differentiation attribute, in line with Berry et al. (1995). However, since we are interested to evaluate the impact of regulatory decisions looking for the setting of download-speed standards on market structure and performance, following Economides (1993), the model of variety-differentiated products is augmented to include quality differentiation. Hence, in our model each differentiated product, i.e., a fixed Internet contract supplied by as ISP at a given location, featuring a monthly fee and a specific combination of down- and up-load speed; is defined by one feature of variety and one feature of quality.

In our model, products are differentiated in two dimensions, one being the horizontal differentiation and the other being a dimension of quality differentiation. In fact, consumers or potential fixed Internet subscribers are differentiated according to the uses they want to give to their Internet connections, but they all prefer higher speed at the same monthly fee. From the varietal or horizontal differentiation perspective, there are two main types of Internet connection. Symmetric connections refer to technologies that provide the same bandwidth upstream (sending) and downstream (receiving).[12] On the other side, asymmetric connections provide relatively lower rates upstream but higher rates downstream.

When considering broadband needs, an asymmetric connection is ideal for most homes and small businesses. Most of its two-way or duplex bandwidth is devoted to the downstream direction, sending data to the user. Only a small portion of bandwidth is available for upstream or user-interaction messages. Most broadband data (graphics and multi-media, for example) need lots of downstream bandwidth. At the same time, the average homes or small business connection generally requires little upstream bandwidth. On the contrary, a symmetric connection is generally used for wideband digital transmission within a corporate site and between the telephone company and a customer, since an equal amount of bandwidth is available in both directions and the data rate is the same in both directions.

[12]Symmetric Internet services provide identical data rates whether we are sending information, like an email, or receiving information, downloading a file or accessing a web site.

From the vertical differentiation perspective, due to information constraints for the period to be studied, we reduce the quality represented by the download speed-level of every contract supplied by an ISP. It is straightforward to assume that every potential Internet subscriber prefers faster speed rates for the same monthly fee.

Our model constitutes an extension to Economides (1993) and Berry et al. (1995) since the order of moves for the choice of quality, variety and price is as follows. First, the ISP enter the local relevant market of fixed Internet provision. Second, it commits to an aggregate quality level following the infrastructure investments to be deployed to serve the municipality. Third, provided that aggregate quality, i.e., peak download speed level has been set, the ISP decides simultaneously on the variety differentiation variable, i.e., download/upload speed asymmetry, together with price, i.e., the monthly fee.

The use of this specific game structure reflects the fact that the capacity constrained variable, that is, quality represented by download speed-level, is not flexible in the short run. Therefore, when facing demand of potential subscribers, the strategic variables for the ISP are prices (monthly fees) and asymmetry levels.

In terms of measuring the impact of a regulated Broadband quality label on market structure and performance, at this stage of our research agenda, we concentrate in the market-level effects. As we have already mentioned, the geographic scope of our market is local, and therefore we need to specify aggregate measures of quality, variety, price and service penetration. Related to quality, we employ the variable $s_{i,t}$ which corresponds to the weighted average, in respect of subscribers, of download speed of all varieties or contracts supplied by the ISPs serving the municipality. As far as price, we call for the variable $p_{i,t}$, which represents the weighted average, in terms of effective subscribers, of the monthly fees for the contracts provided in the municipality. As to penetration rate, i.e., $penetration_{i,t}$, it is calculated as the aggregate fixed Internet local subscribers divided by the total population of the municipality.

Since the horizontal differentiation variable at a contract-level is represented by the asymmetry ratio between download and upload speed, and those measures are dependent of the aggregate quality (download speed) at a given local market, we build a proxy for aggregate varieties' diversity, taking advantage of the informational features of our data set. Since every contract reported by an ISP at a given municipality is the specific combination of five variables, namely, supply technology, segment (residential or business), download speed, upload speed, and price; it is direct to see that the aggregate number of contracts by an ISP reflects the feasible combination of strategic variables available to the ISP at the price and variety setting stage. Thus, we appeal to the average number of contracts supplied by ISP in every location as a proxy for horizontal differentiation measure, namely, the variable $d_{i,t}$ of our data set described in Section 4.

As a consequence, at the price and variety setting stage, aggregate market level demand is given by:

$$\begin{aligned}\text{penetration}_{i,t} = \beta_1 \text{p}_{i,t} + \beta_2 \text{d}_{i,t} + \beta_3 \text{08-BL} + \beta_4 \text{10-BL} \\ + \beta_5 X_{i,t} + \alpha_i + \alpha_t + \varepsilon_{i,t}\end{aligned} \tag{1}$$

From (1), we observe that the impact of the regulatory definition of Broadband-level speed is measured by means of the effect of intercept-dummy variables, i.e., $08-BL$ and $10-BL$, on the structural demand estimation. Since we follow a log-log specification, we can interpret estimated parameters as elasticities. Furthermore, in order to avoid bias problems in our structural demand estimation we introduce a set of control variables.

First, fixed Internet provision, as an ICT service, is subject to the effect of technological progress. Then, there is a uniform trend pattern for every local market in the country, which is captured by coefficient $\alpha_t$.[13] Second, in order to control for any municipality-related specific feature which could exert an impact in local fixed Internet penetration, we introduce local-fixed effects through the parameter $\alpha_i$. Third, to control for the omitted variable bias problem, income and technology diversity effects are incorporated to the demand estimation. Consequently, $X_{i,t}$ is a vector formed by two variables, namely, per capita income ($pc - income_{i,t}$) and the count of technologies employed by ISPs to effectively cover the local market ($tec_{i,t}$).

Estimating demand inevitably raises questions about endogeneity and identification. Following Hausman (1978), we find the presence of simultaneity between the average local monthly fee ($p_{i,t}$) and the contract diversity measure ($d_{i,t}$); and the local market penetration rate. This result is consistent with the game structure described above in this section. To correct for endogeneity we instrument both $p_{i,t}$ and $d_{i,t}$ using download speed and supply-side competitive structure variables. That is,

$$\text{p}_{i,t} = \gamma_1 \text{s}_{i,t} + \gamma_2 \text{HHI}_{i,t} + \gamma_3 X_{i,t} + \delta_i + \delta_t + v_{i,t} \tag{2}$$

$$\text{d}_{i,t} = \phi_1 \text{s}_{i,t} + \phi_2 \text{HHI}_{i,t} + \phi_3 X_{i,t} + \psi_i + \psi_t + \zeta_{i,t} \tag{3}$$

[13] This parameter avoids any omitted variable bias, and consists of period-dummies which control for any trend linked to aggregate technological progress.

Download speed seems to be the most obvious choice of instruments for the price of Internet. Intuitively, download speed appears uncorrelated with the error term in the demand for fixed Internet, measured by the penetration rate at a given local market, and performs as the primary ingredient of an Internet contract. Indeed, the particular game structure assumed in our model considers that by the time of setting price and variety, the ISP considers quality, i.e., download speed as a fixed set. Therefore, download speed should be highly correlated with Internet prices and varieties.[14]

Moreover, a stream of research that examines the relationship between market structure and prices has been developed over the last decades. Weiss (1989) provides a large number of price-concentration studies. These studies include a wide range of industries such as grocery (Cotterill 1986), banking (Calem and Carlino 1991), airlines (Borenstein and Rose, 1994), hospitals (Keeler et al., 1999), cable television (Emmons and Prager, 1997), and movie theaters (Davis, 2005).

A general finding in this literature is that high concentration is associated with significantly higher prices (Weiss 1989, see also various studies cited in a recent survey by Newmark, 2004). However, both Bresnahan (1989) and Schmalensee (1989) point out that the price-concentration regressions, such as those used in the literature, suffer from serious endogeneity issues.[15] In particular, there might be unobserved demand and cost shocks in a market that influence not only prices but also the underlying market structure.[16]

Evans et al. (1993) formally address this issue and propose a combination of fixed effects and instrumental variable procedures that are applicable when panel data are accessible. They study the price-concentration in the airline industry and find that the impact of concentration on price is severely biased using OLS procedures. Following Evans et al. (1993) this bias arises for two reasons: (i) performance feeds back into structure, among these feedback processes are investment in new capacity, research and development, and entry and exit to the industry; and (ii) measured concentration as function of outputs is correlated with price determinants, and then also correlated with the error term. They obtain that fixed-effects estimation, which

[14]Peak download speed of Internet services, at an aggregate level, reflects the capacity constraint faced by an Internet service provider, and indeed is the main cost driver of a single Internet offer.

[15]The fundamental problem arises because market structures are not randomly assigned but rather are strategic decisions by firms that evaluate demand and cost conditions as well as potential competitors in the market in their entry decisions.

[16]For example, markets with unobserved high costs are likely to have higher prices, but these markets are also likely to attract fewer entrants. In this case, a regression of prices on the number of firms may lead to the inference that high prices are associated with a low number of firms, but this finding may partially be driven by the unobserved costs. Similarly, unobserved positive demand shocks may result in higher prices and an unusually large number of firms in a market, in which case the impact of competition on prices may be understated.

uses only within-market variation over time, solves the endogeneity problem derived from the feed back of performance into structure. Moreover, they conclude that IV estimation would help to solve the bias problem derived from the correlation of concentration measures with the error term.

Thus, following Evans et al. (1993) we observe that the estimation of (2) includes municipality and period fixed effects which allow us to rule out the endogeneity bias present in OLS estimation. In addition to this, we should highlight that $HHI_{i,t}$ is a vector of three market structure variables, namely: (i) $hhi_{1,i,t}$ which measures concentration of contract varieties among ISPs in every local market; (ii) $hhi_{2,i,t}$ which measures concentration of subscribers over the aggregate diversity contracts in every municipality; and (i) $hhi_{3,i,t}$ which amounts to the standard measure of subscribers over ISPs.

We apply this procedure to the local fixed Internet market data set, which offers several advantages over previous applications in this stream of research. As we discuss in the data section, we observe a wide range of market structures, represented by the heterogeneity of variables ($hhi_{1,i,t}$, $hhi_{2,i,t}$, $hhi_{3,i,t}$) in Table 2. Such large variation in market structure provides a unique setting to study the relationship between prices and market structure.

This approach allows us to make two contributions to the research in the area. First, we highlight the importance of accounting for the endogeneity of market structures that arises in the empirical analysis of price competition in a market. Second, we are able to show how the price choices of ISPs depend upon the market characteristics.

## 5.1 Results

This paper explores the issue of how the regulator's objective of guaranteeing adequate quality provision of Internet services to potential users, typically emphasized in reducing information asymmetry by setting download-speed standards, should affect the market structure and performance in the provision of Internet services. For the particular effect of the Broadband speed-level setting in Internet adoption, we are interested in estimating (1) in an instrumental variables framework, taking into account (2) and (3).

As far as Internet demand estimations, or more specifically for Broadband services, relevant literature has been developed by Madden and Simpson (1997), Varian (2000), Savage and Waldman (2004 and 2005), and Goel et al. (2006). In the case of

Goel et al. (2006), using a simple model and cross-country OECD data for the year 2000, they obtain that the demand seems price-inelastic in all estimated variants. Related to technology-specific demand estimations, Rappaport el al. (2003) and Crandall et al. (2002) report that DSL own price elasticity is found to be elastic. In this line, the work of Pereira and Ribeiro (2006) is highlighted since they conclude, for the case of Portugal, that the demand for broadband access is more elastic than the demand for narrowband access, with an estimate of $-2.836$ and $-1.156$, respectively.[17]

Alternatively, Cardona et al. (2009) study the demand for Internet services in Austria, which performs close similarities to the Colombian case. Provided the high penetration of cable Internet connections, they estimate own- and cross-price elasticities between cable and xDSL technologies allowing for the possibility of fixed and mobile Internet substitution. The estimation results suggest that demand for DSL is elastic and that cable networks are likely to be in the same market as DSL connections both at the retail and at the wholesale level. Similarly to Pereira and Ribeiro (2006), the authors obtain enough evidence to affirm that narrowband and broadband markets are separate.

Following the literature review, we believe that our approach is novel, since we are interested in evaluating if the regulatory definition of $08-BL$ and $10-BL$ brought with themselves two effects, i.e., (i) the increase/decrease of the average local market penetration rate, which is measured in terms of the sign and statistical significance of the parameters of the respective intercept-dummy variables; and (ii) the separation/integration of markets around the regulatory definition of Broadband Internet.

To measure the separation/integration effect of quality standards, we proceed to develop alternative estimations of the structural demand model taking into account that the Broadband speed-level defines two markets, namely, one composed of contracts which download speed is under the non-mandatory Broadband level, and another which covers contracts satisfying regulatory compliance. Finally, in order to check for existence of the market, we apply the above mentioned criteria for the whole estimation period.[18] Table 3 summarizes the instrumental variables demand estimation results.

[17] As far as the relationship between narrowband and broadband markets, Flamm and Chaudhuri (2007), Hausman et al. (2001), and Srinuan and Bohlin (2013) constitute relevant literature around this issue.

[18] This methodology could be an approximation to check for ex-post optimality of the Broadband speed-level set by the regulatory labelling procedure.

| | Total Market (1) | <512Kbps (2) | ≥512Kbps (3) | <1024Kbps (4) | ≥1024Kbps (5) |
|---|---|---|---|---|---|
| | *Panel A: First Stage for Monthly-fee* | | | | |
| s | 0.0992*** | 0.0154 | 0.122 | 0.0305* | 0.331*** |
| | (0.0177) | (0.0209) | (0.0866) | (0.0171) | (0.0913) |
| $hhi_1$ | 0.745*** | 0.893*** | 0.491*** | 0.706*** | 0.0193 |
| | (0.0776) | (0.0743) | (0.0812) | (0.0614) | (0.0963) |
| $hhi_2$ | 0.181*** | -0.181*** | 0.475*** | -0.0384 | 0.260*** |
| | (0.0338) | (0.0288) | (0.0501) | (0.0295) | (0.0590) |
| $hhi_3$ | -1.599*** | -1.061*** | -1.740*** | -1.225*** | -1.074*** |
| | (0.0889) | (0.0690) | (0.104) | (0.0672) | (0.107) |
| | *Panel B: First Stage for Contracts/ISP* | | | | |
| s | 0.0651*** | 0.0205*** | 0.0385* | 0.0459*** | -0.244*** |
| | (0.00505) | (0.00589) | (0.0233) | (0.00459) | (0.0281) |
| $hhi_1$ | 0.470*** | 0.113*** | 0.827*** | 0.304*** | 0.623*** |
| | (0.0360) | (0.0290) | (0.0530) | (0.0240) | (0.0482) |
| $hhi_2$ | -0.764*** | -0.767*** | -0.817*** | -0.758*** | -0.677*** |
| | (0.0160) | (0.0156) | (0.0219) | (0.0146) | (0.0279) |
| $hhi_3$ | 0.603*** | 0.815*** | 0.497*** | 0.665*** | 0.356*** |
| | (0.0350) | (0.0292) | (0.0462) | (0.0261) | (0.0518) |
| | *Panel C: Two-Stage Least Squares* | | | | |
| | *Dependent Variable: Always-on Internet Services Penetration* | | | | |
| p | -0.809*** | -1.561*** | -1.156*** | -1.257*** | -1.153*** |
| | (0.0442) | (0.0704) | (0.0575) | (0.0586) | (0.114) |
| d | 1.116*** | 0.953*** | 0.645*** | 1.007*** | 0.375*** |
| | (0.0326) | (0.0512) | (0.0445) | (0.0405) | (0.0845) |
| 08-BL | 0.241*** | -0.525*** | 0.575*** | -0.203*** | 1.507*** |
| | (0.0467) | (0.0576) | (0.0941) | (0.0610) | (0.185) |
| 10-BL | 0.119*** | -0.146*** | 0.279*** | -0.334*** | 0.604*** |
| | (0.0322) | (0.0485) | (0.0454) | (0.0460) | (0.0708) |
| pc income | 0.0705** | 0.0772 | 0.0967* | 0.133*** | -0.0427 |
| | (0.0295) | (0.0522) | (0.0552) | (0.0423) | (0.0825) |
| tec | 1.105*** | 1.022*** | 0.964*** | 0.906*** | 0.907*** |
| | (0.0348) | (0.0503) | (0.0512) | (0.0391) | (0.0620) |
| Observations | 14,169 | 13,116 | 8,212 | 13,906 | 5,744 |
| R-squared | 0.765 | 0.306 | 0.831 | 0.515 | 0.851 |
| Municipalities | 1,048 | 1,030 | 747 | 1,046 | 518 |
| Fixed Effects | ✓ | ✓ | ✓ | ✓ | ✓ |

*Notes:* Robust standard errors in parentheses. Observations and municipalities information is drawn from the unbalanced panel. Fixed Effects include period and municipality control variables. Sample period quarterly (when available) 2005q4-2012q1. *** p<0.01, ** p<0.05, * p<0.1.

**Table 3:** Always-on fixed Internet Demand Estimation

From the first column of panel $C$ in Table 3 we observe that the $2SLS$ estimation of (1) leads to a price elasticity of demand estimate of $-0.809$ for the whole period $2005q4 - 2012q1$ which lies on the inelastic results obtained in Goel et al. (2006). Additionally, it is direct to see that the horizontal differentiation proxy, namely, average contract diversity per local market, has an estimated elasticity of 1.116, implying that local market penetration is elastic and positively related to increases in the level of horizontal differentiation of fixed Internet contracts. This result is in line with Economides (1993), and shows that fixed Internet subscribers, ceteris paribus, prefer a higher level of quality (in the aggregate) and a larger number of varieties.

As regards to the impact of download speed-levels in market adoption, we infer that the settlement of $08 - BL$ contributed to expand the average fixed Internet penetration in 24.1%, whereas the adoption of $10 - BL$ just had an incremental effect over aggregate market penetration of 11.9%. Adding-up both effects, allows us to stated that regulatory intervention for consumer protection and quality purposes had a significative impact on average market penetration of fixed Internet services, which amounts to an increase of 36.0%.

Linked to control indicators which avoid the omitted variable bias of parameter estimates, we see from column 1 in panel $C$ of Table 3, that income elasticity of demand is less than one, which means that per capita income increases do not have a great impact on fixed Internet demand, showing that probably fixed Internet is a necessity service in Colombia. Concerning technology diversity, as expected, elasticity of demand to the availability of additional provision technologies is unitary.

Conversely, interpreting the separation/integration effect of quality standards, columns 2 and 3 show the parameter estimates of sampling our data set in terms of compliance of the label $08 - BL$, at the contract level. From panel $C$ in Table 3, we see that for both markets, price, income and technology diversity elasticity of demand are not statistically different.[19] However, markets differ in the sensitivity of local market penetration to contract variety measure ($d$) and the intercept-dummies representing the settlement of Broadband labels. See the bottom sections of Figure 3 and 5.

In the first case, the elasticity of market penetration to contract variety, a measure of horizontal differentiation in the local market, is statistically less than one for the sub-market complying with $08 - BL$, that is, for fixed Internet connections with download speed over 512 kbps. This result, together with the fact that column 3 of

[19] Appendix E performs reverse recursive estimations to test for the stability of price elasticity of demand for the whole market. See the upper sections of Figure 3 and 5.

panel B in Table 3 implies that the sensitivity of contract variety in this sub-market to download speed is almost not different from zero, allows us to affirm that horizontal differentiation is being employed intensively to meet the lower bound of the label $08 - BL$, that is contracts with download speed of 512 kbps. Thus, following that consumers prefer more contract variety, this implies that aggregate fixed Internet consumption is happening at speeds too close to the regulatory standard. This could provide an explanation to the feature highlighted by OECD (2014a) in which agreggate download speed in Colombia lag behind of OECD standards.

In the second case, the intercept-dummy linked to $08 - BL$ is significative and negative for the sub-market with contract download speeds under 512 kbps, which approximates the effect of a MQS in reducing vertical differentiation (see Ronnen, 1991, and Crampes and Hollander, 1995), through the increase of quality provision of the contracts under the regulated broadband speed level. This effect is represented by the fact that the setting of $08 - BL$ reduced the average market penetration of under-the-standard contracts in 52.5% On the contrary, the decision to impose a broadband speed-level in 2008 implied an average increase of market penetration of 57.5% in fixed Internet contracts meeting the regulatory quality standard.

Similarly, interpreting the separation/integration effect of quality standards, columns 4 and 5 show the parameter estimates of sampling our data set in terms of compliance of the label $10 - BL$, at the contract level. From panel $C$ in Table 3, we see that for both markets, price, income and technology diversity elasticity of demand are again not statistically different. However, markets differ in the sensitivity of local market penetration to contract variety measure ($d$) and the intercept-dummies representing the settlement of Broadband labels[20].

In the first case, the elasticity of market penetration to contract variety, is statistically less than one (0.375) for the sub-market complying with $10 - BL$, that is, for fixed Internet connections with download speed over 1024 kbps. This result is more significative than that obtained for the label $08 - BL$, since column 5 of panel B in Table 3 shows that the sensitivity of contract variety in this sub-market to download speed is negative and significative. In such a framework, this means that horizontal differentiation is being employed uniquely to meet the lower bound of the label $10 - BL$, that is contracts with download speed of 1024 kbps. Consequently, there is enough evidence to explain that one of the main reasons for Colombia's fixed Internet speed stagnation is that since the regulatory label $10 - BL$ a negative relationship between contract variety and quality arose in the Colombian Broadband Internet market.

[20]See appendix B and C for descriptive statistics and mean test of market separation

# 6 The contract varieties model

We should highlight that the novel approach of our paper stems from the specific game structure that lies behind the fixed Internet market, in which: (i) the ISP enters the market of fixed Internet provision; (ii) it commits to an aggregate quality level following the infrastructure investments to be deployed to serve the municipality; and (iii) the ISP decides simultaneously on the variety differentiation variable, i.e., download/upload speed asymmetry, together with price, i.e., the monthly fee.

However, we have seen in subsection 5.1 that the separation/integration effect of quality standards, implies statistically significant differences in demand elasticities with respect to the contract variety measure $d_{i,t}$. Then, it is important to independently estimate the contract variety equation, as follows:

$$\mathrm{d}_{i,t} = \lambda_1 \mathrm{s}_{i,t} + \lambda_2 \mathrm{HHI}_{i,t} + \lambda_3 \text{08-BL} + \lambda_4 \text{10-BL} + \rho_i + \rho_t + \mu_{i,t} \tag{4}$$

In (4) we follow the approach of Evans et al. (1993) and introduce period-($\rho_t$) and local-($\rho_i$)-fixed effects to solve for endogeneity problems in the contract varieties equation in terms of supply-side structural conditions. Moreover, from (4), we observe that the impact of the regulatory definition of Broadband-level speed is measured by means of the effect of intercept-dummy variables, i.e., $08 - BL$ and $10 - BL$, on the structural demand estimation. Since we again follow a log-log specification, we can interpret estimated parameters as elasticities.

## 6.1 Results

Table 4 summarizes the OLS contract varieties equation estimation results.

| | Total Market (1) | <512Kbps (2) | ≥512Kbps (3) | <1024Kbps (4) | ≥1024Kbps (5) |
|---|---|---|---|---|---|
| s | 0.0708*** | 0.0202*** | 0.0444* | 0.0465*** | -0.259*** |
| | (0.00514) | (0.00583) | (0.0251) | (0.00467) | (0.0287) |
| $hhi_1$ | 0.358*** | 0.0858*** | 0.525*** | 0.276*** | 0.420*** |
| | (0.0312) | (0.0254) | (0.0387) | (0.0229) | (0.0385) |
| $hhi_2$ | -0.771*** | -0.769*** | -0.846*** | -0.761*** | -0.684*** |
| | (0.0165) | (0.0154) | (0.0229) | (0.0146) | (0.0283) |
| $hhi_3$ | 0.642*** | 0.819*** | 0.633*** | 0.672*** | 0.407*** |
| | (0.0356) | (0.0295) | (0.0489) | (0.0270) | (0.0535) |
| 08-BL | 0.242*** | 0.212*** | 0.611*** | 0.364*** | 0.698*** |
| | (0.0701) | (0.0525) | (0.0686) | (0.0567) | (0.0657) |
| 10-BL | 0.198*** | -0.152*** | 0.695*** | -0.139*** | 0.421*** |
| | (0.0159) | (0.0140) | (0.0374) | (0.0146) | (0.0357) |
| Constant | -0.189*** | 0.00907 | -0.514*** | -0.131** | 1.706*** |
| | (0.0705) | (0.0535) | (0.170) | (0.0574) | (0.202) |
| Observations | 14,169 | 13,116 | 8,212 | 13,906 | 5,744 |
| R-squared | 0.652 | 0.705 | 0.699 | 0.682 | 0.713 |
| Municipalities | 1,048 | 1,030 | 747 | 1,046 | 518 |
| Fixed Effects | ✓ | ✓ | ✓ | ✓ | ✓ |

*Notes:* Robust standard errors in parentheses. The number of observations and municipalities refers to the total number of observations and municipalities in the unbalanced panel. Fixed Effects include time and municipality controls variables. Sample period: Quarterly 2005q4-2012q1. *** p<0.01, ** p<0.05, * p<0.1.

**Table 4:** Contract varieties estimation

From the first column of panel $C$ in Table 4 we observe that the estimation of (4) leads to a quality (download speed) elasticity of contract varieties estimate of 0.0708 for the whole period $2005q4 - 2012q1$ which implies that faster download speeds (higher quality levels) are linked to greater contract variety, as in the framework developed by Economides (1993).[21] Additionally, it is direct to see that the concentration measure of contract varieties over ISPs ($hhi_{1,i,t}$), which shows if in a given local market an ISP is hoarding or not the provision of varieties, significatively and positively affects the provision of diversity (positive elasticity of 0.358). However, the concentration of subscribers in a given class of contract variety ($hhi_{2,i,t}$), negatively affects the average measure of contract varieties in the local market. This an intuitive, but powerful result, in which if a contract is accepted by the majority of potential customers, in a given municipality, the incentives to supply contract varieties is negatively affected.

Finally, the concentration of subscriber over ISPs in a local market ($hhi_{3,i,t}$) affects positively the provision of varieties which at the same time expands local

[21] See Figure 4 in appendix E for reverse recursive estimation of this parameter for stability purposes.

market penetration. Therefore, as far as an ISP manages to enlarge its market share in terms of subscribers, more incentives are provided to extract consumer surplus by means of horizontal differentiation and this will counterbalance the negative impact of market concentration on local fixed Internet adoption.

As regards to the impact of download speed-levels in the supply of contract varieties, we infer that the settlement of $08 - BL$ contributed to expand the average contract varieties in 24.2%, whereas the adoption of $10 - BL$ just had an incremental effect over aggregate market penetration of 19.8%. Adding-up both effects, allows us to stated that regulatory intervention for consumer protection and quality purposes had a significative impact on average market contract varieties of fixed Internet services, which amounts to an increase of 44.0%.

Conversely, interpreting the separation/integration effect of quality standards, columns 4 and 5 show the parameter estimates of sampling our data set in terms of compliance of the label $10 - BL$, at the contract level. From panel $C$ in Table 3, we see that markets differ in the sensitivity of local contract variety measure ($d$) to the quality variable, i.e., download speed ($s$), and the intercept-dummy representing the settlement of Broadband label $10 - BL$.

In the first case, the elasticity of contract varieties (horizontal differentiation) to download speed (vertical differentiation), is statistically significant and negative ($-0.259$) for the sub-market complying with $10 - BL$, that is, for fixed Internet connections with download speed over 1024 kbps.[22] This result shows that the implementation of the quality label $10 - BL$, if considered as MQS induces a negative relationship between quality and contract diversity. Even if welfare consequences of this result under the specific game structure of the paper is part of the future research agenda, the permanent increase in contract varieties during the period of study, provide preliminary evidence to confirm that aggregate fixed Internet consumption is happening at speeds too close to the regulatory standard. This could provide an explanation to the feature highlighted by OECD (2014a) in which aggregate download speed in Colombia lag behind of OECD standards.

# 7 Conclusions

This paper develops a structural model which allows estimating the impact of regulatory decisions looking for the setting of download-speed standards on market

[22] Appendix E performs reverse recursive estimation of this parameter in order to check for stability. See Figure 6.

structure and performance. We characterize a setting under which quality standards improve both service quality and availability. As to quality, we evaluate the impact of quality standards on the performance of local demand from a detailed database of broadband internet subscribers, discriminated by the main attributes of an internet subscription contract as location, supplier, monthly-fee, download- and upload-speed features.

The main objective of this paper is to measure the impact of Broadband quality labeling on product adoption and variety and we follow the traditional structural demand estimation of discrete choice models with exogenous product attributes, in line with Berry et al. (1995). In our model, products are differentiated in two dimensions, one being the horizontal differentiation and the other being a dimension of quality differentiation. In fact, consumers or potential fixed Internet subscribers are differentiated according to the uses they want to give to their Internet connections, but they all prefer higher speed at the same monthly fee. From the vertical differentiation perspective, due to information constraints for the period to be studied, we reduce the quality represented by the download speed-level of every contract supplied by an ISP. It is straightforward to assume that every potential Internet subscriber prefers faster speed rates for the same monthly fee.

Our model constitutes an extension to Economides (1993) and Berry et al. (1995) since the order of moves for the choice of quality, variety and price is as follows. First, the ISP enter the local relevant market of fixed Internet provision. Second, it commits to an aggregate quality level following the infrastructure investments to be deployed to serve the municipality. Third, provided that aggregate quality, i.e., peak download speed level has been set, the ISP decides simultaneously on the variety differentiation variable, i.e., download/upload speed asymmetry, together with price, i.e., the monthly fee.The use of this specific game structure reflects the fact that the capacity constrained variable, that is, quality represented by download speed-level, is not flexible in the short run. Therefore, when facing demand of potential subscribers, the strategic variables for the ISP are prices (monthly fees) and asymmetry levels.

From our results, we are able to identify the effect of quality regulation on the behavior of internet providers in a differentiated product market approach. As a consequence, we are able to assert that the response of internet service providers to quality regulation is a more intense product differentiation that contributes to demand expansion and therefore to improve broadband penetration indicators.

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# Appendix

## A. Data set consolidation and average main indicators by period

| Quarters | Data set 1 | Data set 2 Monthly-fee zero | Municipalities | Download Speed($\bar{s}$) | Monthly-fee($\bar{p}$) | Contracts/ ISP($\bar{d}$) |
|---|---|---|---|---|---|---|
| 2005q4 | 1049 | 1049 | 54 | 290.71 | 106399.74 | 8.25 |
| 2006q2 | 1044 | 383 | 376 | 287.12 | 105624.77 | 8.49 |
| 2006q4 | 1060 | 958 | 509 | 327.74 | 95295.70 | 9.57 |
| 2007q2 | 1109 | 1095 | 563 | 335.00 | 83688.65 | 10.07 |
| 2007q4 | 1109 | 968 | 675 | 424.51 | 87795.65 | 11.90 |
| 2008q2 | 1110 | 900 | 760 | 573.00 | 81784.21 | 12.98 |
| 2008q4 | 1109 | 1002 | 902 | 940.44 | 82420.52 | 13.06 |
| 2009q1 | 1111 | 1025 | 950 | 1068.81 | 81740.57 | 12.15 |
| 2009q2 | 1111 | 1030 | 973 | 1150.10 | 82223.04 | 13.20 |
| 2009q3 | 1110 | 1036 | 994 | 1335.01 | 87486.85 | 14.05 |
| 2009q4 | 1110 | 1034 | 1014 | 1376.15 | 87337.07 | 13.49 |
| 2010q1 | 1111 | 829 | 720 | 1414.10 | 82811.93 | 12.76 |
| 2010q2 | 1111 | 806 | 749 | 1482.38 | 68866.16 | 13.66 |
| 2010q3 | 1110 | 795 | 749 | 1622.17 | 85136.77 | 13.20 |
| 2010q4 | 1107 | 773 | 753 | 1665.66 | 76504.27 | 14.27 |
| 2011q1 | 1100 | 749 | 747 | 1830.13 | 68969.67 | 14.47 |
| 2011q2 | 1113 | 756 | 741 | 2007.76 | 73237.11 | 15.72 |
| 2011q3 | 1113 | 1110 | 765 | 2151.38 | 59314.26 | 15.81 |
| 2011q4 | 1111 | 726 | 710 | 2181.60 | 73268.49 | 14.84 |
| 2012q1 | 1104 | 735 | 732 | 2218.34 | 69914.70 | 14.76 |

**Table 5:** Always-on fixed Internet Acces Data set

# B. Varieties comparation by Broadband standards

| Quarters | $\geq 1024$ | $< 1024$ | Stat F. | $\geq 512$ | $< 512$ | Stat F. |
|---|---|---|---|---|---|---|
| 2005q4 | 1.839 | 6.670 | 1743.169 | 3.589 | 4.703 | 152.537 |
| 2006q2 | 3.014 | 6.815 | 38.906 | 5.694 | 4.979 | 4.041* |
| 2006q4 | 3.632 | 7.580 | 24.421 | 6.091 | 5.359 | 1.249* |
| 2007q2 | 3.868 | 7.826 | 46.533 | 6.034 | 5.569 | 0.687* |
| 2007q4 | 6.356 | 8.803 | 14.083 | 7.836 | 6.326 | 2.647* |
| 2008q2 | 6.015 | 9.248 | 16.867 | 8.679 | 6.144 | 6.979 |
| 2008q4 | 8.065 | 8.288 | 0.068* | 9.488 | 5.457 | 13.002 |
| 2009q1 | 7.513 | 7.613 | 0.021* | 8.770 | 5.078 | 15.752 |
| 2009q2 | 7.667 | 8.346 | 0.596* | 9.801 | 5.483 | 19.994 |
| 2009q3 | 8.621 | 7.970 | 0.778* | 10.408 | 5.538 | 19.114 |
| 2009q4 | 8.611 | 7.113 | 3.361* | 10.121 | 5.427 | 18.654 |
| 2010q1 | 8.905 | 6.108 | 6.808 | 10.702 | 5.141 | 15.903 |
| 2010q2 | 9.149 | 6.189 | 12.340 | 10.869 | 4.365 | 36.813 |
| 2010q3 | 9.270 | 5.810 | 17.680 | 10.778 | 3.930 | 50.314 |
| 2010q4 | 10.209 | 5.885 | 16.614 | 11.883 | 3.803 | 48.507 |
| 2011q1 | 11.207 | 5.564 | 22.777 | 12.585 | 4.162 | 51.785 |
| 2011q2 | 12.847 | 5.216 | 36.929 | 14.265 | 3.740 | 60.453 |
| 2011q3 | 12.454 | 5.578 | 35.867 | 13.809 | 4.096 | 85.866 |
| 2011q4 | 11.387 | 4.791 | 42.443 | 12.939 | 3.328 | 80.959 |
| 2012q1 | 11.853 | 4.883 | 46.171 | 13.157 | 3.083 | 88.797 |

* Contracts/ISP statistically equals between download-speed segments

**Table 6:** Weighted Average Contracts/ISP($\bar{d}$) by Broadband standards

# C. Fixed-Internet-contract implicit price

| Quarters | $\geq 1024$ | $< 1024$ | Stat F. | $\geq 512$ | $< 512$ | Stat F. |
|---|---|---|---|---|---|---|
| 2005q4 | 665.381 | 431.338 | 2.916* | 451.308 | 432.701 | 0.043* |
| 2006q2 | 827.086 | 506.338 | 4.438* | 342.187 | 532.129 | 2.303* |
| 2006q4 | 614.086 | 347.940 | 3.474* | 292.458 | 360.350 | 1.505* |
| 2007q2 | 405.524 | 292.689 | 4.201* | 244.726 | 301.657 | 15.799 |
| 2007q4 | 168.208 | 275.521 | 7.321 | 182.842 | 296.945 | 4.464* |
| 2008q2 | 128.878 | 211.354 | 9.439 | 117.983 | 341.699 | 66.628 |
| 2008q4 | 69.237 | 176.537 | 18.673 | 82.324 | 395.270 | 70.027 |
| 2009q1 | 61.404 | 159.438 | 59.594 | 71.667 | 412.499 | 137.921 |
| 2009q2 | 54.410 | 166.906 | 53.766 | 69.378 | 563.966 | 115.224 |
| 2009q3 | 51.786 | 222.611 | 123.733 | 65.464 | 677.766 | 123.437 |
| 2009q4 | 52.376 | 224.601 | 71.263 | 62.930 | 743.227 | 104.694 |
| 2010q1 | 48.438 | 186.829 | 55.928 | 56.779 | 708.874 | 23.691 |
| 2010q2 | 43.302 | 134.930 | 23.083 | 49.244 | 570.383 | 16.272 |
| 2010q3 | 48.430 | 135.298 | 16.627 | 53.697 | 688.164 | 6.062 |
| 2010q4 | 42.732 | 146.116 | 16.971 | 49.316 | 822.865 | 5.978 |
| 2011q1 | 36.478 | 169.102 | 14.235 | 40.825 | 824.270 | 7.931 |
| 2011q2 | 38.086 | 157.269 | 10.305 | 42.039 | 1306.929 | 4.503 |
| 2011q3 | 32.548 | 273.356 | 7.512 | 35.212 | 1625.820 | 5.356 |
| 2011q4 | 35.012 | 309.315 | 6.458 | 37.250 | 1862.851 | 5.083 |
| 2012q1 | 32.838 | 282.915 | 7.259 | 34.741 | 1525.524 | 5.356 |

* Monthly-fee/Download speed statistically equals between download-speed segments

**Table 7:** Fixed-Internet-contract implicit price (Monthly-fee/Download Speed)

# D. Aggregate subscribers

| | Standard 1024kbps | | Standard 512kbps | |
|---|---|---|---|---|
| Quarters | $\geq 1024$ | $< 1024$ | $\geq 512$ | $< 512$ |
| 2005q4 | 2542 | 225928 | 15243 | 213227 |
| 2006q2 | 3408 | 295615 | 34847 | 264176 |
| 2006q4 | 8513 | 522489 | 63693 | 467309 |
| 2007q2 | 14894 | 897115 | 114147 | 797862 |
| 2007q4 | 62591 | 1132023 | 283167 | 911447 |
| 2008q2 | 106274 | 1465162 | 954756 | 616680 |
| 2008q4 | 471392 | 1417519 | 1481878 | 407033 |
| 2009q1 | 612340 | 1420300 | 1685325 | 347315 |
| 2009q2 | 737924 | 1367282 | 1857923 | 247283 |
| 2009q3 | 1253923 | 911743 | 1959678 | 205988 |
| 2009q4 | 1340798 | 854895 | 2013331 | 182362 |
| 2010q1 | 1410755 | 879800 | 2133138 | 157417 |
| 2010q2 | 1669797 | 738423 | 2305848 | 102372 |
| 2010q3 | 1590165 | 711243 | 2223133 | 78275 |
| 2010q4 | 1956857 | 673686 | 2562893 | 67650 |
| 2011q1 | 2237886 | 584275 | 2738910 | 83251 |
| 2011q2 | 2485896 | 515853 | 2962523 | 39226 |
| 2011q3 | 2933893 | 247353 | 3149126 | 32120 |
| 2011q4 | 3101853 | 216507 | 3289898 | 28462 |
| 2012q1 | 3313339 | 162173 | 3452745 | 22767 |

**Table 8:** Aggregate subscribers by Broadband Standards

# E. Structural stability market coefficients

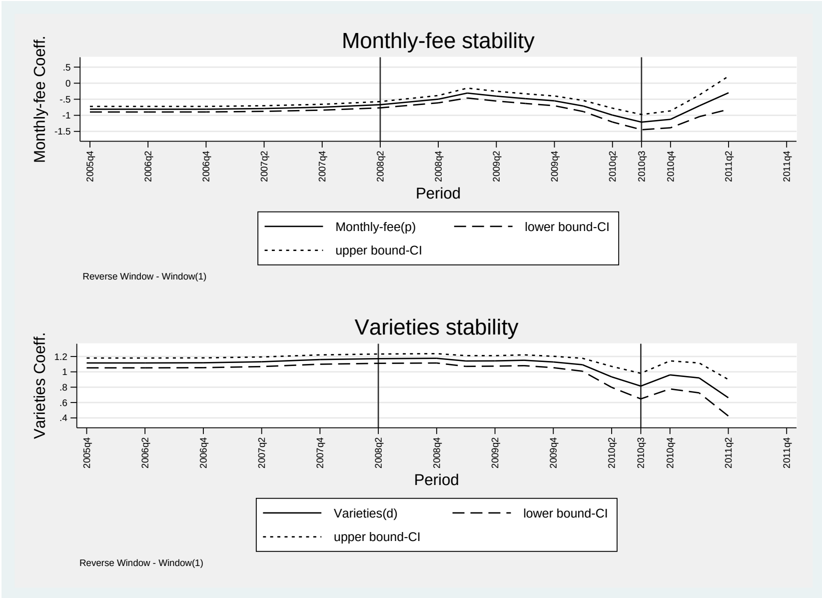



**Figure 3:** Structural stability of demand parameter estimates

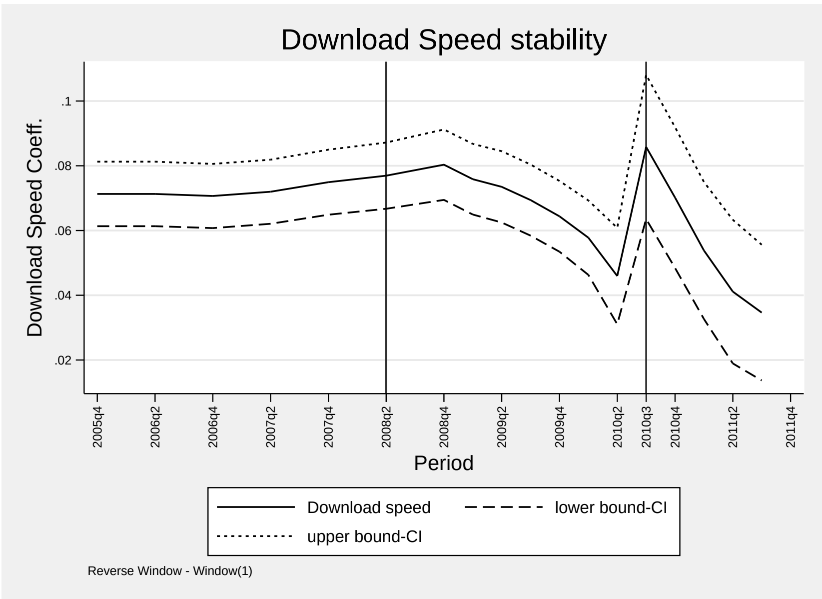
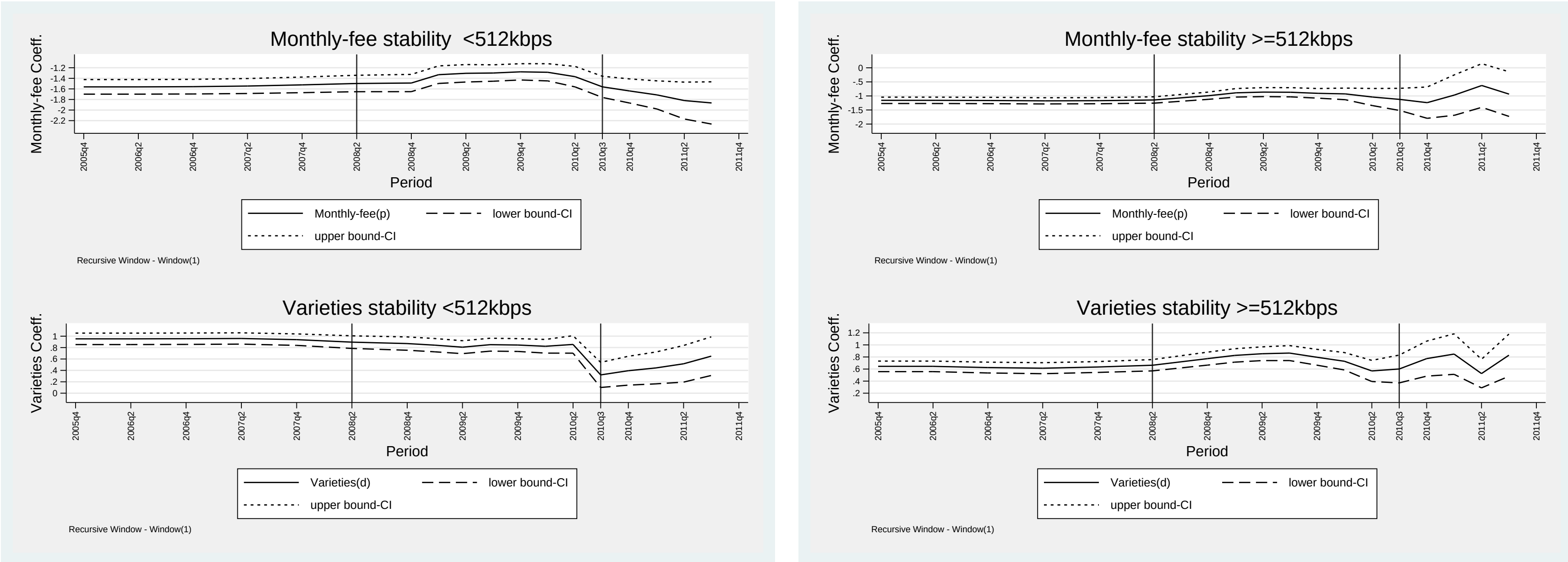



**Figure 4:** Structural stability of the elasticity of contract varieties to quality

### Structural stability of demand - Broadband standard 512kbps




### Structural stability of demand - Broadband standard 1024kbps

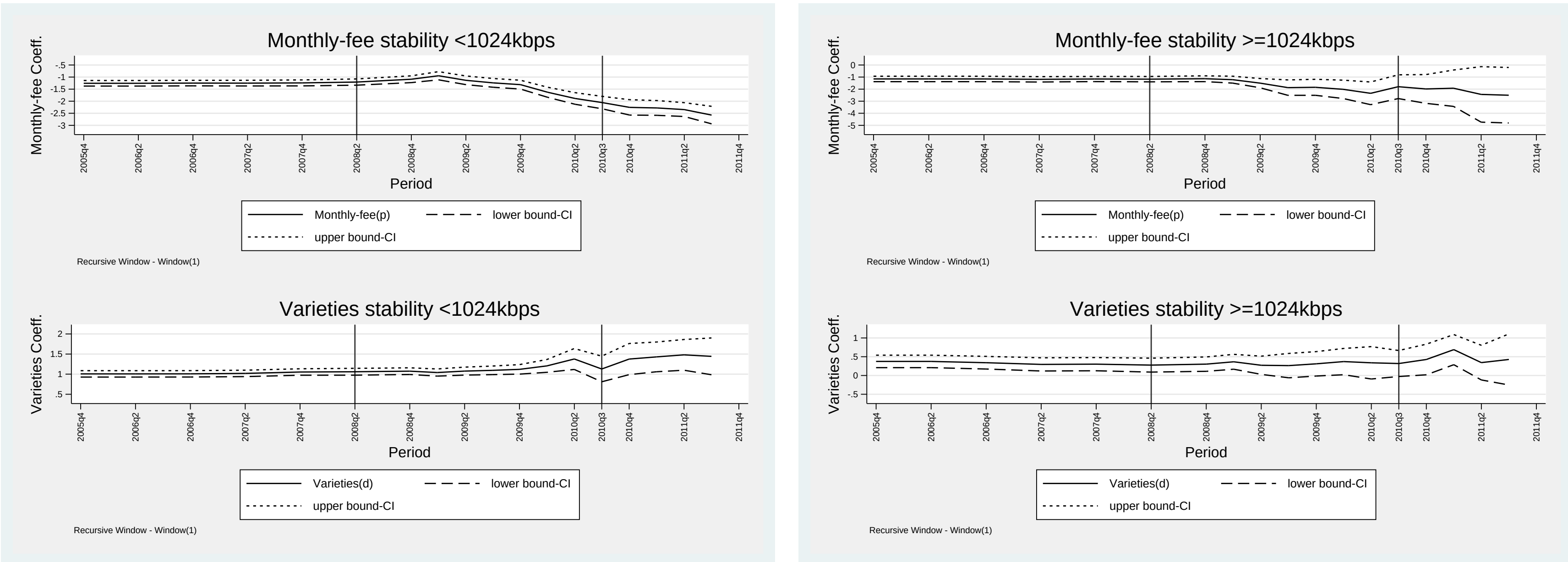
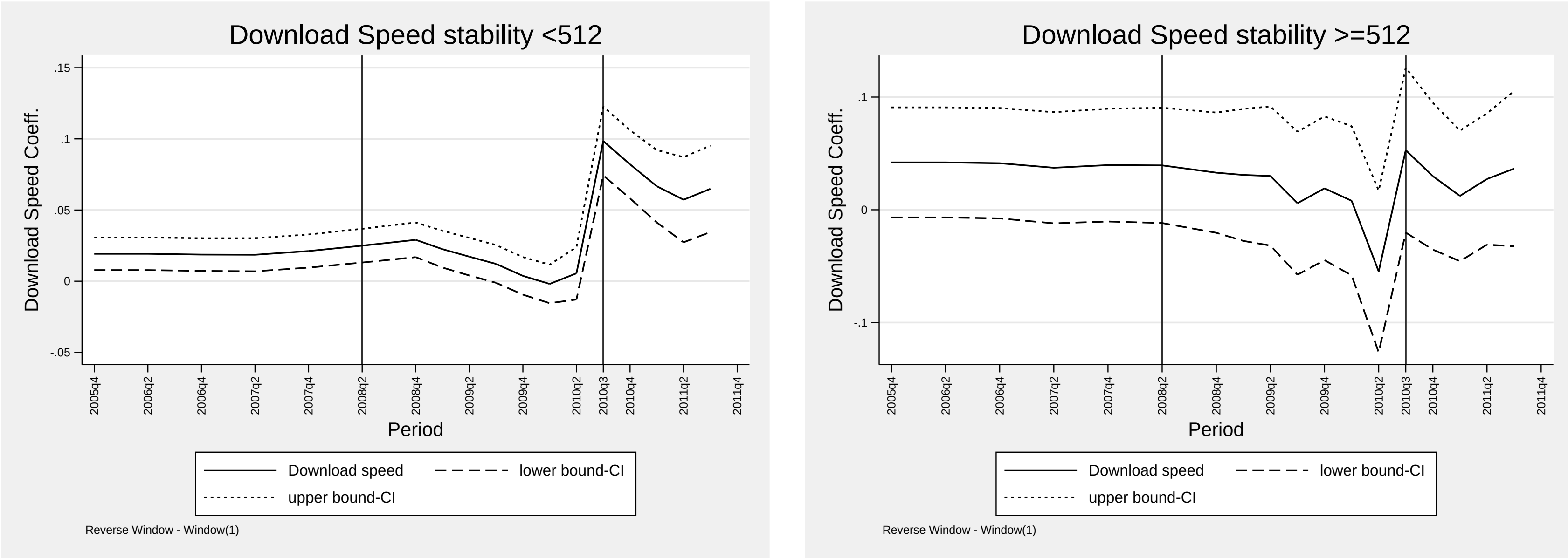



**Figure 5:** Structural stability of demand parameter estimates

**Structural stability of demand - Broadband standard 512kbps**




**Structural stability of demand - Broadband standard 1024kbps**

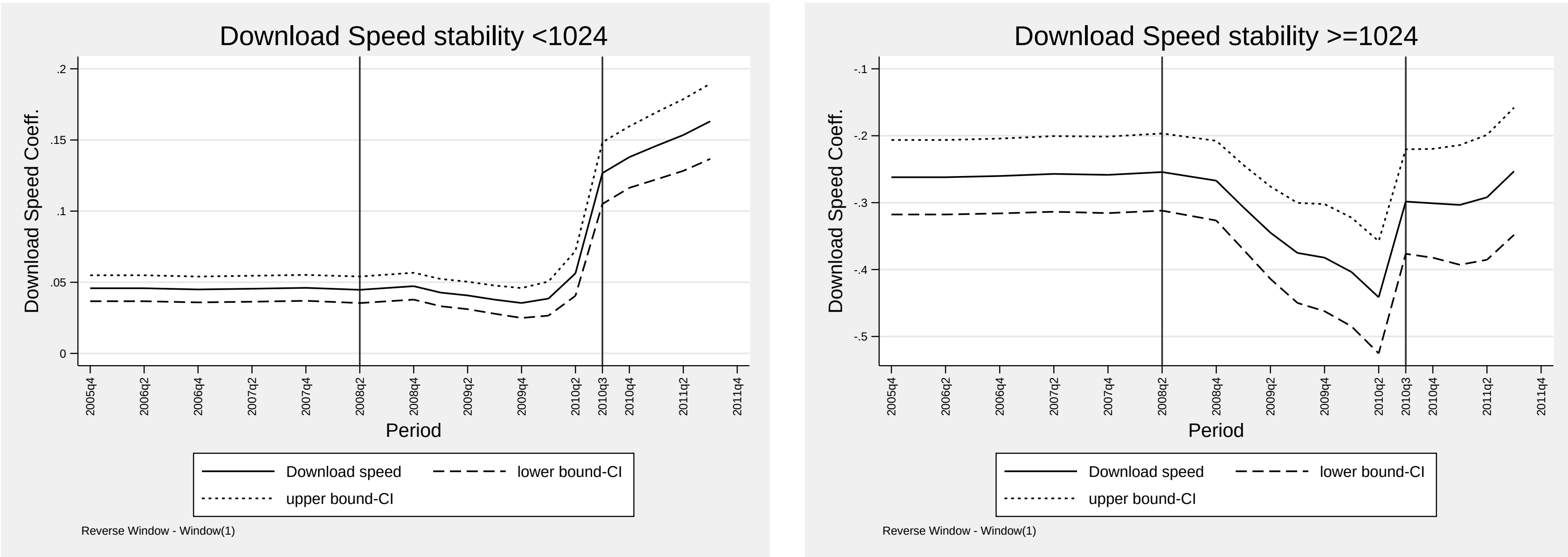



**Figure 6:** Structural stability of elasticities of contracts varieties to quality