Market definition for broadband internet in Austria: Need boundaries be drawn along bandwidth or between technologies?

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Abstract

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Emerging fiber networks can provide bandwidth capacities far beyond traditional copper-based and even cable networks. With continuously increasing demand for higher bandwidth the question arises whether existing asymmetric regulation targeting incumbent operators needs to be adjusted. In this paper, I use rich data on broadband internet usage from RTR-NetTest in Austria to determine price sensitivity of contract choices in the framework of discrete choice modeling. I determine own-price as well as cross-price elasticities of demand between contracts with different maximum attainable download and upload speeds by estimating an alternative specific mixed-logit model, where alternatives are defined along bandwidth each for mobile and fixed-line technologies. Investigating the role of bandwidth is novel for market definition and adds to the literature that models choices between technologies like DSL, coaxial cable or mobile internet, among others. My results point towards a high price sensitivity and two distinct markets for contracts up to 80 Mbps and for more than 80 Mbps. Substitution between fixed-line technologies and mobile internet exists. Moreover, substitution within each technology dominates. Nevertheless, I suggest a market definition which combines the fixed-line and the mobile broadband internet market and which is divided at the tariff plan border of 80 Mbps. These two markets might be regulated in a way to ensure that the lower bandwidth market stays relatively cheap, whereas the higher bandwidth market is set more liberal to foster fiber and higher bandwidth technology rollout.

1 Introduction

Regulation is essential to provide an efficient distribution of goods and prevent market failure. Besides (negative) externalities and asymmetric information, natural monopolies are the main issues in regulatory policies. If a monopoly is regarded to be regulated, the regulatory policy tries to make sure that the monopoly's market power will not lead to monopoly prices but will still lead to an efficient distribution. Typical examples of monopolies are railway companies, as natural monopolist, or telecommunication providers, where a former state monopolist has unequal starting conditions as incumbent over new market entrances. Both cases have in common, that a huge network is needed to provide a service and that this network is very costly. Also entering only in a regional market is an option in both cases, which might be less costly than serving the whole country. But these are not the only cases of monopolies considered to be regulated. In today's discussion, there exist voices pleading to regulate the market power of Facebook or Google, as well as other tech giants. Monopolies often are defined by market power regarding prices. However, the essential part is market penetration. Hence, market power which is not measurable with prices becomes measurable. However, before analyzing market penetration, the market which should be analyzed has to be defined. In this paper, I will define the market for broadband internet for Austria.

Policy makers across Europe increasingly care about the quality of broadband internet connection. The Digital Agenda for Europe aims at connecting all (50 percent) households to broadband internet with at least 30 Mbps (100 Mbps) by 2020. Only five years later, full household coverage with 100 Mbps or more shall be attained across Europe. According to Europe's Digital Progress (Country) Report, the coverage rates indicate that Europe is on a good way to succeed. The coverage rates for these bandwidths aims already achieved 79.0 percent (55.1 percent) in 2017, compared to 55.3 percent (39.9 percent) in 2013.

Due to increased bandwidth usage across Europe in recent years, policy makers set these targets mentioned above. While in 2012, only 7.2 percent (1.3 percent) of all European households subscribed to at least 30 Mbps (100 Mbps), the number increased by more than 20 percentage points (nearly 10 p.p.) to 27 percent (11 percent) until 2017, according to the EU Digital Single Market Report. This is also stressed in a study by Grzybowski et al. (2017) for the case of France. The authors find that broadband customers' valuations of bandwidths have increased substantially during January 2014 until December 2014.

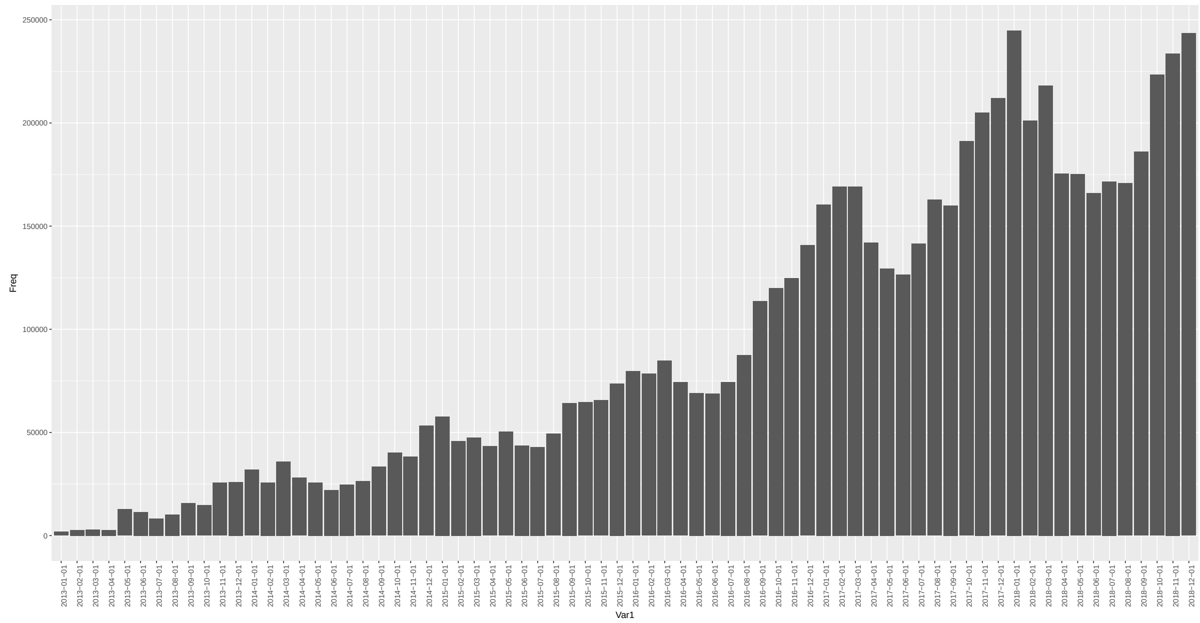
The growing importance of bandwidth raises the question of whether and how market analysis, and in particular market definition, needs to take high bandwidths into account. For example, if there existed a particular market for ultra-fast broadband internet, regional differences in the competitive environment regarding high-speed broadband internet should be evaluated. In many places, a single operator could offer ultra fast connections, for example via fiber. Yet, with a technological upgrade different providers could supply fast connections of 100 Mbps or higher as well. Nevertheless, local single providers with a high capacity network could gain local market power in their specified segment, allowing them to earn monopoly rents. However, whether this is ultimately possible depends not only on infrastructure competition regarding ultra-fast broadband networks but may also depend on the overall competitive environment, if low and high bandwidths are substitutable. Hence, a single fiber provider cannot act like a monopolist if there is enough substitution to lower bandwidths which are available by other providers. Deciding whether this substitution is sufficient or not, it is not enough to consider only fiber as different technologies can reach 100 Mbps and more. Hence, if fiber is a policy goal, net neutrality might harm the fiber rollout as providers with a network which can be updated have lower costs to offer high bandwidths. The substitutability of contracts along different bandwidths and across technologies and providers is the paper's central question.

A great advantage of this paper is the data which is used. Regulatory procedures, especially market definition, demand rich data. Often regarding this data, regulators depend on data from the companies they are regulating, for example the number of people using the train on certain ways or of subscribers of internet service contracts. This is one major advantage of this study: The data is collected from the users and not from the internet providers and without a specific expensive survey. One major data base comes from usage data where the realized speed is tested on the regulation authority's website (RTR-NetTest). The number of internet users testing their speed increased sharply in recent years (Figure 1), which makes new methods like the one presented in this paper feasible.

The increase of speed tests is not caused by a higher internet penetration in Austria. In 2013, already 98 percent of households had a broadband coverage of at least 2 Mbps and four out of five Austrians had the possibility to access the internet from home, meaning that the household did have a valid internet subscription. The increase in tests rather shows that users are not anymore satisfied by merely being connected to the Internet but care about the speed they have available. This might come due either discussions in the media about the fiber rollout or the actual need for higher speed connection for example for watching videos online.

I approach the question of substitutability in the market for stationary broadband internet subscription by estimating a mixed-logit model, which allows me to derive price elasticities of demand. Therefore, I exploit extensive data on more than 200,000 Austrian stationary broadband internet tests, performed between January and June 2017, for which I take one test per user by averaging over all performed tests. I observe the contract chosen and its price as well as the competitive environment in the household's locality, which allows me to define choice sets for every user in the sample. I exploit estimates of the mixed-logit

Figure 1: Increase of speed tests from 2013 to 2018



Note: Data: RTR-NetTest from the Austrian Regulatory Authority for Broadcasting and Telecommunications (RTR)

model to determine own- as well as cross-price elasticities of demand with regard to the bandwidth.

The derived own-price elasticities indicate that demand is generally very elastic. This suggests that a joint price increase in contracts of a particular bandwidth, induces a shift of demand from contracts of this particular bandwidth towards contracts of different bandwidths. My results point towards a high price sensitivity shown through high own-price elasticities of demand. Moreover, I find two distinct markets for contracts up to 80 Mbps and for more than 80 Mbps. These were defined by cross-price elasticities pointing in different directions, to higher contracts or lower contracts, for contracts with more or less than 80 Mbps. Substitution between fixed-line technologies and mobile internet exists as well. However, substitution within each technology dominates. Nevertheless, I suggest a market definition which combines the fixed-line and the mobile broadband internet market and which is divided at the tariff plan border of 80 Mbps. Regulators, then, have to ensure that the lower bandwidth market stays relatively cheap, whereas the higher bandwidth market is set more liberal to foster fiber and higher bandwidth technology rollout. A Willingness-to-pay analysis and a Hypothetical Monopolist Test (HM test) supports this finding.

The remainder of this paper is organized as follows. After this introduction, Section 2 describes broadband coverage in Europe and in Austria and the regulatory framework in Austria and Section 3 gives an overview over the market definition literature in the bit-stream market. Then, the data sets I use and merge are introduced in Section 4. Followed by Section

5 which explains the discrete choice model, while Section 6 presents estimation results as well as price elasticities of demand and willingness-to-pay estimates. The paper concludes in Section 7.

2 Broadband coverage and the regulatory framework

Coverage data for Europe shows different ways to provide users with high bandwidth and that different countries have a different mixture of technologies for their Next Generation Access (NGA). Technologies include VDSL, FTTP and DOCSIS 3.0 cable. Overall, there is an NGA coverage of 80.1 percent in 2017 (46.9 percent in rural areas). In particular, Europe has coverage with VDSL of 53.4 percent (32.5 percent), with FTTP of 26.8 percent (11.3 percent) and with DOCSIS 3.0 of 44.7 percent (10.8 percent). For instance, Belgium has a very low FTTP coverage, only 0.8 percent. However, there is nearly full coverage with download speeds of at least 100 Mbps, achieved with VDSL and DOCSIS 3.0. Certainly, Belgium is an extreme case. Yet, it shows that for high-speed internet several technologies need to be considered, and therefore, it appears to be necessary to evaluate different bandwidths rather than technologies.

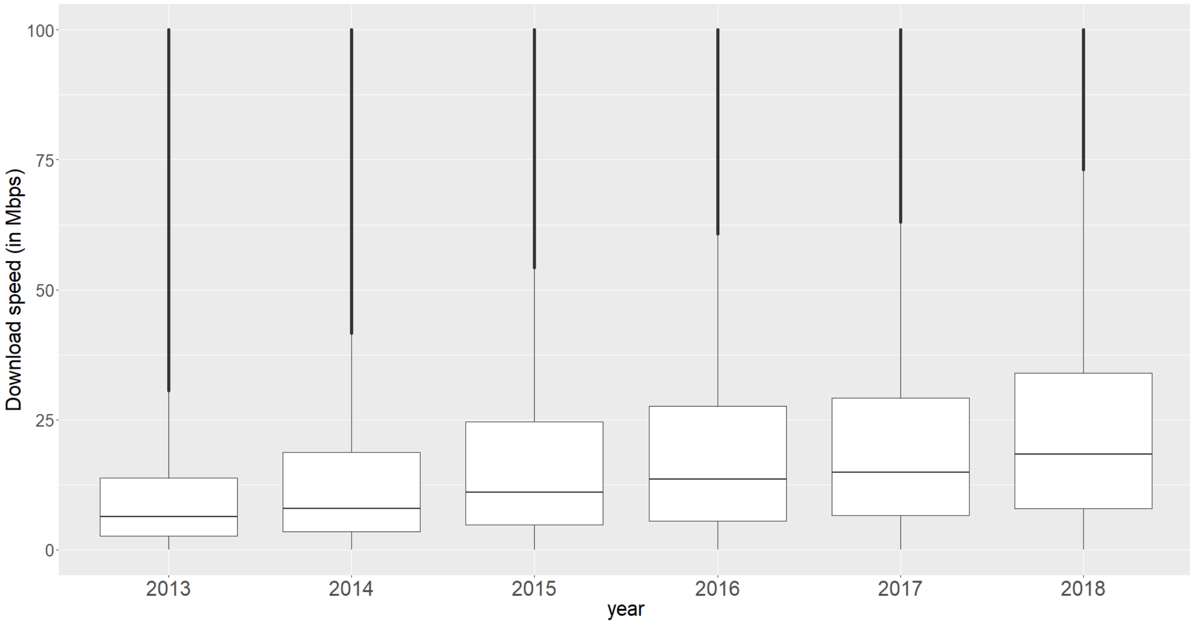
Austria is an average country regarding coverage rates and subscription. The coverage of households connected with at least 30 Mbps (100 Mbps) is slightly above the European average with 81.1 percent (57.2 percent) as can be seen in Table 2.1 in the two right columns. The coverage with NGA, in general, rose from 69.5 percent in 2012 to 90.0 percent in 2017 and more than trebled for rural areas in this period. This increase was mostly driven by the expansion of VDSL and DOCSIS 3.0 Service. The coverage of VDSL increased from 50.5 percent to 82.2 percent in Austria and from no availability to 22.1 percent for its rural areas. The expansion of the DOCSIS 3.0 technology was moderate and similar in size for both, rural and urban areas. Fiber (FTTP) still plays a minor role in the provision of fast broadband access to Austrian households. The coverage rate of FTTP rose from 6.3 percent to 13.5 percent and from 1.2 percent to 5.4 percent for rural areas, which is a small fraction compared to the EU 28 average of 23.7 percent. Although, the availability of FTTP in Austria is below EU average, above average coverage for connection speeds of at least 30 Mbps and at least 100 Mbps is achieved. Hence, I consider Austria as a good representative for this study.

A boxplot of the evolvement of speed tests (Figure 2) additionally shows the improvement of high-speed broadband internet in Austria. Moreover, Austria has a strong mobile net and therefore a high demand for stationary mobile contracts as well. Possibly, mobile internet might be a substitute for fixed-line broadband internet. This was already shown in former studies. However, mobile substitution might also differ along the bandwidth. This should make Austria even more an interesting case.

Table 2.1: Broadband coverage in Austria, overall and for rural areas, for 2012 and 2017, compared to EU 28 (different technologies and different bandwidths in the columns)

	NGA	VDSL	FTTP	DOCSIS 3.0	>30Mbps	>100Mbps
Austria (2012): total	69.5%	50.5%	6.3%	35.3%	-	-
Austria (2012): rural	14.4%	0.0%	1.2%	13.4%	-	-
Austria (2017): total	90.0%	82.2%	13.5%	52.8%	81.1%	57.2%
Austria (2017): rural	45.0%	22.1%	5.4%	20.5%	-	-
EU 28 (2017): total	80.1%	53.4%	26.8%	44.7%	79.0%	50.8%
EU 28 (2017): rural	46.9%	32.5%	11.3%	10.8%	-	-

Figure 2: Boxplot of speed tests from 2013 to 2018



Note: Data: RTR-NetTest from the Austrian Regulatory Authority for Broadcasting and Telecommunications (RTR)

Regulation in the telecommunication market is updated about every five years to react to innovation and changing market power. Since the TKG 2003, the regulation follows a three-step approach. Regulation always starts with a thorough market definition, before the market is analyzed in a second step, and if a company with considerable market power is detected, specific regulatory tools are imposed on this company to ensure a functioning competition on this relevant market.[1]

The current regulation status applies to the incumbent A1 Telekom Austria, as the owner of the copper network through with DSL is provided, and defines the wholesale market for

[1] Telecommunications law by the Austrian Regulatory Authority for Broadcasting and Telecommunications (RTR): https://www.rtr.at/en/tk/Marktanalyse

broadband internet independent of the download or upload speed. The relevant market contains DSL and fiber (FTTX[2]) as technologies. Other technologies like cable (CATV), mobile or satellite, among others, are not part of the relevant market. Also leased lines and unbundling are not part of the market. There is no regional segregation, meaning the relevant market cover Austria as a whole.[3]

3 Literature overview

This paper relates to a well developed literature, investigating market definition for broadband internet and substitution behavior in the telecommunication market. So far, the literature focused on investigating potential technology-level boundaries. Early papers by Crandall et al. (2002), Rappoport et al. (2003) and Flamm and Chaudhuri (2007) analyzed demand for dial-up, DSL and cable modem in the US and focus on the substitution between narrowband and broadband. Flamm and Chaudhuri (2007) analyze cross-price elasticities of demand and find that dial-up and broadband are substitutes. They confirmed the results of a previous study. Rappoport et al. (2003) find that if only one broadband technology is available, either DSL or cable, the narrowband technology dial-up is a strong substitute. In the general case, where both broadband technologies are available this does not hold. Crandall et al. (2002) also look into the substitution within broadband and conclude that both technologies are in the same market. They apply a nested logit discrete choice model and find high price elasticities for DSL. On the other hand, dial-up is not a good substitute for broadband. Similar results have been found by Pereira and Ribeiro (2011) for Portugal. In particular, they found that DSL and cable are both very elastic. However, cable is seen to be more elastic than DSL. Moreover, the demand for these technologies is not effected by the price of narrowband access. In a more recent study for the US, Dutz et al. (2009) calculate elasticities for each year from 2005 to 2008 for 100 Metropolitan Statistical Areas. They find high elasticities for DSL, cable, fiber and satellite and low elasticities for dial-up. Furthermore, they find declining elasticities over time, especially for DSL.

More recent evidence, increasingly focusing on whether fixed and mobile technologies are substitutes, has been presented by Cardona et al. (2009), Srinuan et al. (2012) and Grzybowski et al. (2014) for Austria, Sweden and Slovakia, respectively. The price elasticities derived point towards high price-sensitivity for all technologies, indicating them to be close substitutes. Hence, in all studies they are suggested to form a common market. Additionally, Cardona et al. (2009) exploit the fact that about half of Austria is connected to the cable network. They find higher elasticities in areas connected to the cable network than in areas without the

[2] FTTX stands for FFTH, FFTC and FTTB collectively
[3] https://www.rtr.at/en/tk/Breitband

possibility to access the cable network. They all use survey data and while the first too studies apply a nested logit model, the latter study applies a mixed-logit model.

These studies use data from early 2010 or before when in Europe the subscription of internet with a higher bandwidth than 10 Mbps was only 23 percent of all households and the mobile net was still UMTS (3G) with bandwidths allowing for maximal 15 Mbps but usually only allowed for half the bandwidth. Since then not only the subscription of contracts with bandwidth of 30 Mbps, 100 Mbps or higher increased but also innovations made it possible to reach these bandwidths with different kinds of technologies, like VDSL, DOCSIS 3.0 cable, fiber (FTTX). LTE for the mobile net was introduced in Europe first in Norway in December 2009 and Austria, for instance, in October 2010. Although Srinuan et al. (2012) and Grzybowski et al. (2014) already applied fiber as an alternative, the available download speeds were not higher than with DSL or cable modem. This might be a reason why they found that fiber might be part of the broadband market as well.

For Japan, Ida and Kuroda (2006) analyze a market with higher available bandwidths applying a nested logit discrete choice model. For fiber, up to 48 Mbps, for ADSL, up to 24 Mbps and for cable, still 16 Mbps were measured. They find that DSL demand is inelastic whereas cable and fiber internet demand turns out to be highly elastic. In a further analysis, they divide DSL in three submarkets along the bandwidth. They find that the low and the high speed submarkets are very price sensitive and that for high speed ADSL users fiber is a close substitute while for low speed ADSL users narrowband is a close substitute. The later points to the early literature of analyzing the market of narrowband and broadband while the first is more relevant for this study and points towards the role of bandwidth in substitution behavior. Ida and Horiguchi (2008) confirms the findings applying a mixed-logit discrete choice model. Nonetheless, explicit studies investigating the topic are at most rare.

4 Data

4.1 Data sets

In this section, I describe the different data sets which I merged applying a geo-coding software. Afterwards, I describe how I defined the choice and alternative from the available contracts. For the merge, I exploited the fact that each data set is either geo-coded or it prevents information on either municipality level or on a 100×100 meters grid. Starting with usage data, which contains the test location, I merged data on broadband coverage and network providers, before I merged price data to the providers' tariffs. This procedure resulted in a data set where I know for each test the measured download and upload speed as well as other characteristics, the available contracts and the bandwidth coverage at the households location from 2015 to 2017.

Usage Data

From RTR-NetTest, I derived information on broadband usage of 216,554 tests across Austria between January and July 2017. This data is publicly available for download on the web page of the Austrian regulatory agency's (RTR). By providing a web browser tool and mobile applications (for Android and iOS), RTR enables users to test the quality of their current mobile and stationary internet connections.

For the purpose of this study, I restricted the data to tests of stationary internet connections. This includes tests of fixed-line as well as mobile network quality. Yet, tests of stationary internet connections that are established via mobile networks are restricted to offers, designed for the use *at home* rather than standard smartphone contracts. While the former offers typically include non-constraint broadband usage at a particular bandwidth, smartphone contracts are limited with regards to the consumable volume and bandwidth.

Besides the exact timing of the test (date and time), importantly, the data provides the exact (geo-coordinates of the) test location and the network provider, establishing the internet connection. Information on measured upload as well as download speed is included, too. These distributions are shown in Figure 3, distinguished by fixed-line and mobile tests. Finally, it provides a rich set of additional information, such as the type of internet connection (WLAN / LAN). Furthermore, if the test was performed via LAN, additionally, the applied browser is transmitted and if the test was performed via WLAN the model of the used device is transmitted.

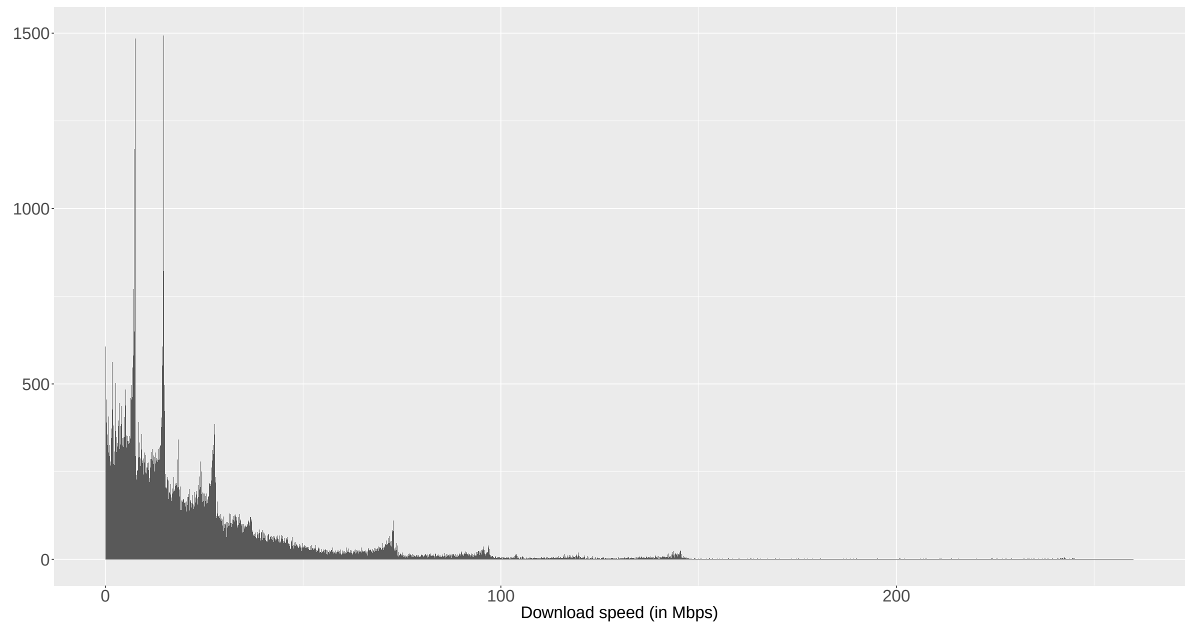
I only observe the network provider rather than actual service providers, meaning that provider with no own infrastructure are not shown in the data. For instance, A1 Telekom Austria, the Austrian incumbent operator is required to grant access to its network for service providers, e.g. via local loop unbundling. While the contracts offered by these service provider may be similar to A1 Telekom contracts, bandwidth allowances and prices may differ. Also, for A1 Telekom, I do not observe whether it is a fixed-line or a mobile test. This last problem will be discussed in more detail when choices are assigned. Though, I collected data from the first half of 2017, this might not be the dates were testers signed their contract. It is noteworthy that these are only the test date. However, I assume that most of the testers did not sign their contract long before they tested it.

Importantly, 7,349 testers performed multiple tests of the same broadband internet connection of which 1,791 testers performed more than two tests. In these cases, all but the first test were removed from the data, such that the number of tests was reduced to 209,205.

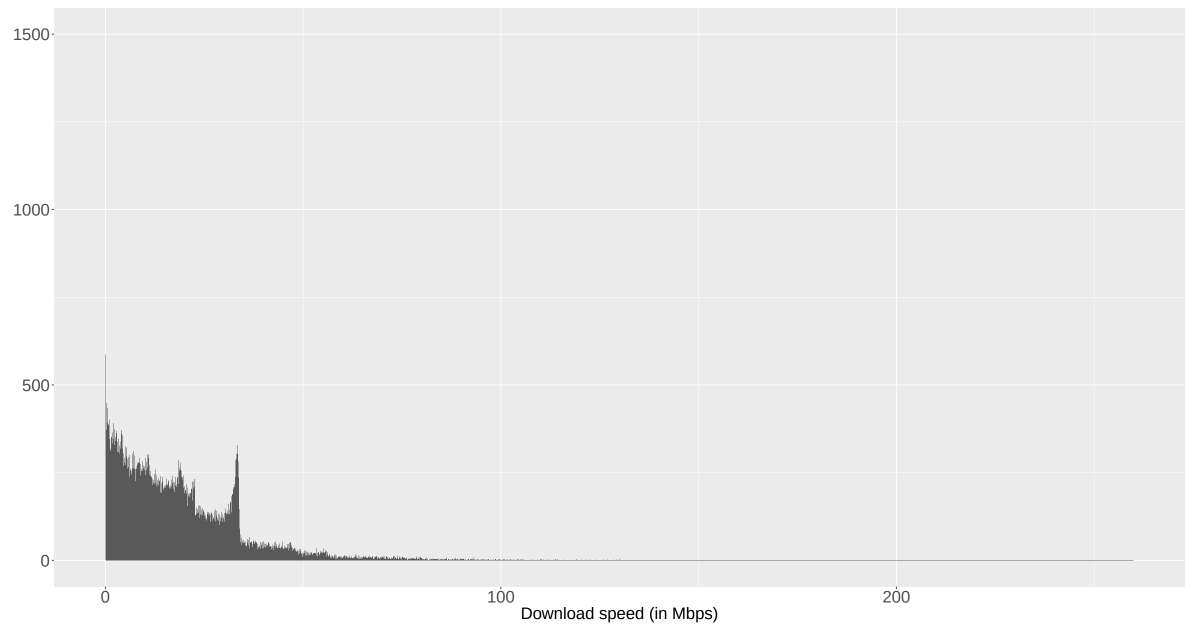
Broadband Coverage & Network Providers

Figure 3: Meassured download speed for tests with fixed-line and mobile providers

(a) Fixed-line test



(b) Mobile tests



Note: The figure depicts the distribution of download speeds of performed tests with fixed-line and mobile providers from January to June 2017. Data: RTR-NetTest from the Austrian Regulatory Authority for Broadcasting and Telecommunications (RTR)

From the Austrian broadband atlas, I used fine-grained (100 × 100 meters) data on the maximum available download speed in June 2017 (and for 2015 and 2016) via fixed-line networks which is provided by the Ministry for Transport, Innovation and Technology (bmvit). In detail, the maximum attainable bandwidth is assigned to a particular grid-cell, once at least one provider can technically realize the bandwidth in at least one household in that cell. For 2017, the coverage information is available in certain categories with <2 Mbps, <10 Mbps, <30 Mbps, <100 Mbps, and at least 100 Mbps. Coverage from the years before is reassigned to the same categories. Similarly, data on mobile coverage is made available as geodata, i.e. polygon shape files that indicate which Austrian regions are covered by a particular bandwidth. Figure 4 illustrates fixed-line as well as mobile broadband coverage. It turns out that attainable bandwidth in 2017 is rather high overall, especially with regards to mobile coverage. While high-speed Internet access via fixed-line concentrates in rather urban areas, mobile broadband is distributed allover Austria. Yet, actual attainable bandwidths, especially via mobile networks, may significantly deviate from the theoretical availability, depending on the number of users and the intensity of usage within a particular mobile cell.

Apart from data on available bandwidth across the country, the broadband atlas also lists all network providers on municipality level. From these, I considered only A1 Telekom, kabelplus, Tele2, UPC, Salzburg AG and LIWEST as fixed-line providers. It is important to notice that these providers have different network technologies and have these partly only in specific regions. Whereas A1 Telekom, as the incumbent, owns the copper network all over Austria, kabelplus, Tele2 and UPC are active in specific regions with their coaxial networks. The same is true for the fiber networks of Salzburg AG and LIWEST. The regional distribution can be seen in Figure 3c. From the mobile providers, only Hutchinson Drei, A1 Telekom Mobile and T-Mobile offer stationary contracts and are therefore considered in the analysis. These fixed-line and mobile providers account for about 95 percent of all tests from the usage data.

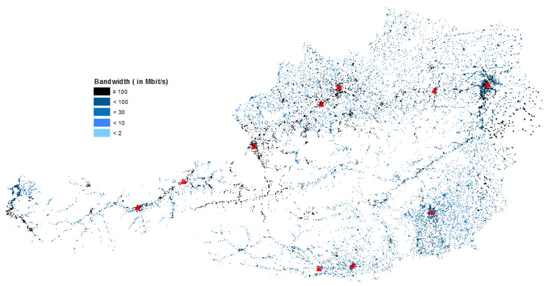
Price Data

From AK-Tarifwegweiser, I gathered basic contract data. The data includes monthly information on all contracts, raising major interest among broadband internet customers that were offered between 2014 to 2017. In detail, it includes all contracts offered by major network providers which I named above as well as service providers without their own network such as MMC, A.K.I.S., Comteam, CNet, DIC, Telematica and TeleTronic. Apart from prices (regular, specific discounts) and contract duration, the data includes information on maximum download bandwidth and maximum capacity. I complemented this data with information on contractual upload speed by scraping the provider's webpage. In Table 4.1 and 4.2, the tariff plan information for providers I applied can be found. These include price (in euros) and upload speed (in Mbps) for each offered download bandwidth (in Mbps).

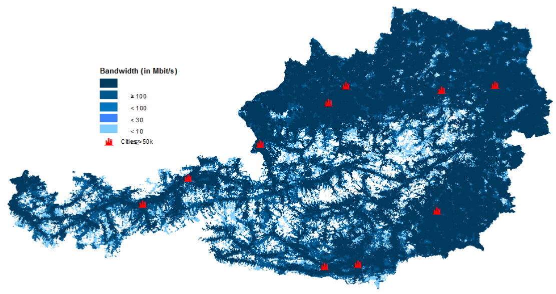
The contractual maximum download speed varies between 8 and 250 Mbps. However, offered bandwidths depend on the provider. For instance, only UPC and kabelplus offer

Figure 4: Broadband internet coverage (fixed-line and mobile) across Austria in 2017 and location of all tests showing the assigned provider

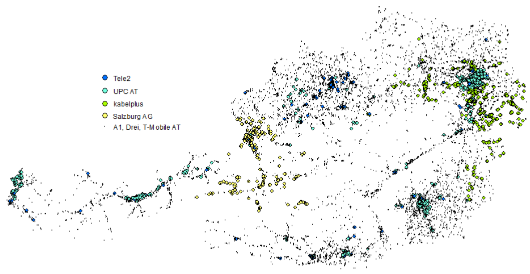
(a) Fixed-line coverage



(b) Mobile coverage



(c) Test location (assigned to provider)



Note: The upper figures depicts available fixed-line as well as mobile bandwidth across Austria in June 2017. The lower panel shows the location of all test. The dots are colorized with respect to the provider or a small, black point for A1 Telekom and mobile providers. Data: broadband atlas, provided by Ministry for Transport, Innovation and Technology (bmvit)

Table 4.1: Contract prices in euros by provider and download tariff plan

	8	10	12	15	16	20	25	30	35	40	50	70	75	80	100	125	150	250
A1TA	19.90	22.90			26.80	26.90		32.80		32.90	44.80			44.90	59.80		59.90	
Tele2	17.80		19.90			24.90		29.90		29.90								
UPCAT	24.90				31.80	24.90	23.75		29.90				29.90		29.90	39.90	39.90	56.82
HutchisonDrei		18.00						25.00			35.00						45.00	
SalzburgAG				19.90				29.00			39.00	49.00					79.00	
kabelplus					19.90			29.90					39.90				69.90	99.90
LIWEST						19.90			29.90						39.90		59.90	
T-MobileAT											29.99						49.99	
A1TAMobile														49.90			64.90	

Table 4.2: Contractual upload by provider and download tariff plan

	8	10	12	15	16	20	25	30	35	40	50	70	75	80	100	125	150	250
A1TA	0.75	0.90			3.00	5.00		6.00		10.00	10.00			15.00	20.00		20.00	
Tele2	0.75		1.00			4.48		4.00		10.00								
UPCAT	0.70				1.00	1.00	1.50		4.00				7.50		10.00	12.50	15.00	25.00
HutchisonDrei		4.00						10.00			20.00						50.00	
SalzburgAG				1.50				3.00			5.00	7.00					10.00	
kabelplus					1.00			3.00					7.50				15.00	25.00
LIWEST						3.00			6.00						10.00		20.00	
T-MobileAT											10.00						30.00	
A1TAMobile														20.00			50.00	

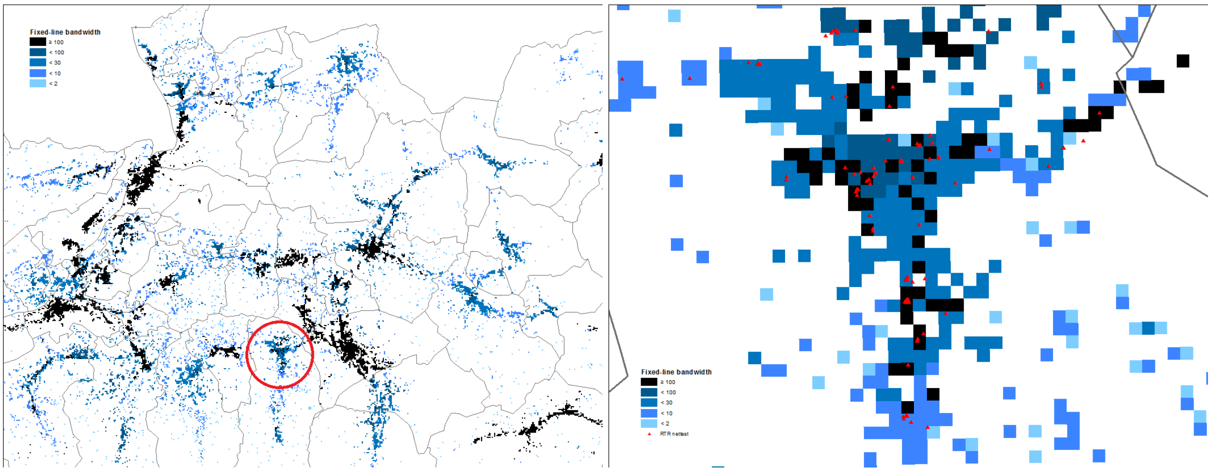
contracts with 250 Mbps. This contract offered by kabelplus is rather expensive, whereas the one by UPC lies in the price range of contracts of other providers, like A1 Telekom or LIWEST, with a contractual download speed of 150 Mbps, which cost 59.9 Euros. In general, prices vary between 17.8 and 99.9 Euros. All fixed-line providers offer at least one contract with no more than 20 Mbps. These contracts cost 24.9 Euros at the most.

As tests were performed in the first half of 2017, I restricted the contracts to be available from April 2016 on. Therefore, I could also avoid some changes in the provider's tariff structure which might have introduced noise due to difficulties assigning tests to the correct tariff. The only changes that remained are those from A1 Telekom and Tele2 which were set in March 2017 and mainly increased the allowed bandwidth but did not raise prices.

For each contract, I applied the minimum price per month and took the mean over time. I considered only unlimited capacities or with *fair use* specified and at least 150 GB. Therefore, all contracts considered are unlimited except for the ones from Salzburg AG which contain a *fair use* policy. This contract data was merged, at the end, to the provider data from the broadband atlas.

Figure 5: Illustration of data linkage

(a) Municipalities and fixed-line coverage (b) Fixed-line coverage and tests in one municipality



Note: Figure illustrates municipality borders, broadband coverage on grid level (blue cells) and household test locations (red dots). Data provided by GfK GeoMarketing GmbH, Ministry for Transport, Innovation and Technology (bmvit), RTR

4.2 Geospatial Matching

I linked the different data sets by exploiting the fact that all data is geographically referenced. The linkage is illustrated in Figure 5. First, the municipalities, with their information on active the providers and the providers' tariff plans, were matched to the fixed-line coverage grid via a geo-information software (Figure 5a). Then, each particular test was related to its grid and the information assigned above (Figure 5b). As a result, I ended with a data set at the household (actually test-location) level. This data not only includes information on the contract chosen, i.e. the provider and bandwidth, but also on the maximum available bandwidth. Furthermore, it identifies potential alternative providers other than the one serving the household. I removed 2,040 tests, where I could not clearly assign a coverage grid to either a municipality or a postal code.

Unfortunately, the level of precision in the data with regards to the related information deviates from an ideal setup. Preferably, I would want to know i) which providers a household could connect to rather than the providers that are active in the household's municipality and ii) which bandwidth each provider can offer in the grid than the maximum available bandwidth of all providers collectively. A minor issue is iii) that the coverage is not available for the household location rather than around a small area of the household. This is important to remember when defining choice sets.

Before assigning choices, further preparation steps needed to be taken. First, I updated information on active providers and coverage from the test data: If a test was performed with a transmitted provider not shown in the broadband atlas in this municipality, the municipality data was updated to include this provider. Similarly, if a test was performed with a higher download speed than covered in this specific grid, the grid information was updated for all tests in this grid. The updated speeds were assigned, afterwards, to the same categories as defined before. Moreover, I removed 11,137 tests from minor, less important providers other than the nine mentioned above as I did not have information on the offered tariff plans for these providers.

4.3 Choice set & actual choice

Individual's choice assigned

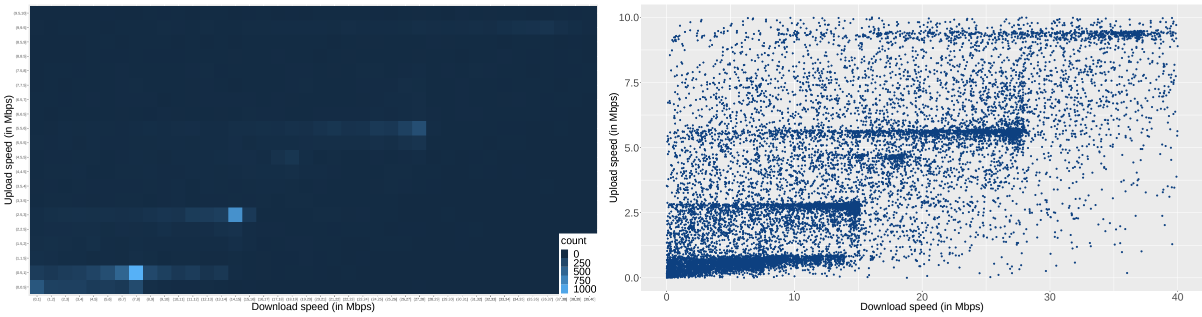
The information on download and upload speed as well as the network provider chosen and the location where the test was performed, allows to determine the contract that has been chosen by a particular tester. As the noise might reduce the measured speeds, the choice assignment cannot rely on the measured download speed only. Figure 6a and 6b show a heat map and a scatter plot for A1 Telekom tests with a measured download speed below 40 Mbps and a measured upload speed below 10 Mbps. The data in these figures was reduced to A1 Telekom tests and regarding the download and upload speed due to higher visibility. The horizontal tails in the heatmap show that there are many tests with a certain upload bandwidth but different download bandwidth with a (relatively) bright hot spot and the contract borders for the upload bandwidth. For instance, A1 Telekom offers a contract with 30 Mbps (download bandwidth) and 6 Mbps (upload bandwidth) and one with 16 Mbps and 3 Mbps (as shown in Table 4.2). Only very few tests have a measured upload speed with about 6 Mbps and more than 30 Mbps measured download speed. However, many tests with about 6 Mbps measured upload speed have 25 Mbps or even lower measured download speeds. On the other hand, a similar vertical tail cannot be found. Therefore, it is important to consider the upload bandwidth as well, although the download bandwidth is presumably more important to the consumer. Nevertheless, one still can detect the spikes at certain download bandwidths as was shown in Figure 3. These spikes are also very viable by the density of the scattered dots. Moreover, these reflect the noisiness of the data also regarding the upload speed.

In the following, I describe the exact procedure how I assigned the choice to each test. First, I restricted the choice to contracts of the stated provider and then selected the tariff plan with the contractual speeds that was closest to the measured speeds. However, tariff plans had to allow at least the measured speeds in upload and download. Closest is defined

Figure 6: Measured download and upload (A1 Telekom tests restricted to lower contracts for clarity)

(a) Heatmap

(b) Scatter plot



Note: The figure depicts the distribution of download speeds of performed tests with fixed-line and mobile providers

by the lowest euclidean distance. An exception was made if the measured speed was above the maximum contract a provider offers. In these few cases, the test was assigned to this maximum tariff plan. Regarding the problem that for A1 Telekom tests I could not distinguish between fixed-line and mobile tests, I followed the described procedure but removed mobile contracts if they were not distinguishable in allowed download and upload speed from an A1 Telekom fixed-line contract.

Restricted sample

In principal, the information on download and upload speed as well as the network provider chosen and the location where the test was performed, allows to determine the contract that had been chosen by a particular tester. In practice however, determining the actual choice was complicated by the fact that the test data contains noise. Thus, a measured speed might deviate dramatically from the one assigned in the contract. While a particular tester may not surf the Internet at a higher speed than the contractually assigned maximum bandwidth, in many cases she will surf with a speed below the latter. For example, unfortunate location of broadband routers may result in actual download and upload speeds lower than the contractually assigned ones when using WLAN instead of LAN connections. Besides, broadband connections established through CATV / HFC or LTE likely vary in speed during the course of the day due to the fact that available bandwidth needs to be shared with other users in the network section.

In pursuit of most possible cleanliness of the data, in a next step the data was restricted to tests with a realized download and upload speed within a certain corridor below an offered tariff plan. This corridor was defined differently for fixed-line and mobile providers and reflects the assumption that the measurement of the upload speed is more trustworthy than for the download speed. For fixed-line providers, the corridors were either a deviation of 15 percent in the download speed and 30 percent in the upload speed or 15 percent in the upload speed and 50 percent in the download speed. These different corridors reflect the different quality in the measurement of upload and download speed. For mobile providers, an deviation of 40 percent either in upload or in download from the tariff plan was allowed. This broader restriction is necessary as mobile tests vary more in both upload and download speed. However, it is still legit as there were less different mobile contracts, and therefore, a more precise assignment of choices was still possible. Figure 7 illustrates the remaining tests for A1 Telekom, UPC and Hutchinson Drei. These are the most important provider for copper, cable, and mobile internet. The left column shows all tests for each provider. In the right column, observation with a measured download or upload speed which does not fall into one of the corridors are removed. These tests were measured imprecisely. Additionally, tests which were performed in a grid with less than the maximum coverage (at least 100 Mbps) were removed. This step is necessary for the regression to only allow for tests with a comparable choice set. Eventually, the data comprises 91,955 tests.

Individual's choice set

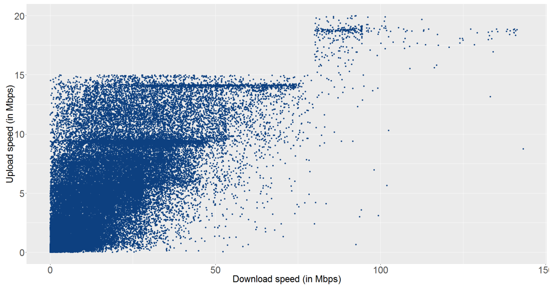
As a last step, I focused on the alternatives from which the choice was made. Each consumer can choose from a wide set of alternative tariff plans. Nonetheless, it is unlikely that a consumer considers all available contracts as alternatives. However, it is not clear how to define sets of alternatives. In the main specification, I defined four categories for fixed-line and three for mobile contracts. For the fixed-line contracts, the category borders start at 20 Mbps and double two times, resulting in category borders at 40 Mbps and 80 Mbps. Hence, the lowest category tariff plans with a download bandwidth of at the most 20 Mbps and the highest category contains tariff plans with a download bandwidth of more than 80 Mbps, which in fact are the tariff plans with a three-digit download bandwidth (≥ 100 Mbps). Therefore, this category can be considered as the very high bandwidth category. The lowest mobile category border is at 40 Mbps. The higher categories are the same as for the fixed-line categories. These categories make it possible to answer questions regarding substitution within fixed-line tariffs and between them and mobile tariffs.

Besides the technology (fixed-line and mobile) and the speed category, the price is part of a category's characteristic. For chosen categories, I applied the price from the tariff plan. Therefore, the mean price and its standard deviation is 32.39 Euros and 10.88 respectively. For alternatives, I took a weighted average price over available tariff plans for each alternatives. I took the weights from the number of times a choice was taken in area starting with the same postal code digit such that I could account for regional variation of available fixed-line providers and of the taste for mobile providers.

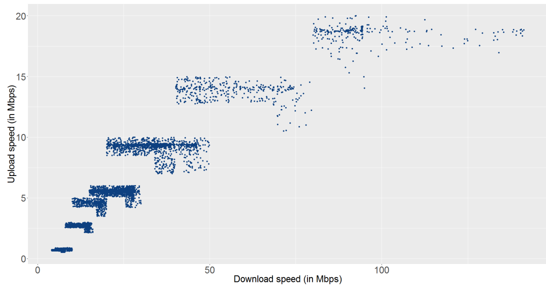
Figure 7: Measured download speed for tests with fixed-line and mobile providers.

A1

(a) Whole sample

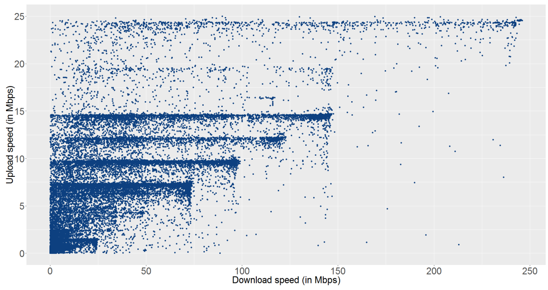


(b) Reduced sample

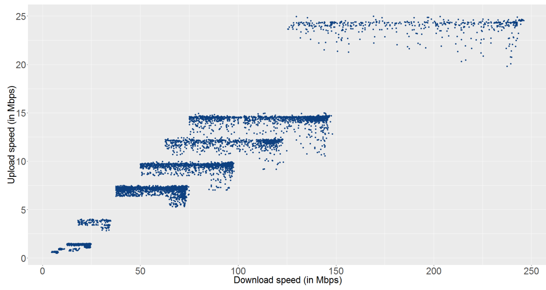


UPC

(c) Whole sample

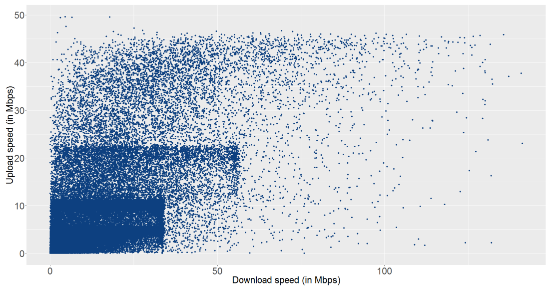


(d) Reduced sample

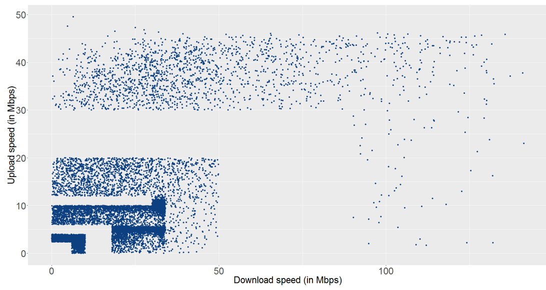


Drei

(e) Whole sample



(f) Reduced sample



Note: The figure depicts the distribution of download speeds of performed tests with fixed-line and mobile providers

4.4 Descriptive statistics of the estimation data

Before going to the model and the estimation, descriptive statistics provide some broad insights into the data. For the estimation the data was restricted to tests in grids with highest available coverage (at least 100 Mbps). This was necessary to have comparable tests, which can all choose from the same alternatives. Therefore, at first the development of fixed-line coverage was examined. The highest coverage was improved especially in 2017 (Table 4.3),

Table 4.3: Development of fixed-line coverage from 2015 to 2017

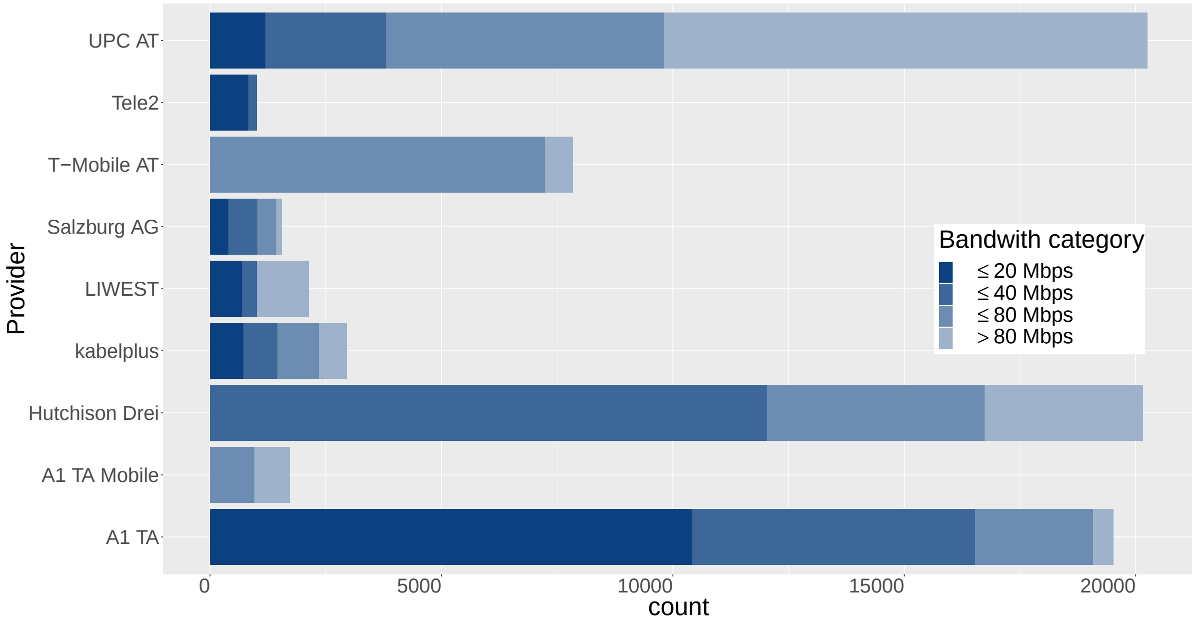
year	< 10	< 30	< 100	≥ 100
2017	237	10110	39301	146384
2016	3608	21263	81543	89618
2015	4624	29926	72641	88841

after a stagnation in 2016. However, already in 2015 about half of the tests were performed at a location with full fixed-line coverage. In 2017, only very few places still had a coverage of less than 10 Mbps and also for middle coverage categories strong improvements can be found.

Linking the usage data to the provider data, one can also see a distribution over the providers. Restricting to the tests which have had full fixed-line coverage since 2015, those that will be analyzed in the regression, the following image came up (Figure 8). First, one noticed that there are three mayor providers. Hutchison Drei is the biggest among the mobile providers. Regarding fixed-line, A1 Telekom and UPC unite most of the tests under one another. However, more than half of the A1 tests fall in the lowest bandwidth category, whereas more than half of UPC tests fall in the highest bandwidth category. Comparing the prices from Table 4.1, the found distribution makes sense. UPC offers the cheapest high bandwidth contracts, whereas they are weaker regarding lower bandwidth contracts. For lower bandwidths, A1 Telekom might still have market power and is therefore regulated. However, just looking at the numbers for higher bandwidths, Telekom's market share declines heavily, at least for regions where there has been high coverage over several years. Already these raw numbers might suggest thinking about regional regulation and separating the market along the bandwidth as the composition of providers' market share differs dramatically along the bandwidth.

Looking lastly at the mean prices for the categories (Table 4.4), surprisingly mobile contracts are both the cheapest and the most expensive option. Hence, the lowest mobile category is on average cheaper than the lowest fixed-line category and the highest mobile category is on average more expensive than the highest fixed-line category. It seems like providing basic internet is cheaper with mobile technology but it is more costly when it comes to high bandwidth connections. Fixed-line categories have a price range of about 20 Euros and a price difference between categories between 5 and 8 Euros. For mobile contracts, the difference between the categories is wider. The middle mobile categories ranges between the two middle fixed-line categories regarding the mean price. Also the number of chosen categories is presented in this table.

Figure 8: Number of tests for each provider, classified into four bandwidths categories



Note: The figure depicts the distribution of tests over the providers. Moreover, the distribution over the four bandwidth categories, representing the choice set, is shown as well.

Table 4.4: Mean prices and standard deviation by alternative

	fixed-line				mobile		
category	$\leq$ 20 Mbps	$\leq$ 40 Mbps	$\leq$ 80 Mbps	$>$ 80 Mbps	$\leq$ 40 Mbps	$\leq$ 80 Mbps	$>$ 80 Mbps
count choice	46193	30447	18137	15045	33970	39057	13183
mean price	23.49	30.83	35.21	43.60	22.61	33.30	48.79

5 Model

I applied a discrete choice model based on McFadden and Train (2000), which is the method used as standard in the regarding literature. In this frame work, testers choose among different alternatives, in this case different contracts with a certain provider that differ regarding download and upload speed and price. The choices were combined into speed categories as described above to reduce the number of alternatives. These categories form an exhaustive and mutually exclusive discrete choice set.

The most basic regression method in this context would be a multinomial logit model. However, this model relies on several assumptions. Especially, it imposes the independence of irrelevant alternatives (IIA) property.

As IIA might not be guaranteed, I applied a more general approach, a mixed logit regression, which relaxes IIA by allowing for correlation of choices across the alternatives. Hence, the model allows for unobserved heterogeneity among the individuals, which might apply in this case as I observed only very few individual characteristics of the testers. Furthermore, testers consider for their choice not only the speed but also other characteristics, especially the price. A random coefficient for the price will, therefore, apply for the unobserved heterogeneity among testers. All together, I decided to apply a mixed-logit regression which fits best for my purpose.

Choice set

I defined choices as contracts selected by the testers. The contract was assigned by the in the test observed provider, download and upload speed and the contractual maximum download and upload speeds offered by network providers for fixed-line broadband internet or by mobile providers which offer stationary broadband internet. The alternatives are represented by speed categories each for fixed-line and mobile tests. In total, there exist seven alternatives: surfing with (i) at the most 20 Mbps, (ii) 40 Mbps (iii) 80 Mbps or (iv) more than 80 Mbps using a fixed-line contract and (v) at the most 40 Mbps (vi) 80 Mbps or (vii) more than 80 Mbps using a mobile contract. Importantly, within each alternative I did not distinguish between providers or technologies. The only technological differentiation was drawn between the fixed-line and the stationary mobile choice. Furthermore, I considered the different providers only when I assigned the choice and not when I defined the alternatives.

Utility

The utility V_{ij} is defined for each tester i and for each contract category j. It depends on test- and alternative-specific valuations (β_j and γ) and the user's price sensitivity $\widetilde{\alpha_i}$. Hence, it is given by:

$$V_{ij} = \widetilde{\alpha_i} p_{ij} + \beta_j x_i + \gamma z_{ij} + u_{ij},$$

where x_i is a vector of test-specific variables and β_j are fixed, alternative-specific coefficients on x_i. Additionally, γ is estimated on z_{ij}, a vector of alternatives-specific variables. Finally, u_{ij} is the logit error term, which is, as suggested by the theory, identically and independent distributed across contracts according to the Type I extreme value distribution. The random price coefficient $\widetilde{\alpha_i}$ accounts for the heterogeneity among the individual testers, which is unobserved. It cannot be estimated directly, but only by estimating the parameters of $f(\widetilde{\alpha})$. Assuming a normal distribution ($\widetilde{\alpha} \sim N(\alpha, \Sigma)$), $\widetilde{\alpha_i}$ is calculated as follows:

$$\widetilde{\alpha_i} = \alpha + \sigma_\alpha \nu_i, \tag{5.1}$$

where α is the price coefficient's mean valuation, σ_α refers to its standard deviation and v_i is a random variable, following a standard normal distribution ($v \sim N(0,1)$).

Choice probabilities

It is assumed that each tester maximizes her utility. With the previous defined utilities, individual choice probabilities for each category can be calculated as:

$$l_{ij}(\widetilde{\alpha_i}) = P(V_{ij} = \max_{k \in C_i} V_{ik}) = \frac{\exp(\widetilde{\alpha_i} p_{ij} + \beta_j x_i + \gamma z_{ij})}{\sum_{k \in C_i} \exp(\widetilde{\alpha_i} p_{ij} + \beta_j x_i + \gamma z_{ij})},$$

where C_i is the choice set containing the different categories for each individual i and the last equation equation follows from the distributional assumptions of the logit error term u_{ij}. The mixed logit model with unobserved heterogeneity requires integration over the distribution over $\widetilde{\alpha_i}$, the random coefficient:

$$s_{ij} = \int_{\widetilde{\alpha_i}} l_{ij}(\widetilde{\alpha}) f(\widetilde{\alpha}) d\widetilde{\alpha}.$$

I used a simulation method to estimate $\hat{s_{ij}}$. I drew M standard normal distributed v_i to calculate $\widetilde{\alpha_i^m}$, m=1,...,M, and applied them to get an averaged choice probability:

$$\hat{s}_{ij} = \frac{1}{M} \sum_{m=1}^{M} \frac{\exp(\widetilde{\alpha_i^m} p_{ij} + \beta_j x_i + \gamma z_{ij})}{\sum_{k \in C_i} \exp(\widetilde{\alpha_i^m} p_{ij} + \beta_j x_i + \gamma z_{ij})}.$$

This estimate is applied in the maximum likelihood estimation, which takes the following form:

$$\mathscr{L}(\theta) = y_{ij} \sum_i \sum_j \log(\widehat{s_{ij}}),$$

where y_{ij} equals 1 if individual i has chosen alternative j and 0 otherwise.

Price elasticities of demand

I am interested in own- and cross-price elasticities for the choice set averaged on the country-level. These elasticities are based on the regression's outcome, the choice probabilities, which were derived before, and the prices. From the mixed logit regression, the random coefficient for the price $\widetilde{\alpha_i}$ is simulated according to equation (5.1). The regression output is applied as well for the choice probabilities $\widehat{s_{ij}}$. The individual own-price elasticities of demand are then defined as follows:

$$\epsilon_{ij}^{indv} = \frac{\delta s_{ij}}{\delta p_{ij}} p_{ij} = \widetilde{\alpha_i} s_{ij}(1 - s_{ij}) p_{ij}. \tag{5.2}$$

As in Grzybowski et al. (2014), I calculated elasticities of demand instead of semi-elasticities of demand, i.e. I was not just averaging of individual's price elasticities but weighting these by the individual's choice probabilities. Hence, following the individual's own-price elasticity (equation (5.2)), the country level elasticity is:

$$\epsilon_{ij}^{country} = \frac{\sum_i \widetilde{\alpha_i} s_{ij}(1 - s_{ij}) p_{ij}}{\sum_i s_{ij}}.$$

The cross-price elasticities are accordingly calculated from the individual cross-price elasticities:

$$\epsilon_{ik}^{indv} = \frac{\delta s_{ij}}{\delta p_{ik}} p_{ik} = \widetilde{\alpha_i} s_{ij} s_{ik} p_{ik}, \; for \; k \neq j.$$

6 Estimation results

First, results for the whole sample and the reduced sample are shown. Afterwards, I focus on the reduced sample and present several specifications. I start this section by regression results for own- and cross-price elasticities, before going to regression results for the willingness-to-pay.

6.1 Elasticities

In this section the results of the alternative specific mixed-logit regression will be discussed shortly before I focus on the elasticities of demand to give insides for a broadband market definition. First, I will consider the model with four fixed-line and three mobile alternatives. Later on, I will also present results for other numbers of alternatives. Regarding the regression, I am mainly interested in the random price coefficient from which the own- and cross-price elasticities are calculated.

Regression results

As described above, I reduced the data to tests with an available bandwidth of at least 100 Mbps at their location grid, prior to the regression. This is necessary to make sure that all choices are eligible and that the results are comparable. To make sure that most of the testers had the whole coverage when signing their contract, the condition is applied for the years from 2015 to 2017. This reduces the sample to 77,143 tests. Furthermore, all regressions contain weights regarding the number of mobile and fixed-line contracts all over Austria and robust standard errors are applied.

In the main specification, most control variables were taken from the usage data. I control for whether the device, from which the test was performed, was connected via WLAN or LAN. In the case of a LAN test, I control for the used browser. In case of a WLAN test, I control for the company which produced the device. Furthermore, the first digit of the postal code and the mobile upload coverage from the *broadband atlas* were applied as geographic covariates. Only the last one is not included in the usage data. For later regression, I can apply control variables on municipality and individual level for robustness. On the municipality level, I control for population size, education, gender, age distribution and the number of providers. On the individual level, I apply again geo-coded information on distances to the next motorway, park, forest, riverbank and water as proxies for the user's wealth.

In the first regression tables, the main specification for the whole and the reduced sample is presented (Table 6.1). In the first table more tests with a rather low bandwidth are included. Therefore, its estimates for the price coefficients are higher in absolute terms. The estimation gives the following results for the random coefficient with mean valuation of $\hat{p} = -0.150$ and -0.136 and standard deviation of $\hat{\sigma}_p = 0.102$ and 0.110 (both highly significant). In both cases, it reveals a lower standard deviation (in absolute values) to the mean which yields a negative $\widetilde{\alpha_i}$ for most of the observations. Moreover, the reduced sample also shows not significant coefficients due to the reduced sample size, making its results also more trustful. The complete regression output can be found in Table **??**. For reasons of visibility, it is cut off after the first choices, showing the two price coefficients and all control coefficients for one choice.

Table 6.1: Regression of the whole and the reduced sample for the specification with four fixed-line and three mobile alternatives (reduced each time to test which have had full fixed-line coverage since 2015)

	(1) whole sample	(2) reduced sample
cat		
price	-0.149***	-0.122***
	(0.000828)	(0.000789)
Normal		
sd(price)	0.101***	0.0733***
	(0.000419)	(0.000632)
2		
mobile_upload	0.0251***	0.0244***
	(0.000445)	(0.000536)
mun_first=2	0.183***	0.203***
	(0.0101)	(0.00911)
mun_first=3	-0.303***	-0.202***
	(0.0113)	(0.0100)
mun_first=4	-0.342***	-0.542***
	(0.00900)	(0.00802)
mun_first=5	0.0488***	-0.222***
	(0.00932)	(0.00889)
mun_first=6	-0.198***	-0.243***
	(0.00989)	(0.00947)
mun_first=7	-0.0737***	-0.0651***
	(0.0121)	(0.0106)
mun_first=8	-0.0870***	0.135***
	(0.0120)	(0.0119)
mun_first=9	-0.410***	-0.264***
	(0.0227)	(0.0201)
wlan	0.268***	0.168***
	(0.00613)	(0.00610)
Constant	0.599***	0.662***
	(0.00944)	(0.00927)
⋮	⋮	⋮
Observations	8513106	8593571

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Price elasticities of demand

Next, I present own- and cross-price elasticities for the download speed alternatives for fixed-line and mobile tariff plans, which are calculated according to equation (**??**) applying the estimates of Table 6.1. The two shown tables present elasticities for the whole sample (Table 6.2) and the reduced sample (Table 6.3).

Own-price elasticities show demand changes after a price increase for a specific choice. Hence, they detect products that are elastic or inelastic in their demand regarding higher prices. The diagonal shows that all alternatives are elastic, with values starting from −2.2 for the lowest mobile bandwidth and for the lowest fixed-line bandwidth. Consequently, an increase in price by 1 percent reduces the demand by at least 2.2 percent. The own-price elasticity for other fixed-line choices increases with the bandwidth to a value of −6.3 which is driven conceptually by the higher prices. Therefore, this value should not be interpreted as an demand decrease of 6.3 percent after a price increase of 1 percent for mobile contracts with at least 80 Mbps. The own-price elasticity for the mobile alternative is comparable to the fixed-line contracts. Only for the second fixed-line category no mobile counterpart exists. For the others, one can at least compare own-price elasticity and price. For instance, the own-price elasticity for the lowest mobile category is higher, in absolute terms, than the one for the lowest fixed-line category. Therefore, one might expect that mobile choices in general more price sensitive.

Turning to cross-price elasticities, one detects movement patterns between the alternatives. The cross-price elasticity is defined as the demand increase of each contract if the price of the alternative in a specific row is increased by 1 percent. Hence, for each row it can be seen how the demand of the contract in that specific row is effected by an price increase of one percent for each row individually.

I now describe the results of Table 6.3, the elasticities derived from the reduced sample. They do not differ a lot in the other specifications. In general, the highest cross-price elasticities can be found for the alternative ≤ 40 Mbps. Additionally, if the price of one of the fixed-line contract is increased, the other fixed-line contracts instead of the mobile contracts are more demanded. The same holds for mobile contracts vice versa. This shows that same technologies are more likely to be substitutes. The closest contracts in allowed download speed and with the same technology usually are the ones with the highest cross-price elasticity in each row. For the alternatives at the border, for each technology the category with the lowest or highest possible bandwidth (≤20 Mbps and >80 Mbps for fixed-line and ≤40 Mbps and >80 Mbps for mobile) the next higher, respectively next lower, alternative has the highest cross-price elasticity. For the contracts in between, the cross-price elasticity points upwards for the ≤80 Mbps alternative for both technologies and downwards for the ≤40 Mbps fixed-line alternative. This and the relatively low cross-price elasticities for the

≤80 Mbps alternative indicate that between 40 Mbps and 80 Mbps there might exist a market border. This should be investigated more thoroughly in the following.

But before, I want to discuss cross-price elasticities for mobile alternatives. The lowest cross-price elasticity is shown for the highest mobile alternative in the case of a fixed-line alternative with ≤20 Mbps , ≤40 Mbps and ≤80 Mbps. For the highest fixed-line alternative, the lowest fixed-line alternative has the lowest cross-price elasticity. Showing that users with a demand for high bandwidths prefer a 40 Mbps mobile contract over a 20 Mbps fixed-line contract. Hence, they might substitute across technologies. For the mobile alternative, the cross-price elasticities of other mobile alternatives are always higher than of any fixed-line alternative. Showing again no great ability for substitution with fixed-line contracts. The lowest cross-price elasticities are shown for the highest fixed-line alternative, in case of the lowest mobile alternative and of the lowest fixed-line alternative in case of the other mobile alternatives. However, for the two lower mobile alternative the fixed-line cross-price elasticities do not differ a lot. Comparing the whole sample and the reduced one, shows that, in general, elasticities are lower in the reduced sample. This follows again from the more price sensitive whole sample.

I conclude from these findings that for users mobile and fixed-line are different technologies and therefore in general no good substitute. Hence, they prefer changing within their technology. However, slightly substitution exists, especially in the case of high bandwidths. For fixed-line users, a substitution to mobile alternatives is more likely. Users which prefer a mobile contract might have good reasons to do so. Mobile contracts are easier and quicker to install as their routers just have to be plugged into a socket. Users with a low bandwidth need might always migrate to the cheapest alternative. Therefore, for them a mobile contract with low download speed which is rather cheap is a substitute where as a fixed-line contract with high download speed is not.

If a market separation exist, it might be drawn at a tariff plan border between 40 Mbps and 80 Mbps of the fixed-line technologies. At this border users tend to downgrade where as users with a higher tariff plan tend to upgrade their contracts. However, this interpretation is not shown very strongly in the data. Nevertheless, one has to consider that only user with full broadband coverage where analyzed. This should be investigated more thoroughly in the following by changing the choice set and the number of alternatives.

Table 6.2: elasticities with no controls 1000 1517 private

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-2.207	1.178	.412	.598	.287	.529	.184
≤ 40 Mbps	1.15	-3.237	.472	.702	.29	.534	.214
≤ 80 Mbps	.98	1.145	-5.127	.932	.294	.533	.28
> 80 Mbps	.866	1.036	.573	-5.891	.295	.537	.372
mobile ≤ 40 Mbps	1.01	1.041	.437	.716	-2.763	.693	.391
mobile ≤ 80 Mbps	1.008	1.04	.429	.704	.377	-4.775	.462
mobile > 80 Mbps	.628	.753	.41	.889	.39	.851	-6.343

Table 6.3: elasticities 1000 1517 red new private red

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-1.858	1.142	.227	.358	.225	.534	.114
≤ 40 Mbps	.888	-2.484	.269	.435	.229	.562	.139
≤ 80 Mbps	.673	1.013	-4.332	.779	.247	.637	.219
> 80 Mbps	.483	.744	.362	-4.347	.244	.675	.383
mobile ≤ 40 Mbps	.667	.867	.251	.552	-2.239	.848	.344
mobile ≤ 80 Mbps	.614	.828	.25	.586	.329	-3.545	.436
mobile > 80 Mbps	.301	.47	.202	.809	.311	1.044	-4.758

6.2 Robustness and heterogeneous effects

In the following, I will describe different specifications which I tested to see the robustness of the results and heterogeneous effects. The reduced sample will be the basis for all test as before was discussed that the results might be more precise. The tables discussed here can be found in the appendix. Most convincing might be in general to apply different random subsets to show that there was no data crunching, p-value fishing or anything involved. Therefore, I apply several random data splits, first into two halves (Table A.3 and A.4), and then, into ten subsets, where just one will be presented (Table A.2). In all subsets the results look very similar, which makes me confident about my findings.

Next, more control covariates on municipality and individual level are added and do not change elasticities. They are added in two steps first only covariates on the municipality level are added. These are merged by the postal code and contain information about the population, like share of man and women, age, education, job situation, etc. Then, covariates derived from the individual geo test location is added, like distance to the next park, the next river and lake, the next railway and highway, etc. The results are shown in Table A.5 and A.6. In the contract data, it was not observable which provider made the highest bandwidths possible and whether these bandwidths were offered by several providers. Therefore, in a next test, I dropped alternatives which were not chosen in a municipality. This still does not show whether in a certain grid a household could have chosen from several providers or just from one. Nevertheless, this procedure might clean the data a little further. Nonetheless, the elasticities do not change a lot after removing these alternatives. The result stays robust (Table A.7). In the main specification, I was rather strict, when only applying grids which have had maximum fixed-line coverage at least since 2015. Therefore, I tested the changes if restricting to 2016 instead of 2015. Again, no big changes are found (Table A.8).

Heterogeneous effects might depend on the time and the location / the municipality. Therefore, at first, the data will be split along the test date. The usage data was collected for the first half of 2017. I will split the data into three groups, each containing data from two months. In the Tables A.9, A.10 and A.11, a decline in the elasticities can be detected. However, elasticities are not declining under a certain level of unimportance. As in the motivation was seen, the number of tests vary seasonal. However, for the restricted sample a similar amount of tests remain and the last sample contains only some fewer tests. This might be a point to dig deeper into a regulation policy and observe these trends over a longer time horizon.

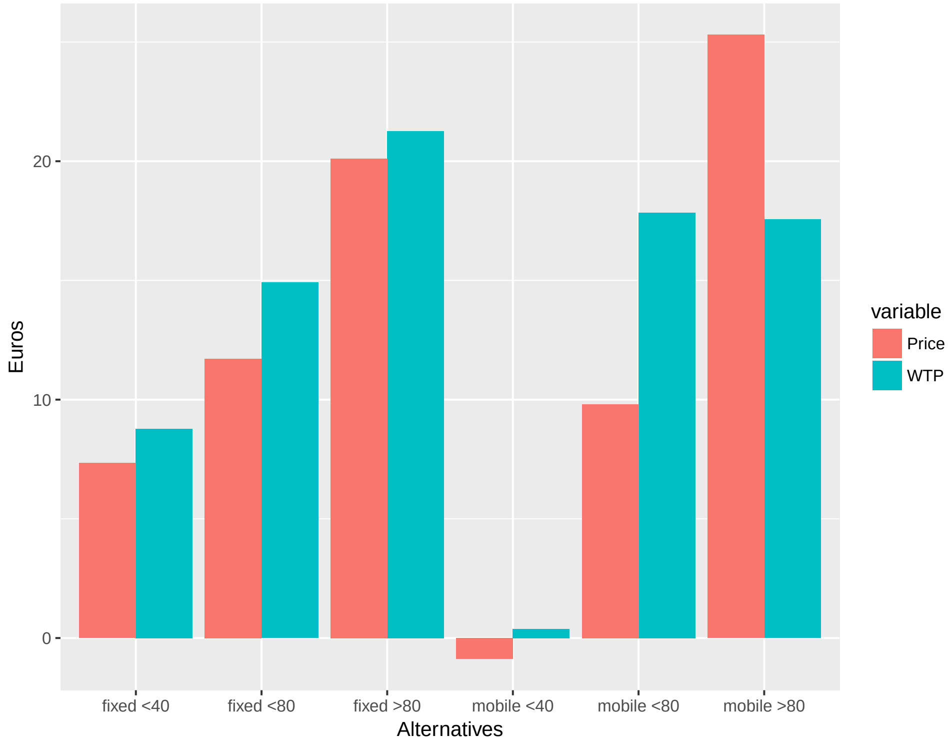
Regarding local difference, I can restrict the sample to certain region and municipalities with a certain number of performed tests (with a high speed choice). So, at first, we look at the three biggest cities in Austria, Vienna, Graz and Linz (Table A.12, A.14 and A.15), whereby one has to notice that Vienna is a lot bigger than the other two with 1,9 mio inhabitants. Graz has about 300.000 and Linz about 200.000 inhabitants. For Vienna and Linz, elasticities are a lot higher. This might be caused by a higher competition of providers. However, the numbers drop a bit if further control variables are added (Table A.13). Graz is below average. This might be caused by the location more close to the mountains and with less penetration of cable operators.

Next, the number of tests per municipality will be restricted. I will present elasticities for municipalities with more than 10, 20 and 50 tests (Table A.16, A.17 and A.18). One can see that elasticities are getting higher if the municipalities with fewer tests are removed. These removed municipalities might be smaller ones. Again, I would argue that elasticities increase due to higher market competition. The same results hold true, if municipalities with at least a certain number of tests in the highest fixed-line category are considered (Table A.19, A.20).

6.3 Interpretation

The border at 80 Mbps might indicate that there are to different groups of internet users. This is also backed up by relatively high standard deviation for the price coefficient in the regression, showing a broad deviation of price sensitivity. For internet users with a need for more than 40 Mbps can see that that there is high movement from the highest category to the second highest, each for mobile and fixed-line technologies. This means, that the second highest category is a good substitute for the highest category. Hence, regulators do not need to worry about high prices for very fast broadband internet. Limited internet users with no need for high speed broadband internet might need to be protected. Mobile users do mostly substitute to other mobile contracts. However, they do also move to lower fixed-line contracts.

Figure 9: WTP wrt fixed-line contracts with less than 20 Mbps and mean prices (substracted the mean price a contracts with less than 20 Mbps)



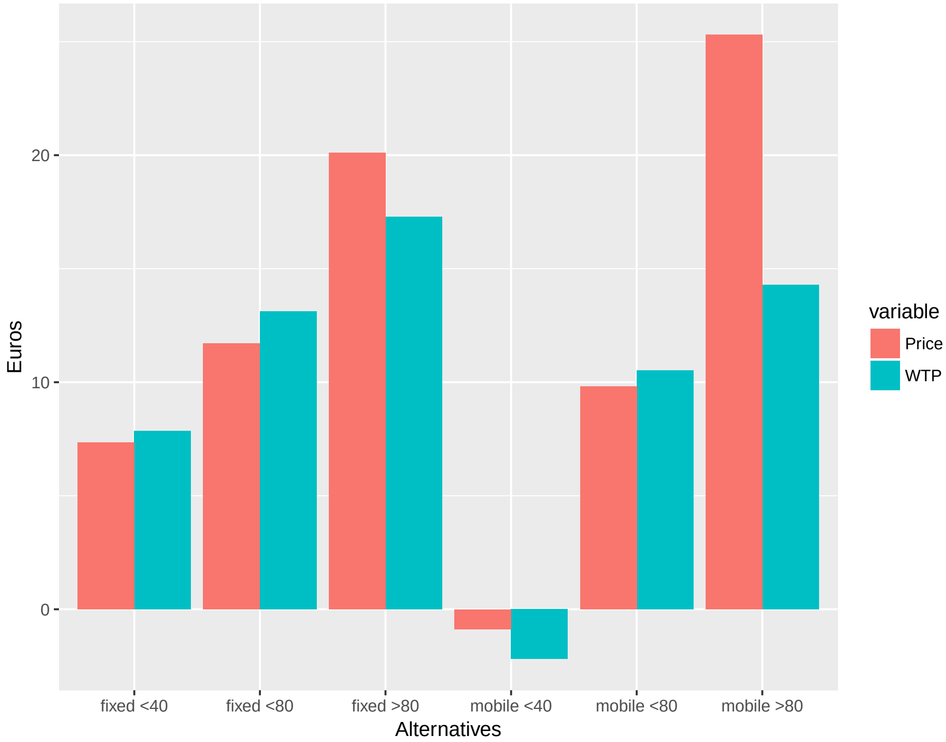
This might be reasoned by the higher deviation from the contractual speed for mobile users. Hence, their realized speed might be more comparable to a 80 Mbps fixed-line contract, and therefore, this lower fixed-line category might form a different market.

6.4 Willingness-to-pay

Figure 9 shows willingness-to-pay (WTP) for the categories analyzed above. Fixed-line contracts with less than 20 Mbps are defined as a reference category. For comparison, mean prices of the categories are provided as well. The "Price-bar" shows the difference of the mean price of each category minus the mean price of the reference category ("less than 20 Mbps"). One has to consider that the price of the reference category might not be equal to the WTP for this category.

Especially for mobile alternatives, one can see that the middle category has a higher WTP than it price would be, whereas for the highest category the price is a lot higher than its WTP. I could assume that mobile broadband internet only seldom reaches a download speed of more than 80 Mbps. Therefore, internet users might not evaluate mobile contracts with more than 80 Mbps higher than contracts close to 80 Mbps. For the fixed-line contracts, the WTP is always estimated to be higher than its prices.

Figure 10: WTP wrt fixed-line contracts with less than 20 Mbps and mean prices (substracted the mean price a contracts with less than 20 Mbps) whole sample



At the end the regression table is shown.

Figure 11: WTP wrt fixed-line contracts with less than 40 Mbps and mean prices (substracted the mean price a contracts with less than 40 Mbps) whole sample

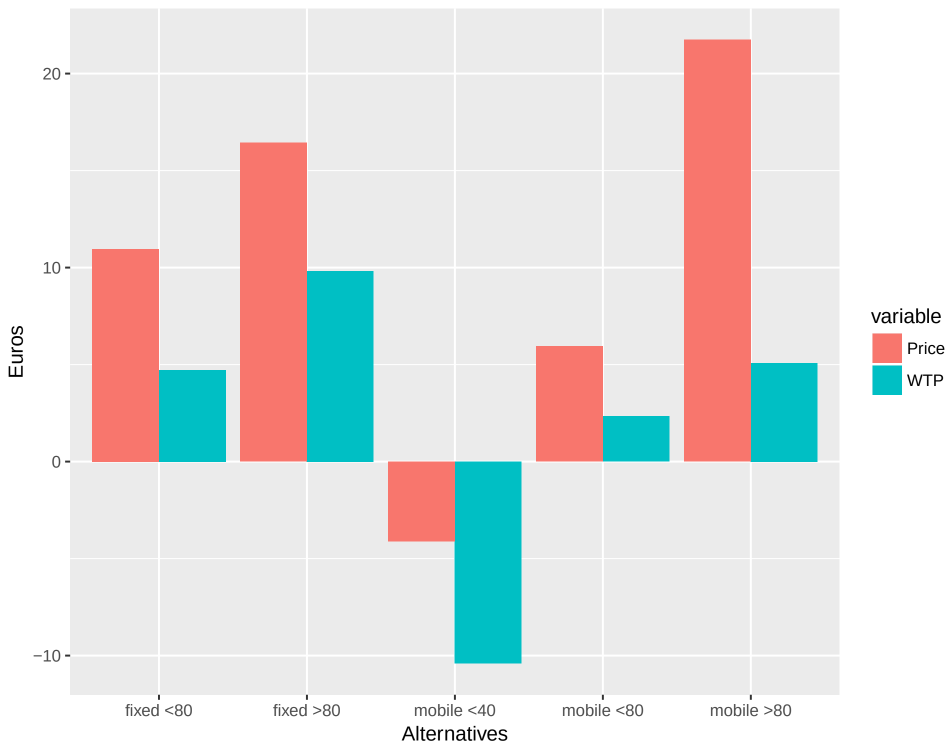


Table 6.4: Regression WTP

	(1)
	choice
cat_random	
cat=1	0
	(.)
cat=2	1.796***
	(0.0308)
cat=3	3.051***
	(0.0398)
cat=4	4.350***
	(0.0460)
cat=5	0.0779***
	(0.0200)
cat=6	3.651***
	(0.0383)
cat=7	3.591***
	(0.0530)
price	-0.205***
	(0.00228)
Normal	
sd(price)	0.163***
	(0.00189)
2	
Constant	0.0478*
	(0.0199)
3	
Constant	0.0484*
	(0.0198)
4	
Constant	0.0382
	(0.0199)
5	
Constant	0.0388
	(0.0199)
6	
Constant	0.0160
	(0.0199)
7	
Constant	0.0389
	(0.0199)
Observations	338632

Standard errors in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

7 Conclusion

In summary, I conclude that regulators could think of regulating broadband internet in a different manner, as it is done today. First, they could regulate contracts of less than 80 Mbps differently than contracts with at least 80 Mbps. Second, they could think of tearing down the wall between the fixed-line and the mobile broadband internet market as it was suggested before in the literature. Here again, it might make sense to regulate mobile contracts with less than 80 Mbps differently than contracts with at least 80 Mbps. The results might suggest the interpretation that the regulation of lower broadband internet works and is useful, whereas one could try to limit the regulation for higher broadband. Here, I am also keeping in mind that a more restricted regulation might foster the rollout of fiber and faster internet.

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A Appendix

Table A.1: TEST: elasticities with no controls private (random05)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-2.371	1.285	.287	.536	.278	.792	.182
≤ 40 Mbps	1.155	-3.208	.353	.591	.254	.735	.187
≤ 80 Mbps	.97	1.289	-5.385	.962	.242	.705	.261
> 80 Mbps	.753	.91	.423	-5.388	.247	.723	.424
mobile ≤ 40 Mbps	1.07	1.119	.289	.72	-3.022	1.052	.42
mobile ≤ 80 Mbps	.976	1.039	.264	.668	.328	-4.489	.483
mobile > 80 Mbps	.495	.59	.216	.92	.305	1.258	-5.822

A.1 Random subset TEST

Table A.2: elasticities with no controls private (random1)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-1.889	1.073	.248	.401	.227	.574	.131
≤ 40 Mbps	.915	-2.527	.283	.435	.218	.567	.153
≤ 80 Mbps	.758	.99	-4.336	.795	.22	.595	.222
> 80 Mbps	.568	.71	.36	-4.338	.222	.639	.405
mobile ≤ 40 Mbps	.753	.834	.243	.554	-2.318	.852	.373
mobile ≤ 80 Mbps	.694	.8	.239	.56	.307	-3.571	.456
mobile > 80 Mbps	.33	.447	.192	.723	.275	.94	-4.431

Table A.3: elasticities with no controls private (random5)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-1.803	1.106	.229	.346	.214	.514	.106
≤ 40 Mbps	.857	-2.403	.272	.425	.217	.547	.137
≤ 80 Mbps	.646	.981	-4.171	.762	.233	.616	.21
> 80 Mbps	.461	.721	.364	-4.216	.234	.666	.377
mobile ≤ 40 Mbps	.648	.836	.252	.552	-2.191	.838	.334
mobile ≤ 80 Mbps	.583	.794	.248	.581	.314	-3.417	.425
mobile > 80 Mbps	.276	.457	.203	.811	.292	1.01	-4.573

Table A.4: elasticities with no controls private (randomg5)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-1.934	1.188	.228	.374	.238	.559	.124
≤ 40 Mbps	.913	-2.555	.267	.444	.242	.577	.143
≤ 80 Mbps	.688	1.029	-4.443	.799	.26	.648	.223
> 80 Mbps	.506	.772	.365	-4.484	.256	.693	.389
mobile ≤ 40 Mbps	.681	.898	.252	.557	-2.296	.868	.359
mobile ≤ 80 Mbps	.643	.856	.249	.594	.341	-3.644	.441
mobile > 80 Mbps	.329	.487	.207	.832	.338	1.086	-5.008

Table A.5: elasticities (1517 1000 private control plz red new)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-1.908	1.17	.234	.374	.23	.544	.117
≤ 40 Mbps	.913	-2.552	.28	.446	.235	.577	.14
≤ 80 Mbps	.69	1.039	-4.434	.805	.257	.653	.22
> 80 Mbps	.48	.724	.357	-4.324	.245	.671	.384
mobile ≤ 40 Mbps	.679	.885	.262	.58	-2.302	.877	.353
mobile ≤ 80 Mbps	.621	.842	.257	.611	.34	-3.622	.449
mobile > 80 Mbps	.304	.465	.203	.843	.319	1.075	-4.836

Table A.6: elasticities (1517 1000 private control red new)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-1.993	1.221	.246	.389	.242	.568	.122
≤ 40 Mbps	.951	-2.664	.294	.464	.245	.605	.146
≤ 80 Mbps	.726	1.094	-4.616	.816	.269	.686	.228
> 80 Mbps	.481	.73	.347	-4.389	.249	.683	.397
mobile ≤ 40 Mbps	.712	.923	.274	.612	-2.41	.916	.371
mobile ≤ 80 Mbps	.647	.881	.268	.64	.354	-3.771	.464
mobile > 80 Mbps	.315	.482	.208	.892	.332	1.106	-5.009

Table A.7: elasticities with no controls (cat43 highred)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-1.859	1.138	.23	.355	.226	.537	.116
≤ 40 Mbps	.879	-2.479	.274	.435	.228	.561	.14
≤ 80 Mbps	.668	1.01	-4.318	.773	.247	.639	.219
> 80 Mbps	.471	.732	.356	-4.263	.237	.663	.368
mobile ≤ 40 Mbps	.667	.86	.253	.552	-2.241	.853	.348
mobile ≤ 80 Mbps	.612	.818	.252	.595	.329	-3.531	.44
mobile > 80 Mbps	.301	.474	.207	.821	.319	1.057	-4.796

Table A.8: elasticities with no controls (cat43 1617)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-1.522	.982	.179	.253	.175	.433	.092
≤ 40 Mbps	.721	-1.966	.209	.309	.178	.453	.11
≤ 80 Mbps	.537	.834	-3.485	.581	.199	.526	.182
> 80 Mbps	.376	.607	.292	-3.591	.206	.59	.34
mobile ≤ 40 Mbps	.531	.725	.204	.434	-1.829	.709	.279
mobile ≤ 80 Mbps	.487	.686	.197	.452	.26	-2.846	.358
mobile > 80 Mbps	.24	.39	.167	.662	.25	.885	-3.917

Table A.9: elasticities with no controls private (month le2)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-2.125	1.354	.295	.406	.233	.555	.131
≤ 40 Mbps	1.095	-2.879	.348	.473	.229	.575	.16
≤ 80 Mbps	.851	1.202	-4.894	.881	.253	.637	.221
> 80 Mbps	.592	.828	.458	-4.813	.268	.701	.408
mobile ≤ 40 Mbps	.815	.979	.314	.668	-2.638	.935	.439
mobile ≤ 80 Mbps	.755	.961	.3	.67	.361	-4.191	.559
mobile > 80 Mbps	.366	.553	.228	.868	.366	1.235	-5.504

Table A.10: elasticities with no controls private (month34)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-1.773	1.006	.206	.353	.241	.567	.109
≤ 40 Mbps	.829	-2.37	.239	.417	.245	.554	.12
≤ 80 Mbps	.667	.935	-4.166	.701	.257	.618	.2
> 80 Mbps	.5	.714	.311	-4.254	.239	.651	.362
mobile ≤ 40 Mbps	.657	.803	.221	.471	-2.083	.822	.277
mobile ≤ 80 Mbps	.624	.737	.212	.518	.332	-3.298	.357
mobile > 80 Mbps	.318	.428	.192	.804	.313	1.002	-4.663

A.2 Random subset

A.3 Other controls

A.4 Robustness: Reduction of alternatives and coverage

A.5 Robustness: coverage 1617

A.6 Heterogeneous effects over time

Table A.11: elasticities with no controls private (month g4)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-1.558	.988	.174	.295	.181	.439	.091
≤ 40 Mbps	.681	-2.032	.211	.382	.195	.505	.127
≤ 80 Mbps	.469	.825	-3.634	.711	.21	.617	.219
> 80 Mbps	.336	.631	.301	-3.634	.198	.623	.353
mobile ≤ 40 Mbps	.488	.765	.211	.486	-1.884	.734	.317
mobile ≤ 80 Mbps	.428	.721	.221	.543	.263	-2.91	.382
mobile > 80 Mbps	.191	.399	.181	.722	.256	.872	-3.893

Table A.12: elasticities with no controls 1000 1517 private (vienna)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-3.552	1.688	.732	1.291	.359	.808	.231
≤ 40 Mbps	1.154	-4.115	.717	1.242	.365	.786	.219
≤ 80 Mbps	1.113	1.595	-6.617	1.53	.358	.796	.259
> 80 Mbps	.826	1.162	.658	-5.857	.305	.706	.358
mobile ≤ 40 Mbps	1.032	1.537	.683	1.406	-3.802	.965	.439
mobile ≤ 80 Mbps	.985	1.416	.656	1.399	.408	-6.207	.542
mobile > 80 Mbps	.641	.89	.488	1.664	.427	1.259	-8.325

Table A.13: elasticities with no controls 1000 1517 private (vienna)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-3.201	1.575	.723	.977	.328	.743	.205
≤ 40 Mbps	1.059	-3.6	.689	.88	.33	.701	.202
≤ 80 Mbps	1.054	1.488	-5.896	1.031	.335	.783	.278
> 80 Mbps	.521	.694	.389	-3.832	.195	.52	.29
mobile ≤ 40 Mbps	.941	1.409	.668	1.092	-3.466	.944	.439
mobile ≤ 80 Mbps	.877	1.237	.645	1.194	.388	-5.543	.53
mobile > 80 Mbps	.496	.731	.487	1.471	.381	1.121	-7.037

Table A.14: elasticities with no controls 1000 1517 private (graz)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-1.311	.653	.156	.359	.213	.362	.041
≤ 40 Mbps	.485	-1.657	.156	.434	.205	.388	.054
≤ 80 Mbps	.478	.642	-2.81	.43	.216	.397	.055
> 80 Mbps	.333	.537	.131	-2.761	.206	.471	.178
mobile ≤ 40 Mbps	.358	.461	.12	.38	-1.207	.527	.073
mobile ≤ 80 Mbps	.354	.508	.128	.508	.305	-2.307	.112
mobile > 80 Mbps	.182	.328	.084	.884	.2	.521	-3.356

Table A.15: elasticities with no controls 1000 1517 private (linz)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-2.339	1.594	.098	.098	.387	.808	.115
≤ 40 Mbps	1.717	-4.018	.122	.188	.488	1.071	.218
≤ 80 Mbps	1.075	1.308	-7.44	.545	.663	1.541	.726
> 80 Mbps	.284	.57	.151	-7.514	.506	1.499	2.655
mobile ≤ 40 Mbps	1.068	1.244	.164	.462	-3.259	1.482	.67
mobile ≤ 80 Mbps	1.003	1.325	.185	.674	.691	-5.784	.866
mobile > 80 Mbps	.263	.529	.183	2.514	.689	1.819	-8.562

A.7 Regional differences

Table A.16: elasticities with no controls (cat43 numtest10)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-1.887	1.139	.235	.376	.23	.543	.117
≤ 40 Mbps	.873	-2.491	.276	.453	.233	.571	.142
≤ 80 Mbps	.667	1.009	-4.303	.787	.246	.63	.216
> 80 Mbps	.491	.761	.367	-4.358	.244	.669	.375
mobile ≤ 40 Mbps	.667	.875	.254	.565	-2.256	.852	.341
mobile ≤ 80 Mbps	.614	.835	.253	.592	.327	-3.555	.425
mobile > 80 Mbps	.303	.481	.208	.827	.316	1.048	-4.831

Table A.17: elasticities with no controls (cat43 numtest20)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-1.975	1.172	.247	.41	.243	.577	.12
≤ 40 Mbps	.881	-2.562	.287	.486	.241	.595	.145
≤ 80 Mbps	.686	1.041	-4.436	.836	.251	.644	.216
> 80 Mbps	.505	.783	.379	-4.429	.245	.669	.37
mobile ≤ 40 Mbps	.687	.896	.261	.583	-2.302	.865	.334
mobile ≤ 80 Mbps	.637	.865	.26	.615	.337	-3.666	.424
mobile > 80 Mbps	.319	.508	.217	.869	.321	1.061	-5.007

Table A.18: elasticities with no controls (cat43 numtest50)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-2.214	1.252	.301	.51	.272	.644	.134
≤ 40 Mbps	.903	-2.746	.331	.567	.264	.642	.15
≤ 80 Mbps	.742	1.118	-4.696	.912	.263	.666	.208
> 80 Mbps	.562	.85	.416	-4.721	.257	.689	.358
mobile ≤ 40 Mbps	.741	.993	.296	.664	-2.487	.896	.321
mobile ≤ 80 Mbps	.695	.953	.294	.696	.356	-3.996	.421
mobile > 80 Mbps	.37	.57	.243	.984	.329	1.118	-5.513

Table A.19: elasticities with no controls (cat43 tests1)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-2.206	1.246	.302	.584	.255	.61	.139
≤ 40 Mbps	.917	-2.767	.334	.642	.251	.614	.154
≤ 80 Mbps	.755	1.116	-4.76	.984	.258	.663	.215
> 80 Mbps	.59	.866	.406	-4.828	.254	.716	.367
mobile ≤ 40 Mbps	.762	1.015	.311	.773	-2.551	.849	.322
mobile ≤ 80 Mbps	.699	.948	.306	.824	.324	-4.081	.424
mobile > 80 Mbps	.392	.584	.249	1.095	.306	1.083	-5.647

Table A.20: elasticities with no controls (cat43 lowtets10)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-2.342	1.246	.366	.715	.271	.581	.143
≤ 40 Mbps	.899	-2.93	.406	.812	.268	.606	.162
≤ 80 Mbps	.768	1.168	-4.861	1.081	.26	.632	.204
> 80 Mbps	.587	.905	.428	-4.698	.245	.653	.334
mobile ≤ 40 Mbps	.779	1.062	.363	.888	-2.648	.789	.32
mobile ≤ 80 Mbps	.695	1.001	.363	.972	.326	-4.344	.436
mobile > 80 Mbps	.398	.621	.28	1.249	.313	1.051	-5.921

Table A.21: elasticities with no controls (cat22 40 80)

	≤ 40 Mbps	> 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 40 Mbps	-1.243	1.272	.587	.053
> 40 Mbps	.805	-2.292	.51	.076
mobile ≤ 80 Mbps	.671	.977	-1.621	.355
mobile > 80 Mbps	.222	.497	1.44	-3.339

Table A.22: elasticities with no controls (cat22 80 80)

	≤ 80 Mbps	> 80 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 80 Mbps	-.884	.72	.469	.053
> 80 Mbps	.989	-2.539	.441	.078
mobile ≤ 80 Mbps	.815	.559	-1.386	.314
mobile > 80 Mbps	.301	.322	1.102	-2.651

Table A.23: elasticities with no controls (cat32 80)

	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 40 Mbps	-1.052	.557	.268	.551	.096
≤ 80 Mbps	.999	-2.634	.457	.526	.11
> 80 Mbps	.639	.629	-3.303	.665	.3
mobile ≤ 80 Mbps	.821	.439	.42	-1.709	.284
mobile > 80 Mbps	.447	.294	.645	.954	-3.507

Table A.24: elasticities with no controls (cat33 80)

	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 40 Mbps	-1.246	.645	.307	.197	.476	.108
≤ 80 Mbps	1.195	-3.192	.545	.191	.478	.131
> 80 Mbps	.744	.735	-3.83	.214	.599	.345
mobile ≤ 40 Mbps	1.039	.547	.476	-1.909	.752	.306
mobile ≤ 80 Mbps	.984	.531	.511	.294	-3.04	.378
mobile > 80 Mbps	.508	.34	.715	.285	.922	-4.128

Table A.25: elasticities with no controls (cat43)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 40 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-1.858	1.142	.227	.358	.225	.534	.114
≤ 40 Mbps	.888	-2.484	.269	.435	.229	.562	.139
≤ 80 Mbps	.673	1.013	-4.332	.779	.247	.637	.219
> 80 Mbps	.483	.744	.362	-4.347	.244	.675	.383
mobile ≤ 40 Mbps	.667	.867	.251	.552	-2.239	.848	.344
mobile ≤ 80 Mbps	.614	.828	.25	.586	.329	-3.545	.436
mobile > 80 Mbps	.301	.47	.202	.809	.311	1.044	-4.758

A.8 Robustness: Tests per municipality

A.9 Robustness: High-Tests per municipality

A.10 Robustness: Different choice sets red

A.11 Robustness: one mobile alternative