Low demand despite broad supply: Is high-speed Internet an infrastructure of general interest?*

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Abstract

Although the recent years have witnessed a stark increase in the availability of high-speed Internet, adoption rates remain low. One potential explanation is that for most users high-speed Internet does not increase their utility. Using a mixed logit discrete choice model, this paper analyzes whether high-speed and basic Internet are substitutes. I find that they are not. Users who do not need higher speeds, choose basic speeds regardless of high-speed availability. Therefore, high-speed Internet is not an infrastructure of general interest. Consequently, policy-makers cannot increase usage of high-speed Internet by solely fostering its rollout.

Keywords: high-speed Internet, broadband, discrete choice, mixed logit

JEL-Codes: L96; L13; L51

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1. Introduction

The Internet is widely regarded as a general-purpose technology as it is used on a large scale and has had significant social and economic effects. Czernich et al. (2011) and Kolko (2012), among others, have shown that the introduction of DSL

*I am very thankful to Andreas Mazat for his exceptional input. Furthermore, I would like to thank Lukasz Grzybowski and Alan Crawford for discussing this work at a workshop in Paris and at a conference in Madrid. I also thank Oliver Falck, seminar participants at the Ifo Institute and conference attendants at Trento (ITS), Athens (EARIE), Madrid (JEI), and Leipzig (VfS). I thank the Deutsche Telekom AG for financial support to conduct this research. I further thank the Ministry of Transport (BMVIT) and in particular Christof Falkenberg and Stefanie Krames for providing data on fixed-line and mobile coverage (from Broadband Atlas), active providers, and socio-economic data from Austrian municipalities and AK-Tarifwegweiser and especially Miriam Süsür for providing data on provider contracts. All errors are my own.

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at basic speeds accelerated economic growth. It is almost considered a truism that higher speeds will again go hand in hand with economic growth. It is thus unsurprising that policy-makers throughout Europe are concerned about raising broadband quality. The Digital Agenda for Europe from 2016 aims to connect all (50 percent) households to broadband Internet with at least 30 Mbps (100 Mbps) by 2020.[1] Coverage rates for these bandwidths already reached 79.0 percent (55.1 percent) in 2017.[2] In contrast to the adoption of Internet at basic speeds, however, the adoption of high-speed Internet remains low: only one-third (one-fifth) of households with higher available speeds have also subscribed to at least 30 Mbps (100 Mbps).[3] This apparent subscription gap raises the question whether high-speed Internet is of general interest or only demanded by a very specific subset of users. Without a broad subscription, it is different from broadband Internet at basic speeds and cannot be described as a general-purpose technology.

There is still little research analyzing Internet at higher speeds. When investigating the effects of broadband Internet, the focus remains on basic speeds. More recent work on higher speeds relates to availability and therefore misses the role of adoption. This paper establishes a link between availability and adoption of high-speed Internet and provides one explanation for the lack of economic effects of high-speed Internet availability. It analyzes why high-speed Internet is not adopted widely in Austria, despite high coverage rates. I consider specifically contracts of more than 100 Mbps. The adoption of high-speed Internet depends on the substitutability over bandwidths and between stationary fixed-line and mobile technologies. Only if basic and higher speeds are considered substitutes, high-speed Internet will be adopted widely. If basic and higher speeds are not considered substitutes, there is only one specific type of Internet user with high benefits from high-speed Internet. Other users do not have such high benefits and will always choose a cheaper basic contract. In this case, the adoption rate will remain low because the high prices

[1] https://ec.europa.eu/digital-single-market/en/broadband-strategy-policy

[2] https://ec.europa.eu/digital-single-market/en/connectivity

[3] https://ec.europa.eu/digital-single-market/en/european-digital-progress-report

do not match the low utility that most users receive from higher bandwidths. Then, high-speed Internet would not be an infrastructure of general interest.

I apply a mixed logit discrete choice model, from which own-price and cross-price elasticities of demand are derived. While own-price elasticities show how price-sensitive consumers are, cross-price elasticities define substitutes. I apply a cross-sectional setting for Austria with regional differences in terms of active providers at the municipality level. The methodology applied in this paper is widely used in the market definition literature, where different technologies or bandwidths are analyzed in terms of their substitutability when deciding whether they form a single market or different markets.

I find that high-speed and basic Internet are not substitutes as cross-price elasticities show a different pattern for basic and higher speeds. Users who are satisfied with basic speeds refrain from adopting high-speed Internet even if it is available. I conclude that there is a certain type of users who needs higher speeds. So, increasing the availability of high-speed Internet will only increase the use of high-speed Internet if these users live in the area that gets an upgrade. By contrast, users who do not require higher speeds will always choose the relatively cheap basic-speed alternative, regardless of the availability of high-speed Internet. I find that for lower speeds, fixed-line and mobile technologies are substitutes. At higher speeds, these technologies do not function as substitutes. Furthermore, the derived own-price elasticities indicate that the demand is generally very elastic.

This paper uses novel geo-referenced data. I use extensive information from around 150,000 Austrian stationary broadband Internet tests conducted on the regulatory authority's web site (RTR-NetTest) between April and November 2016. I observe the selected provider and the measured download and upload speed and can use this information to infer the selected contract. The number of Internet users testing their speed has increased sharply in recent years (Figure A.1), making new methods such as the one presented in this paper feasible.[4] The increase in speed

[4] The annual increase shows a certain seasonality. In the colder half of the year, the number of tests increases, such that the highest number of tests is always found in December. In the warmer months,

tests is not due to the higher Internet penetration in Austria.[5] Rather, the increase in tests shows that users are no longer satisfied with just being connected to the Internet, but are concerned with the speed at which they can use it. This data also makes it possible to track the increased average download speed (Figure A.2). In addition, I observe the price of the selected contract as well as the competitive environment at the household's place of residence, which enables me to define a choice set for each user in the sample.

Austria is examined as a representative country for Europe in terms of (bandwidth) coverage rates and Next Generation Access (NGA) coverage. As in many other countries, there is an incumbent provider (A1 Telekom Austria)[6] that owns the copper network and is under regulation. The incumbent mainly offers high-speed contracts by copper-based VDSL technology. In addition, there are regional cable providers (kabelplus, Tele2, and UPC) that have historically been active in the TV market and therefore own a coaxial cable network. Their NGA technology is DOCSIS 3.0. In recent years, fiber network providers (Salzburg AG and LIWEST) have entered the market with very high-speed contracts at a more local level. Austria's NGA mix contains only to a lesser extent fiber technologies (FTTP). Finally, Austria has one of the strongest mobile networks in Europe. Three providers (Hutchinson Drei, A1 Telekom Mobile, and T-Mobile) offer contracts for mobile broadband Internet at home. Importantly, A1 Telekom Mobile is one of them. So, the incumbent also offers mobile contracts.

This paper proceeds as follows. Section 2 gives an overview of the related literature. Section 3 defines the discrete choice mixed logit regression model and how the elasticities are derived. In Section 4, broadband coverage in Europe and the case of Austria are explained. Then, I introduce the data sets I use and merge. Section 5

households spend more time outdoors and perform fewer tests of their Internet quality.

[5] In 2013, already 98 percent of households had a broadband coverage of at least 2 Mbps, and four out of five Austrians could access the Internet from home, meaning that the households did have a valid Internet subscription.

[6] In the following, I will always refer to A1 Telekom Austria as A1 Telekom or A1 TA.

presents the estimation results and the price elasticities of demand. Section 6 concludes.

2. Related Literature

The literature so far has concentrated on the effects of the introduction of DSL, i.e. on Internet at basic speeds (among others Czernich et al. (2011) and Kolko (2012)). Very few more recent studies focus on higher speed (among others Ford (2018) and Briglauer et al. (2019)). Although, these analyses are based on the availability of higher speeds. Additionally, higher speeds refer to higher speeds compared to the introduction of DSL, but not to the currently available speeds of more than 100 Mbps. To the best of my knowledge, this is the first paper that analyzes the adoption of high-speed Internet where it is available on a broad scale. The estimated utilities and price elasticities of demand from this analysis show limitations in the use of high-speed Internet that are necessary before economic effects of higher speeds can be found. Finally, it applies methodology from the literature on market definition in the broadband market and adds here by providing substitution patterns between fixed-line and mobile technologies across different bandwidths.

Starting with the literature on the impact of broadband Internet on economic outcomes, Czernich et al. (2011) identify an effect of broadband infrastructure on annual per capita growth for OECD countries. For the US, Kolko (2012) finds a positive relationship between broadband expansion and local economic growth. He applies the slope of the terrain as an instrument for broadband expansion and detects growth in population, employment, the average wage, and the employment rate. Focusing on labor market effects, Atasoy (2013) discovers that gaining access to broadband services in a county is associated with approximately a 1.8 percentage points increase in the employment rate. This contrasts with Czernich (2014), who finds no effect on the unemployment rate for Germany. On the firm level, Akerman et al. (2015) identify different broadband Internet effects depending on the skill level of workers on labor market outcomes and productivity for Norway. For Germany, Bertschek et al. (2013) detect broadband Internet effects on the firms' innovation activity, but not on their labor productivity. Colombo et al. (2013) find that the productivity performance of small and medium enterprises in Italy is not influenced by basic broadband applications. However, depending on the sector, advanced broadband applications do influence productivity. On broadband adoption, Grimes et al. (2012) discover an increase in firm productivity. All of these studies use basic DSL at lower speeds than are used in this paper.

More recent studies analyze various broadband speeds. Ford (2018) compares 10 Mbps and 25 Mbps in the US and finds no economic payoff at the county level in terms of jobs and income. Similar results are shown in a correction of Bai (2017) by Whitacre et al. (2018). For Germany, Briglauer et al. (2019) evaluate the Bavarian state aid program for speed upgrades in broadband Internet availability. They detect no effect on the employment rate. However, 16 Mbps and above is the highest category. Therefore, I investigate whether there might not exist enough users with a high utility from high-speed Internet.

Methodologically, this paper builds on the literature on market definition in the broadband market. So far, the literature has concentrated on the investigation of potential technology-level boundaries. Early papers by Crandall et al. (2002), Rappoport et al. (2003), and Flamm and Chaudhuri (2007) analyze the 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. Similar results are found by Pereira and Ribeiro (2011) for Portugal.

In a more recent study, Cardona et al. (2009) also analyze the Austrian broadband market applying a nested logit model. They find a strong substitution between DSL and cable where cable exists and suggest adding cable to the DSL market. Additionally, they exploit the fact that about half of Austria is connected to the cable network. They detect higher elasticities in areas connected to cable network than in areas without the possibility to access cable network. Stationary mobile Internet was not yet very important in the market. Therefore, the authors, expecting it to gain importance, leave it to further research to discuss the substitution pattern between fixed-line and mobile Internet. Other more recent studies, which increasingly focus on whether fixed-line and mobile technologies are substitutes, were presented by Srinuan et al. (2012) and Grzybowski et al. (2014) for Sweden and Slovakia, respectively. The derived price elasticities point towards a high price-sensitivity for all technologies, indicating them to be close substitutes. While Cardona et al. (2009) and Srinuan et al. (2012) apply a nested logit model, Grzybowski et al. (2014) apply a mixed logit model. They all use survey data. Here, this paper contributes by providing substitution patterns across speed and technology as first indications of future market definition for the broadband Internet market in Austria.

3. Discrete choice model

I apply a discrete choice model following McFadden and Train (2000), which is the standard methodology in the literature on market definition. Internet subscribers choose a contract with a specific provider, bandwidth, and price. All available contracts are defined as the choice set's alternatives. The alternatives form an exhaustive and mutually exclusive discrete choice set.

The most basic regression method in this context would be a multinomial logit model. However, it imposes the independence of irrelevant alternatives (IIA) property. Since the IIA might not be guaranteed, I apply a more general approach, a mixed logit regression, which relaxes the IIA by allowing correlation of choices between the alternatives. This model allows for unobserved heterogeneity among individuals, which might apply in this case as I observe only very few individual characteristics of the Internet subscribers. Moreover, Internet subscribers do not only consider speed when making their choice, but also other characteristics, in particular the price. Therefore, to account for the unobserved heterogeneity among Internet subscribers, a random coefficient for the price is applied.

3.1. Choice set

The choice is defined by the contract selected by the Internet subscriber. The alternatives are represented according to speed categories for fixed-line and mobile providers, respectively. There are seven alternatives in total: surfing at a maximum of (i) 20 Mbps, (ii) 40 Mbps (iii) 80 Mbps or (iv) at more than 80 Mbps with a fixed-line provider and (v) surfing at a maximum of 20 Mbps, (vi) 80 Mbps or (vii) at more than 80 Mbps with a mobile provider. Note that I do not differentiate among providers nor technologies (DSL, cable, and fiber) within each alternative.

3.2. Utility

The utility V_{ij} is defined for each Internet subscriber i and each alternative j. It depends on subscriber- and alternative-specific valuations (β_j and γ) and the Internet subscriber's price sensitivity $\widetilde{\alpha_i}$:

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

where x_i is a vector of subscriber-specific variables and z_j is a vector of alternatives-specific variables. Finally, u_{ij} is the logit error term, which is, as suggested by theory, identically and independently distributed across contracts according to the Type I extreme value distribution. The random price coefficient $\widetilde{\alpha_i}$ accounts for unobserved heterogeneity among the individual Internet subscribers. Assuming a normal distribution ($\widetilde{\alpha} \sim N(\alpha, \Sigma)$), $\widetilde{\alpha_i}$ is calculated as follows:

$$\widetilde{\alpha_i} = \alpha + \sigma_\alpha \nu_i, \tag{1}$$

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

3.3. Choice probabilities

I assume that Internet subscribers maximize their utility. With the previously defined utilities, the 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 for each Internet subscriber i as defined above. The last 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, which has to be simulated.:

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

The estimate $\widehat{s_{ij}}$ is then applied to the maximum likelihood estimation:

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

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

3.4. 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 (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:

$$\epsilon_{ij}^{indv} = \frac{\delta s_{ij}}{\delta p_{ij}} p_{ij} = \widetilde{\alpha_i} s_{ij}(1 - s_{ij}) p_{ij}. \tag{2}$$

As in Grzybowski et al. (2014), I calculate elasticities of demand instead of semi-elasticities of demand, i.e. I do not simply average over individual's price elasticities but weight these by the individual's choice probabilities. Hence, following the individual's own-price elasticity (equation (2)), the country level elasticity is:

$$\epsilon_{ij}^{country} = \frac{\sum_i \widetilde{\alpha_i} s_{ij}(1 - s_{ij}) p_{ij}}{\sum_i s_{ij}}. \tag{3}$$

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

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

4. Data on broadband alternatives

4.1. Broadband coverage in Europe and the case of Austria

The broadband coverage data for Europe shows that across countries the mix of technologies for their Next Generation Access (NGA) to provide high bandwidths to users varies. These technologies include copper-based (VDSL), fiber (FTTP), and coaxial cable (DOCSIS 3.0) technologies. Table A.1 shows that NGA coverage is 80.1 percent in 2017 (46.9 percent in rural areas).[7]

Austria is examined because it is a representative country in terms of coverage rates. The coverage of households connected with at least 30 Mbps (100 Mbps) is 81.1 percent (57.2 percent), which is marginally above the European average. NGA coverage has generally increased from 69.5 percent in 2012 to 90.0 percent in 2017 and has more than tripled for rural areas over this period. This increase was mainly due to the expansion of VDSL and DOCSIS 3.0.[8] Although the availability of FTTP in Austria is below the EU average, above-average coverage was achieved for connection speeds of at least 30 Mbps and at least 100 Mbps. Moreover, Austria has a strong mobile network and thus a high demand for stationary mobile contracts. This makes Austria an even more interesting case. I, therefore, consider Austria to be a good representative for this study.

4.2. Spatial broadband data

I exploit usage data from the national regulators from speed tests, network providers, and coverage data from the *Broadband Atlas* as well as broadband Internet contracts collected by *AK-Tarifwegweiser*. Although prices do not vary a lot over

[7] Europe in particular has a coverage with VDSL of 53.4 percent (32.5 percent in rural areas), with FTTP of 26.8 percent (11.3 percent) and with DOCSIS 3.0 of 44.7 percent (10.8 percent).

[8] VDSL coverage increased from 50.5 percent to 82.2 percent and from no availability to 22.1 percent for its rural areas. The expansion of DOCSIS 3.0 was moderate and similar in size for both rural and urban areas. FTTP continues to play a minor role in providing 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.

time, there are changes in the contracts offered with regard to download (and upload) speed. Taking the period from April to November 2016, there are no new contractual bandwidths and very few changes in prices. Therefore, tests can easily be assigned to the contracts. In addition, almost the entire NGA roll-out was privately financed during this period. Therefore, I can assume that the network providers did not expect much demand for high-speed Internet in the locations that did not have full coverage and are therefore not included in my analysis. Hence, my sample, which is limited to tests performed between April and November 2016, is ideal for my research question.

4.2.1. Usage data

From the RTR NetTest, I derive information on broadband usage throughout Austria from around 150,000 speed tests, which were performed by Internet subscribers.[9] Besides the exact timing of the individual 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 about the measured upload and download speed is also included. Finally, it provides a rich set of additional information, such as the type of Internet connection (wireless LAN / LAN).[10]

I limit the data to tests of stationary Internet connections.[11] This includes tests of both fixed-line and mobile networks. Yet, tests of stationary Internet connections

[9] The data is publicly available for download on the website of the Austrian regulatory agency (RTR - Rundfunk und Telekom Regulierungs-GmbH): https://www.netztest.at/en/. 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.

[10] If the test was performed via LAN, the browser in use is transmitted, and if the test was performed via wireless LAN, the model of the device in use is transmitted.

[11] Additionally, if a tester has performed several tests in one session, only the last test is taken and the others are removed from the data. I only observe the network provider and not the actual service provider, i.e. providers without their own infrastructure are not shown in the data. For example, A1 Telekom, the Austrian incumbent, is obliged to grant service providers access to its network, e.g. by unbundling the local loop.

that are established via mobile networks are restricted to offers designed for the use *at home* rather than standard smartphone contracts. While the former usually include unrestricted broadband use with a certain bandwidth, smartphone contracts are limited in terms of consumable volume and bandwidth.

I address the issue of sample selection. This problem might occur if only users with an incorrect working Internet connection perform the test. However, this case is handled by reducing the sample to tests close to an existing contract. Although I have information on the date of the tests, this might not be the date on which the testers signed their contract. I assume that if the test was not performed due to a faulty Internet connection, most tests were carried out shortly after the contract was signed to ensure that the provider would deliver the contractually agreed speed. If there is a large number of tests with newly signed contracts, my results are not representative of all contracts but explain the behavior of a subgroup of Internet users who have recently signed a new contract. However, for policy-makers, this subgroup could be the relevant group to be interested in their behavior.

4.2.2. Broadband coverage & network providers

From the Austrian *Broadband Atlas*, I use fine-grained (100×100 meters) data on the maximum available download speed in mid-2015 via fixed-line networks, which is provided by the Ministry for Transport, Innovation and Technology (bmvit).[12] Similarly, data on mobile coverage is provided as geodata, indicating which Austrian regions are covered by a certain bandwidth.[13] While high-speed Internet access via fixed-line concentrates in rather urban areas, mobile broadband is distributed throughout Austria.

Apart from data on available bandwidths across the country, the *Broadband Atlas* lists all network providers at the municipality level. Among them, I consider the

[12] The maximum attainable bandwidth is assigned to a specific network cell as soon as at least one provider can technically realize the bandwidth in at least one household in that cell.

[13] Yet, actual attainable bandwidths, especially via mobile networks, can deviate considerably from the theoretical availability, depending on the number of users and the intensity of use within a particular mobile cell.

fixed-line providers A1 Telekom, kabelplus, Tele2, UPC, Salzburg AG, and LIWEST. It is important to note that these providers have different network technologies and most of them are only active in certain regions. While A1 Telekom, as the incumbent, owns the copper network throughout Austria, kabelplus, Tele2, and UPC are active with their coaxial networks in certain regions. The same applies to the fiber optic networks of Salzburg AG and LIWEST. Of the mobile providers, only Hutchinson Drei, A1 Telekom Mobile, and T-Mobile offer stationary contracts and are therefore included in the analysis. These fixed-line and mobile providers account for around 90 percent of all tests from the usage data.

4.2.3. Contract data

From *AK-Tarifwegweiser*, I gather contract data. The data contains monthly information on all contracts offered by the major network providers mentioned above as well as by service providers without their own network.[14] Apart from the price, the data includes information on maximum download bandwidth, maximum capacity[15], and duration. I supplement this data with information on maximum upload bandwidth from the providers' websites and the Internet archive *Wayback Machine*.[16] For each contract, I apply the minimum price per month and average over the whole period. I only consider unlimited capacities or with stated *fair use* of at least 150 GB per month.

In Table A.2 and A.3, contract information for the above-mentioned providers can be found. These include price (in Euro) and upload speed (in Mbps) for each offered download bandwidth (in Mbps). The contract data is visualized in Figure A.3 for the case of A1 Telekom, where each line represents one download speed.

The contractual maximum download speed varies between 8 and 250 Mbps, and largely depends on the provider. For example, only UPC and kabelplus offer contracts with 250 Mbps. This contract offered by kabelplus is relatively expensive,

[14] MMC, A.K.I.S., Comteam, CNet, DIC, Telematica, and TeleTronic, among others

[15] All contracts considered are unlimited, with the exception of the contracts of Salzburg AG, which contain a *fair use* policy.

[16] https://archive.org/web/

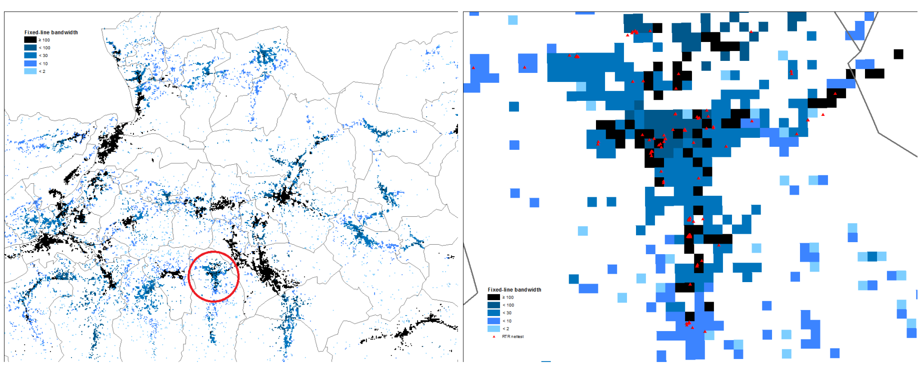
whereas the one offered by UPC is within the price range of contracts from other providers such as A1 Telekom or LIWEST, which have a contractually agreed download speed of 100 Mbps or 150 Mbps respectively and cost slightly less than 60 Euros. In general, prices vary between 17.8 and 99.9 Euros.

4.2.4. Estimation data with the choice set

The linkage of the data sets is illustrated in Figure 1. First, the municipalities, with their information on active providers and the providers' contracts, are matched to the fixed-line coverage grid (Figure 1a). Then, each test is related to its cell and the information assigned above (Figure 1b), resulting in a data set at the household level. This data contains not only information on the selected contract, i.e. the provider and bandwidth, but also on the maximum available bandwidth. It also identifies possible alternative providers in addition to the one serving the household.[17]

Figure 1: Illustration of the spatial merge

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



Note: The figure illustrates the municipality boundaries (gray lines), broadband coverage on grid level (blue cells), and the test locations of households (red dots). The circle in the left figure marks the municipality in the right one. Data provided by GfK GeoMarketing GmbH, Ministry for Transport, Innovation and Technology (bmvit), RTR

[17]Unfortunately, the degree of accuracy of the data deviates from an ideal setup. Preferably, I would want to know i) which providers a household could connect to, rather than the providers active in the household's municipality, and ii) which bandwidth each provider can offer in the grid, rather than the maximum available bandwidth of all providers collectively. A minor issue is iii) that coverage is not available for the location of the household, but rather for a small area around the household.

The combined data set allows me to compare the distribution of download speed by fixed-line coverage (Figure A.4). Up to a maximum fixed-line coverage of 50 Mbps, the median of the measured download speed is rather close to the maximum fixed-line coverage. However, with a higher maximum fixed-line coverage (100 Mbps or >100 Mbps), the median of the measured download speed does not increase anymore.[18] These figures provide first descriptive evidence that up to 50 Mbps many consumers are restricted by the maximum fixed-line coverage, so that they would sign contracts with higher download speeds if they were available. By contrast, many consumers do not sign contracts with download speeds above 50 Mbps, even if they are available.

A comparable set of choices is needed for the regression. Therefore, tests conducted in a cell with less than the maximum fixed-line coverage (at least 100 Mbps) in 2015 are removed. Eventually, the data comprises to 64,182 tests.[19]

The mixed logit model requires a choice variable and a choice set containing all alternatives. The choice is assigned based on the information on download and upload speed as well as the chosen network provider, and the location where the test was performed.[20] The choice is defined as the closest contract with respect to the measured upload and download speeds from the displayed provider.[21]

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[18] Up to a maximum coverage of 30 Mbps, the median of the measured download speed is at least 50 percent of the maximum coverage. At 10 Mbps, it is even more than 70 percent. At a maximum coverage of 100 Mbps, the median of the measured download speed is only 26 percent of the maximum coverage.

[19] Table A.4-A.6 shows in more detail how the sample shrinks when it is reduced for reasons of measurement or limited fixed-line coverage, particularly with regard to the number of tests from each provider. Summary statistics comparing the selected observations and the removed ones can be found in Table A.7.

[20] I update information on active providers and fixed-line coverage from the usage data. If a test transmitted a provider that is not listed in the *Broadband Atlas* in that municipality, the municipality data is updated to include that provider. Similarly, if a test is run at a higher download speed than it is covered in this specific cell, the information for all tests in this cell is updated.

[21] Contracts must allow at least the measured upload and download speeds. An exception is made if the measured speed is above the maximum contract offered by a provider. In these 2,105 cases, the test is assigned to this maximum contract. Closest is defined by the lowest Euclidean distance. Regarding the problem that for A1 Telekom tests I cannot distinguish between fixed-line and mobile tests, the contracts for mobile and fixed-line are so different that I can follow the described procedure.

The choice set is defined as four alternatives for fixed-line and three for mobile contracts.[22] The lowest alternative allows a maximum of 20 Mbps download bandwidth and the highest alternative includes contracts with a download bandwidth of more than 80 Mbps, which are in fact contracts with a three-digit download bandwidth ($\geq$ 100 Mbps). Therefore, the alternative with more than 80 Mbps can be considered as the very high bandwidth alternative. Alternatives are formed from several contracts, as it is unlikely that a consumer would consider all available contracts as alternatives. These alternatives make it possible to answer questions on substitution patterns within fixed-line contracts and between them and mobile contracts. For chosen alternatives, I apply the price from the contract. The average price and its standard deviation for the whole sample are 31.13 and 10.84 Euros, respectively.[23] For alternatives, I apply a weighted average price over the available contracts for each alternative. I take the weights from the number of times a choice has been made in the area starting with the same zip-code digit such that I can account for regional variations in active fixed-line providers and in the preference for mobile providers.

Figure A.5 shows the speed distribution across selected providers. Most A1 Telekom tests fall into the lowest bandwidth alternative, while most UPC tests fall into the two highest bandwidth alternatives. The distribution reflects the prices in Table A.2: UPC offers the cheapest high bandwidth contracts, while low bandwidth contracts are more expensive compared to other providers. A1 Telekom could still have market power within the lower bandwidths. However, the market share decreases sharply at higher bandwidths.

[22] As explained in Section 3, the alternative borders start at 20 Mbps and double twice, resulting in alternative borders at 40 Mbps and 80 Mbps for the fixed-line contracts. It is important that all different fixed-line technologies are present in each fixed-line alternative. As there exist fewer mobile contracts, borders for the alternatives are drawn differently: The lowest alternative border is 20 Mbps (with contracts of 10 Mbps and 20 Mbps) and the middle alternative border is 80 Mbps (with contracts of 30 Mbps, 40 Mbps, and 50 Mbps).

[23] For fixed-line choices, the average price and its standard deviation are 30.30 and 11.50 Euros, respectively. For mobile choices, the values are very similar at 32.01 and 9.90 Euros.

Determining the choice is complicated due to the fact that the test data contains noise (Figure A.6). Thus, a measured speed might deviate dramatically from the one assigned in the contract.[24] In pursuit of highest cleanliness possible, the data is restricted to tests with a realized download and upload speed within a certain corridor below a contract offered. The corridors are defined differently for fixed-line and mobile providers (Figure A.7). They also reflect the assumption that the measurement of upload speed is more reliable than the measurement of download speed.[25]

5. Different types of Internet users

The results of the alternative-specific mixed logit regression are briefly discussed before focusing on the elasticities of demand to analyze substitution patterns. I show that there are different types of broadband users: Consumers with a high (low) utility from high-speed Internet, those who have a contract in the second highest (lowest) fixed-line category, upgrade (downgrade) their contracts to the highest (lowest) category if the price of their contract is increased. Hence, an increase in broadband availability will only marginally increase high-speed usage. Moreover, mobile users are rather different from fixed-line users. However, this holds stronger for higher speeds than for basic Internet, where users might substitute between mobile and fixed-line.

[24] While a particular tester is not allowed to surf the Internet at a speed higher than the contractually assigned maximum bandwidth, in many cases she will surf at a speed below the latter. For example, an unfavorable location of the broadband router can lead to actual download and upload speeds being lower than the contractually assigned ones if a wireless LAN connection is used instead of a LAN connection.

[25] For fixed-line providers, the corridors are 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. This means that if the download speed was measured accurately, the upload speed may differ more and vice versa. For mobile providers, a deviation of 40 percent either in upload or in download from the contract is allowed. This broader restriction is necessary because mobile tests differ more in both upload and download speeds. However, it is still legitimate, as there are fewer different mobile contracts and therefore a more precise allocation of choices is possible.

5.1. Price sensitivity and substitution patterns

5.1.1. Regression results

Prior to the regression, I reduce the sample to tests with an available fixed-line coverage of at least 100 Mbps in 2015. Furthermore, all regressions contain weights with respect to the number of mobile and fixed-line contracts throughout Austria and robust standard errors are applied. As described in Section 3, the price of the alternatives is the weighted average of all contracts of all providers in an alternative. The weights are defined by the number of chosen providers within a region (first zip-code digit). Specifications with the unweighted average and without weights are provided as robustness checks.

Before presenting results of the mixed logit regression, I rule out alternative approaches for which the IIA does not hold. Starting with a multinomial logit model, I run the Hausman-McFadden test, excluding alternatives in different ways. Excluding single alternatives, the Hausman-McFadden test shows statistically very significant violations of the IIA, especially for the high-speed alternatives (both for fixed-line and mobile technologies). Between the broader categories, fixed-line and mobile, the Hausman-McFadden test shows a statistically very significant violation when all mobile choices are excluded. However, this could be handled applying a nested logit model. Still, within fixed-line alternatives, the Hausman-McFadden test shows statistically very significant violations of the IIA for the lowest and highest speed alternatives. Within mobile alternatives, the Hausman-McFadden test cannot unambiguously reject a violation of the IIA for all alternatives. Therefore, I reject the multinomial logit model and apply the mixed logit model as the main specification. For robustness, I show some estimates with the nested logit model.

In the main specification, I control for whether the device from which the test was performed was connected via wireless LAN or LAN. Furthermore, the first zip-code digit and the mobile upload coverage from the *Broadband Atlas* are applied as geographical covariates. In later regressions, I apply further control variables at the zip-code level for robustness.[26]

[26]These variables control for population size, level of education, gender and age distribution, propor-

Table 1: Mixed logit regression results

	(1)	(2)	(3)	(4)
price	-0.176***	-0.194***	-0.196***	-0.196***
	(0.000635)	(0.000621)	(0.000606)	(0.000606)
sd(price)	0.104***	0.127***	0.127***	0.128***
	(0.000354)	(0.000392)	(0.000399)	(0.000400)
basic control	X	X	X	X
further zip-code level controls			X	X
all zip-code level controls				X
sample	whole	reduced	reduced	reduced
Observations	449,274	234,514	234,514	234,514
Cases	64,182	33,502	33,502	33,502

Note: The regression table shows the results for the whole (first column) and the reduced sample (second to fourth column) with four fixed-line and three mobile alternatives. The sample is reduced to tests that had full fixed-line coverage (at least 100 Mbps) in 2015 to ensure that all alternatives are eligible and that the results are comparable. Weights with respect to the number of mobile and fixed-line contracts throughout Austria and robust standard errors are applied. It is controlled for whether the device from which the test was performed was connected via wireless LAN or LAN. Furthermore, the first zip-code digit and the mobile upload coverage from the *Broadband Atlas* are applied as geographical covariates. In the third column, population size, gender, (un-)employment, retirees, and age structure are added at the zip-code level. In the last column, level of education and the proportion of newborns at the zip-code level are added. Standard errors are shown in parentheses. * p<0.05, ** p<0.01, *** p<0.001

In Table 1, the main specification for the whole (first column) and the reduced sample (second column) is presented.[27] The random coefficient has a mean valuation of $\hat{p} = -0.176$ and -0.194 and a standard deviation of $\hat{\sigma}_p = 0.104$ and 0.127 (all highly significant). A lower standard deviation (in absolute values) than the mean is revealed, which yields a negative $\widetilde{\alpha_i}$ for most of the observations, meaning that consumers are price-sensitive. In the third and fourth column, further control variables are added, which does not change the results. Therefore, I will concentrate on the

tion of newborns, and (un-)employment/retirement status.

[27]For robustness, I show the same specifications estimated with a nested logit model. The price coefficient is very similar. However, the dissimilarity parameters show that the IIA is violated. Therefore, I follow showing my results only applying the mixed logit model. The results of the nested logit model are available upon request.

second column, as this model is more sparse. The coefficients for the choices are presented later with a focus on the socio-economic implications.

5.1.2. Price elasticities of demand

I present the own-price and cross-price elasticities calculated according to equation (3) for the reduced sample, applying the estimates from the second column of Table 1. Table 2 shows the mean values over 100 repetitions of an each time newly simulated random coefficient.

Table 2: Own- and cross-price elasticities

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-2.992	1.204	.931	1.187	.283	.698	.092
≤ 40 Mbps	1.323	-4.542	.994	1.202	.31	.808	.191
≤ 80 Mbps	1.039	.988	-5.562	1.744	.26	.66	.179
> 80 Mbps	.969	.883	1.308	-7.105	.25	.711	.227
mobile ≤ 20 Mbps	1.025	1.008	.841	1.079	-3.691	1.191	.759
mobile ≤ 80 Mbps	.666	.701	.577	.839	.314	-4.251	1.582
mobile > 80 Mbps	.109	.207	.196	.324	.256	2.011	-4.549

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients from the reduced sample (Table 1, second column) and according to equation (3).

Own-price elasticities show demand changes following a price increase for a particular choice, whereas cross-price elasticities detect 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 for the contract in that specific row is affected by a price increase. Cross-price elasticities can also be interpreted column by column. For each alternative, it is possible to detect the alternative from which the highest demand increase comes from.

The diagonal in Table 2, the own-price elasticities, shows that all alternatives are elastic, with values starting from -2.99 for the lowest fixed-line alternative. Consequently, an increase in price by 1 percent reduces the demand for the lowest fixed-line alternative by 2.99 percent. For other alternatives, the demand decreases even stronger.[28] The own-price elasticities for the mobile alternatives are comparable

[28]The own-price elasticity for other fixed-line alternatives decreases with the bandwidth to a value of

with the respective fixed-line alternatives. Similar elasticities are found in the literature for substitution between technologies. For example, Grzybowski et al. (2014) find elasticities between −1.5 and −4.9, Cardona et al. (2009) find elasticities of −2.5 for all three technologies.

Cross-price elasticities are more important to detect substitution patterns.[29] Same technologies (mixed-line or mobile) are principally more likely to be substitutes. If the price of one of the fixed-line alternative is increased, the other fixed-line alternatives rather than the mobile alternatives are more demanded. For instance, the cross-price elasticities for fixed-line alternatives in the first row (second to fourth column) are higher than those of the mobile alternative (fifth to seventh column). The same applies in reverse for mobile alternatives. However, here it is more present for the two higher alternatives with cross-price elasticities of 1.58 and 2.01.

The best substitute within the technology is the alternative with the closest bandwidth. For the alternative with the lowest (highest) bandwidth, the next higher (lower) alternative, again within the technology, has the highest cross-price elasticity.

The alternatives in between show the substitution patterns relevant for this analysis. Within the fixed-line technology, for the ≤ 80 Mbps alternative, the cross-price elasticity points upwards and for the ≤ 40 Mbps alternative downwards.[30] This shows that between these alternatives users are different in their utility, they receive from high-speed Internet. The lowest two fixed-line alternatives and the highest two

−7.11. It is defined by the choice probability and the price. Therefore, conceptually, choices with higher prices are less likely to be chosen. Nevertheless, the choices are also less demanded partly because of the higher price. Hence, the relatively high value of −7.11 reflects that as prices increase, the usage of higher speeds does not decrease uniformly but stronger.

[29] However, one has to take into account the correlation within columns. The correlation indicates a generally higher preference for certain alternatives, such as the fixed-line > 80 Mbps alternative, which always has higher values than the fixed-line ≤ 80 Mbps alternative.

[30] For the fixed-line ≤ 80 Mbps alternative (third row), the cross-price elasticity of the > 80 Mbps alternative is 1.744, whereas the respective value for the ≤ 40 Mbps alternative is with .988 smaller. For the fixed-line ≤ 40 Mbps alternative (second row), the cross-price elasticity of the ≤ 20 Mbps alternative is 1.323, whereas the respective value for the ≤ 80 Mbps alternative is with .994 smaller.

fixed-line alternatives are the closest substitutes within each other. It is therefore appropriate to define the low-speed user for all fixed-line contracts up to 40 Mbps.

For mobile, three alternatives are defined. For the middle alternative ($\leq$ 80 Mbps), the cross-price elasticities point upwards. For the lowest mobile alternative, substitution also exists between technologies. The two highest mobile alternatives are the closest substitutes. If the price of one of these alternatives is increased, the highest fixed-line alternative will receive a higher increase in demand than the lowest mobile alternative. Hence, the lowest mobile alternative is demanded by a different type of users than the higher mobile alternatives, but by the same users as the lower fixed-line alternatives.

In conclusion, as there is substitution from the lowest mobile alternative to basic fixed-line technologies, the low-speed type of users is defined for all technologies. For high-speed Internet, fixed-line and mobile contracts are signed by different users.

5.2. Robustness & heterogeneity

5.2.1. Robustness

First robustness checks show that the results are not determined by the decisions of the researcher in defining the sample and the estimation specifications. For the whole sample, elasticities look very similar (Table A.8) compared to the reduced sample elasticities. Also, adding more control covariates at the zip-code level does not change the elasticities much (Table A.9 & A.10).[31] I apply weights when calculating average prices to account for how often providers are chosen. Taking the unweighted average, less frequently chosen providers might become too important. Nevertheless, I present the elasticity results for the unweighted average prices with the reduced sample in the Appendix (Table A.11). Here, again, the elasticity results are very similar to the previous ones.

[31] At the zip-code level, I control for population size, gender, (un-)employment, retirees, and age distribution (as in Table 1, third column). I also add the proportion of newborns and the level of education as controls (as in Table 1, fourth column).

I also apply regression weights with respect to fixed-line and mobile contracts. The sample contains only tests and might not be representative for these technologies. One can imagine that mobile networks might react strongly to seasons, weather, and most importantly to the correct position of the router. Therefore, tests with stationary mobile contracts might occur more frequently in my data. Elasticity results without these weights suggest that elasticities are somewhat lower (Table A.12). However, the patterns remain the same. In addition, one might think that A1 Telekom could be signed more often due to its incumbent position. Adding a preference for the choice of the incumbent slightly increases the elasticities (Table A.13). Nevertheless, the results still look very similar to the initial results.

Since it has been shown that the results are not determined by the decisions of the researcher, I continue with further robustness checks before turning to the heterogeneous effects. I apply several random data splits: into two halves (Table A.14 & A.15) and a randomly selected five percent subset (Table A.16). With the smaller samples, I can show that the results do not depend on my choice, which has already been shown above, but also hold in smaller randomly selected samples. Furthermore, since the sample is quite large, I can show that significant estimates do not come from a large number of observations, but also hold in smaller samples. In all subsets, the results look very similar.

Next, the number of tests per municipality is restricted. I present elasticities for municipalities with more than 10, 20, and 50 tests (Table A.17-A.19). In these municipalities, a few tests may already generate an outlier. The removed municipalities might also be rather small, corresponding more to rural and poorer locations. It can be seen that the elasticities become only slightly higher. However, the substitution patterns for the cross-price elasticities are still very robust. The same is true when the municipalities with very high number of tests are removed (Table A.20 & A.21), which might be very dense and urban locations. In this case, the elasticities become somewhat lower. These small changes could be explained by increased competition in more urban areas. Nevertheless, the results regarding substitution patterns in cross-price elasticities are again very robust.

5.2.2. Heterogeneity

Heterogeneous effects are observed in a regional and a time dimension. With regard to regional differences, I analyze Vienna separately and compare it with the rest of Austria. Vienna is the capital of Austria and with 1.9 million inhabitants the largest city in Austria. Moreover, Vienna is significantly larger than the next largest city Graz (with less than 300,000 inhabitants). Due to a higher number of active providers, competition in Vienna is higher. It can, therefore, be seen that the own-price elasticities are also higher in absolute terms: People are more price-sensitive. However, the substitution patterns in the cross-price elasticities remain the same. Hence, I observe the same substitution patterns in Vienna (Table A.22) and the rest of Austria (Table A.23). For the rest of Austria, I compare the larger cities (Graz, Linz, Salzburg, and Innsbruck), each of which has more than 100,000 inhabitants, and the other regions. For the cities combined (Table A.24), the own-price elasticities are again higher than in the regions without larger cities (Table A.25), as there is less substitution where there is less competition. This might potentially be even more true for the not-included regions with less fixed-line coverage.

Next, the data is split along the test date. I divide the data into four groups, each containing data for two consecutive months. Tables A.26-A.29 show a decrease in own-price elasticities. However, the own-price elasticities do not fall below a certain level of unimportance and can still be explained by random variation. Only the last table for October and November has higher values again. During these months, more tests were performed compared to the previous periods. A longer time horizon is necessary to obtain a clearer picture of these time trends.

Finally, I examine the utilities across the controls. Table A.30 shows the estimates for all applied covariates for all alternatives. The estimates refer to the base alternative (fixed-line ≤ 20 Mbps). Before I come to the socio-economic characteristics, the base controls (mobile upload coverage, first zip-code digit, and wireless LAN) are interpreted. The higher the mobile upload coverage is, the higher is the utility of a mobile alternative (first row, fourth to sixth column). Next, the utilities for the different regions are observed. The estimate for the first zip-code digit is interpreted with respect to the baseline, which is Vienna, for each alternative. It is therefore not surprising that most estimates are negative and that especially for the highest fixed-line alternative the estimates are highly negative. Internet users with a high utility from higher speeds are more present in Vienna. For mobile alternatives, this image is less clear, and for some regions also positive estimates can be found for some mobile alternatives. This shows that in certain regions, stationary mobile contracts are more popular than in Vienna. Even though a test was conducted via wireless LAN instead of LAN, the estimates for mobile and for the highest fixed-line alternative are negative, whereas the estimates for medium fixed-line speeds are positive with respect to the lowest fixed-line alternative.

In terms of the socio-economic characteristics, in smaller cities, higher speeds for both fixed-line and for mobile have highly negative estimates. Medium-sized cities show high utilities for medium speed fixed-line and for all mobile alternatives, especially for these with higher speeds. In contrast, larger cities show high utilities for high fixed-line speeds but less utility for mobile alternatives. Therefore, it appears that mobile alternatives are more demanded in rather rural areas, regardless of the region defined by the first zip-code digit. However, it should be borne in mind that the sample only includes areas where high fixed-line speeds are available.

Areas with a higher proportion of newborns also show higher utilities for high-speed fixed-line Internet. This could reflect the average household size and shows that with more people using the Internet, higher bandwidths are needed. A higher proportion of men also corresponds with higher utilities for higher speeds. This might reflect a generally higher interest in new technologies and more expensive devices among men compared to women. The level of education does not seem to play a major role. However, for lower education levels, higher speeds show much less utility. This group might be most budget-constrained and therefore does not demand higher bandwidths. The age distribution plays a large role. Younger people prefer higher speeds on both fixed-line and mobile alternatives. Older people prefer mobile alternatives. However, they do so less than younger people. Younger people use the Internet differently. They stream more movies and music and might use it also for work at home. Older people may appreciate the simplicity of using a mobile router that only needs to be plugged into the wall socket to be ready for use. It should be noted that all these estimates are not causal and are only indicative.

6. Conclusion

A novelty of this paper is its data. I apply speed tests, with which Internet users measure their realized download and upload speed to compare it with their contractual bandwidth. This data is geo-referenced, such that I was able to merge it with coverage data and data on active providers. I showed that Internet in Austria is demanded by three different types of users. Only a very specific subset of Internet subscribers demands high-speed Internet. Thus, high-speed Internet is not of general interest. I add to the literature further findings regarding substitution patterns between technologies but within a bandwidth range. Whereas fixed-line and mobile are substitutes for Internet at basic speeds, at higher speeds, fixed-line and mobile are demanded by different types of users. Especially, high-speed fixed-line Internet (100 Mbps and more) is only demanded by a certain type of users. Hence, an increase in the availability of such speeds does not necessarily expand its usage as well. However, a high usage is necessary for a technology to have a broad (economic) impact and to be regarded as a general purpose technology. If the usage of high-speed Internet does not adjust to increased availability, there is no need for a government to foster its expansion, as demanded by the European Commission. It should be noted that only users with full fixed-line coverage were analyzed. However, in areas with less fixed-line coverage, the usage of high-speed Internet will not be high as even the users in this study show a high price-sensitivity.[32]

The results are robust in terms of the decisions of the researcher regarding data preparation and regression specifications. First, the whole sample and the reduced sample estimates are very similar. Adding more controls, changing the weights, reducing the sample with a random split, or by specific restrictions does not affect the result. The heterogeneity analysis shows that substitution varies between cities and

[32] If usage were high, providers would have provided high speeds.

between cities and smaller towns. Individual variation based on socio-economic characteristics is also shown.

The methodology applied in this paper is also employed in the literature on market definition. Regulation in the telecommunications market is updated approximately every five years in response to innovation and changing market power. Since the TKG 2003, the regulation has followed a three-step approach. Regulation always begins with a thorough market definition before the market is analyzed in a second step, and if a company is identified as having significant market power, specific regulatory instruments are imposed on that company in order to ensure effective competition on this relevant market.[33]

The current regulatory status applies to the incumbent A1 Telekom as the owner of the copper network over which DSL is provided and defines the wholesale market for broadband Internet regardless of the bandwidth. The relevant market comprises DSL and fiber (FTTX[34]) as technologies. Other technologies such as cable (CATV), mobile telephony, or satellite, among others, are not part of the relevant market. Leased lines and unbundling are also not part of the market. There is no regional separation, i.e. the relevant market comprises the whole of Austria.[35]

As far as regulation or a thorough market definition is concerned, this paper naturally provides only a first insight. Nevertheless, it has been shown that there are different types of users for higher speeds. This indicates that regulation should also consider basic speed as a different market from high-speed Internet. However, regulators might also consider including mobile Internet in the same market as basic speeds, as has been shown for the type of users who do not has high utilities for high-speed Internet. Finally, as only areas with full fixed-line coverage have been considered in this paper, regulators could consider regional regulation.

In the coming years, 5G mobile Internet will become very important and will in-

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

[34]FTTX stands for FFTH, FFTC and FTTB collectively

[35]https://www.rtr.at/en/tk/Breitband

fluence the substitution between fixed-line and mobile technologies. This is likely to have a particular impact on technological substitution between higher speeds. For this substitution, it has been shown here that it is not yet very strong. Although this paper analyzes data prior to the introduction of 5G, the results still serve as a baseline for future changes. Since 5G may not directly dominate the stationary mobile Internet, this paper is also important for current technological substitution. Moreover, a lack of substitution between fixed-line and mobile technologies for high-speed Internet before the introduction of 5G does not necessarily mean that there is no substitution after the introduction of 5G. Lower quality of mobile high-speed Internet compared to fixed-line high-speed Internet might be the reason for the lack of substitution. With 5G, the quality of high-speed mobile internet will increase, making substitution more likely.

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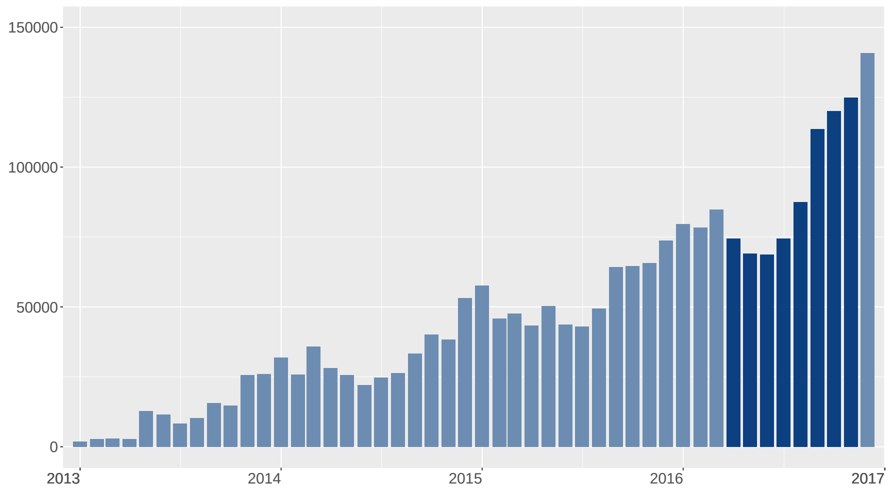
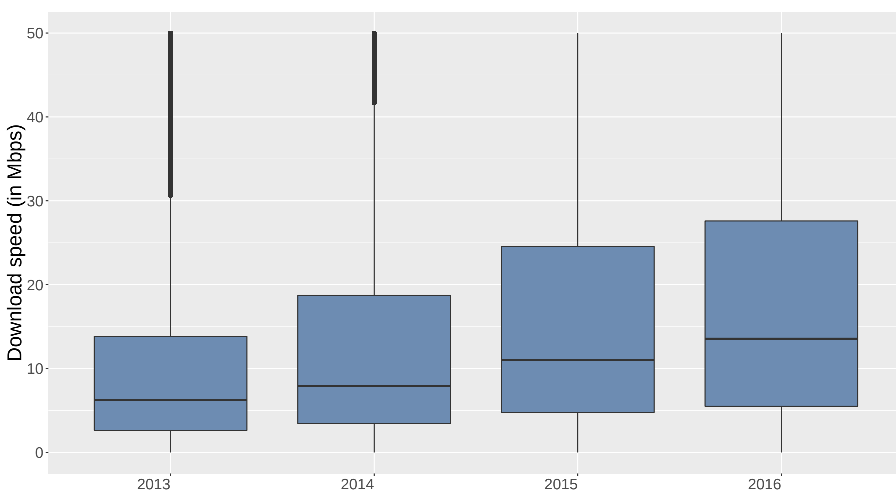
Appendix A.

Figure A.1: Number of speed tests from 2013 to 2016 (darker blue analysis period)



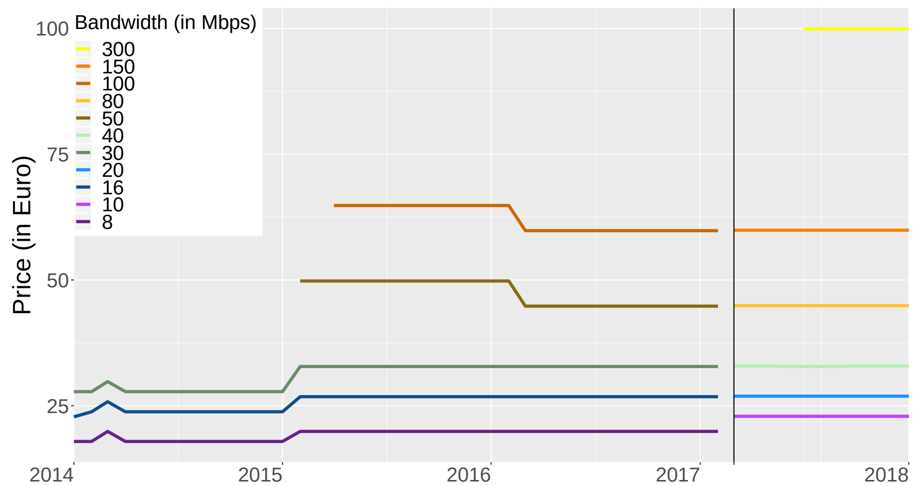
Note: Data from RTR-NetTest from the Austrian Regulatory Authority for Broadcasting and Telecommunications

Figure A.2: Boxplot of speed tests from 2013 to 2016



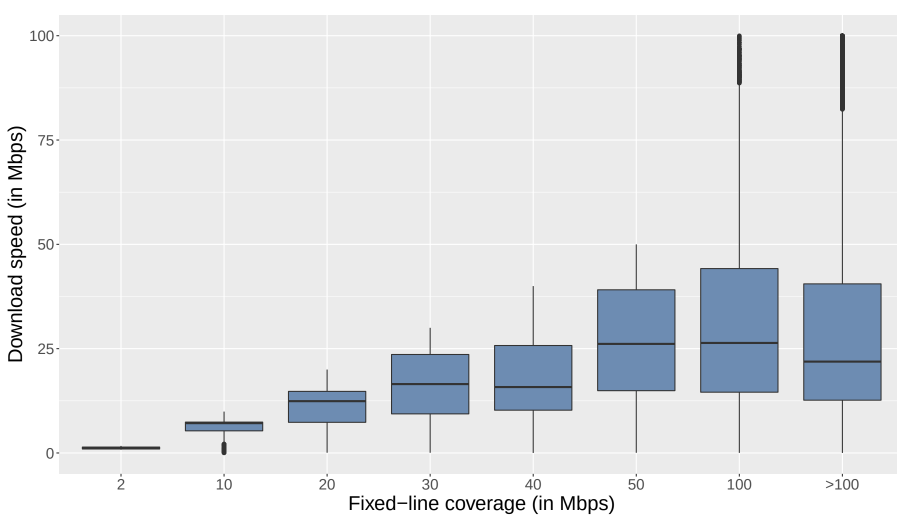
Note: Data from RTR-NetTest from the Austrian Regulatory Authority for Broadcasting and Telecommunications

Figure A.3: A1 Telekom contracts (download speed and prices from 2014 to 2017)



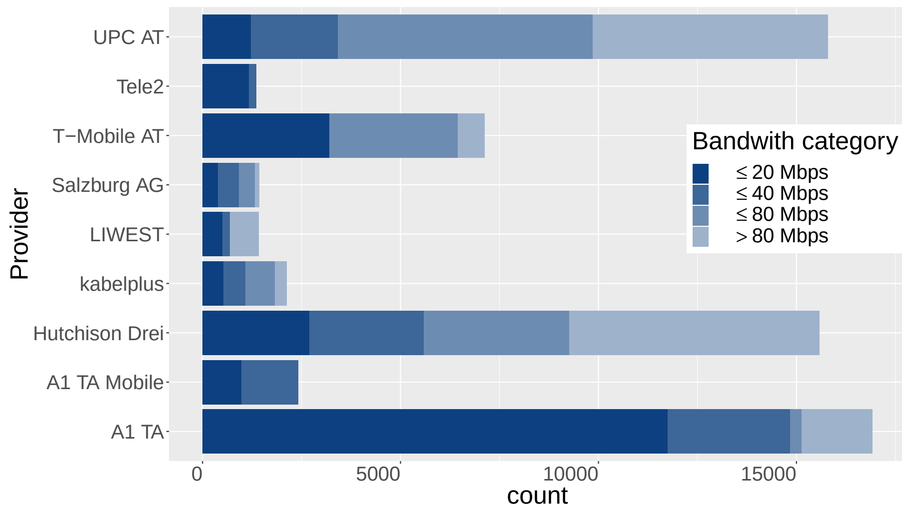
Note: Data from *AK-Tarifwegweiser*

Figure A.4: Distribution of download speed by fixed-line coverage



Note: Data from RTR-NetTest from the Austrian Regulatory Authority for Broadcasting and Telecommunications and *Broadband Atlas* provided by the Ministry for Transport, Innovation and Technology (bmvit)

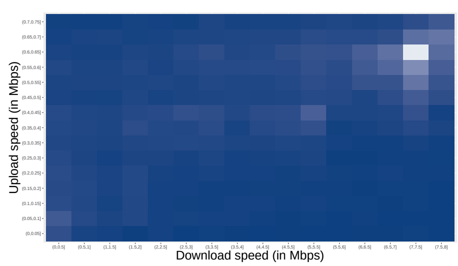
Figure A.5: Number of tests for each provider, classified into four bandwidths alternatives



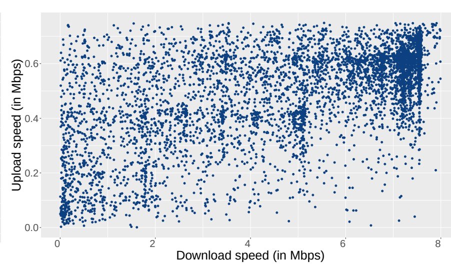
Note: Data from RTR-NetTest from the Austrian Regulatory Authority for Broadcasting and Telecommunications

Figure A.6: Measured download and upload

(a) Heatmap



(b) Scatter plot

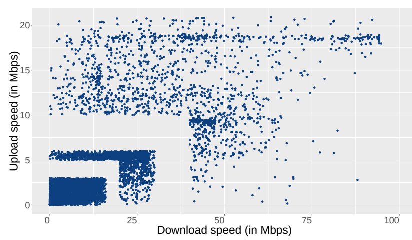


Note: The figures show a heat map and a scatter plot for A1 Telekom tests with a measured download speed below 8 Mbps and a measured upload speed below .75 Mbps. These values refer to the lowest A1 Telekom contract in my data (Table A.3). The data in these figures was reduced to A1 Telekom tests and with respect to the download and upload speed due to higher visibility. The heat map depicts a bright hot spot just below the contractual bandwidths. Additionally, a horizontal tail shows that there are many tests within a certain upload speed corridor but with very different download speeds. However, a similar vertical tail cannot be found. Therefore, it is more important to consider the upload bandwidth when filtering the noise, although the download bandwidth is presumably more important to the consumer. Moreover, the figure displays why it is important to filter the noise: There are many tests above 5 Mbps download speed and below .5 upload speed. It is very likely that there exists an old contract with these contractual speeds. However, I have no information on the price of this contract. Therefore, it is better to remove these tests than assigning a wrong contract to them. Data from RTR-NetTest from the Austrian Regulatory Authority for Broadcasting and Telecommunications.

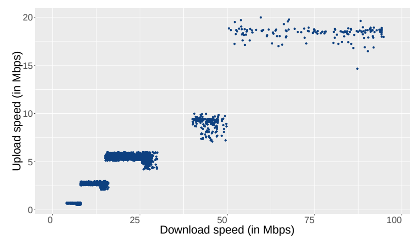
Figure A.7: Measured download speed for tests with fixed-line and mobile providers

A1

(a) Whole sample

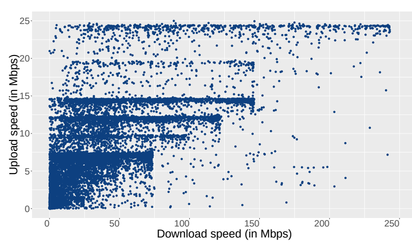


(b) Reduced sample

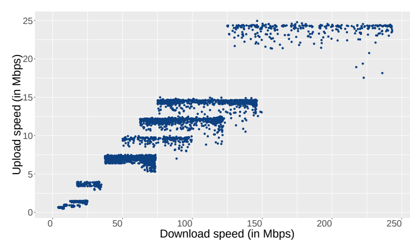


UPC

(c) Whole sample

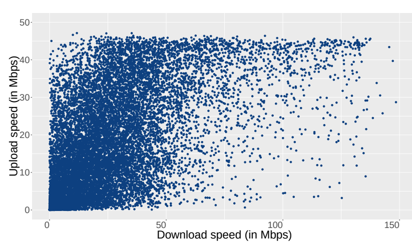


(d) Reduced sample

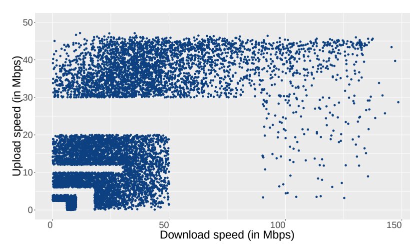


Drei

(e) Whole sample



(f) Reduced sample



Note: The figures plot the tests for the most important providers for copper, cable, and mobile Internet. The data is already reduced to locations with full fixed-line coverage. In the left column, the whole sample is shown. In the right column, only the tests close to a known contract are shown (reduced sample). This column illustrates the corridors when filtering the noise. The observations with a measured download or upload speed which does not fall into one of the corridors are removed. In these tests, the speeds were measured imprecisely.Data from RTR-NetTest from the Austrian Regulatory Authority for Broadcasting and Telecommunications.

Table A.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	>30 Mbps	>100 Mbps
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%	-	-

Note: Data from the Europe's Digital Progress (Country) Report

Table A.2: Contractual prices (in Euro) by provider and contractual download (in Mbps)

	8	10	15	16	20	25	30	35	40	50	70	75	100	125	150	250
A1 TA	19.90			26.80			32.80			44.80			59.80			
Tele2	17.80				24.90		29.90									
UPC AT	24.90			31.80	24.90	26.15		29.90				29.90	29.90	39.90	39.90	58.03
Hutchison Drei		18.00					25.00			35.00					45.00	
Salzburg AG			19.90				29.00			39.00	49.00				79.00	
kabelplus				19.90			29.90					39.90			69.90	99.90
A1 TA Mobile					26.33				39.90							
LIWEST					19.90			29.90					39.90		59.90	
T-Mobile AT					19.99					29.99					49.99	

Note: Data from *AK-Tarifwegweiser*

Table A.6: Number of choices (with full fixed-line coverage in 2015)

	alternative							
	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps	Total
A1 TA	4336	2143	201	692	1596	1630	0	10598
Hutchison Drei	0	0	0	0	1257	4832	3627	9716
LIWEST	119	86	0	85	0	0	0	290
Salzburg AG	161	318	193	54	0	0	0	726
T-Mobile AT	0	0	0	0	1789	2804	343	4936
Tele2	341	159	0	0	0	0	0	500
UPC AT	230	734	2596	2222	0	0	0	5782
kabelplus	317	292	280	65	0	0	0	954
Total	5504	3732	3270	3118	4642	9266	3970	33502

Note: This table shows how the choices distribute between alternatives and choices. The numbers are shown for the reduced set, restricted to full fixed-line coverage in 2015.

Table A.3: Contractual upload (in Mbps) by provider and contractual download (in Mbps)

	8	10	15	16	20	25	30	35	40	50	70	75	100	125	150	250
A1 TA	0.75			3.00			6.00			10.00			20.00			
Tele2	0.75				4.00		4.00									
UPC AT	0.70			1.00	1.00	1.50		4.00				7.50	10.00	12.50	15.00	25.00
Hutchison Drei		4.00					10.00			20.00					50.00	
Salzburg AG			1.50				3.00			5.00	7.00				10.00	
kabelplus				1.00			3.00					7.50			15.00	25.00
A1 TA Mobile					5.00				10.00							
LIWEST					3.00			6.00					10.00		20.00	
T-Mobile AT					5.00					10.00					30.00	

Note: Data from *AK-Tarifwegweiser*, complemented with upload information from the providers' websites

Table A.4: Number of choices (in the whole sample)

	alternative							
	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps	Total
A1 TA	34987	8646	833	4791	3182	4642	0	57081
Hutchison Drei	0	0	0	0	7003	19681	15332	42016
LIWEST	653	210	0	754	0	0	0	1617
Salzburg AG	414	538	419	117	0	0	0	1488
T-Mobile AT	0	0	0	0	8623	8317	1701	18641
Tele2	1991	560	0	0	0	0	0	2551
UPC AT	2474	2725	7486	6547	0	0	0	19232
kabelplus	659	862	975	461	0	0	0	2957
Total	41178	13541	9713	12670	18808	32640	17033	145583

Note: This table shows how the choices distribute between alternatives and choices. The numbers are shown for the whole set.

Table A.5: Number of choices (in the reduced sample)

	alternative							
	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps	Total
A1 TA	11619	5849	641	1699	4897	5214	0	29919
Hutchison Drei	0	0	0	0	3276	14416	8109	25801
LIWEST	123	93	0	88	0	0	0	304
Salzburg AG	167	322	195	64	0	0	0	748
T-Mobile AT	0	0	0	0	5046	7130	799	12975
Tele2	531	518	0	0	0	0	0	1049
UPC AT	450	883	3005	2404	0	0	0	6742
kabelplus	365	355	324	82	0	0	0	1126
Total	13255	8020	4165	4337	13219	26760	8908	78664

Note: This table shows how the choices distribute between alternatives and choices. The numbers are shown for the reduced set.

Table A.7: Summary of control variables with respect to full fixed-line coverage in 2015

coverage	<100 Mbps	≥ 100 Mbps
population (<5000)	0.56	0.17
population (<10000)	0.15	0.13
population (<100.000)	0.25	0.54
population (>100.000)	0.29	0.71
age (young)	0.20	0.19
age (middle)	0.49	0.51
age (old)	0.31	0.30
male	0.49	0.48
newborns	0.88	0.78
education (low)	0.23	0.23
education (middle)	0.52	0.49
education (high)	0.09	0.12

Note: This table shows how observations with and without full fixed-line coverage in 2015 differ. Number are calculated from the whole sample. Population is divided into the following categories: less than 5000, less than 10,000, less than 100,000, at least 100,000 in 2014. Comparison is also provided for the number of newborns, the share of males, education level (compulsory, secondary and tertiary) and age distribution (young is defined as not older than 20 and old is defined as at least 60 years old).

Table A.8: Own- and cross-price elasticities (whole sample)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-2.559	.755	.876	1.299	.258	.524	.203
≤ 40 Mbps	1.347	-4.425	1.04	1.353	.264	.54	.241
≤ 80 Mbps	1.117	.734	-5.031	1.603	.239	.467	.227
> 80 Mbps	1.092	.636	1.081	-6.205	.225	.469	.245
mobile ≤ 20 Mbps	1.12	.632	.809	1.126	-3.358	.869	.852
mobile ≤ 80 Mbps	.832	.479	.591	.886	.319	-4.259	1.553
mobile > 80 Mbps	.307	.204	.275	.437	.302	1.498	-4.547

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the whole sample (Table 1, first column).

Table A.9: Own- and cross-price elasticities of the reduced sample with more control variables on municipality level

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-3.005	1.2	.946	1.19	.286	.704	.093
≤ 40 Mbps	1.318	-4.533	1.019	1.177	.31	.805	.189
≤ 80 Mbps	1.052	1.012	-5.527	1.652	.262	.659	.176
> 80 Mbps	.97	.866	1.238	-6.987	.249	.697	.204
mobile ≤ 20 Mbps	1.032	1.004	.848	1.079	-3.701	1.208	.748
mobile ≤ 80 Mbps	.664	.692	.574	.823	.317	-4.216	1.57
mobile > 80 Mbps	.109	.202	.191	.29	.25	1.991	-4.459

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the reduced sample and with some control variables on the zip code level (Table 1, third column).

Table A.10: Own- and cross-price elasticities (control variables on zip code level)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-3.011	1.2	.936	1.195	.288	.711	.093
≤ 40 Mbps	1.321	-4.553	1.03	1.181	.311	.808	.189
≤ 80 Mbps	1.046	1.025	-5.52	1.638	.261	.657	.177
> 80 Mbps	.977	.868	1.221	-6.994	.253	.704	.201
mobile ≤ 20 Mbps	1.041	1.009	.845	1.095	-3.721	1.215	.748
mobile ≤ 80 Mbps	.672	.695	.571	.833	.318	-4.242	1.577
mobile > 80 Mbps	.11	.202	.191	.286	.25	1.996	-4.465

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the reduced sample and with the complete set of control variables on the zip code level (Table 1, fourth column).

Table A.11: Own- and cross-price elasticities (unweighted mean prices)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-3.182	1.297	.946	1.256	.309	.751	.101
≤ 40 Mbps	1.418	-4.87	1.022	1.326	.34	.866	.216
≤ 80 Mbps	1.097	1.071	-5.804	1.79	.267	.689	.181
> 80 Mbps	1.045	1.001	1.26	-7.575	.272	.762	.243
mobile ≤ 20 Mbps	1.125	1.117	.834	1.167	-3.985	1.275	.847
mobile ≤ 80 Mbps	.727	.767	.588	.898	.339	-4.583	1.711
mobile > 80 Mbps	.118	.23	.185	.334	.279	2.103	-4.785

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the reduced sample which was estimated with unweighted mean prices.

Table A.12: Own- and cross-price elasticities (no weights)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-2.467	.722	.598	.724	.468	.874	.023
≤ 40 Mbps	.829	-3.68	.641	.759	.495	.974	.047
≤ 80 Mbps	.659	.601	-4.397	1.149	.435	.828	.051
> 80 Mbps	.594	.536	.877	-5.66	.42	.888	.096
mobile ≤ 20 Mbps	.618	.564	.524	.668	-2.556	1.321	.309
mobile ≤ 80 Mbps	.382	.371	.337	.482	.437	-2.907	1.019
mobile > 80 Mbps	.016	.028	.033	.081	.165	1.641	-2.917

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the reduced sample which was estimated with no weights.

Table A.13: Own- and cross-price elasticities (control for incumbent choice)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-2.594	1.59	.404	1.065	.275	.423	.04
≤ 40 Mbps	2.158	-5.885	.879	1.688	.387	.884	.166
≤ 80 Mbps	.492	.778	-6.525	3.609	.353	1.04	.319
> 80 Mbps	.599	.7	1.708	-8.364	.335	1.293	.396
mobile ≤ 20 Mbps	1.055	1.052	1.057	2.086	-4.611	1.621	1.041
mobile ≤ 80 Mbps	.365	.579	.777	2.086	.386	-5.06	2.036
mobile > 80 Mbps	.044	.134	.287	.755	.318	2.519	-5.694

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the reduced sample and with a control variable if a tester had a A1 Telekom contract.

Table A.14: Own- and cross-price elasticities (random sample split in halves)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-2.978	1.198	.941	1.194	.283	.678	.09
≤ 40 Mbps	1.338	-4.537	1.017	1.197	.309	.777	.187
≤ 80 Mbps	1.049	.995	-5.584	1.71	.263	.659	.187
> 80 Mbps	1	.888	1.311	-7.154	.251	.696	.219
mobile ≤ 20 Mbps	1.025	.99	.853	1.061	-3.691	1.184	.793
mobile ≤ 80 Mbps	.664	.68	.589	.824	.32	-4.269	1.635
mobile > 80 Mbps	.106	.196	.2	.302	.262	1.981	-4.486

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the reduced sample which was estimated with a random subset of only half of the observations.

Table A.15: Own- and cross-price elasticities (other half of the random subset)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-3.003	1.209	.921	1.18	.283	.718	.093
≤ 40 Mbps	1.314	-4.564	.974	1.212	.312	.843	.194
≤ 80 Mbps	1.027	.981	-5.536	1.781	.258	.661	.17
> 80 Mbps	.941	.881	1.308	-7.072	.249	.726	.232
mobile ≤ 20 Mbps	1.025	1.028	.831	1.094	-3.702	1.208	.729
mobile ≤ 80 Mbps	.669	.724	.566	.857	.31	-4.239	1.524
mobile > 80 Mbps	.113	.219	.192	.348	.251	2.045	-4.625

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the reduced sample which was estimated with the other half of the random subset.

Table A.16: Own- and cross-price elasticities (five percent random subset)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-2.792	1.081	.835	1.246	.241	.628	.097
≤ 40 Mbps	1.062	-3.971	.893	1.076	.263	.779	.233
≤ 80 Mbps	.945	1.002	-5.102	1.631	.229	.573	.097
> 80 Mbps	.912	.787	1.074	-6.021	.19	.563	.131
mobile ≤ 20 Mbps	.907	.988	.75	.974	-3.312	1.047	.573
mobile ≤ 80 Mbps	.605	.766	.502	.759	.269	-3.853	1.315
mobile > 80 Mbps	.123	.301	.112	.222	.196	1.77	-4.033

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the reduced sample which was estimated with a random subset that only contains five percent of the original observations.

Table A.17: Own- and cross-price elasticities (at least 10 tests per municipality)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-3.075	1.224	.966	1.237	.28	.714	.095
≤ 40 Mbps	1.318	-4.588	1.016	1.243	.308	.823	.194
≤ 80 Mbps	1.037	.994	-5.607	1.788	.259	.672	.186
> 80 Mbps	.971	.897	1.338	-7.155	.25	.715	.231
mobile ≤ 20 Mbps	1.012	1.019	.869	1.12	-3.747	1.218	.775
mobile ≤ 80 Mbps	.665	.712	.597	.858	.314	-4.288	1.574
mobile > 80 Mbps	.113	.215	.213	.345	.262	2.053	-4.685

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the reduced sample which was estimated with a subset containing only municipalities were at least 10 tests were performed.

Table A.18: Own- and cross-price elasticities (at least 20 tests per municipality)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-3.184	1.246	1.023	1.287	.286	.724	.104
≤ 40 Mbps	1.314	-4.69	1.064	1.291	.314	.841	.212
≤ 80 Mbps	1.04	1.009	-5.68	1.83	.263	.681	.197
> 80 Mbps	.969	.913	1.382	-7.214	.253	.714	.239
mobile ≤ 20 Mbps	1.017	1.044	.917	1.165	-3.825	1.224	.782
mobile ≤ 80 Mbps	.67	.739	.635	.892	.319	-4.394	1.584
mobile > 80 Mbps	.124	.238	.238	.372	.268	2.069	-4.841

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the reduced sample which was estimated with a subset containing only municipalities were at least 20 tests were performed.

Table A.19: Own- and cross-price elasticities (at least 50 tests per municipality)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-3.34	1.252	1.099	1.431	.287	.719	.119
≤ 40 Mbps	1.284	-4.772	1.13	1.414	.315	.82	.23
≤ 80 Mbps	1.014	1	-5.682	1.94	.259	.674	.218
> 80 Mbps	.963	.919	1.44	-7.205	.252	.695	.255
mobile ≤ 20 Mbps	1.003	1.062	.976	1.28	-3.919	1.204	.816
mobile ≤ 80 Mbps	.687	.764	.715	1.001	.33	-4.585	1.546
mobile > 80 Mbps	.146	.273	.296	.458	.292	2.007	-5.068

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the reduced sample which was estimated with a subset containing only municipalities were at least 50 tests were performed.

Table A.20: Own- and cross-price elasticities (less than 1000 tests per municipality)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-3.073	1.249	1.031	1.152	.282	.733	.069
≤ 40 Mbps	1.359	-4.767	1.137	1.192	.316	.871	.188
≤ 80 Mbps	1.077	1.069	-5.716	1.671	.263	.699	.166
> 80 Mbps	1.051	.99	1.504	-7.571	.244	.677	.12
mobile ≤ 20 Mbps	1.049	1.067	.939	.974	-3.88	1.311	.834
mobile ≤ 80 Mbps	.676	.738	.631	.695	.324	-4.358	1.711
mobile > 80 Mbps	.075	.191	.18	.143	.254	2.089	-4.372

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the reduced sample which was estimated with a subset containing only municipalities were less than 1000 tests were performed.

Table A.21: Own- and cross-price elasticities (less than 1500 tests per municipality)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-2.853	1.162	.895	1.151	.26	.666	.076
≤ 40 Mbps	1.272	-4.362	.96	1.168	.286	.783	.181
≤ 80 Mbps	.979	.941	-5.335	1.714	.237	.642	.18
> 80 Mbps	.917	.841	1.279	-6.812	.227	.68	.222
mobile ≤ 20 Mbps	.974	.968	.812	1.044	-3.564	1.167	.742
mobile ≤ 80 Mbps	.63	.676	.565	.814	.294	-4.089	1.539
mobile > 80 Mbps	.088	.193	.197	.319	.237	1.932	-4.322

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the reduced sample which was estimated with a subset containing only municipalities were less than 1500 tests were performed.

Table A.22: Own- and cross-price elasticities of the reduced sample for Vienna

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-3.796	1.037	1.786	1.974	.223	.565	.117
≤ 40 Mbps	1.054	-5.291	1.847	2.003	.252	.692	.272
≤ 80 Mbps	.887	.89	-5.468	2.364	.229	.576	.246
> 80 Mbps	.747	.74	1.829	-6.449	.203	.532	.287
mobile ≤ 20 Mbps	.83	.916	1.728	1.979	-4.257	.953	.688
mobile ≤ 80 Mbps	.601	.724	1.273	1.524	.271	-5.048	1.289
mobile > 80 Mbps	.18	.414	.805	1.178	.289	1.89	-6.568

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the reduced sample which was estimated with a subset containing only tests from Vienna.

Table A.23: Own- and cross-price elasticities of the reduced sample for all locations but Vienna

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-2.535	1.16	.634	.876	.276	.677	.07
≤ 40 Mbps	1.312	-3.939	.665	.839	.302	.778	.126
≤ 80 Mbps	1.244	1.136	-5.659	.938	.291	.735	.089
> 80 Mbps	1.226	1.038	.68	-7.662	.308	.876	.1
mobile ≤ 20 Mbps	.983	.934	.52	.749	-3.222	1.19	.699
mobile ≤ 80 Mbps	.615	.623	.344	.565	.304	-3.66	1.531
mobile > 80 Mbps	.077	.124	.051	.078	.224	1.909	-3.717

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the reduced sample which was estimated with a subset containing only outside Vienna.

Table A.24: Own- and cross-price elasticities of the reduced sample for all of the cities (Graz, Linz, Salzburg, Innsbruck)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-2.758	1.206	.419	1.1	.326	.703	.18
≤ 40 Mbps	1.242	-3.88	.461	1.071	.353	.703	.18
≤ 80 Mbps	.981	1.043	-5.506	1.691	.364	.519	.078
> 80 Mbps	1.015	.96	.66	-6.394	.36	.656	.129
mobile ≤ 20 Mbps	.904	.937	.427	1.064	-3.134	1.052	.711
mobile ≤ 80 Mbps	.7	.682	.228	.736	.381	-3.814	1.258
mobile > 80 Mbps	.272	.263	.052	.212	.401	1.933	-4.89

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the reduced sample which was estimated with a subset containing only tests from Graz, Linz, Salzburg, and Innsbruck.

Table A.25: Own- and cross-price elasticities of the reduced sample for remaining locations (without Vienna, Graz, Linz, Salzburg, and Innsbruck)

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-2.524	1.184	.692	.773	.268	.712	.047
≤ 40 Mbps	1.386	-4.081	.745	.76	.298	.837	.099
≤ 80 Mbps	1.319	1.195	-5.857	.818	.28	.817	.081
> 80 Mbps	1.333	1.12	.753	-8.295	.291	.903	.054
mobile ≤ 20 Mbps	1.036	.971	.565	.629	-3.357	1.33	.684
mobile ≤ 80 Mbps	.627	.628	.38	.452	.301	-3.676	1.597
mobile > 80 Mbps	.048	.087	.043	.031	.185	1.899	-3.447

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the reduced sample which was estimated with a subset containing only tests outside Vienna, Graz, Linz, Salzburg, and Innsbruck.

Table A.26: Own- and cross-price elasticities of the reduced sample for April and May

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-2.912	1.092	.961	1.287	.275	.621	.127
≤ 40 Mbps	1.348	-4.426	.986	1.236	.307	.669	.173
≤ 80 Mbps	1.056	.853	-5.292	1.695	.275	.598	.152
> 80 Mbps	1.077	.83	1.339	-7.502	.257	.719	.253
mobile ≤ 20 Mbps	1.003	.895	.928	1.088	-3.57	1.077	.821
mobile ≤ 80 Mbps	.638	.554	.576	.873	.303	-4.247	1.859
mobile > 80 Mbps	.127	.139	.142	.29	.23	1.844	-4.071

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the reduced sample which was estimated with a subset containing tests from April and May.

Table A.27: Own- and cross-price elasticities of the reduced sample for June and July

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-3.465	1.476	1.13	1.334	.307	.769	.068
≤ 40 Mbps	1.535	-5.354	1.156	1.358	.384	1.013	.219
≤ 80 Mbps	1.214	1.174	-6.499	2.124	.281	.737	.191
> 80 Mbps	1.093	1.053	1.628	-8.549	.279	.896	.332
mobile ≤ 20 Mbps	1.184	1.402	.996	1.265	-4.452	1.371	.869
mobile ≤ 80 Mbps	.75	.953	.684	1.09	.35	-5.058	1.779
mobile > 80 Mbps	.078	.243	.208	.462	.269	2.128	-4.903

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the reduced sample which was estimated with a subset containing tests from June and July.

Table A.28: Own- and cross-price elasticities of the reduced sample for August and September

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-3.088	1.318	.935	1.079	.292	.73	.103
≤ 40 Mbps	1.48	-4.736	1.001	1.061	.312	.857	.211
≤ 80 Mbps	1.179	1.092	-5.879	1.738	.257	.668	.15
> 80 Mbps	1.102	.953	1.454	-7.44	.249	.675	.154
mobile ≤ 20 Mbps	1.197	1.12	.836	.969	-3.947	1.284	.763
mobile ≤ 80 Mbps	.783	.814	.582	.717	.335	-4.416	1.488
mobile > 80 Mbps	.16	.293	.193	.233	.298	2.215	-5.1

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the reduced sample which was estimated with a subset containing tests from August and September.

Table A.29: Own- and cross-price elasticities of the reduced sample for October and November

	≤ 20 Mbps	≤ 40 Mbps	≤ 80 Mbps	> 80 Mbps	mobile ≤ 20 Mbps	mobile ≤ 80 Mbps	mobile > 80 Mbps
≤ 20 Mbps	-2.683	1.025	.797	1.105	.268	.68	.079
≤ 40 Mbps	1.074	-3.99	.875	1.169	.274	.747	.17
≤ 80 Mbps	.836	.862	-4.944	1.584	.243	.638	.198
> 80 Mbps	.766	.767	1.068	-5.93	.227	.623	.195
mobile ≤ 20 Mbps	.835	.807	.719	1.006	-3.168	1.11	.631
mobile ≤ 80 Mbps	.562	.586	.51	.753	.293	-3.683	1.333
mobile > 80 Mbps	.086	.177	.21	.304	.225	1.795	-4.064

Note: The own- and cross-price elasticities are simulated 100 times with the regression coefficients of the reduced sample which was estimated with a subset containing tests from October and November.

Table A.30: Heterogeneous effects across covariates

	fixed-line			mobile		
alternative	$\leq 40\ Mbps$	$\leq 80\ Mbps$	>80 Mbpps	$\leq 20\ Mbps$	$\leq 80\ Mbps$	>80 Mbpps
mobile upload	0.0452***	0.0503***	0.0684***	0.0782***	0.141***	0.294***
	(0.000549)	(0.000597)	(0.000652)	(0.000511)	(0.000539)	(0.000924)
first zip code digit=2	-0.190***	-0.513***	-2.118***	-0.862***	-0.846***	-0.0579
	(0.0137)	(0.0171)	(0.0264)	(0.0201)	(0.0172)	(0.0331)
first zip code digit=3	-0.174***	-1.856***	-3.955***	-0.865***	-1.376***	-0.762***
	(0.0156)	(0.0216)	(0.0293)	(0.0225)	(0.0201)	(0.0421)
first zip code digit=4	-0.298***	-2.730***	-1.765***	-0.571***	-0.708***	-0.193***
	(0.0150)	(0.0255)	(0.0316)	(0.0199)	(0.0174)	(0.0386)
first zip code digit=5	0.562***	-1.348***	-3.814***	0.281***	-0.341***	-0.228***
	(0.0147)	(0.0179)	(0.0258)	(0.0186)	(0.0172)	(0.0395)
first zip code digit=6	0.128***	-1.056***	-0.865***	-0.0476*	-0.0757***	0.169***
	(0.0153)	(0.0208)	(0.0259)	(0.0195)	(0.0173)	(0.0395)
first zip code digit=7	-0.863***	-2.455***	-5.250***	-0.696***	-1.304***	-1.594***
	(0.0218)	(0.0313)	(0.0547)	(0.0288)	(0.0253)	(0.0564)
first zip code digit=8	-0.380***	-2.253***	-2.292***	-0.191***	-0.755***	-0.453***
	(0.0164)	(0.0200)	(0.0289)	(0.0208)	(0.0191)	(0.0414)
first zip code digit=9	0.602***	-0.207***	-0.0323	-0.0314	0.483***	1.772***
	(0.0219)	(0.0244)	(0.0359)	(0.0316)	(0.0250)	(0.0572)
wireless LAN	0.0325***	0.0547***	-0.0516***	-0.695***	-0.632***	-0.0803***
	(0.00706)	(0.00752)	(0.0107)	(0.00867)	(0.00759)	(0.0191)
population=low	-0.0901***	0.137***	-0.848***	-0.120***	-0.0620***	-0.299***
	(0.0110)	(0.0152)	(0.0232)	(0.0147)	(0.0122)	(0.0255)
population=medium	0.381***	-0.0471***	-0.951***	0.0215	0.280***	0.510***
	(0.0106)	(0.0110)	(0.0154)	(0.0137)	(0.0127)	(0.0248)
population=high	-0.420***	-0.211***	0.268***	-0.110***	-0.426***	-1.562***
	(0.0155)	(0.0181)	(0.0240)	(0.0205)	(0.0184)	(0.0378)
newborns	-3.284***	-3.318***	0.767***	0.184	-1.782***	-5.587***
	(0.104)	(0.145)	(0.205)	(0.145)	(0.122)	(0.266)
male	22.67***	31.46***	65.00***	17.63***	21.73***	15.36***
	(0.495)	(0.614)	(0.901)	(0.678)	(0.576)	(1.271)
education=low	2.079**	25.40***	-26.60***	-0.128	5.300***	25.70***
	(0.671)	(0.804)	(1.221)	(0.868)	(0.767)	(1.651)
education=medium	2.340***	23.74***	-11.89***	1.310	6.373***	28.73***
	(0.654)	(0.773)	(1.170)	(0.851)	(0.768)	(1.600)
education=high	6.122***	26.31***	-2.352*	2.203**	6.297***	21.30***
	(0.570)	(0.689)	(1.033)	(0.744)	(0.665)	(1.379)
age=young	1.694***	2.298***	25.41***	2.172***	13.49***	23.26***
	(0.329)	(0.422)	(0.599)	(0.456)	(0.397)	(0.818)
age=old	1.723***	8.540***	-40.45***	-0.0169	4.050***	15.08***
	(0.352)	(0.448)	(0.696)	(0.507)	(0.410)	(0.914)
	(0.700)	(0.838)	(1.288)	(0.924)	(0.787)	(1.711)
Constant	-9.274***	-5.960***	-38.62***	-9.303***	-13.81***	-15.26***
	(0.383)	(0.505)	(0.731)	(0.539)	(0.439)	(0.960)

Standard errors in parentheses

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

Note: The regression shows the results for the reduced sample with four fixed-line and three mobile alternatives. The sample was reduced to test which have had full fixed-line coverage (at least 100 Mbps) in 2015 to make sure that all choices are eligible and that the results are comparable. It was control for whether the device, from which the test was performed, was connected via WLAN or LAN. Furthermore, the first digit of the postal code and the mobile upload coverage from the *Broadband Atlas* were applied as geographic covariates. Moreover, characteristics on zip code level were included. It was controlled for population (less than 10,000, less than 100,000, at least 100,000 in 2014, compared to less than 5,000), number of newborn, share of males, education level (compulsory, secondary and tertiary) and age distribution (young is defined as not older than 20 and old is defined as at least 60 years old).