

Demand for Internet Services in Austria

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March 2007

preliminary, please do not quote

Abstract

This paper analyses residential demand for internet access in Austria with a focus on broadband internet connections. Austria has a cable network coverage of about 50% and is, therefore, a good candidate to analyse the elasticity of demand for DSL where cable is available and where it is not. We also include mobile broadband via UMTS or HSDPA in our analysis. We estimate various nested logit models and are able to derive conclusions for market definition by comparing estimated elasticities to critical elasticities. The preliminary estimations results show that the demand for DSL is elastic suggesting that cable networks are part of the same market.

Keywords: Estimation of discrete choice models, broadband internet access, market definition, regulation

JEL classifications: L51, L96

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1. Introduction

The 2003 regulatory framework for electronic communications networks and services⁴ requires the national regulatory authorities (NRAs) of EU-countries to periodically review a number of electronic communications markets which potentially may be subject to ex ante regulation. One of these markets is the market for wholesale broadband access. According to the recommendation on relevant markets,⁵

[t]his market covers 'bit-stream' access that permit the transmission of broadband data in both directions and other wholesale access provided over other infrastructures, if and when they offer facilities equivalent to bit-stream access. It includes 'Network access and special network access' referred to in Annex I(2) of the Framework Directive, but does not cover the market in point 11 above [remark: local loop unbundling], nor the market in point 18 [remark: Broadcasting transmission services].

Wholesale broadband access, also called 'bitstreaming' (in particular if realised over a copper network), is a wholesale product which allows alternative operators to offer broadband internet access to the final consumer without having an own access line. The alternative operator receives traffic at a higher network level (e.g. an ATM node) and will forward this traffic to the public internet. It is usually providing the internet connectivity, e-mail addresses and web-space and can influence the quality of service (e.g. by setting the overbooking factor).⁶

⁴ See Directives 2002/19/EC, 2002/20/EC, 2002/21/EC and 2002/22/EC, OJ L108, 24.4.2002.

⁵ Commission Recommendation of 11 February 2003 on relevant product and service markets within the electronic communications sector susceptible to ex ante regulation in accordance with Directive 2002/21/EC of the European Parliament and of the Council on a common regulatory framework for electronic communication networks and services, OJ L 114/45. ('Recommendation on Relevant Markets').

⁶ For details on bitstreaming see ERG (2005).

According to the 2003 regulatory framework, NRAs are required to analyse the state of competition on the wholesale broadband access market. If an undertaking is found to have significant market power (SMP),⁷ NRAs have to impose appropriate ex ante remedies⁸ to prevent anti-competitive or exploitative abuses. Before the process starts, however, a relevant market has to be defined. The Recommendation on Relevant Markets quoted above is a starting point, however, NRAs have to check which products (and geographic areas) exactly to include or whether their national circumstances are such that they have to deviate from the Recommendation.

The instrument applied to define markets is, as in general competition law, the hypothetical monopolist test (HM-Test). This test asks whether, starting from the competitive level, a non-transitory 5-10% price increase would be profitable for a hypothetical monopolist in the market of consideration. The smallest set of products for which the price increase can be sustained constitutes the relevant market.⁹

Market definition on wholesale broadband access markets has attracted some attention since Oftel (now Ofcom) and Comreg (the NRAs of the UK and Ireland) have notified their decisions to the European Commission in 2003 and 2004.¹⁰ One of the main questions was whether access via cable networks (CATV-networks) forms part of the same market as access via copper networks (digital subscriber line - DSL). Whereas DSL wholesale products provided by the incumbent telecommunications operator (in most cases due to regulatory obligations or regulatory pressure) are available in many EU Member States,¹¹ wholesale

⁷ The concept of SMP is based on the concept of dominance in general competition law (see European Commissions Guidelines on market analysis and the assessment of significant market power under the Community regulatory framework for electronic communications networks and services ('SMP-Guidelines')).

⁸ Ex ante remedies available to NRAs are listed in the access directive (Directive 2002/19/EC)

⁹ For a description of the HM-Test see, for example, Bishop/Walker (1999), OFT (2001), and §§ 49 et sqq. of the SMP-Guidelines.

¹⁰ See Oftel (2003) and Comreg (2004). Decision on market definition and market analysis have to be notified to the European Commission which has a veto power.

¹¹ See ERG (2005) pp. 9-11.

broadband access via cable networks is only provided rarely. Therefore, a direct competitive constraint from cable on DSL on the wholesale level is unlikely to exist.¹²

However, as Ofcom, Comreg and later a number of other NRAs (although not all of them) argued, there is an (indirect) constraint from cable on DSL which goes via the retail level. The argument is that a hypothetical monopolist for DSL access could not increase his bitstream prices profitably by 5-10% as this would also increase retail prices which would make customers switch from DSL to cable access at the retail level. This would also reduce access demand and if retail substitution is strong enough, the price increase would not be profitable. The elasticity of retail demand is therefore crucial not only for the definition of retail markets but also for the definition of the wholesale broadband access market.

Only few papers have analysed the extent of retail demand elasticities for broadband internet services so far. Rappoport et al. (2002) use a nested logit discrete choice model to describe the demand for internet access of residential customers in the US. They conclude that demand for DSL is elastic (own price elasticity of -1.462) and that therefore DSL and cable belong to the same retail market. Crandall et al. (2003) confirm these results (DSL own price elasticity of -1.184). Ida/Kuroda (2006) estimate a similar model for Japan including fibre (FTTH) – a rapidly growing access technology in Japan – in their choice set. They conclude that demand for DSL (at this time the main access technology with a share of 75%) is inelastic (own price elasticity of -0.846) but demand for cable and FTTH is elastic (own price elasticities of -3.150 and -2.500). They also find that the upper and lower end of the DSL market (very high and low bandwidths) are highly elastic as they directly compete with FTTH and cable on the high end and dial-up and ISDN (narrowband) on the low end.

This paper analyses residential demand for internet access in Austria with a focus on broadband internet connections. Like the studies quoted above, we use a nested logit

¹² See however the notification of the Maltesian NRA, MCA (2006) which argues that there would be sufficient wholesale substitution if cable networks offered a wholesale product.

discrete choice model, however, there are several new features: (i) To our knowledge, this is the first analysis for an European country. Austria has a cable network coverage of about 50% and therefore is a good candidate to analyse the elasticity of demand for DSL where cable is available and where it is not. (ii) We include mobile broadband via UMTS or HSDPA in our analysis. These broadband services, offered by mobile operators, are available for 2-3 years and experienced high growth rates in 2006 with the introduction of HSDPA, which allows download speeds of (theoretically) up to 7.2 Mbit/s. The total number of residential users is still limited but there appears to be potential for becoming a substitute to fixed broadband in the future. (iii) While the other studies use a two-level nested logit model, we use a three-level model which performs better than the two-level specification. (iv) We are able to derive conclusions for market definition by comparing estimated elasticities to critical elasticities.

The rest of the paper is structured as follows: Section 2 gives an overview of the Austrian retail and wholesale market for broadband access including the current status of regulation. Section 3 describes the data and discusses the question how to allocate non-chosen alternatives to households. Section 4 describes the choice model. Section 5 presents the preliminary estimation results for the area where all four types of internet access (DSL, cable, mobile and narrowband) are available and for an area where only DSL and narrowband are available. Section 6 discusses how conclusions for retail and wholesale market definition can be derived. Section 7 summarizes and concludes.

2. The Austrian market for broadband internet services

In Austria, 52% of all private households have an internet connection. While narrowband connections (dial-up and ISDN) still have a significant share (19% of all households in 2006), the share of broadband connections is increasing rapidly, from 10% in 2002 to 33% in

2006.¹³ The Austrian market for broadband internet services therefore is characterised by high and steady growth.

Broadband internet via cable networks became available in 1996 and DSL followed in 1999. Today, there are 1.36 Mio. broadband connections, more than 1 Mio. of which are held by residential customers. The broadband penetration in Austria is 39% (households and businesses) and slightly above the EU average.¹⁴

The cable network coverage is approximately 50% of all households and relatively high compared to most other EU countries. There are more than 100 cable network operators which offer broadband services in different regions of Austria (cable networks usually do not overlap), however, almost 90% of all cable connections are offered by six bigger operators. The DSL coverage is, like in most other EU countries, above 90% of all households.

In September 2006, the shares of the different infrastructures on the market for fixed broadband connections were as follows: DSL: 61%, cable: 37%, other (fixed wireless access, fibre): 2%.¹⁵ While most business users prefer DSL over cable, cable still holds a strong position in the residential market. Most DSL and cable operators offer a menu of three to five (and sometimes more) tariffs, which vary by price, download speed and download volume.

Since 2003, mobile broadband via UMTS and since 2006, mobile broadband via HSDPA is available. By end of 2006, there are about 200.000 mobile broadband connections, more than half of which are used by business customers – often complementary to fixed access. Residential customers on the other hand seem to use mobile broadband rather as a substitute than a complement. Mobile broadband via HSDPA is usually available in cities with more than 5000 inhabitants where in most cases also cable networks exist. Hereby, Austria

¹³ See Statistik Austria (2006).

¹⁴ See RTR (2007).

¹⁵ See RTR (2007).

is one of the leading countries in the deployment of mobile broadband services via UMTS/HSDPA.

Mobile tariffs are designed somewhat differently from fixed network tariffs insofar as price does not vary with download speed but only with download volume. While on-off connection fees are usually lower than in the fixed network, volume is still more expensive.

There are two regulated wholesale products based on which alternative operators, which do not own infrastructure all the way to the final consumer, can enter the retail market: local loop unbundling (LLU) and bitstream access (described in section 1), both of which allow alternative operators to offer DSL connections on the retail market. While more own infrastructure is needed for local loop unbundling there is also more value added and there are more degrees of freedom for designing the products (e.g. bundles with voice telephony, etc.).

3. Data and descriptive statistics

The data we use is from a survey commissioned by RTR (the Austrian National Regulatory Authority) which was conducted in November 2006. 4,029 households were asked about the type and characteristics of the internet connection they are using as well as the monthly expenses. Individual specific data such as age, education and household size was also collected. After eliminating missing and implausible values we are left with almost 3,000 observations. For the estimation, these observations are divided into two sub-samples: One for the area where all four internet access technologies (DSL, cable, mobile, and narrowband) are available and one for the area where only DSL and narrowband are available.¹⁶ The number of observations is reported in Table 1. The share of the different

¹⁶ Data on cable network and DSL coverage are available from the operators. Data on mobile coverage are not available. However, it can be concluded from the operators' press releases that HSDPA coverage is available in urban areas where usually also cable networks are present.

types of access in the sample is unbalanced. There are too many DSL households and too few narrowband and cable households. We therefore use weights in order to correct for that. The weights are taken from the distribution between the different access types from a micro census carried out by the central bureau of statistics (see Statistik Austria (2006)).

Table 1: Number of observations

Number of observations						
	DSL	cable	mobile	narrowb.	no internet	total
total unweighted	712	252	30	270	1713	2977
total weighted	435	300	35	498	1681	2949
cable/mobile area unweighted	405	252	30	147	981	1815
cable/mobile area weighted	239	300	35	285	985	1844
dsl/narrowband area unweighted	307	0	0	123	732	1162
dsl/narrowband area weighted	196	0	0	213	696	1105

Table 2 reports the descriptive statistics of the main product-specific variables which we use in the analysis.

Table 2: Descriptive Statistics – product specific variables

	mean	std. dev.	min	max
price in € per month				
DSL	31.95	9.55	9.90	73.00
cable	40.69	13.83	19.00	75.00
mobile	31.98	10.12	9.50	59.00
narrowband	19.65	13.56	4.00	60.00
download speed in kbit/S				
DSL	1,372	995	210	6,144
cable	3,151	2,474	128	16,384
mobile	900	0	900	900
narrowband	56	0	56	56
download volume included in MB (for non-flat rate products)				
DSL	1,541	2,367	250	21,000
cable	4,187	5,546	400	20,000
mobile	757	810	250	4,000
narrowband	0	0	0	0
share of flat rate products (dummy_flat)				
DSL	8.70%			
cable	56.86%			
mobile	0.00%			
narrowband	0.00%			

As can be seen, users on average spend less on DSL than on cable products, however, the DSL products come – on average – with lower speed and volume. Cable products are also

much more frequently bought with flat rate (56.86%) than DSL products (8.70%). For mobile products it is difficult to determine a download rate as this depends on the number of users in the cell. We have taken 900 kbit/s as a maximum value a consumer could expect to get by end of 2006. The included volume for mobile broadband is much lower than for fixed broadband connections.

Individual specific variables are reported in Table 3.

Table 3: Individual specific variables

	DSL	cable	mobile	narrowb.	no internet
age (head of household - mean)	44.9	42.44	40.19	45.19	60.5
household size (mean)	3.1	2.6	2.7	3.1	2.0
education: compulsory school	38%	29%	39%	29%	69%
education: high school without graduation	22%	15%	22%	25%	17%
education: high school with graduation	24%	32%	28%	30%	10%
education: university degree	15%	23%	11%	16%	3%

The discrete choice approach we use for the analysis of demand requires us to allocate each household all four internet access types. The question now is how price and characteristics of the non-chosen alternatives are determined. This is a crucial point as it can significantly influence the result of the analysis. We describe our approach by type of internet access.

Narrowband: Narrowband is most difficult to match as it is quite hard to say how much a broadband or 'no internet' household would spend on narrowband services which are metered by minute. Narrowband expenses are also hard to explain by the individual specific variables available, however, they seem to vary with region and age. We therefore form eight

groups (four regions combined with age smaller or larger than 50), calculate group averages and impose those on broadband and 'no internet' households.¹⁷

Cable: We use the tariffs from the web pages of eight big cable operators which cover all of the nine federal states of Austria. We assume that smaller cable operators (which have very low market shares in total) charge similar prices as the bigger local operator we use. 'No internet' households and narrowband households which spend less than €25 per month are assigned the 'low user' package of the local operator. Narrowband households which spend more than €25 per month are assigned the 'medium' package. DSL households are assigned the package which is closest in bandwidth and mobile households are assigned the package closest in price.

DSL: DSL is basically done in the same way as cable. We use the tariffs from the web pages of the largest three DSL operators. Geographic differences result from two operators which offer DSL access based on local loop unbundling in different parts of Austria. Where only Telekom Austria – the incumbent DSL operator – is present, we take the packages of Telekom Austria. Where also one or two of the LLU operators are present, we take average values (weighted by national market shares).

For both DSL and cable there is a problem with households which are assigned a non-flat rate tariff. It can be assumed that these households – on average – have to pay an additional amount per month for exceeding their included download volume. We solve this problem by comparing actual amounts paid to monthly fixed charges for DSL and cable households over several groups of included download volume. We find that the mean difference between actual amounts paid and monthly fixed charges is significantly different from zero for low download volumes. The result of the t-test is depicted in Table 4. We use the mean as 'mark-

¹⁷ This causes an endogeneity problem as pointed out by Ida/Kuroda (2006, footnote 9). However there does not seem to be a good alternative and since we use this method only for narrowband we think that this should not be too problematic.

up” for matched DSL and cable products if it is significantly different from zero at least at the 10% level.

Table 4: Results of test ‘H₀: Difference between actual paid amounts and monthly fixed charges for DSL and cable = 0’

volume	obs.	mean	std. err.	t-value
<500	268	4.003	0.565	7.083***
>500 <1000	233	4.903	0.693	7.071***
>1000 <5000	100	1.910	1.031	1.853*
>5000	184	-0.314	0.997	-0.315
falt rate	152	-0.414	1.094	-0.378

***, ** and * denote significance on 1%, 5% and 10% level

Mobile: Mobile products are assigned according to the monthly charge which is currently paid by the household. We use averages of the prices of the four mobile operators weighted by market share.

4. Empirical models of consumer behaviour

To empirically analyse consumer behavior, we assume a random utility model of internet access in which consumers choose from a set of five choices. These are no internet access, dialup internet access, cable network, DSL and mobile internet access. The utility a consumer derives from a particular product depends on characteristics of that consumer and on the characteristics of the product. To account for characteristics that are unobserved by the econometrician, the utility of consumer i for product j is of the form

$$(1) U(ij) = V(ij) + \varepsilon(ij),$$

where i and j are the indices for consumer i , $i=1, \dots, I$, and product j , $j=1, \dots, J$, and where the term $V(ij)$ reflects the deterministic part of consumers’ utility. The error $\varepsilon(ij)$ is a residual that captures for example, the effects of unmeasured variables or personal idiosyncrasies. It is assumed to follow an extreme value distribution of type I.

Consumers are assumed to purchase that internet access that gives them the highest utility. The probability $P(ij)$ that consumer i purchases product j is equal to the probability that $U(ij)$ is larger than the utility consumer i experiences from any other product, i.e. $U(ij) > U(ij')$ for all $j' \neq j$. This probability is equal to

$$(2) P(ij) = P[U(ij) > U(ij') \text{ for all } j' \neq j] = P[\varepsilon(ij') - \varepsilon(ij) \leq V(ij) - V(ij') \text{ for all } j' \neq j].$$

Under the assumption that $\varepsilon(ij)$ follows an extreme value distribution of type I, the probability $P(ij)$ has a closed form solution (McFadden, 1974). It is equal to

$$(3) P(ij) = \exp[V(ij)] / \sum \exp[V(ij')],$$

where the summation in the denominator runs over j' . This is the well-known conditional logit model. Within this model, we have to assume independence of irrelevant alternatives. To additionally model correlations between choices, nested logit models have been developed.¹⁸

In a nested logit model with three layers, the probability $P(ij|lm)$ that consumer i purchases product j is equal to

$$(4) P(ij|lm) = P(im) \times P(il|m) \times P(ij|lm),$$

where we index the first layer alternatives as m and m' , the second layer alternatives as l and l' , and the third layer alternatives as j and j' . The probability $P(ij|lm)$ is equal to

$$(5) P(ij|lm) = \exp[V(ij|lm)] / \sum \exp[V(ij'|lm)],$$

¹⁸ See for example, Maddala (1983) or Greene (2003).

where the summation in the denominator runs over j' . The probability $P(l|m)$ is equal to

$$(6) P(l|m) = \exp[V(lm) + \lambda(lm) IV(lm)] / \sum \exp[V(l'm) + \lambda(l'm) IV(l'm)],$$

with the inclusive value $IV(lm)$ to be equal

$$(7) IV(lm) = \ln\{\sum \exp[V(j'lm)]\},$$

where the summation in the denominator of $P(l|m)$ runs over l' and the summation in the inclusive value $IV(lm)$ runs over j' . The probability $P(m)$ is equal to

$$(8) P(m) = \exp[V(m) + \lambda(m) IV(m)] / \sum \exp[V(m') + \lambda(m') IV(m')],$$

with the inclusive value $IV(m)$ equal to

$$(9) IV(m) = \ln\{\sum \exp[V(l'm) + \lambda(l'm) IV(l'm)]\},$$

where the summation in the denominator of $P(m)$ runs over m' and the summation in the inclusive value $IV(lm)$ runs over l' .¹⁹

In areas where all types of internet access are available we model consumers' decisions using two alternative nested logit models. Our first model is a three-layer nested logit model, which assumes that the consumers first decide, whether they would like to have internet access or not. Then, they decide which type of internet they want to use. We partition the types of internet access into the subsets narrowband and broadband, where the first subset only contains dialup internet access and the second contains cable, DSL and mobile broadband internet access. The alternative to this model is a two-layer model, where the

¹⁹ Our presentation of the nested logit model follows Greene (2003).

consumers decide first whether they would like to have internet access or not and then, at the bottom level, are then faced with the choice between narrowband and three broadband services: cable, DSL and mobile internet access.

In rural areas, cable network and mobile broadband cannot be chosen. Here we model the decision process as follows: Consumers first decide whether they get internet access or not. If they choose internet access, they decide between narrowband and DSL.

The decision trees are depicted in Figure 1.

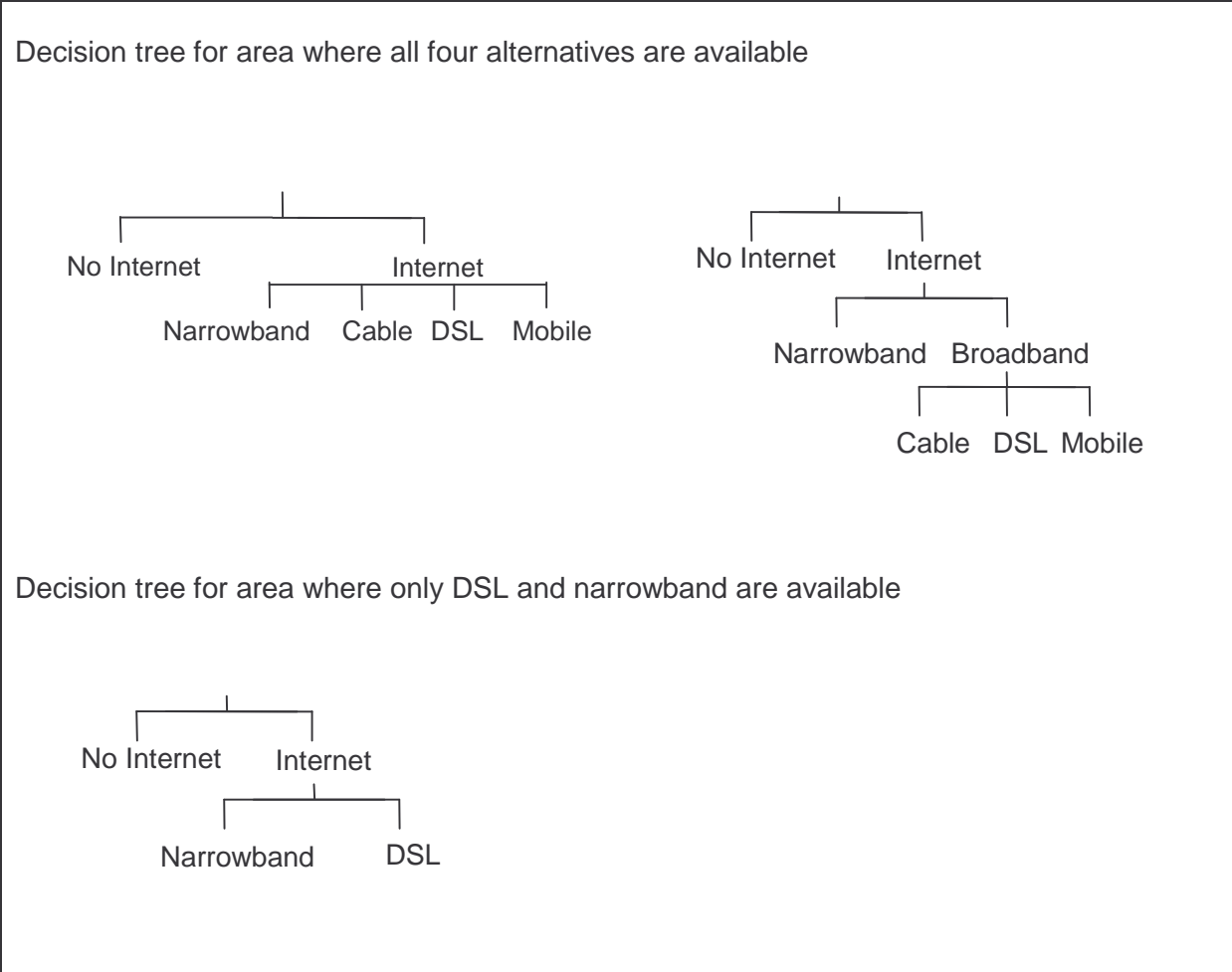


Figure 1: Decision trees for the nested choice model

We specify the deterministic part $V(ij)$, respectively $V(ijlm)$, as a linear function of consumer characteristics, Z , and product characteristics, X including the price of the product, such that

$$(10) V(ij) = \gamma Z(i) + \beta X(j),$$

where γ and β are the parameters to be estimated. As a first step, we assume a simple specification so that the β 's are constant over all choices j . Consumer characteristics are for example, age, educational dummy variables or household size. Product characteristics are for example, the price, the downloadrate and the downloadvolume.

For the estimation of these models, we use the NLOGIT command of STATA Version 9. Under certain conditions, the results using this command are not in line with utility maximization.²⁰ Therefore, we also use the NLOGITRUM command developed by Heiss (2002). Currently, however, we can only report the results using the NLOGIT command as we have problems with convergence using the NLOGITRUM command. We weight the observations as discussed in section 3.

5. Preliminary estimation results

This section presents the preliminary estimation results. We start with the results for the region where all four types of internet access are available (section 5.1) and then present the results for the region where only DSL and narrowband are available (section 5.2).

5.1. Area 1: DSL, cable, mobile, narrowband

The estimation results of the three-layer model are given in Table 5 (see Appendix). Two specifications with a different number of explanatory variables are depicted. As the results are quite similar, we are going to describe the first specification only. We use the size of the households and four educational indicator variables (compulsary school, highschool without graduation, highschool with graduation, and university degree) as factors that influence the

²⁰ See Heiss (2002) for a detailed discussion.

choice between the demand for internet services and no demand for internet services (after interacting them with the internet dummy). The household size has the expected positive sign and it is significant at conventional levels. The three indicator variables on the educational level suggest that it becomes more likely to have internet access as consumers' educational level rises (university education is the omitted dummy variable). At the second layer, we use the age and again the three educational variables (after interacting them with the broadband dummy) as factors that influence the choice between broadband and narrowband services. The age variable is negative and significant suggesting that older consumers are less likely to choose broadband. All three education dummies are negative two of them being significantly so. The coefficients suggest that it is more unlikely to have a broadband connection if education is 'high school with graduation' compared to 'high school without graduation' for which in turn it is again more unlikely compared to 'compulsory school'. While this result may seem a little awkward, we believe that this pattern is consistent with the following explanation: more educated individuals are more likely to have broadband internet access at work and the more educated they are, they may reach higher ranks with higher possibility of using their at-the-job internet access for private purposes.

At the bottom level, the independent variables are price, the download rate, the download volume and three dummy variables indicating the fixed term of cable and DSL alternatives and the flat rates. The download rate and the download volume both have the expected positive signs and they are significantly different from zero at better than one percent level. The price has the expected negative sign which is highly significant. The cable and DSL dummies are both positive and significantly different from zero. The flat rate dummy is negative and significant which might seem odd but can be explained as follows: In order to be able to use the observation in the estimation, we have to assign some value to the variable 'volume' even if the product has a flat rate. We have chosen a value of 55,000 MB (55 GB), which is just a little larger than the largest volume of non-flat rate products. The

negative sign on flat can now be interpreted such that the actual value a consumer derives from a flat rate measured in volume is less than 55,000 MB.

The goodness of fit of the model is evaluated using the McFadden R² or the likelihood-ratio index, which compares the likelihood for the intercept only model to the likelihood for the model with the predictors. The value of the McFadden R² of the three stage model is 0.41.²¹

Table 5 (see Appendix) reports the inclusive value parameters in the bottom section. The inclusive value parameters are not only important in themselves, they are also important because they provide a specification test for the overall model. McFadden (1981) shows that a necessary and sufficient condition for the model to be consistent with rational utility maximization is that the inclusive value parameters must lie in the unit interval. If the inclusive value parameter is equal to 1.0, then it is an indication that the appropriate functional form is a one level model (a conditional logit model). However, if the estimated inclusive value parameter lies outside the 0-1 interval, it indicates that the model does not suit the data generating process (Maddala, 1983). In other words the model does not fit the behaviour pattern of households from which the data were generated. Unfortunately, not all of the inclusive values from the three layer nested logit model are in the range of 0-1. The inclusive value parameter for the ‘no internet’ option is substantially above 1.0 (4.39) and the inclusive value for the broadband option is equal to 1.4. While these values suggest that our estimates from this model should be considered with some caution, the alternative model – a two layer nested logit – does also not provide better values for the inclusive value parameters.

²¹ The McFadden R² is useful for comparing nested models. The model fit can also be based on measures of information such as Akaike's information criterion (AIC) and the Bayesian information criterion (BIC). One advantage to using information criterion measures is that they can be used to compare non-nested models. The values of AIC and BIC for the three layer model are 0.383 and 0.397, respectively.

Coming now to the own price elasticities of access demand, our three-layer nested logit model implies elasticities in the range of -2.97 – -1.18 (see Table 6 in the Appendix). The elasticity of DSL services is highest with -2.97 indicating that a one percent increase in the price decreases the demand for DSL services at about 3 percent. The corresponding figures for mobile and cable services are -2.43 and -2.21, respectively. The lowest elasticity is estimated for narrowband services, which is equal to -1.18. The elasticities indicate that demand for all services is elastic. However, broadband services appear to be more elastic than narrowband services. An interpretation of this may be that different broadband services (in particular DSL and cable) constrain each other, while those consumers still using narrowband do not consider broadband as an equally good substitute.

The second model that we estimate is a two-layer nested logit model where the consumers decide first whether they would like to have internet access or not (see Table 7 in the Appendix). At the bottom level, the consumers are then faced with the choice between three broadband services, cable, DSL and mobile, and narrowband access. Again there are two specifications with a different number of explanatory variables at the bottom level. The results are also similar. Therefore, we are going describe the first specification only.

We use the age of the consumers, the household size, and three dummy variables on educational level to explain the choice of having internet access at all. Similar to the three-layer model, our estimates suggest that older consumers tend not to have internet access and consumers who live in larger households are more likely to have it. The higher the educational level of the consumers the more likely it becomes that they will choose to have internet access. At the bottom level, the independent variables are price, the download rate, the download volume and a dummy indicating the flat rates. The estimated coefficient of price has the expected negative sign and it is highly significant. The download rate and the download volume both have positive signs as expected and they are significantly different

from zero at better than one percent level. The coefficient on the flat dummy is again negative and significant (see explanation above).

The McFadden R2 for this two-layer model is equal to 0.37. This figure is lower than the McFadden R2 of the three-layer model. The values of AIC and BIC for the two-layer model are 0.416 and 0.426, respectively. Since the McFadden R2 is higher in the three-layer model we are inclined to put greater weight on the implied elasticities derived from it. Also similar to the three-layer model is the inclusive value parameter estimated for the option ‘no internet’ (see the bottom part of the table) which is substantially outside of the unit interval (4.28) suggesting similar consistency problems of the model with the rational choice behaviour of consumers. The implied elasticities from the two-layer model are presented in Table 8 (see Appendix). The first thing we note from this table is that all own price elasticities of internet access demand are uniformly lower than those implied by the three-layer model. The elasticity of DSL services is highest with -1.04. The corresponding figures for mobile and cable services are -0.99 and -0.91, respectively. The lowest elasticity is estimated for narrowband services, which is equal to 0.69. While the elasticities for DSL, cable and mobile are around unity, the demand for narrowband services is estimated to be inelastic.

5.2. Aera 2: DSL and narrowband

As it was mentioned earlier cable networks and mobile broadband is not available in all regions. Mobile broadband via HSDPA is available in cities with more than 5000 inhabitants where in most cases also cable networks exist. In this section we consider only those observations where these two alternatives are not in the choice set of consumers.

For this sample we estimate a two-layer nested logit model where the consumers decide first whether they would like to have internet access or not. At the bottom level, the consumers are then faced with the choice between DSL and narrowband access. We again use the age of the consumers, the household size, and three dummy variables on educational to explain

the choice of having internet access at all. However, for this model we interact these variables with the 'no internet' dummy variable and therefore the sign of the coefficients has to be interpreted differently to the previous estimates, where we interacted with the 'internet' or the 'broadband' dummy variable.

The coefficients on the individual specific variables are significant and have the expected sign (see Table 9 in the Appendix). Also the size of the coefficients for the educational dummy variables are as expected, with 'compulsory school' having the largest coefficient and 'highschool with graduation' the smallest.

At the bottom level, the independent variables are price, the download rate, the download volume and two dummy variables indicating the choices for 'no internet' and for narrowband. The estimated coefficient of price is negatively significant though its magnitude is substantially lower than in the two- and three-layer specifications reported for the full sample. Both the download rate and download volume take on positive coefficients which are of comparable size to earlier estimation results and they are significantly different from zero at conventional levels. The dummy for 'no internet' has a very large coefficient it is however not significant. The dummy variable for narrowband is positive significant. In this sample we use 3,486 observations. Similar to the models above, here we encounter again the problem of having at least one inclusive value parameter to be outside the unit interval. The inclusive value for the option 'no internet' is very large (10.99) and significant. The McFadden R² shows that the model performs reasonably well with a value of 0.45 which is the highest R² observed in all of our estimation results.

Turning now to the elasticities implied by this sample (see Table 10 in the Appendix), we note that the own price elasticity of demand for DSL is equal to -1.14 and for narrowband to -1.37. While the coefficient on narrowband is roughly the same as for the three-level model (see Table 6 in the Appendix), the elasticity of DSL is much lower. DSL therefore appears to

be constrained mainly by cable (and possibly mobile) but to a much smaller extent by narrowband.

6. Market definition

Section 5 has derived a (preliminary) estimate of the retail demand elasticity for DSL services. However, what NRAs need in order to define the market for wholesale broadband access is the elasticity of demand at the wholesale level. As demand for inputs at the wholesale level is derived from demand at the retail level, the elasticity of demand at the wholesale level will be related to the elasticity of demand at the retail level.²²

The relationship between wholesale and retail demand elasticity has first been investigated by Alfred Marshall (1920) and has later been formalised by John R. Hicks (1963) in the context of labour economics. The Marshall-Hicks formula for the elasticity of derived demand is:²³

$$(11) \quad \varepsilon_W = c\varepsilon_R - (1-c)\sigma$$

where ε_W is the (derived) elasticity of demand for the wholesale input, ε_R is the elasticity of demand for the final good, c is the share of the costs of the wholesale input in total costs, and σ is the elasticity of substitution between the respective input and another input. The underlying assumptions are a constant returns to scale production function, competitive supply (at the wholesale as well as at the retail level), and a fixed price of the other factor.²⁴

If there is no other wholesale input available, $\sigma=0$ and (11) simplifies to $\varepsilon_W = c \varepsilon_R$. The wholesale elasticity therefore can simply be calculated by multiplying the retail elasticity with

²² For a discussion on the relation between wholesale and retail demand see also Schwarz (2007).

²³ A derivation can be found e.g. in Ewerhart (2003)

²⁴ Furthermore, for (1) to hold, σ must be larger than ε_R

the share of wholesale costs in total costs. This share can be estimated to be 0.7-0.8 in the case of bitstream products in Austria.²⁵

The wholesale elasticity than has to be compared to the critical elasticity, i.e., the elasticity above which a 5-10% price increase would not be profitable. In case of linear demand, the critical elasticity can be calculated as follows:

$$(12) \quad \epsilon_k = \frac{1}{m+t},$$

where m is the price cost margin $m = \frac{P_0 - c}{P_0}$ and t the percentage price increase

$$t = \frac{P_1 - P_0}{P_0} \quad .^{26}$$

As the provision of wholesale broadband access services involves a high share of fixed costs, the price cost margin is quite high; a rough estimation is around 60-80%.²⁷ This would result into an interval of the critical elasticity of -1,11 to -1,53. As our estimates are still preliminary it is too early to derive a firm conclusion for market definition. However, the current estimates suggest that DSL does not form a separate market neither at the retail nor at the wholesale level. The wholesale elasticity would be between -2.08 and -2.38 (-2.96 multiplied by 0.8 and 0.7 respectively) which would be clearly beyond the range of the critical elasticity. This means that the next best substitute would have to be include into the relevant market. We cannot do it based on the estimates of cross-price elasticities as they are not yet meaningful. However, taking into account similarities between tariffs and product characteristics as well as current penetration, it seem plausible to assume that cable exerts the highest competitive constraint on DSL and therefore would have to be included in the market.

²⁵ This estimate is based on data available from operators.

²⁶ See Church/Ware (2000), p. 609.

²⁷ This estimate is based on data available from operators.

7. Conclusion

Our preliminary results indicate that demand for broadband internet access services is rather elastic ($|\epsilon| > 2$ for DSL, cable and mobile) in those areas where several types of broadband access are available. This would indicate that different broadband access technologies constrain each other and that DSL and cable probably form a single market at the retail as well as at the wholesale level. The elasticity of narrowband is lower (-1.19) which may indicate that those users which are still using narrowband do not perceive broadband as an equally good substitute. In areas where only DSL and narrowband are available, the DSL elasticity is much lower (-1.15) which suggests that the constraint from narrowband on DSL is limited.

However, the estimation results are not yet consistent with utility maximization, which is indicated by inclusive value parameters outside the unit interval. We are currently working on a specification according to Heiss (2002) to solve this problem. Once the problem is solved we will also perform a number of robustness checks and further model specification tests.

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Appendix A: Tables

Table 5: Results for the three layer nested logit model – all four alternatives available		
	Specification 1	Specification 2
Choice of product (bottom level)		
Price	-0.0838 (-9.94) ^{***}	-0.0416 (-7.08) ^{***}
Download rate	0.0011 (15.92) ^{***}	0.0009 (13.65) ^{***}
Download volume	0.0001 (10.75) ^{***}	0.0001 (8.58) ^{***}
Dummy variable for flat tariffs	-5.6844 (-10.43) ^{***}	-5.3202 (-8.31) ^{***}
Dummy variable for cable	0.9218 (6.66) ^{***}	
Dummy variable for DSL	1.0322 (7.42) ^{***}	
Type of product		
Age (interacted with broadband dummy)	-0.0278 (-9.76) ^{***}	-0.0301 (-10.37) ^{***}
Educational dummy variables interacted with broadband dummy (reference: University degree)		
Compulsary school	-0.1891 (-1.08)	-0.2757 (-1.59)
Highschool without graduation	-0.4477 (-2.47) [*]	-0.5274 (-2.92) ^{**}
Highschool with graduation	-0.5931 (-3.51) ^{***}	-0.6817 (-4.07) ^{***}
Internet: yes/no		
Household size (interacted with internet dummy)	0.4053 (7.43) ^{***}	0.364 (6.80) ^{***}
Educational dummy variables interacted with internet dummy (reference: University degree)		
Compulsary school	-2.0721 (-4.54) ^{***}	-2.0536 (-4.49) ^{***}
Highschool without graduation	-0.6054 (-1.33)	-0.6309 (-1.38)
Highschool with graduation	-0.187 (-0.44)	-0.1886 (-0.45)
Inclusive values		
Narrowband	0.4953 (6.83) ^{***}	1.0124 (5.55) ^{***}
Broadband	1.4037 (9.15) ^{***}	1.3528 (9.32) ^{***}
Internet	4.3917 (10.42) ^{***}	4.2653 (10.58) ^{***}
Number of observations	9075	9075
McFadden R-squared	0.4099	0.3989

Table 6: Elasticities implied by the three-layer nested logit model – all four alternatives available (Specification 1)

	Own price elasticity	Cross Price elasticity
cable	-2.218	-3.251
DSL	-2.967	-2.745
mobile	-2.425	-1.101
Narrowband	-1.186	-2.774

Table 7: Results for the two layer nested logit model – all four alternatives available		
	Specification 1	Specification 2
Choice of product (bottom level)		
Price	-0.0317 (-5.73) ^{***}	-0.0331 (-6.28) ^{***}
Download rate	0.0006 (11.41) ^{***}	0.0006 (11.43) ^{***}
Download volume	0.0001 (6.43) ^{***}	0.0001 (6.72) ^{***}
Dummy variable for flat tariffs	-3.8576 (-6.04) ^{***}	-3.7703 (-6.25) ^{***}
Dummy variable for cable	-0.064 (-0.67)	
Dummy variable for DSL	-0.0639 (-0.71)	
Internet: yes/no		
Household size (interacted with internet dummy)	0.3233 (6.29) ^{***}	0.3238 (6.31) ^{***}
Educational dummy variables interacted with internet dummy (reference: University degree)		
Compulsary school	-2.673 (-11.31) ^{***}	-2.6708 (-11.30) ^{***}
Highschool without graduation	-1.8233 (-7.13) ^{***}	-1.8218 (-7.13) ^{***}
Highschool with graduation	-1.6434 (-6.45) ^{***}	-1.6436 (-6.46) ^{***}
Inclusive values		
Internet	4.2795 (10.49) ^{***}	4.2891 (10.51) ^{***}
Number of observations	9075	9075
McFadden R squared	0.3574	0.3573

Table 8: Elasticities implied by the two-layer nested logit model – all four alternatives available (Specification 1)

	Own price elasticity	Cross Price elasticity
cable	-0.914	0.309
DSL	-1.039	-0.0004
mobile	-0.987	-0.147
Narrowband	-0.687	-0.071

Table 9: Results for the two layer nested logit model – cable, mobile not available	
Choice of product (bottom level)	
Price	-0.0252 (-4.60)***
Download rate	0.0007 (6.23)***
Download volume	0.0002 (2.28)*
Dummy variable for no internet	7.9325 (0.07)
Dummy variable for narrowband	0.7866 (5.16)***
Internet: yes/no	
Age (interacted with no internet)	0.0324 (5.13)***
Household size (interacted with no internet)	-0.4854 (-7.73)***
Educational dummy variables interacted with no internet (reference: University degree)	
Compulsary school	2.5407 (5.51)***
Highschool without graduation	1.7925 (3.77)***
Highschool with graduation	1.1726 (2.34)*
Inclusive values	
No internet	0.9854 -0.07
Internet	10.9938 (5.52)***
Number of observations	3486
McFadden R squared	0.4521

Table 10: Elasticities implied by the two-layer nested logit model – cable, mobile not available

	Own price elasticity	Cross Price elasticity
DSL	-1.147	-0.330
Narrowband	-1.374	-0.895

Appendix B: Derivation of elasticities

Let us define the own price elasticity to be $\mu(jj)$. It is equal to $\mu(jj) = \partial P(j|lm) / \partial X(j|lm) \times X(j|lm) / P(j|lm)$ with $P(j|lm)$ the probability of choice j and $X(j|lm)$ the price of that choice. We index the first layer alternatives as m and m' , the second layer alternatives as l and l' , and the third layer alternatives as j and j' . For simplicity, we suppress the consumer-specific index i .

The probability $P(j|lm)$ is equal to $P(j|lm) = P(m) \times P(l|m) \times P(j|lm)$. Its derivative with respect to $X(j|lm)$ is equal to

$$\begin{aligned} \partial P(j|lm) / \partial X(j|lm) &= \partial P(m) / \partial X(j|lm) \times P(l|m) \times P(j|lm) \\ &+ P(m) \times \partial P(l|m) / \partial X(j|lm) \times P(j|lm) \\ &+ P(m) \times P(l|m) \times \partial P(j|lm) / \partial X(j|lm) \end{aligned}$$

The probability $P(j|lm)$ is equal to $P(j|lm) = \exp[V(j|lm)] / \sum \exp[V(j'|lm)]$. The summation in the denominator runs over j' .

The probability $P(l|m)$ is equal to $P(l|m) = \exp[V(lm) + \lambda(lm) IV(lm)] / \sum \exp[V(l'm) + \lambda(l'm) IV(l'm)]$ with the inclusive value $IV(lm) = \ln\{\sum \exp[V(j'|lm)]\}$. The summation in the denominator of $P(l|m)$ runs over l' and the summation in the inclusive value $IV(lm)$ runs over j' .

The probability $P(m)$ is equal to $P(m) = \exp[V(m) + \lambda(m) IV(m)] / \sum \exp[V(m') + \lambda(m') IV(m')]$ with the inclusive value $IV(m) = \ln\{\sum \exp[V(l'm) + \lambda(l'm) IV(l'm)]\}$. The summation in the denominator of $P(m)$ runs over m' and the summation in the inclusive value $IV(m)$ runs over l' .

The derivative of $P(j|lm)$ with respect to $X(j|lm)$ is equal to

$$\partial P(j|lm) / \partial X(j|lm) = \partial V(j|lm) / \partial X(j|lm) \times P(j|lm) \times [1 - P(j|lm)]$$

The derivative of $P(l|m)$ with respect to $X(j|l|m)$ is equal to

$$\partial P(l|m) / \partial X(j|l|m) = \partial V(j|l|m) / \partial X(j|l|m) \times P(l|m) \times [1 - P(l|m)] \times \lambda(l|m) \times P(j|l|m)$$

The derivative of $P(m)$ with respect to $X(j|l|m)$ is equal to

$$\partial P(m) / \partial X(j|l|m) = \partial V(j|l|m) / \partial X(j|l|m) \times P(m) \times [1 - P(m)] \times \lambda(m) \times P(l|m) \times \lambda(l|m) \times P(j|l|m)$$

The own price elasticity is then equal to

$$\begin{aligned} \mu(j,j) = \partial V(j|l|m) / \partial X(j|l|m) \times X(j|l|m) \{ [1 - P(m)] \lambda(m) P(l|m) \times \lambda(l|m) \times P(j|l|m) \\ + [1 - P(l|m)] \times \lambda(l|m) \times P(j|l|m) + [1 - P(j|l|m)] \} \end{aligned}$$

Let us define the cross price elasticity to be $\mu(j',j)$. It is equal to $\mu(j',j) = \partial P(j'|l|m) / \partial X(j|l|m) \times X(j|l|m) / P(j'|l|m)$ with $P(j'|l|m)$ the probability of choice j' and $X(j.l.m)$ the price of an alternative choice.

The probability $P(j'|l|m)$ is equal to $P(j'|l|m) = P(m) \times P(l|m) \times P(j'|l|m)$. Its derivative with respect to $X(j.l.m)$ is equal to

$$\begin{aligned} \partial P(j'|l|m) / \partial X(j|l|m) = \partial P(m) / \partial X(j|l|m) \times P(l|m) \times P(j'|l|m) \\ + P(m) \times \partial P(l|m) / \partial X(j|l|m) \times P(j'|l|m) \\ + P(m) \times P(l|m) \times \partial P(j'|l|m) / \partial X(j|l|m) \end{aligned}$$

The derivative of $P(j'|l|m)$ with respect to $X(j|l|m)$ is equal to

$$\partial P(j'|l|m) / \partial X(j|l|m) = \partial V(j|l|m) / \partial X(j|l|m) \times P(j|l|m) \times P(j'|l|m)$$

The cross price elasticity is then equal to

$$\mu(j'.j) = \partial V(j|lm) / \partial X(j|lm) \times X(j|lm) \{ [1 - P(m)] \lambda(m) P(l|m) \times \lambda(lm) \times P(j|lm) + [1 - P(l|m)] \times \lambda(lm) \times P(j|lm) + P(j|lm) \}$$