Cost and Benefits from Infrastructure Competition.

Estimating Welfare Effects from Broadband Access Competition

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Abstract

Infrastructure versus service competition is one of the key question in infrastructure industries. Regulators face the question whether to promote competition on the basis of a single infrastructure with regulated infrastructure access (service competition) or the build-up of competing, parallel infrastructures. Infrastructure competition itself incorporates conflicting welfare effects. The gain from reduced deadweight loss due to higher competition might be outweighed by the inefficient duplication of an existing infrastructure. While this is theoretically well understood this paper investigates which effect prevails empirically using data from broadband internet access for Western Europe 2000-2004. We find that infrastructure competition between DSL and cable TV had a significant but relatively weak impact on the broadband penetration. Service competition has had no significant effect. Confronting the resulting estimate for the additional consumer surplus with the investment of cable companies into broadband we conclude that infrastructure competition has not been welfare enhancing.

Keywords: Infrastructure Competition, Service Competition, Broadband, Internet, Cable TV, DSL.

JEL-Classification: L51, L86, L96, L12, K23.

1. Introduction

Infrastructure versus service competition is one of the key question in infrastructure industries. Regulators face the question whether to promote competition on the basis of a single infrastructure with regulated infrastructure access (service competition) or to promote the build-up of competing, parallel infrastructures. Although there exists a basic trade-off between these two objectives (see e.g. [Bourreau and Dogan 2003], [Bourreau and Dogan 2004], [Foros 2004]), most telecommunications regulators try to provide a framework enabling both forms of competition. The UK regulator OFTEL stated: "By achieving the right level of regulation ..., both network and service competition can develop."[Oftel 2002]

Furthermore, network competition itself incorporates opposing welfare effects. The gain from reduced deadweight loss due to higher competition might be outweighed by the inefficient duplication of an existing infrastructure. This is theoretically well understood (see e.g. [Laffont and Tirole 2000, p. 127-128]). What is far less clear is which effect prevails empirically. In this paper we try to contribute to closing this gap with an empirical investigation into the uptake of broadband internet access. We find that infrastructure competition has a significant but relatively weak effect on the broadband penetration. In Western Europe[1]- ceteris paribus - penetration would have been at maximum 20% lower without competition from broadband cable. Using pricing data from the retail market we estimate the maximum additional consumer and producer surplus from competition. Confronting this with the investment of cable companies into broadband we conclude that cable competition has not been welfare enhancing.

Broadband access is a good example for the general question concerning the pros & cons of infrastructure competition. Technologically, broadband access is usually realized using one of two underlying infrastructures: DSL (digital subscriber line) uses the PSTN (public switched telephone network), cable modem uses the cable TV infrastructure. Significant network upgrade is required in both cases. However, while PSTN covers all households only a fraction is passed by cable TV limiting the extent to which infrastructure competition is possible. A brief comparison of the US and Western Europe suggest the basic intuition. The percentage of homes passed by cable TV is far higher in the US therefore the market share of cable in the broadband market is higher leading eventually to higher broadband penetration levels (see figure 1).

[1] Western Europe in the following comprises the European Union excluding Greece but including Norway and Switzerland. (There are virtually no broadband subscribers in Greece (according to the EU-Commission only 10.000 in January 2004)).

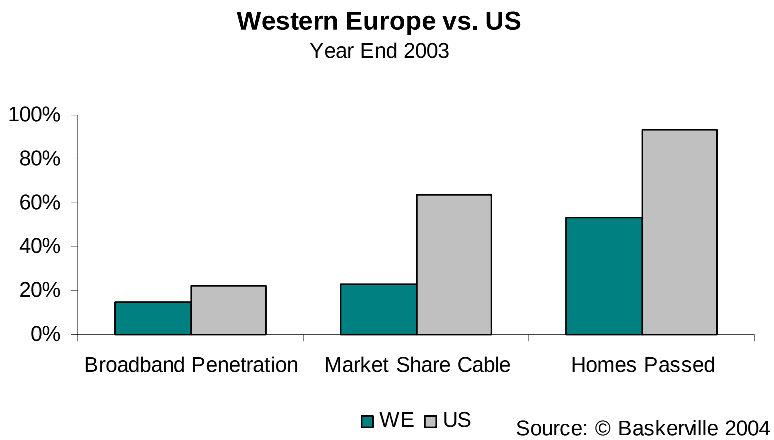

Figure 1.1: Cable Competition in the US and Western Europe

We investigate this intuition in first formalizing it theoretically and then using the heterogeneity within Western Europe with respect to cable competition as well as other explanatory variables to focus on the empirical question. We propose two alternative theoretical settings. The first is a simple asymmetric entry model where either one or two companies can enter a market with a sunk investment in infrastructure. While the first one faces no capacity constraint (the PSTN operator) the second faces an exogenously given capacity constraint (the percentage of homes passed by cable TV). The higher the capacity constraint the higher the market share will be and the more intense competition. The model predicts a clear positive correlation between the capacity constraint and the equilibrium quantity (the cable penetration) up to the maximum degree of competition (50% market share for each technology). Entry of the second firm will be socially beneficial (and profitable for the cable company) if the sunk cost of entry sufficiently small. The second model is slightly more tailored to the broadband industry by taking into account that network build up cost for both technologies are far lower in cities compared to rural areas. Thus we assume that both firms enter regional markets along a (Hotelling) line and compete in Cournot style in the second stage within each market. In line with observations from broadband markets we assume a uniform price across all regions. This model leads to an ambiguous prediction on the relation between competition and broadband penetration. A new region will be covered only if the second stage profit in this market is sufficiently large. Thus, low competition will lead to more regions being served while competition results in lower prices and higher quantities in each market covered but with less regions served. The overall effect on the household penetration is not clear.

We confront the theoretical discussions with empirical evidence from Western Europe for the period 2000-2004. We consider a list of additional explanatory variables (as PC penetration, GDP, population density and other) and run a pooled regression on the data panel. We find that cable competition has the predicted inverted U-shaped effect on the penetration with broadband access peaking at

50% market share of cable. However, the coefficients - being highly significant - are relatively small. We evaluate lower consumer surplus according to the lower penetration estimated, evaluated at the current retail prices and deduct estimates for the upgrade investments. Though no definite evaluation of the overall welfare effect can be give (as we can give only ranges for the estimates of relevant cable investment with respect to common cost problems and uncertain lifetime of the equipment), it seems most likely that the welfare effect was at most neutral if not negative.

There exists an extensive literature on network and service competition in particular for telecommunications and for the adoption of broadband services. Most closely related in terms of the theoretical question is [Bourreau and Dogan 2003]. They investigate the incentives a regulator sets with unbundling obligations for the local loop for the timing of entry and the entrants decision to use the unbundled local loop or to build up own infrastructure. Their theoretical model highlights that an unregulated incumbent has an incentive to delay the adoption of a alternative (i.e. cable) infrastructure which can be welfare decreasing if the alternative is quality improving. Similar theoretical questions are addressed in [Bourreau and Dogan 2004] and [Foros 2004]. The related question on the geographical coverage of competing network roll-outs has been addressed in [Faulhaber and Hogendorn 2000] and [Foros and Kind 2003]. We add to this literature the empirical focus on the overall welfare effects including the investments in the alternative infrastructure. Related in terms of empirical research are attempts to explain different uptakes of internet penetration and the so called "digital divide" [Chinn and Fairlie 2004].

Broadband access is not only an interesting test case for the general question of network versus service competition. It is also of high political relevance. In their eEurope program the European Union is highly committed to increase broadband penetration [EU 2002], [EU Council 2002]. Apart from the more fundamental economic question, whether this goal makes sense per se, the question arises, by which means this goal is best achieved. While many EU members have chosen (demand or supply) subsidies to boost broadband penetration, competition policy is also discussed and for instance advocated by the OECD as the instrument of choice [OECD 2003]. The EU actively supports service competition with the recent introduction of regulated wholesale obligations for DSL [EU 2003 (2)]. At the same time the EU commission has always recommended a separation of ownership between cable and PSTN with arguments based on positive effects from network competition. Although not the focus of this paper, the empirical results can also contribute to this discussion. The data suggest that so far service competition has been less effective than network competition. Countries with more intense service competition do not exhibit significantly higher penetration rates.

The remainder of the paper is organized as follows. Section 2 explains in more detail the broadband market. Section 3 discusses the policy issues of the sector. Section 4 proposes the theoretical models and their predictions to be tested. In section 5 we discuss the data. Section 6 contains the model estimated and the estimation results and discusses the results. Section 7 concludes in discussing the policy implications.

2. Broadband Industry

Technology Broadband describes an internet access with a relatively high transmission rate. At a minimum, broadband must exceed the standard ISDN data transmission rate of 128 kbps. We will focus - similar to the OECD [EU 2004 (1), p.6] - on products with more than 250 kbps. As most of the mass market products are not in excess of 1.000 kbps (1 mbps), in the following broadband means roughly transmission rates between 0,5 and 1 mbps.

The two main access technologies in Europe as well an in the US are digital subscriber line (DSL) and cable modem (cable). DSL is based on the PSTN network. Several upgrades are required: at the customer premise a splitter (to split the data traffic from the voice traffic) and a DSL modem, and several upgrades in the public network (in particular to reinforce signals depending on the distance to the next local exchange). The typical mass market product is ADSL (asynchronous DSL). Aligned with typical consumer preferences, download speed is much higher than upload (e.g. 512 kbps download, 128 kbps download).

Alternatively, the infrastructure of cable TV can be used. As cable TV infrastructure has been build originally for broadcasting only it is in a "tree" structure and only "one-way". Upgrading also requires cable modems at the customer premise as well as (i) digitalization of the network (ii) introducing a back-channel, which is the main cost driver (iii) reducing the homes per segment to ensure bandwidth (iv) backbone upgrades (see e.g. [Ovum 2003]). There exist also other technological solutions which might play a role in the far future but are of no relevance now. These are satellite (e.g. with PSTN as upload channel), and wireless broadband access (fixed-wireless access, WiFi, WiMax, UMTS). [2] By the beginning of 2004, these technologies accounted for less than 5% of all broadband access in the European Union [EU 2004 (2), p.55].

[2] All these technologies are immature at the end of 2004. WiFi is a shared bandwith medium and suffers from the fact that the bandwith decreases with each customer locked into the same hot spot, thus bandwith is hard to guarantee. WiMAX is still immature in technological terms. UMTS does typically not offer download capacities in excess of 500 kbps, and like WiFi availability decreases with the number of user in the same radio cell.

The most expensive part of providing a broadband access in both cases is to physically lay the cable (construction work). These cost are usually prohibitively high (except where new housing areas are developed) just for broadband access and either a whole region is covered with the physical network or no household at all. This implies a basic asymmetry between both technologies. All households are connected to the PSTN and therefore (after the necessary network upgrade) in principle eligible for DSL, only so called "cable homes passed" can be supplied with a cable broadband access (again after network upgrades). Homes passed just means all homes which can be connected to the existing network without new construction work. The proportion of homes passed and therefore the potential for competition varies widely in Europe, as depicted in figure 2.

Market Structure In all countries the incumbent telecommunications operator offers DSL and has a dominant retail market position. Some important DSL markets (UK, Netherlands, France) exhibit a significant wholesale market leading to lower (40-50%) market shares of the incumbents in the DSL retail market. Figure 3 provides an overview of the importance of current cable competition and the broadband penetration across Western Europe. In some countries the telecommunications incumbent used to own the cable infrastructure (Germany, Sweden, in both countries the incumbent sold its cable TV business in 2003). In

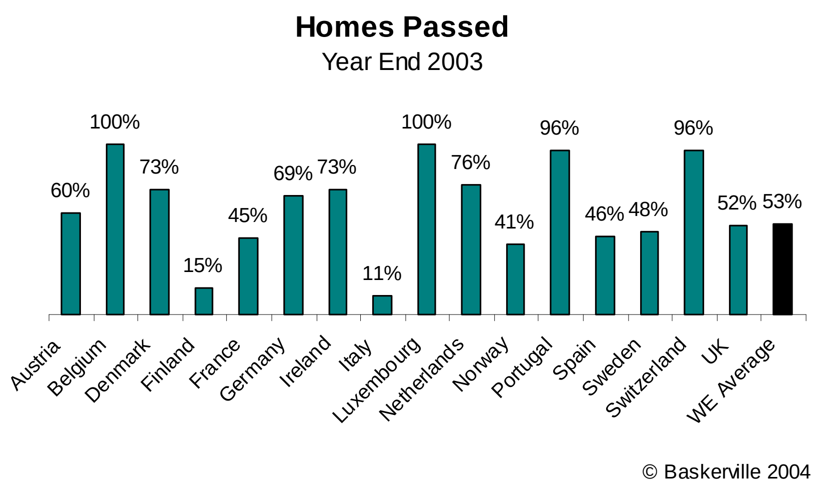

Figure 2.1: Cable Homes Passed in Western Europe

Portugal and Norway the incumbent's cable TV subsidiary still holds a dominant position in the cable TV market (market share > 80% in 1Q2004).

Financial Crisis Nearly all cable companies went through a phase of financial stress 2002/2003. All companies had invested heavily in the 2000 internet bubble following a "build and they will come" approach. With financial markets becoming reluctant to support high risk investments, the largest two European cable operators (NTL and UPC), accounting for almost half of all subscribers in Western Europe, had to file for bankruptcy in 2002. Other large operators like Telewest (UK) or ONO (Spain) went through considerable financial restructuring, involving significant debt-for-equity swaps and equity injections by shareholders.

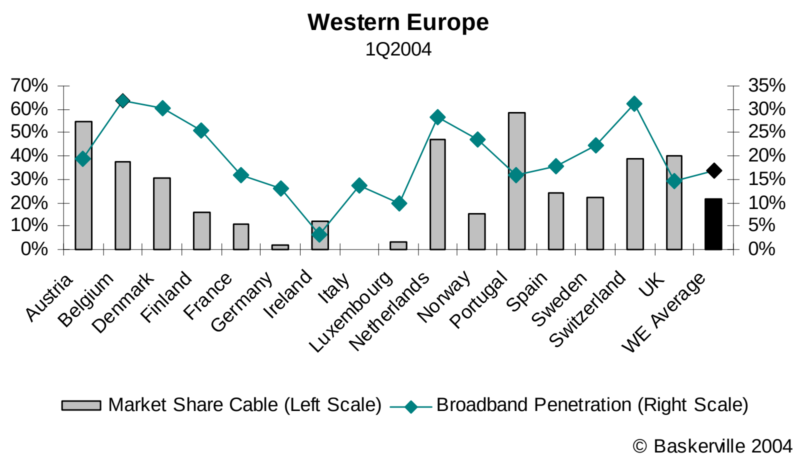

Figure 2.2: Cable Market Share and Broadband Penetration

Reemerging form Chapter 11 bankruptcy proceedings or financial restructuring, investments have been reduced significantly in 2003 and growth strategies been replaced by more short-term cash generating focus.

3. Policy Issues

There exists a widespread common understanding in the political arena that broadband internet access should be politically supported. In its program "eEurope 2005" the EU-commission stated the ambitious goal that by 2005 half of all internet access lines should be broadband.[3] The EU initiated the development of broadband strategies to achieve this goal in all member countries. Germany for instance has set as an objective to reach more than 20 million broadband subscribers by 2010 [Germany, Federal Government 2004] - almost five times the number at the end of 2004.

Views differ significantly how these targets can be met. The OECD clearly favors competition over subsidization of demand and supply [OECD 2004 (1)] without specifying whether this means infrastructure of service competition. The EU-Commission gives scope for subsidies as well as for promotion of competition. Most member countries' initiatives focus on subsidization of either demand (e.g. Austria with tax-deductible broadband expenditures [EU 2004 (2), p. 29]), or supply (Italy plans to support the incumbent operator by upgrading its network with up to 270 million € [Börsenzeitung 2004]).

The EU has also tried to increase service competition with unbundled local loop access which has been of limited success [EU 2004 (1)]. Thus, new initiatives try to reinforce service competition based on wholesale models requiring lower

[3] Reaffirmed by the European Counsil [EU Council 2002]. However, already by the end of 2002 and in the light of the financial crisis of the industry, Errki Liikanen the responsible EU-Commissioner in charge stated: " The EU recognises the importance of exploiting the broadband potential, although the financial problems of the sector are making the 2005-objectives more difficult to achieve" [Liikanen 2002].

investments from competitors compared to solutions realized via unbundled local loop. The EU has identified wholesale DSL as a market which should be ex ante regulated [EU 2003 (1)]. So called BSA (bit stream access, a certain technological realization of DSL wholesale products) has been further specified by the European Regulators Group as a regulated wholesale product [ERG 2004]. However, no overall strategy quantifying the effects from competition, either infrastructure or service, nor subsidization on the broadband penetration does exist yet.

4. Some simple theoretical ideas

The basic intuition to be investigated which is very popular among industry experts (see e.g. [Neumann 2003]) is depicted in Figure 4 which provides a cross-country comparison of the market share of the cable industry (in terms of subscribers) versus the national household penetration with broadband access lines.

It suggests a inverted U-shaped relation. If the market share of cable is very low, competitive pressure on the incumbent with its DSL product is low, prices high, resulting in a low penetration. Vice versa for a dominant cable industry. Striking as this reasoning might be it is not easily formulated in a theoretical model as market shares and competitive pressure are not exogenous (as suggested in the simple picture) but endogenous. Although our focus is on the empirical

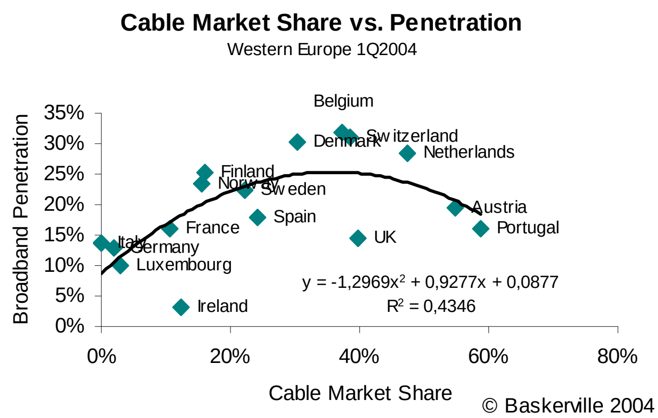

Figure 4.1: An inverted u-shaped relationship?

side, we formulate simple theoretical models to formalize the reasoning of figure 4 and in order to highlight some important aspects.

4.1. A simple duopoly example with an exogenous capacity constraint for one firm

Two firms can serve a market by choosing in the first stage a capacity q_i and competing in prices in stage 2. Firm 1, can choose any capacity level. Firm 2 faces an exogenous maximum capacity constraint $\overline{q_2}$ which we can interpret as the "homes passed" by the cable TV infrastructure. For simplicity we assume (i) equal and constant marginal cost of capacity $c_1 = c_2 = c$ for both companies and zero marginal cost of providing the service in stage 2;[4] (ii) linear demand $D(p) = 1 - p$ and (iii) $\overline{q_2} \leq 1/3$. Given the linear demand specification the last assumption rules out the uninteresting cases in which the exogenous capacity constraint would not be binding.

Lemma 1. *A subgame perfect Nash equilibrium of the simple game with capacity constraint $\overline{q_2} \leq 1/3$ and linear demand has both firms entering the market and Firm 2 choosing $q_2^* = \overline{q_2}$ and Firm 1 choosing $q_1^* = (1 - \overline{q_2})/2$, $p_1 = p_2 = p^* = (1 - \overline{q_2})/2$, for capacity cost sufficiently low ($c \leq 1/2(1 - \overline{q_2})$). Inefficient market entry can happen.*

Proof. *See Appendix.* ■

This simple example has the following further characteristics in line with the initial intuition. (i) The market quantity $Q^* = q_1^* + q_2^*$ is strictly increasing in $\overline{q_2}$. (ii) The market share s_2 of firm 2 is strictly increasing from the monopoly situation (with $\overline{q_2} = 0$ and $s_2 = 0$) up to the symmetric Cournot outcome (with $\overline{q_2} = 1/3$ and $s_2 = 1/2$). (iii) If entry cost c are very large, only one firm can enter the market. If entry cost c are very small, both firms enter and the outcome

[4] This reflects relatively well the situation of broadband access. In a given geography connecting a household has the same cost for each household. Using an existing infrastructure (i.e. serving the internet) causes zero cost.

is welfare superior compared to a monopoly. For intermediate values of c entry occurs but is welfare decreasing.

Transferring the simple example into the broadband industry the prediction is that with an increasing market share of the competing technology the broadband penetration should unambiguously be increasing (up to the maximum competition level of equal market shares).

4.2. A simple model with ordered market entry

The costs for upgrading an existing network depend upon geographical parameters, in particular upon the population density. The less densely populated the more expensive it is to connect a single household. This is true for cable as well as for DSL. We want to introduce this important stylized fact in the following model.

There is a large number of regional markets which can be ordered according to a parameter d closely related to the cost of covering this region with broadband, i.e. with being able to offer the service to all households in this region (e.g. population density). Each market has the identical demand function for broadband services $D_d(p_d)$. We consider again a two stage game in which both firms first decide which markets to enter (choose $d_i, i = 1, 2,$). In the second stage we assume Cournot competition in each market, where providing an internet access in a region covered has constant marginal cost of $c_1 = c_2 = c$. The number of regions is large and we approximate the setting with a continuum of identical markets along a line of length 1, i.e. $d_i \in (0, 1)$. We look for a subgame perfect equilibrium of this game.

We assume ordered market entry, i.e. serving a more "remote" market is possible only if all "more central" markets have been covered already. This ordered market entry might be due to the fact that the network upgrades has to start from the center (cities) and expands into more remote parts and cannot "jump".[5]

Assumption 1 (Ordered market entry): A firm can serve market $\widehat{d}$ only if it covers also all markets $d < \widehat{d}$.

Price discrimination between regions is in principle attractive for the companies. However, in practice regional price differentiation does not play a significant role in any of the existing markets so far, even though no regulatory universal service obligation forces companies to charge the same price throughout a country.[6] One reason might be that communicating different prices in a dynamically growing mass market for a homogenous service is very difficult.

[5] Alternatively, we could impose restrictions on the cost of covering a region. If this cost is sufficiently convex in d, profit maximizing behavior would endogenize the ordered market entry. However, this would only add additional less interesting complexity into the discussion.

[6] At least for the OECD. "In virtually all cases incumbent operators have uniform prices across the country". [OECD 2004 (2), p.13]

Assumption 3 (Uniform price): The price p must be the same in all regions.

We are interested in the most simple case in which one firm is more efficient than the other in serving any of the regions. To ensure unique pure strategy equilibria in the Cournot game we assume $D'' \leq 0$.

Assumption 2 (Entry Cost and Demand): Entry is costly and convex in d and asymmetric. $C_1(0) = C_2(0) = 0$ and $0 < C_1' < C_2'$ and $C_1'', C_2'' > 0$. $D(p)'' \leq 0$

The total quantity Q can be calculated easily. Without loss of generality assume $d_1 > d_2$. As in equilibrium quantities $q^*$are the same in all markets which are covered, we have:

$$Q = q^* * d_1 \tag{4.1}$$

Figure 5 shows the market situation in which both firms entered.

Market quantity is equal to $\overline{0\ d_1\ B\ q(p)}$. Firms 1 and 2 compete in all markets between 0 and d_2, while markets between d_1 and d_2 are served by firm 1 only. Note that the uniform pricing assumption implies that the quantity $\widehat{q_1}$ offered by firm 2 in its "monopoly" segment between d_1 and d_2 is just the sum of the two Cournot quantities $q_1 + q_2$ of both firms in the competitive segment between 0

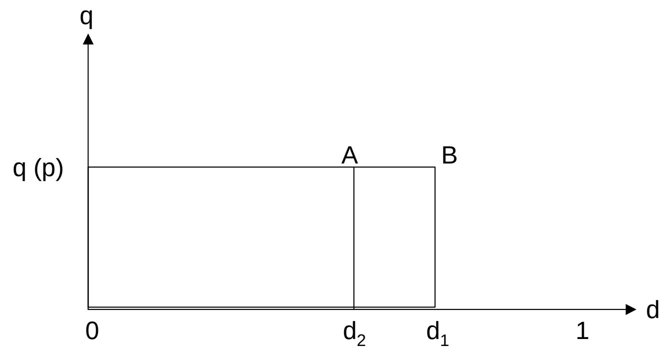

Figure 4.2: Both firms entered the market

and d_2. In the second stage firm 1 thus maximizes its second stage profit π_1 given d_1 and d_2:

$$\pi_1 = [d_1 q_1 + (d_1 - d_2)(q_1 + q_2)]\,(p - c) \rightarrow \max_{q_1} \tag{4.2}$$

Firm 2 maximizes in stage two:

$$\pi_2 = d_2 q_2 (p - c) \rightarrow \max_{q_2} \tag{4.3}$$

Overall profits are given by:

$$\Pi_i(d_i, q_i) = d_i \pi_i - C_i(d_i) \tag{4.4}$$

Thus, each firm covers markets as long as entry cost do not exceed the second stage profit π_i of an additional region.

$$C_i'(d_i) = \pi_i(d) \tag{4.5}$$

Social welfare is given by:

$$W^D = \int_0^{q_1+q_2} p(q_1+q_2)dq - (q_1+q_2)c - C_1(d_1) - C_2(d_2). \tag{4.6}$$

The first best is given by only firm 1 rolling out a network and

$$\int_0^{q_1+q_2} p(q_1) = C'(d_1) \text{ and } p = c. \tag{4.7}$$

The following Lemma compares the monopoly case (only the more efficient firm 1 entered, $d_2 = 0$) with the duopoly case ($d_1 > d_2 > 0$).

Lemma 2. *In the monopoly case more regions will be covered while in the duopoly case the quantity per market is higher. The overall effect on the penetration is indeterminate. Social welfare will be higher in case of duopoly only if penetration increases and entry cost $C_2(d_2)$ are sufficiently small.*

Corollary 3. *Assume that there exists a maximum value $\overline{d_2}$ and that this value is binding, i.e. $d_2^* < \overline{d_2}$. A marginal increase in $\overline{d_2}$ will (i) reduce d_1^* and (ii)*

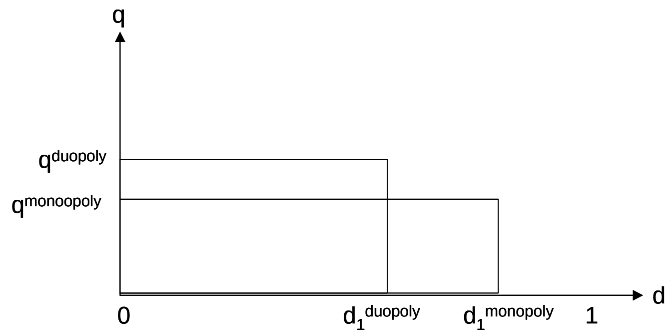

Figure 4.3: Higher quantities per region vs. lower regional coverage

increase q_1^*. The overall effect on the penetration is ambiguous.

Proof. *See Appendix.* ■

The duopoly quantities in each market exceed the monopoly quantities while at the same time industry profits are not maximized per region thus less regions are covered. Figure 6 illustrates the two opposing effects. Which of the two effects prevails in terms of penetration as well as in terms of welfare hinges upon the characteristics of the demand and cost functions.[7]

If firm 1 could price discriminate and choose the monopoly price in the markets he serves alone $(d_1 - d_2)$ he clearly makes higher profits in the marginal market, pushing d_1 further out.

[7] For a simple example with linear demand $Q(p) = A - p$ and symetric cost $C_1 = C_2 = C$ duopoly will be welfare superior if $F < \frac{23}{72}(A - c)^2$, i.e. only if fixed cost o

In the case of broadband competition it is again interesting to discuss the effect of an exogenous maximum value of d_2, e.g. due to a low number of homes passed. This is addressed in Corollary 1. Firm 1's quantities in the competitive regions q_1 are decreasing in d_1 and increasing in d_2. In choosing higher q_1 firm 1 faces a trade-off between higher profits in the competitive markets and lower profits in the monopolistic region from the resulting price decrease and thus a further downward deviation from the monopolistic price. An increase in d_2 (d_1) just means that the latter effects receives a lower (higher) importance in firm 1's considerations. Relaxing firm 2's binding capacity constraint $\overline{d_2}$ thus implies a lower coverage d_1. As quantities are strategic substitutes, firm 2 will react by reducing its quantity q_2 in equilibrium. Whether the market quantity per market $(q_1 + q_2)$ increases is not clear in general and depends on the characteristics of the demand function. Furthermore, the welfare effect of an increase in $\overline{d_2}$ is also ambiguous but can be positive only if the penetration increased in the first place (due to increasing entry cost).

5. Empirical Analysis

We want to estimate by how much the social welfare measured as consumer plus producer surplus would have been lower without cable competition and compare this with the investment incurred to make this cable competition possible. As the basic hypothesis is that network competition has not been welfare increasing we will always tend to take an upper bound for the benefits and a lower bound for the cost. First, we try to explain broadband penetration trying to include all important explanatory variables. Using these results we make a ceteris paribus statement using pricing data on the additional consumer surplus that can be attributed to cable competition. We try to approximate investment into cable upgrade from company filings to finally compare benefits and cost.

5.1. Explaining Broadband Penetration

5.1.1. Data and Model

We use data for all 16 Western European countries on key explanatory variables for broadband penetration provided mainly by the research company Baskerville in August 2004. The Appendix provides a more detailed discussion of the data and the sources. We use quarterly data from 4Q2000 until 1Q2004, implying 224 observations. This data set virtually covers the whole industry history so far as broadband as a mass market just started in the year 2000, with less than 2 million broadband subscribers in Western Europe at the end of 2000 (implying a household penetration of 1,3%), compared to 27 million subscribers in 1Q2004

(16,7% penetration).

We conduct a pooled estimation of the following equation:

$$
\begin{aligned}
pen_{it} &= \beta_0 + \beta_1 cable_{it} + \beta_2 cable_{it}^2 + \beta_3 passed + \beta_4 inctv_{it} + \beta_5 retail_{it} \quad (5.1) \\
&+ \beta_6 isdn_{it} + \beta_7 pc_{it} + + \beta_8 \ln gdp_{it} + \beta_9 density_{it} \\
&+ \beta_{10} t_1 + ... + \beta_{22} t_{13} + \varepsilon_{it}
\end{aligned}
$$

Where for each period t and country i:

Name	Definition
pen	broadband subscriber / all households
cable	cable broadband subscriber / all broadband subscriber
passed	homes passed by cable TV / all households
inctv	incumbent cable TV subscriber / all cable TV subscriber
retail	incumbent DSL subscriber / all DSL subscriber
isdn	ISDN subscribers / all households
pc	PCs / all household
lngdp	ln(gdp/capita), using PPP and annual averages
density	inhabitants / square kilometer
t_k	time dummy

Apart from the time dummies the explanatory variable fall into two classes, four "competition variables" and four "structural variables".

(i) The first competition variable is the market share of cable companies in the broadband market, reflecting the actual infrastructure competition. We use a quadratic specification for the impact of the cable competition for reasons obvious from figure 4. (ii) Homes passed by cable TV are nearly totally historically determined (cable TV has been rolled out typically in the 1980s/90s and do not change significantly in the time frame under consideration here). This variable reflects the degree of potential cable competition. (iii) The market share of the telecommunication incumbent in the cable TV market influences whether cable indeed is a competitor to DSL. The incumbent's engagement might have prevented the incumbent from upgrading cable TV in order not to cannibalize its PSTN network (or vice versa). The effect of this on broadband penetration is nevertheless not obvious (cf. the coverage reasoning of the second theoretical model). The absence of competition might provide incentives to early and complete roll-out of infrastructure. (iv) In some but not all countries there exists a strong wholesale market for DSL. The retail market share of the incumbent in the DSL market is included as a proxy for service competition as opposed to network competition.

Broadband penetration and the market share of cable are to some extend determined simultaneously with generally unclear causality. We argue that high market share of cable implies a high penetration. One could also argue that a high penetration, i.e. a large market size, gives scope for market entry of a second provider, namely cable companies. However, cable competition (as also elaborated in the theoretical models) is closely linked to the homes passed and the determination of homes passed in the 80s/90s predates the arise of broadband access. Including homes passed in the regression thus reduces the problem of endogeneity but clearly causes an autocorrelation problem due to the positive correlation between both variables.

The incumbent's retail market share in the DSL market can be regarded as exogenous at least as long as market growth is strong. In this phase the incumbent will most likely try to catch as much as possible of the market directly and strong demand makes wholesale as an additional sales channels superfluous. Mainly regulatory obligations drive the DSL wholesale market.

Like *inctv*, *passed*, and *retail*, the structural variables are truly exogenous. (v) ISDN, supplying customers with more than one (typically three) channels via one access line is to some degree a substitute to DSL. Though allowing only for narrowband internet access it provides customers with one key feature similar to DSL, namely the ability to be make and receive phone calls while connected to the internet. (vi) PCs are required for almost all broadband applications so far. (v) GDP shall capture general differences in macroeconomic performance as well as differences in disposable income. (vi) Higher population density makes coverage with broadband services less costly. Finally, we use period dummies as cable penetration as well as many explanatory variables exhibit a strong positive trend.

Clearly, there exist country specific heterogeneity in the data which is not covered in the pooled estimation with time dummies. However, by including gdp/capita, population density, homes passed, PC penetration, and ISDN penetration we capture significant country specific heterogeneity.[8]

5.1.2. Estimation Results

Table 1 shows the results for the pooled OLS estimation with robust stand errors.

$Variable$	β	$p > \|t\|$
$cable$	.2306	.000
$cable2$	$-.2280$	.000
$passed$	.0122	.444
$inctv$	.5657	.000
$retail$	.0278	.316
$isdn$	$-.1056$	.000
pc	$-.0202$	.728
$lngdp$	.0539	.118
$density$	.0001	.000

The R^2 equals $0,72$ of the pooled estimation and the time dummies are jointly significant, exhibiting a strong positive trend. The results support strongly the assumed inverted U relationship between cable market share and the broadband

[8] Fixed effects estimations are not meaningful in this case. Important explanatory variables like *density*, *inctv*, *passed* have little of no variance over time for a single country.

penetration. Actual infrastructure competition therefore seems to be of importance to explain broadband penetration. The other competition variables do not support the pro-competition argument. The percentage of homes passed is not significant in this regression. This is partly due to the positive correlation between the homes passed and the cable market share. The retail market share is not significant either. Thus, the data do not support the hypothesis that monopoly rents are decisive to provide incentives for network roll-out. The positive correlation between the incumbents cable TV market share and the broadband penetration is driven by Portugal and Norway. In particular in the early periods broadband penetration in these countries have been driven by the incumbent via its cable subsidiary.

It is surprising that the PC penetration is not significant. This is only to a very limited extent due to the positive correlation between pc and $\ln gdp$. Both variables are not jointly significant at the 5% level ($Prob > F = .0716$). One explanation might be that early broadband adopter will also have been an early PC adopters. It seems plausible that a PC penetration in excess of some critical value will not affect the uptake of broadband. Given a relatively homogeneous country sample (homogeneous with respect to the level of the countries development towards the "information society") all countries seem to be beyond the point where the PC penetration limits the broadband penetration (things might be different when testing for the total internet penetration, including narrowband).

5.2. Welfare Effects from Broadband Competition

We deduce country by country in a ceteris paribus approach by how much the number of broadband subscribers would have been lower in 1Q2004 if no cable competition existed (i.e. we set $cable_{it} = 0 \; \forall i$ in an ex-post estimation and deduct the original values). Without cable competition the number of broadband subscribers would haven been approximately 17% lower (22,4 instead of 26,8 million subscriber in 1Q2004). On average this translates into a delta of 2,7%-points of penetration. In countries with very strong cable competition this delta goes up to almost 6%-points (e.g. Netherlands with 22,6% instead of 28,4%, or Austria with 13,6% instead of 19,4%).

We evaluate the resulting delta to the actual subscriber base using market prices as an approximation for the consumers' willingness-to-pay. The inframarginal consumers have a willingness to pay higher than the actual (i.e. 1Q2004 in our case) market price. We try to account for this by first taking the incumbents price (which typically is above the market average) and secondly by taking prices from October 2003 (broadband markets are still expanding quickly, approaching new customer segments with decreasing willingness to pay, implying a continuous decline in prices.) As there exists virtually no variable cost of broadband access once a subscriber is connected to the network, this gives a good approximation for the sum of consumer and producer surplus (actually the upper bound). Price data stem from the OECD.[OECD 2004 (2)]

For investment into broadband cable we produce an estimate of the capital expenditure of all companies in Western Europe whose subscribers are included in the data set for the years 2000-2003 which amounts to at least 20,5 billion €. This probably significantly underestimates the cost of cable competition as significant investment might have taken place before that.

Cable companies did not only invest in upgrading the network for broadband access. There are also maintenance investments, investments in expanding the coverage, and investments in the digitalization of the network. The latter is a common cost for two distinct services, digital TV and broadband access. A split of 10% maintenance, 15% expansion, 15% digital TV, 60% broadband as a rule of thumb seems reasonable, but real rates differ widely between companies. Lifetime of the assets is also difficult to estimate. Some assets are extremely long lived (like the physical infrastructure), other like network intelligence are more short lived. As the largest investments took place in 2000 (34% of the whole period 2000-

Percentage broadband of total cable capex

Life Time of Assets	0	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
1	2.698	684	-1.331	-3.345	-5.359	-7.373	-9.388	-11.402	-13.416	-15.430	-17.445
2	5.396	3.382	1.367	-647	-2.661	-4.676	-6.690	-8.704	-10.718	-12.733	-14.747
3	8.094	6.079	4.065	2.051	37	-1.978	-3.992	-6.006	-8.020	-10.035	-12.049
4	10.792	8.777	6.763	4.749	2.735	720	-1.294	-3.308	-5.323	-7.337	-9.351
5	13.489	11.475	9.461	7.447	5.432	3.418	1.404	-610	-2.625	-4.639	-6.653
6	16.187	14.173	12.159	10.145	8.130	6.116	4.102	2.088	73	-1.941	-3.955
7	18.885	16.871	14.857	12.843	10.828	8.814	6.800	4.785	2.771	757	-1.257
8	21.583	19.569	17.555	15.540	13.526	11.512	9.498	7.483	5.469	3.455	1.441
9	24.281	22.267	20.253	18.238	16.224	14.210	12.196	10.181	8.167	6.153	4.138
10	26.979	24.965	22.950	20.936	18.922	16.908	14.893	12.879	10.865	8.851	6.836

Figure 5.1: Overall Welfare Effects from Cable Competition in mn. €

2003), these assets are already at least 3 years old in 2004. An average remaining asset lifetime in 2004 of five years might be a good first estimate.

Figure 7 provides estimations for the welfare impact W, equal to consumer + producer surplus minus the attributed capital expenditures.

$$W = CS + PS - s * Capex/L \tag{5.2}$$

where L denotes the lifetime of the assets and s the fraction of total capex attributed to broadband access. We do not discount the positive effects from penetration although there exists an obvious time lag between investment and full network usage. Again, this deliberately biases the results towards the positive welfare effects of competition.

Table 2 shows that for the relevant parameter region the overall welfare effect is just about neutral. Taking into consideration that we significantly biased all estimates in favor of the welfare effect from competition, this suggests that the welfare effect has probably been negative.

6. Conclusion

Actual infrastructure competition from cable TV has had a significant positive effect on broadband penetration in Western Europe. Given penetration rate of 16,7% in Western Europe, on average 2,7%-points can be attributed to cable competition, and a maximum of 6%-points per national market. Therefore any policy dedicated a priori to high penetration rates should support infrastructure competition.

However, the very high investments into the basically redundant alternative cable infrastructure outweigh the gains from competition. The industry history up to 2004 suggests that overall the welfare effect - in the absence of any additional welfare enhancing effects from broadband access - of cable competition is likely to be negative. The critical situation of almost all firms in the industry - high debt burdens, financial stress and restructuring, bankruptcy filings and painful reemergence from chapter 11 - already indicates that producer surplus has been negative. The estimates presented here suggest that the resulting additional consumer surplus from competition could not compensate for that.

Given that the drawback of network duplication is not a purely theoretical one, one might be tempted to advocate service against network competition. The data do not support this simple message either, as service competition has had no significant effect on the broadband penetration so far.

A common regulatory strategy frequently encountered is often described as the "ladder model": In the beginning of the market opening the regulator should enable easy market entry, i.e. entry with limited sunk cost, on the basis of service competition. After some time competitors will try to "go down the ladder", invest more, enabling them to offer differentiated products, and eventually establishing sustainable, infrastructure based competition. Thus, the regulator should switch to a strategy more favorable to infrastructure competition only after some time lag after market opening.

The analysis presented here provides stronger support for an opposite recommendation: In newly developing markets in which investments in infrastructure is of high importance, actual network competition is effective from the start. Pure service competition would decrease incentives to invest into (either) network. After the market has stabilized and growth rates are declining it might be useful (if increasing penetration is still a regulatory and political goal) to enable service competition.

To provide a more solid recommendation in the general discussion of network versus service competition in particular in newly developing markets it is important to gain a better understanding of the effects on investment incentives. Further research could therefore focus on the question whether network coverage is indeed adversely affected by competition. Again, broadband internet access on a more disaggregate level (i.e. to which extent have regions within countries have been upgraded for the new service) could serve a promising empirical test case. Additionally, the question whether demand and supply subsidies (being the most common policy instrument in the EU so far) are more effective than (network) competition awaits empirical investigation.

7. Appendix

7.1. Proofs

7.1.1. Proof of Lemma 1:

Given $q_2 = \overline{q_2}$, firm 1 maximizes its profit by choosing

$$\pi_1 = p(1 - p - \overline{q_2} - \overline{q_2}) \rightarrow \max_p \tag{7.1}$$

which provides p^*. Firm 2 will not choose $p < p^*$ due to its capacity constraint. Choosing $p > p^*$ is also not optimal for firm 2 as this would imply a lower quantity q_2. Straightforward calculations for period 2 profits of firm 2 π_2 show that

$$\frac{\partial \pi_2}{\partial q_2}(q_2 = \overline{q_2}) = \frac{1 - 3\overline{q_2}}{2} \tag{7.2}$$

implying that π_2 is increasing in q_2 for $\overline{q_2} \leq 1/3$.

Overall profits are given by

$$\begin{aligned} \Pi_1 &= \pi_1 - \frac{1}{2}(1 - \overline{q_2})c \\ \Pi_2 &= \pi_2 - \overline{q_2}c \end{aligned} \tag{7.3}$$

implying positive profits in case of market entry of both firms for

$$c < \frac{1}{2}(1 - \overline{q_2}) \tag{7.4}$$

Straightforward calculations show that social welfare W is given by

$$\begin{aligned} W^{monopoly} &= \frac{3}{8} - \frac{1}{2}c \\ W^{duopoly} &= \frac{(1 + \overline{q_2})^2}{8} + \frac{1 - \overline{q_2}}{4} - \frac{1 + \overline{q_2}}{2}c, \end{aligned} \tag{7.5}$$

implying

$$W^{duopoly} > W^{monopoly} \text{ for } c < \frac{1}{2}(1 - \frac{1}{2}\overline{q_2}), \tag{7.6}$$

therefore, comparing the critical values resulting from 7.4 and 7.6 it follows that there exist intermediate values of c s.t. entry occurs and is welfare decreasing.

7.1.2. Proof of Lemma 2

In case of monopoly (only firm 1 serves the market), firm 1 maximizes $aq_1(p(q)-c)$, which yields as first order conditions to determine q^M :

$$p(q) + (q)\frac{\partial p}{\partial q} = c \tag{7.7}$$

Firm 1's second stage profit function is given by:

$$\pi_1 = [d_2 q_1 + (d_1 - d_2)(q_1 + q_2)]\,(p - c) \tag{7.8}$$

with first order condition

$$p(q_1 + q_2) + (q_1 + q_2)\frac{\partial p}{\partial q} = c + \frac{d_2}{d_1}\frac{\partial p}{\partial q}q_2 \tag{7.9}$$

Comparing the left hand side of 7.7 with 7.9 shows that equilibrium quantity in each market is higher in the duopoly case.

Given that in duopoly the optimal choice q_2^* deviates from the monopoly quantity, second stage profits are smaller for firm 1 in case of duopoly, implying with 4.4 the lower choice of d_1 in case of duopoly.

Proof of corollary 1

From the envelope theorem, we can deduce from 4.4:

$$\frac{\partial \pi_1}{\partial d_2} = -q_2(p-c). \tag{7.10}$$

As the optimal choice of d_1 determined by 4.5, we can immediately infer that relaxing a binding capacity constraint of firm 2 reduced the overall coverage. Furthermore, we can deduce from the reaction function F_1 of the second stage game

$$F_1 = a\left[(p-c) + \frac{\partial p}{\partial q} q_1\right] + \frac{\partial p}{\partial q}(a-b)q_2 = 0 \tag{7.11}$$

that the second stage quantity of firm 1 will decrease its quantity by use of the implicit function theorem:

$$\frac{\partial q_1}{\partial d_2} = \frac{-\frac{\partial p}{\partial q} q_2}{d_1\left[p' + p'' q_1 + p'\right] + p''(d_1 - d_2)q_2} > 0 \tag{7.12}$$

By the same reasoning it follows that

$$\frac{\partial q_2}{\partial d_2} = 0 \tag{7.13}$$

As quantities are strategic substitutes

$$\begin{aligned} \frac{\partial q_1}{\partial q_2} &= -\frac{d_1\left[p' + p''q_1\right] + (d_1 - d_2)\left[p' + p''q_2\right]}{d_1\left[p' + p''q_1 + p'\right] + p''(d_1 - d_2)q_2} < 0 \\ \frac{\partial q_2}{\partial q_1} &= \frac{d_2 p' + p''q_2}{d_2 p' + p''q_2 p'} < 0 \end{aligned} \tag{7.14}$$

firm 2 will react with a increase in q_2. The overall effect on the quantity supplied in each market is unclear.

7.2. Regression Data

Most regression data have been provided by the specialized broadband market intelligence company "Baskerville" in August 2004. We have cross-checked the data with the latest cross-country analysis of the EU (from May 2004 [EU 2004 (2)]) and deviations are very small (e.g. aggregate number of broadband subscribers deviates by less than 2% in both sources). Also data from "Point Topic", an alternative research company, are quite similar to the ones used in this analysis.

For some countries no information on the "homes passed" are available from

Baskerville. Missing data have been added using the research company advanced television Ltd. (http://www.advanced-television.com/PDF/homes_passed_projections.pdf). These data focus on digital cable homes passed and therefore underestimate the homes passed for the countries where this source has been used.

Most companies filings state the number of ISDN "channels" as "lines". Thus, we translate the ISDN channels reported by Baskerville on the basis of company information into subscriber figures, by taking 2 ISDN lines = 1 ISDN, subscriber as on average ISDN provides 2 channels per physical access.

GDP data are from Eurostat using annual averages. As we want to interpret GDP/capita as a proxy for differences in the level of economic development rather than for short run deviations from the trend, we used annual averages.

The following two tables provide the summary statistics of the variables and the correlation matrix (excluding the time dummies).

variable	Obs	Mean Std. Dev.	Mean Std. Dev.	Min	Max
pen	224	.0908269	.0764561	0	.3173083
cable	224	.3973484	.2944095	0	1
retail	224	.7752965	.1526288	.3681922	1
isdn	224	.1568416	.1327081	.0114961	.4857143
pc	224	.2659492	.1099533	.0813442	.5643697
gdp	224	25189.29	5668857	15300	45900
passed	224	.6466536	.2424702	.1130454	1085859
inctv	224	.2036127	.3090877	0	.8854054
density	224	1532116	1203885	1169321	4780385
cable2	224	.2441757	.2853476	0	1
lngdp	224	1011298	.1999075	9635608	1073422

Summary Statistics

	pen	cable	retail	isdn	pc	passed	inctv	density	cable2	lngdp
pen	1									
cable	-0.1121	1								
retail	-0.2751	-0.0100	1							
isdn	-0.1526	-0.2386	0.0563	1						
pc	0.0421	-0.2441	0.1464	0.4892	1					
passed	0.1610	0.3018	0.2458	0.1998	0.3209	1				
inctv	0.0028	0.0965	0.0466	0.1757	-0.0285	-0.0763	1			
density	0.1766	0.1381	-0.0942	0.0194	-0.0600	0.3454	-0.3297	1		
cable2	-0.2412	0.9515	0.0874	-0.1194	-0.1997	0.2832	0.1072	0.1372	1	
lngdp	0.0226	-0.3119	0.0493	0.5082	0.8063	0.3084	-0.3703	0.1071	-0.2830	1

Correlation Matrix

7.3. Prices

The following products (plans) have been selected to approximate the inframarginal consumers' willingness to pay in calculating the welfare gain from increased broadband penetration. They are selected as the incumbent's offer for a medium product quality (i.e. average transmission rate) compared to all other plans benchmarked by the OECD. All plans include already significant connectivity on top of the pure access. Prices are therefore an upper bound for the value of the access. (e.g. free 10.000 MB imply already a de facto flat rate for most users with almost 14 hours/month continuous download with 0,5MB/s).

Country	Company	Plan	downstream1	upstream	price in €	connectivity included?
Austria	TA	AonSpeed 500MB	768	128	28,06	500MB
Belgium	Belgacom	ADSL Skynet Go	3000	128	36,06	10.000MB
Denmark	TDC	CableModem	1024	128	44,82	unlimited
Finland	TeliaSonera	ADSL	1024	512	107,69	unlimited
France	FT	eXtense fidelite	1024	128	67,92	unlimited
Germany	DT	T-Online dsl 1000	768	128	27,05	1.000MB
Ireland	eirecom	eircom i-stream starter (residential)	512	128	45,91	4.000MB
Italy	TI	Alice 640	640	128	53,46	unlimited
Luxembourg	p&T	SpeedSurf RUN	512	128	71,67	15.000MB
Netherlands	KPN	ADSL Komfort	1024	160	46,87	unlimited
Norway	Telenor	Online ADSL oppgradert	704	128	42,25	10.000MB
Portugal	SAPO (PT)	SAPO ADSL.PT	512	128	44,47	20.000MB
Spain	Telefonica	Linea ADSL 512	512	128	95,03	unlimited
Sweden	Telia	Telia Broadband 500	500	400	33,28	unlimited
Switzerland	Swisscom	Broadway ADSL600	600	100	35,62	unlimited
UK	BT	BT Yahoo! Broadband Home	512	256	38,71	unlimited

Source: OECD, Benchmarking Broadband Prices in the OECD, 18.6.2004, DSTI/ICCP/TISP (2003)8/final
all prices as of October 2003
prices originally in USD, PPP, including VAT, converted into € using average Interbank exchange rate of October 2003

7.4. Cable Capex

Investment data have been collected for all companies with broadband cable subscribers in the bottom-up analysis of the subscriber data base. Sources are company reports, except for com hem (national filing with the Swedish Companies' House) and Cablecom (Deutsche Bank High Yield Research estimates). Wherever possible we used capital expenditures / cash used for purchase of tangible assets and excluded financial investments. Detailed investment data are available for approximately three quarter of the companies (representing 72% of all subscribers covered). We assume the same investment intensity for the remaining companies and the same investment structure for missing periods (i.e. high investments in 2000, lower in consecutive years).

Country	Company	BB-cable offering since	Capex in EURO (mn.)					Subscriber
			2000	2001	2002	2003	**Sum**	Subscriber 4Q2003 (tsd.)
UK	NTL	2Q01	2.129	1.846	722	385	**5.082**	1.385
UK	Telewest	2Q01	865,6	881,8	713,1	329,7	**2.790,2**	408,0
Denmark	Telia Stofa	1Q00	29,1	292,0	104,1	42,9	**468,1**	104,0
Norway	UPC / chello	1Q00	7,6	67,6	106,0	-	**181,3**	37,0
Finland	Helsinki Television (HTV)	1Q00	-	-	8,9	8,1	**17,0**	43,0
Finland	Sonera (small # cable)	4Q01	-	-	-	-	**-**	24,0
Sweden	Com Hem	1Q00	82,2	61,5	29,3	8,0	**180,9**	103,0
Sweden	UPC Sverige (chello)	1Q00	9,7	32,1	17,4	-	**59,3**	68,6
France	NC Numericable	1Q01	-	-	-	-	**-**	89,0
France	Noos	1Q00	-	-	-	-	**-**	203,0
France	UPC France (chello)	1Q00	21,4	128,0	240,2	-	**389,6**	28,0
Ireland	NTL	4Q01	-	-	-	16,4	**16,4**	6,8
Portugal	TV Cabo (PT subsidiary)	4Q99	-	470,0	34,3	44,4	**548,7**	224,0
Portugal	Cabovisao	1Q00	-	-	-	-	**-**	78,6
Spain	ONO	4Q99	428,0	360,0	252,0	199,0	**1.239,0**	182,0
Spain	Auna		-	-	-	-	**-**	365,0
Germany	iesy (eKabel)	3Q02	-	-	-	-	**-**	1,0
Germany	PrimaCom	1Q00	99,4	64,7	36,6	32,5	**233,2**	81,0
Netherlands	UPC (chello)	2Q99	643,7	286,5	112,1	-	**1.042,3**	322,0
Netherlands	Casema	4Q00	269,6	100,3	71,2	-	**441,1**	161,0
Netherlands	Essent	2Q99	145,0	176,0	79,8	62,8	**463,6**	265,0
Netherlands	Multikabel	3Q00	-	-	-	-	**-**	79,0
Belgium	UPC Belgium	2Q99	3,1	9,3	10,4	-	**22,9**	25,1
Belgium	Telenet	3Q97	200,0	200,0	67,6	100,4	**568,0**	300,0
Austria	UPC TeleKabel	1Q00	30,8	103,5	141,5	-	**275,8**	200,0
Austria	Liwest	4Q97	-	-	-	-	**-**	18,3
Switzerland	Cablecom	1Q98	-	248,9	141,5	116,6	**506,9**	190,0
Total	all cable capex						**14.526,5**	4.991,4

Information on capex for (subscribers)	3.887	- = not available
Total cable subscribers 4Q2003	5.390	
%-age covered	72,1%	
estimate of total capex	**20.143**	

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