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Competition, regulation, and broadband access to the internet

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ABSTRACT

This paper reexamines the effect of the regulatory regime on both penetration and coverage of broadband access to the internet. The framework allows for an evaluation of policy initiatives, guidelines and measures to bridge the digital divide and to promote investment. A welfare analysis compares service-based with facilities-based competition and asks whether and how high-speed access to the internet should be subsidized. Using an approach similar to Valletti, Barros, and Hoernig (2002), the paper highlights the importance of population density for whether firms invest to provide internet access. The analysis reveals a trade-off between coverage and penetration.

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1. Introduction

High-speed access to the internet ranks highly on the political agenda. Penetration and coverage of so-called broadband access to the internet are top political priorities both in the EU and the US. Bridging the 'digital divide' by providing broadband to rural areas is a major goal of EU-policy.[1] The EU's Digital Agenda states both goals in terms of broadband coverage and penetration.[2] However, how to reach both high coverage and high penetration is a much disputed issue.[3] The appropriate amount of regulatory intervention into Very High-Speed DSL networks (VDSL) was the matter of an argument between the European Commission's DG InfSoc and the German regulator. While the Commission took a more interventionist position,[4] the German regulator and the German federal government argued in favor of a regulatory holiday for investments in VDSL infrastructure. Anecdotal empirical evidence shows that more regulation need not yield better performance in terms of broadband access. In 2005 coverage and penetration were 98% and 45%, respectively, in Switzerland, where neither ex-ante regulation of wholesale tariffs nor unbundling of the local loop existed. In much more interventionist Germany, the respective numbers were below 90% and 20%, respectively.[5]

This paper reexamines the effect of the regulatory regime on both penetration and coverage. The framework also allows for an evaluation of different public policy measures such as subsidization of broadband demand and supply. A welfare analysis asks what the optimal regulatory regime is and whether and how high-speed access to the internet should be subsidized. Introducing population density in a model of broadband access along the lines of Faulhaber and Hogendorn (2000),

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[1] See, for instance, the EU commission's initiative "Bridging the Broadband Gap" at http://ec.europa.eu/information_society/events/broadband_gap_2007/index_en.htm.

[2] See http://ec.europa.eu/digital-agenda/.

[3] See the Economist magazine, January 29, 2009 for a discussion of different initiatives.

[4] See the Commission's Press release at http://europa.eu/rapid/pressReleasesAction.do?reference=IP/06/1110&format=HTML&aged=0&language=EN&guiLanguage=en

[5] For an overview of worldwide government activities regarding broadband access see Picot and Wernick, 2007. Recent data on coverage and penetration as well as policy statements with respect to the EU are available in European Commission (2008) and (2010).

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Foros and Kind (2003), and, in particular, Valletti, Barros, and Hoernig (2002), the paper highlights the importance of population density for investment into internet access. Due to fixed investment requirements to serve a local market, costs per potential user depend largely on population density in local markets.[6] Therefore, the spatial distribution of population largely determines geographical coverage. For given technological and economic conditions, a population density threshold exists below which investment will not break even.

The analysis highlights the trade-off between coverage and penetration; high – regulated – wholesale and retail prices, respectively, lead to wide coverage but low penetration. Higher prices create incentives for investment since they lead to higher profits for given market size. Low prices yield high demand in served areas and an increase in penetration even though coverage decreases. However, this holds only as long as the regulator prescribes tariffs which are above a certain threshold value. If the regulator sets prices too low, the negative effect on incentives to invest more than compensates for the demand increasing effect in served areas.

A major contribution of the paper is to provide orders of magnitudes of the various effects where general models often display results with ambiguous effects. Starting from a simple variation of the Valletti et al. (2002) model, the paper presents a simulation, which reproduces key features of the German broadband market. This approach allows putting into perspective how much optimal regulation can improve upon market solutions. An important part of the paper is to explain the developments in Germany in the light of the model, trying to explain differences to Switzerland and Austria. Such a comparison is of particular interest as the regulatory regimes differ considerably. While broadband regulation in Germany is ex-ante cost based, Austria exhibits an ex-ante retail-minus wholesale regulation. At the other end of the regulatory spectrum is Switzerland, which does not have an ex-ante sector-specific regulation, but only ex-post competition policy instruments. The 'calibrated' model allows a discussion whether the above mentioned policy goals and the regulatory regimes to implement these goals are consistent. It also allows examining how certain policy measures such as subsidies perform in terms of economic welfare. Accordingly, as will be shown and done in the remainder, the framework allows the discussion of, what the author considers the most important policy questions with respect to broadband internet.

There is now considerable empirical literature on the effects of both intra-platform and inter-platform competition on broadband uptake (see, e.g., Aron & Burnstein, 2003; Bouckaert, van Dijk, & Verboven, 2010; Denni & Gruber, 2005; Distaso, Lupi, & Maneti, 2006; Höffler, 2007; Wallsten, 2006; see Cambini and Jiang (2009); Lee and Brown (2008) for an overview). Taken together, these studies confirm – with varying levels of significance – that both inter-platform competition and more favorable terms for intra-platform competition have a positive effect on broadband adoption. In the case of intra-platform competition this holds typical for both the prices for local loop unbundling and for the terms on which rival firms obtain access to the telecom incumbent's network. It is reassuring that these studies confirm what one would expect at least within a static framework: More (network) competition and more product differentiation lead to higher demand and output. The same holds if regulators prescribe lower prices and more favorable access conditions. After all, this confirms that demand for broadband access is downward sloping.

The results of my paper put the above studies into perspective and indicate directions of future empirical analysis. They show that lower prices to increase broadband uptake typically come at a cost in terms of investment and coverage. Furthermore, simple requests for "more competition", whatever that means, also face a cost when investments in new networks and technologies are determined by Schumpeterian trade-offs between static and dynamic efficiency (see Schumpeter, 1942). One instance of the problems regulation in a new market faces, arises when regulators try to set tariffs cost-oriented. As I show, geographically averaged tariffs lead to a breakdown of the market if they are cost-based. Firms would not have an incentive to invest at all. Simulations show that the optimum mark-up on average costs is between 70 and 100 percent as long as the population is not served fully.

Formally, the paper compares a scenario where a (fixed line telecom) incumbent faces service-based competition with a scenario of facilities-based competition. In the latter case, up to two infrastructure-based operators offer broadband access in the different regions. In the model there will be an important difference between service-based and facilities-based competition from the viewpoint of consumers. Whereas consumers consider the products offered by different vendors of the DSL product of the incumbent as perfect substitutes, this does not hold for the relation between broadband access via DSL and via cable. Consumers regard these two platforms as differentiated products (see Distaso et al. (2006) for the same assumption).

Germany provides an interesting example of missed opportunities regarding inter-platform competition. Due to fragmentation and to the fact that Deutsche Telekom owned a major part of the cable network still after liberalization, inter-platform competition was almost absent until recently.[7] Simulations show that an earlier separation of the fixed-line and the cable network could have produced a higher welfare level than a sophisticated regulatory strategy based on intra-platform competition and unbundling. Inter-platform competition and the associated competition in infrastructure could have led to higher welfare, higher coverage and more product variety without further regulatory intervention.

In a situation of largely unregulated inter-platform competition, geographical uniform pricing (UP) is a potential constraint on incumbent prices. The paper shows that regulators might introduce UP as a safeguard against preemption by

[6] Due to technical restrictions of the DSL-technology (which change rapidly over time!) the maximum distance between a user and the switch needs to be below about 5.5 km. Otherwise, potential bandwidth is below what is typically considered broadband access. This leads to well-defined local markets around the main switches

[7] See, for instance, Thomas W. Hazlett, *The Wall Street Journal*, August 30, 2006 for an account of "Germany's Cable Problem".

an incumbent if consumers consider the different services as close substitutes. If products are more differentiated, uniform pricing and an unregulated benchmark yield about the same welfare level.

A regime with uniform pricing is also interesting from a technical point of view. In the case of close substitutes pure-strategy equilibrium in prices no longer exists for given coverage areas. The resulting equilibria in mixed-strategies exhibit two interesting and intuitive features. First, only the incumbent randomizes, not the entrant. In the interpretation of Varian (1980), the strategy of charging a high price with a certain probability α and a low price with probability $1-\alpha$ implies that the incumbent makes special offers once in a while for a certain time span. Given that competition is very tough, in the remaining time the monopolist serves only consumers in monopoly regions. The second interesting feature concerns the effect of a change in the degree of product differentiation on equilibrium prices. In the region where pure-strategy equilibria exist, the 'standard' relation applies: As products become closer substitutes, competition intensifies and prices decrease. However, in the region of mixed-strategy equilibria, the opposite holds: A further decrease in the degree of product differentiation leads to higher (expected) prices. More intense competition leads the incumbent to extend the time periods in which she serves only consumers in the monopoly region. The probability that she charges a high price increases.

The article also contributes to the discussion of various public policy instruments to promote broadband penetration.[8] I examine the welfare effects of subsidization of broadband demand and of investments in broadband infrastructure. The important result is that both demand and supply-side subsidies might increase welfare. Their relative effectiveness depends on the specific parameters of the model as well as on the details of the implementation. Simulations show that subsidization leading to 100% broadband coverage might lead to welfare levels which are at least as high as the situation without public policy intervention. This holds without accounting for potential network externalities.

The remainder of the paper proceeds as follows. Section 1 presents the basic model for a single (DSL) infrastructure. Within this framework, Section 2 compares regulated monopoly with the unregulated benchmark in terms of performance with respect to both penetration and coverage. As there are only few unambiguous effects, the paper presents a simulation tailored to the German situation to gain further insights into the order of magnitudes. Section 2 also deals with the setting of regulated tariffs and their dependence on the unevenness of the distribution of the population. Section 3 introduces facilities-based competition. It examines how unregulated platform competition performs compared to a situation with light-handed regulation by a uniform pricing constraint. Building on the simulation introduced in Section 2, it evaluates the welfare effects of the different scenarios of both regulated and unregulated, intra-platform and inter-platform competition. Section 4 addresses public policy in the form of both demand-side and supply-side subsidies. Section 5 concludes.

2. The basic model: A single infrastructure

The potential market for broadband access consists of many regional markets with different population densities. In more formal terms, this means that there is a continuum of "cities/regions" which differ by their respective population density s. For simplicity, I assume a linear relation between the "number" of cities and their population density once we rank the regions according to their population density s. Population density varies between 0 and the highest population density, $\bar{s}$, yielding the pattern depicted in Fig. 1.

Data for German exchanges depicted in Fig. 2 show that the assumption underlying Fig. 1 fits surprisingly well with the empirical pattern for 4500 (out of the actual 8000) German main distribution frames (MDF). The respective 2000 'cities' cover a population of 60 million people, therefore about 3/4 of the German population.

Consumer demand $y(s)$ for broadband access in regional market s consists of the unit-demand of the households which differ with respect to their willingness to pay. I assume that the consumers' willingness to pay is uniformly distributed on [0, a] with a density equal to s. With these simplifying assumptions, one obtains the linear demand function y depending on population density s:

$$y(s) = s(a-p)$$

The total number of households in regional market s is therefore as; an increase in population density affects demand proportionally.

As far as technology is concerned I assume that broadband access requires fixed investments in the local exchanges, which serve the different regions. I assume that each region s is served by one exchange, and that upgrading to allow for either DSL or cable broadband access requires a fixed investment f, which is independent of population size in that region. Note that a market is "covered", i.e., broadband services are potentially available to all consumers in the respective market if investment f is undertaken in the respective market. The marginal costs of connecting costumers are constant and equal to c. Therefore, and contrary to Foros and Kind (2003), these costs do not depend on the size of a regional market. In the next section I will examine the investment and pricing decisions of a monopoly incumbent both in the unregulated benchmark and under regulation.

[8] See (Goolsbee, 2003, chap.12) for an estimation of effects for U.S. states. See Gans (2007) for a policy discussion on the Australian situation.

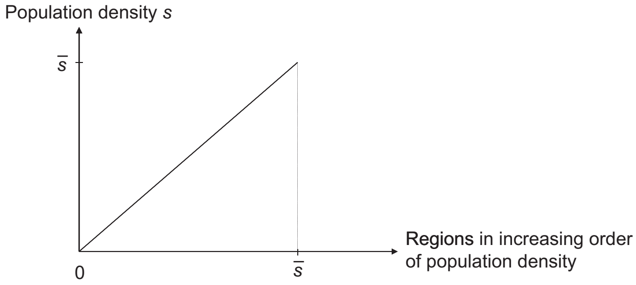

Fig. 1. Distribution of population density across regions depicted in increasing order.

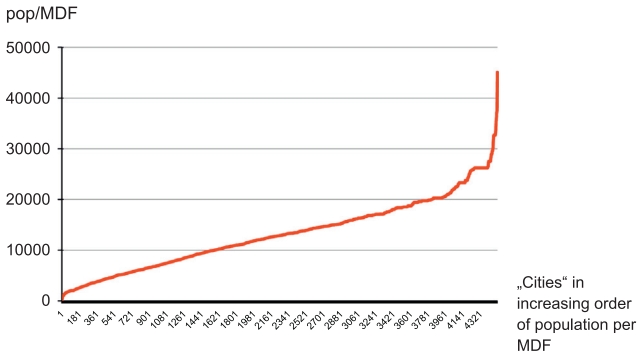

Fig. 2. Population per MDF across German cities. (In cases with multiple MDFs for a single city population is calculated by dividing the total city population by the number of MDFs. E.g. the respective number of MDFs is 132 for Berlin. Source: Own calculations based on data from Deutsche Telekom published on the German Broadband portal www.zukunft-breitband.de and from data of Destatis, the German Federal Statistical Office: https://www.destatis.de/DE/ZahlenFakten/LaenderRegionen/Regionales/Gemeindeverzeichnis/Administrativ/Aktuell/05Staedte.html?nn=50722).

3. Regulated monopoly

In this section I consider a single infrastructure, which is operated by a telecom incumbent. The incumbent determines the coverage of her network by investing in the local exchanges, i.e. by upgrading her network. As concerns regulation, I concentrate on price regulation. The regulator determines the price at which the incumbent must sell her product. The buyers might either be interpreted as resellers or as final consumers. In the later case we have price-cap regulation, with the regulator fixing retail prices. In the former case, the regulator determines wholesale prices and requires the incumbent to provide wholesale access on these terms. The resulting service based competition leads to the same result as a price cap, if one assumes Bertrand competition among homogeneous entrants with zero marginal costs on the retail stage. I will make this assumption and the assumption that incumbent and competitors are equally efficient and their products are perfect substitutes. Further on, I will call the regulatory regime in this section service-based competition, my preferred interpretation.

3.1. Benchmark: coverage and penetration in unregulated monopoly

As a benchmark and in order to demonstrate how the model works, I first present the decision problem of an unregulated monopolist. The monopolist faces a two-stage problem. First, she needs to decide on which markets to cover, i.e. where to invest. Second, she must determine on the price for the service in the regions where she offers it. The calculations are straightforward and start with the solution of the second stage. In this simple model, the monopolist charges identical prices in all markets. Consumer types are identical in all regions, only their number differs. As a consequence, differences in regions are solely due to different population densities and not to other features such as differences in the willingness to pay. Accordingly, price elasticities of demand are the same across all markets and an unregulated monopolist does not have an incentive to discriminate prices across markets. This assumption is particularly important for the analysis of the effects of facilities-based competition performed below. It allows a focus on the effects of market size and competition.

The monopoly price p^M in covered markets reads

$$p^M = (a+c)/2$$

The resulting profit in a market of population density s is

$$\Pi^M(s) = s(a-c)^2/4.$$

Given the reduced profit function, the first-stage investment decision is straightforward. The monopolist upgrades the networks in local markets, in which the profit is greater than the fixed investment cost, i.e. in all markets s where

$$\Pi^M(s) \geq f.$$

Solving this condition for the boundary value gives the population density $\underline{s}$ of the smallest market covered by the monopolist:

$$\underline{s}^M = 4f/(a-c)^2$$

Coverage together with the monopoly price allows calculation of broadband penetration Y under monopoly:

$$Y^M = \int_{\underline{s}^M}^{\bar{s}} y(s)ds = \frac{\bar{s}^2(a-c)}{4} - \frac{4f^2}{(a-c)^3}.$$

In the next subsection, I derive the respective values of coverage and penetration as a function of the price set by the regulator.

3.2. Regulated monopoly: price cap and service-based competition, respectively

In this regime the regulator sets the retail and the wholesale price p, respectively. This determines the profit $\Pi^R(s)$ the incumbent earns in a market of size s:

$$\Pi^R(s) = s(a-p)\,(p-c).$$

The incumbent's decision rule is analogous to that in the previous case: Invest if the profits in a region are greater than the investment costs. In formal terms

$$\Pi^R(s) \geq f.$$

Solving this condition for the population density $\underline{s}^R$ of the smallest market covered by the incumbent under regulation yields

$$\underline{s}^R = f/((a-p)\,(p-c)) \geq \underline{s}^M.$$

Penetration Y^R under regulation depends on the price level p and reads

$$Y^R = \frac{\bar{s}^2(a-p)}{2} - \frac{f^2}{2(a-p)(p-c)^2}.$$

At this stage, I want to highlight what the model tells about coverage and penetration. As already shown in Valletti et al. (2002), coverage is higher under unregulated monopoly than under price regulation. This is a rather general, Schumpeterian result, which does not depend on the specific demand specification:[9]

Monopoly yields the highest profits in local markets. Therefore the incentive to invest is at a maximum. Regulation reduces investment by reducing profits and leads to lower coverage. Furthermore, this result implies that all marketing instruments, which increase profits such as price discrimination increase investment and therefore coverage.

Regulators, who act primarily through (low) retail or wholesale prices, necessarily run into problems with respect to coverage. In Section 4 I will discuss what the importance of other policy instruments and initiatives such as subsidies or coverage constraints could be with respect to coverage and penetration.

The effect of price regulation on penetration is ambiguous. The following example examines the relation in more detail. The parameters are chosen to reproduce the order of magnitude of the German broadband market.

3.3. Regulated vs. unregulated monopoly: an example

The example calculates coverage and penetration as a function of the price set by the regulator. With respect to the parameters of the model I assume: $a=100$, $c=0$, $\bar{s}=1000$, and $f=500,00$. These parameters give a potential market of 50,000,000 households and users, respectively. The (monthly) maximum willingness to pay for broadband access is € 100, monthly capital costs are € 500,000. The population at one of the 1000 local exchanges is between 0 and 100,000 households. Note that I chose 1000 rather than the actual number of about 8000 German local exchanges to obtain nicer values.

The calculation of the unregulated monopoly is straightforward. For the monopolist's price p^M, her smallest covered region s^M, and for monopoly penetration Y^M, we obtain

$$p^M = 50,\ s^M = 200,\ Y^M = 24{,}000{,}000.$$

In percentage terms this implies that 96% of all households are covered, the penetration ratio is 48%.

[9] The general result follows immediately from the fact that profit under regulation must be weakly lower in each market than profit under unregulated monopoly. From the assumption that profit is increasing in market size the result derives.

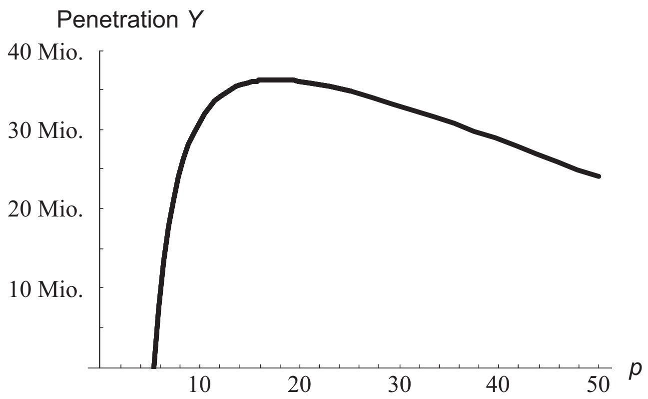

Fig. 3. Penetration as a function of price set by the regulator.

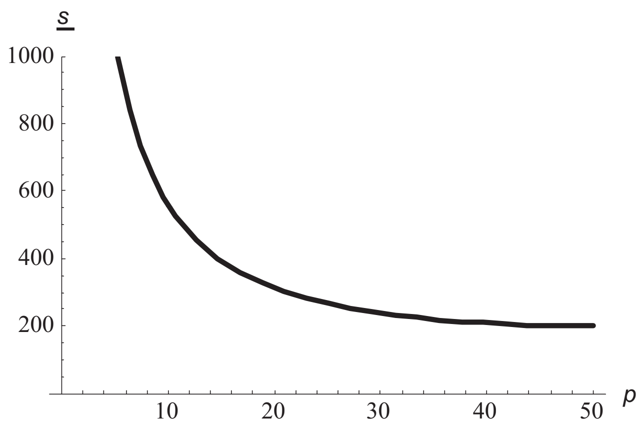

Fig. 4. Coverage (smallest served region) as a function of price set by the regulator.

Figs. 3 and 4 show coverage and penetration as a function of the price set by the regulator, either as a price cap or as wholesale charge.

The figures highlight the non-monotonous relation between the regulated price and penetration: Penetration initially increases with decreasing prices. However, as the price cap becomes very low, penetration eventually decreases. The reason for this pattern is twofold: First, the price decrease increases demand in covered regions. Second, lower prices lead to lower investments by the incumbent, i.e. a lower coverage. As a result the number of potential consumers decreases. Note that both the non-monotonicity result and the investment result do not depend on the specific example. They only require that lower prices (below the monopoly price) lead to lower profits and that profits are lower in smaller markets.

The above results highlight a rather fundamental trade-off from the viewpoint of the regulator in the case of a single infrastructure: If the only available regulatory instrument is price, higher penetration comes inevitably at the expense of low (er) coverage (as long as one is to the right of the maximum in Fig. 3). The development in Germany appears to be a particularly good example for this tradeoff: The number of broadband retail lines increased from about 10 to about 20 million lines from the end of 2005 to the end of 2007, an increase in penetration from below 10 broadband lines per 100 population to almost 24 lines. At the same time coverage in rural regions stagnated at below 60% of all households in rural regions, so that the report “Broadband coverage in Europe” finds that “the gap between coverage in rural areas and national average is particularly significant in Slovakia, Italy, Latvia and Germany”.[10] Due to different conditions regarding topography and population densities, simple comparisons of rates e.g. for the unbundled local loop across countries do not appear to be very meaningful. What is interesting is that rural coverage increased in Austria from a value of close to 60% to almost 80%, whereas penetration rose only from slightly above 10 broadband lines per 100 population to 19 lines.[11] In Austria broadband wholesale access is regulated on a retail-minus basis whereas regulation in Germany is cost-oriented.

Given the trade-off between coverage and penetration, it is interesting to look at the regulator’s choice of prices under different objective functions. Here I distinguish two possible objectives: maximization of total welfare as the sum of

[10] See European Commission (2007), p. 7. Recently coverage improved in Germany, but this might be due to increasing subsidization and other governmental initiatives potentially qualified as state aid (see European Commission, 2010).

[11] For the 2007 data, see European Commission (2008), for the 2005 data see European Commission (2005).

consumer surplus and profits and maximization of penetration. As noted above the unregulated monopoly yields maximum coverage and might therefore serve as a benchmark. Here I want to compare only the different outcomes in terms of prices, coverage and penetration. After introducing facilities-based competition below, I will further discuss the welfare effects.

In the case of regulation according to maximum penetration (and total welfare, resp.), we obtain the regulated price p^{RP} (p^{RW}), the smallest covered region s^{RP} (s^{RW}), and penetration $Y^{RP}(Y^{RM})$ as

$$p^{RP} = 17.6,\ \underline{s}^{RP} = 345.3,\ Y^{RP} = 36{,}300{,}000,\ \text{and}\ p^{RW} = 21.2,\ \underline{s}^{RW} = 299.6,\ Y^{RW} = 35{,}900{,}000,\ \text{respectively.}$$

The results imply that regulation according to maximum penetration increases penetration from 48% in the unregulated case to 72.6%, whereas coverage decreases from 96% to 88.1%. Welfare maximization leads to only a slightly slower penetration compared to the maximum penetration regime (71.8%), but the higher prices imply significantly higher coverage of 91.0% of all households. Clearly, welfare maximization takes into account that slight increase in prices hardly hurts consumers in covered areas but leads to huge gain for consumers who become covered due to the price increase.

I postpone further discussion of welfare for the basic example until I have introduced facilities-based competition. Before doing the latter, I discuss the optimum regulatory mark-up on average costs and its dependence on how even the distribution of the population is.

3.4. Side remark: the impossibility of cost oriented, geographically uniform access charges

Regulation of access charges and rental rates in the EU is cost-oriented according to forward looking long run average incremental costs (FLR(A)IC) in most cases. Furthermore, rates are typically set in geographically uniform way.[12] In our model FLRIC implies regulation according to (economic) average costs. The effect of such a regulation is straightforward and leads to the following

Observation: The monopolist does not invest at all in such a regime!

The reason is that with strictly decreasing population density independent of the smallest covered region $\underline{s}$ about half of the regions (markets) do not break even. Choosing a larger value of $\underline{s}$ would decrease costs and also average costs due to higher population density and would therefore further decrease regulated rates. With strictly increasing population density across regions, geographically uniform FLRIC inevitably leads to a zero investment level.

The general result is rather obvious and probably not much disputed. It is probably more interesting to look at the magnitudes of divergence between costs and regulated rates for the above examples. The results show that optimal regulation leads to rather high mark-ups on average costs. In the case of regulation according to total welfare, the realized average costs AC^{RW} are 9.8. Given that $p^{RW}=21.2$, this gives mark-up of more than 100% and significant pure profits. Even with regulation according to maximum penetration the mark-up is almost 100% since $AC^{RP}=9.0$. These results show that the necessity to encourage investment by the incumbent requires rather high profits for the incumbent, if rates are supposed to be geographically uniform. The alternative, of course, would be to allow the regulated rates to differ geographically meaning that the incumbent is allowed to charge higher rates in the high-cost rural areas. Before I compare the effects of geographically uniform vs. geographically differentiated prices in the framework of facilities-based competition, I explore the effect of the population distribution, i.e. of the slope of the population density function on the optimal (regulatory) mark-up.

3.5. Population distribution and the optimal mark-up

In order to determine the effect of changes in the unevenness in population distributions, I change the basic model by changing the slope of the population density in Fig. 1 and keeping total population constant at the same time. Again, I rank the regional markets n according to size with $n = \bar{n}$ being the largest region and $n=0$ denoting the smallest region. The relation between the regions and their respective population density is now

$$s = k + l\,n,$$

where $k = (1-l)\bar{n}/2$. The value of k is chosen so that total population is unaffected by changes in population distribution. Fig. 5 describes the resulting distributions where the slope l varies from 0, i.e. an equal distribution of the population across regional markets, to 1, the original case.

In the following discussion I employ the values of the above simulation and focus on regulation according to total welfare. The results are comparable for other welfare measures such as regulation according to maximum penetration or according to a consumer standard. Figs. 6 and 7 show the effect of changes in the unevenness of the population distribution on the welfare-optimal markup of prices over average costs and on the regulated prices, respectively. Note that both figures exhibit a kink at $l = .46$. For smaller values of l, population density in the smallest markets is sufficiently large to warrant

[12] For a recent discussion on the level of the EU of how to set rates when population densities differ see the ERG draft Common Position on Geographic Aspects of Market Analysis (definition and remedies), June 2008 (http://www.erg.eu.int/doc/publications/erg08_20rev1_cp_geogr_aspects_080707.pdf).

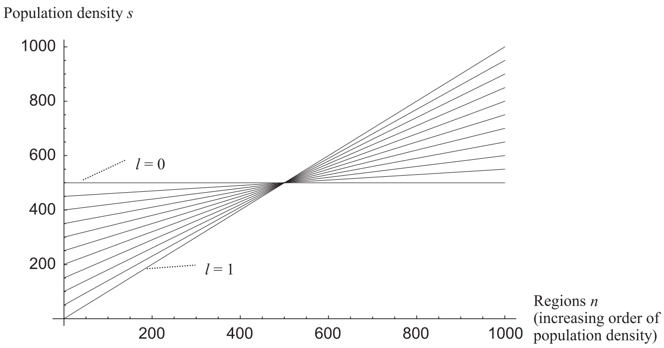

Fig. 5. Different population distributions with l ranging between 0 and 1.

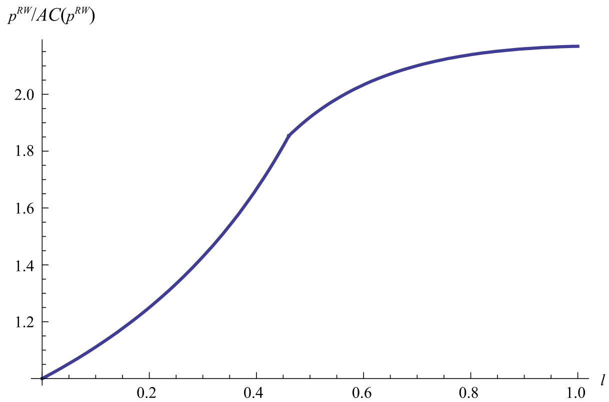

Fig. 6. Ratio of optimal regulated price to average costs as a function of the unevenness of the population distribution.

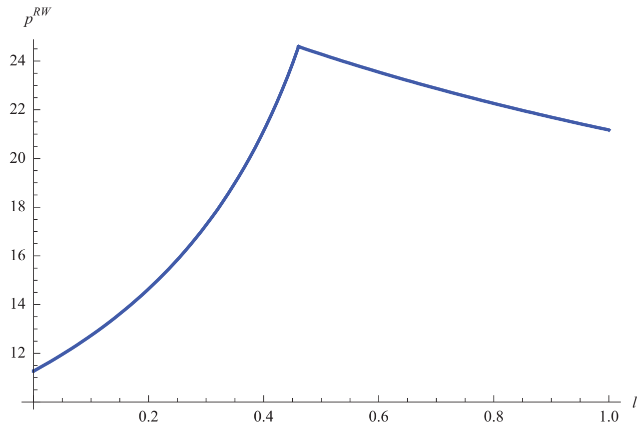

Fig. 7. Optimal regulated price as a function of the unevenness of the population distribution.

100% coverage. To the right of the kink, not all regions have broadband access and the threshold $\underline{n}$ of the smallest region covered increases with l.

A result which derives directly from Fig. 6 is that a more even population distribution (i.e. a lower l) leads to a lower mark up. In the limit of an even distribution of the population across regional markets, price is equal to average costs. Note that the markup decreases only slowly with a decrease in l as long as not the whole population is covered (at the kink at $l=.46$). Therefore, rather high markups are used to provide incentives to invest even if the slope of the population densities is rather modest.

Fig. 7 depicts the effect of a more evenly distributed population on the welfare-optimal price. Surprisingly, Fig. 7 exhibits non-monotonicity. Starting from the original case ($l=1$) and reducing the dissimilarity of regions by reducing l leads to an increase in prices until the kink is reached, i.e. until coverage is 100%. Therefore, we obtain the interesting and not obvious result that, given total population, a more even distribution of the population across regions should be associated with *higher* regulated prices as long as coverage is below 100%. For values to the left of the kink, the expected result applies: a further reduction of l leads to a (steep) price decrease. While the latter effect is straightforward, the former deserves an explanation. We know from Fig. 6 that the mark-up continuously decreases as we decrease l. Therefore, the fact that the graph in Fig. 7 is negatively inclined to the right of the kink implies that prices decrease even though the mark-up increases. The economic reason is that a more even distribution across regions leads to an increase in average costs for the respective parameter values.

The explanation is two-fold: First, distributing the population more evenly across regions without changing total population (i.e. decreasing l) implies that the number of users living in already covered regions decreases. Therefore, higher investment is needed to cover the same population; average costs are higher as a consequence. Second, lower values of l (but still greater than .46) imply that a given increase in price triggers higher investments. Due to the smaller slope of the population density schedule (Fig. 5), more previously uncovered regions become profitable for a given price increase. Therefore, a bigger expansion of coverage both in terms of the regions and in terms of the households covered results. The marginal incentive for the regulator to increase the price increases. This is the reason why markups decrease slowly with a more evenly distributed population, i.e. with a decreasing l. In terms of Fig. 6, it explains why the curve is rather flat in the right part.

Before going back to the original model ($l=1$) and examining the case of infrastructure-based competition, I want to stress an important policy conclusion of the non-monotonicity result: Simple (price) comparisons across countries do not appear to be very helpful when trying to determine the optimal rates and to evaluate regulation. Simple benchmarking rules such as the 'best current practice' rule used in the EU for a long time to determine interconnection rates in the member states[13] can be detrimental to investment incentives. Such a policy goes even wrong in the case where a given population is just differently distributed across a given number of regions ceteris paribus.

4. Facilities-based competition

Now I allow for facilities-based competition. An entrant C, think of a cable company, can enter the regional markets by making also the fixed investments f per regional market. The structure of the game is as follows: The incumbent I and the entrant C play a two-stage game. In stage 1, they simultaneously decide on their coverage, i.e., they choose the smallest regional market they cover $\underline{s}$ and s^C, respectively, and invest. In stage 2, the two firms set prices, that is, they compete a la Bertrand. As Valletti et al. (2002) I assume that the firms serve all regional markets greater than their optimally chosen smallest market. Furthermore, I choose always the equilibrium with the incumbent having higher coverage in equilibrium if two asymmetric equilibria exist which differ with respect to the coverage of the firms.[14]

Fig. 8 depicts the potential market structure with facilities-based competition. There is a duopoly segment, a monopoly segment and a segment of regional markets which is not served.[15] The ratio $\mu\equiv D/(D+M)$ of the monopoly and duopoly areas describes the relative importance of the duopoly region.

With respect to consumer demand I assume that they consider broadband via cable and via DSL as differentiated products.[16] I model this with the linear demand functions

$$y_I(s)=s\frac{a(1-\sigma)-p_I+\sigma p_C}{1-\sigma^2}$$

and

$$y_C(s)=s\frac{a(1-\sigma)-p_C+\sigma p_I}{1-\sigma^2}.$$

Note that this specification can be derived from a linear-quadratic utility function and yields aggregate consumer surplus CS

$$CS=a(y_C+y_I)-\frac{y_C^2}{2}-\frac{y_I^2}{2}-\sigma y_C y_I-p_I y_I-p_C y_C.$$

I assume that $\sigma\in[0,1]$ with the boundary values implying independent products and perfect substitutes, respectively. Note that this specification exhibits love of variety in the sense that aggregate demand and utility increases as products get

[13] See, e.g., the Commission Recommendation of 29 July 1998 amending Recommendation 98/195/EC on interconnection in a liberalised telecommunications market http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:31998H0511:EN:NOT.

[14] A more technical account of the model can be found in a companion paper (Götz, 2009).

[15] Note that this market structure corresponds with the black, grey, and white areas identified by the European Commission in their 2009 Community Guidelines for the application of State aid rules in relation to rapid deployment of broadband networks Text with EEA relevance (see http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52009XC0930%2802%29:EN:NOT).

[16] Distaso et al. (2006) and Valletti et al. (2002) employ the same assumption and the same demand specification. Another dimension of product differentiation in the context of internet access is quality differentiation in terms of upload and download speed. This might be of particular importance when considering competition between mobile and wireline internet access.

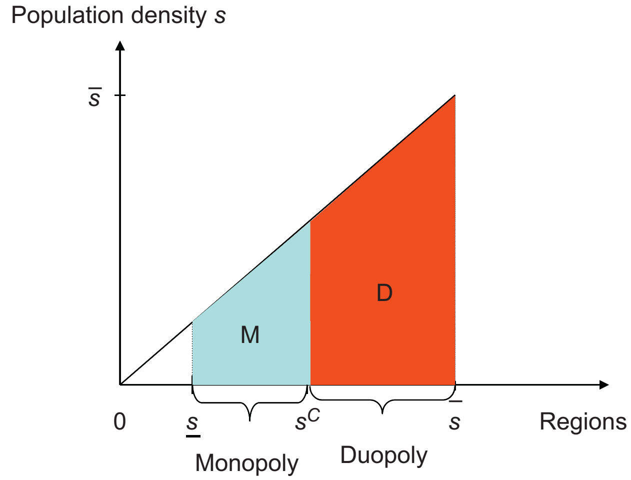

Fig. 8. Market structure under facilities-based competition.

more differentiated (i.e. as σ decreases). With our interpretation of demand as being unit demand for broadband access by heterogeneous consumers, taken literally the specification implies that some customers might demand both cable and DSL access to the internet. The product differentiation parameter σ is the key parameter both with respect to the intensity of competition and the welfare effects.

4.1. *Unregulated duopoly*

If there is no regulation at all, the results are straightforward. Solving the game backwards, we obtain the price p^D charged by both firms in the duopoly area

$$p_I^D = p_C^D = p^D = \frac{a(1-\sigma)+c}{2-\sigma}.$$

Clearly, the monopolist price discriminates between the monopoly and the duopoly area and charges the monopoly price in the former. As a consequence, the incumbents coverage is the same as in the unregulated monopoly and is determined by s^M. The coverage choice of the cable entrant determines from the reduced profit function, where the equilibrium prices are already used.

$$\Pi^C = \int_{s^C}^{\bar{s}} ((p^D - c)y_C(s) - f)ds$$

Differentiating the reduced profit function with respect to s^C reveals the simple decision rule of the cable firm: Markets are covered as long as profits are at least as high as the investment cost. In formal terms, we obtain

$$s^C = \frac{f(2-\sigma)^2(1+\sigma)}{(a-c)^2(1-\sigma).}$$

The parameters have a straightforward effect on coverage of the cable firm. Higher investment costs lead to lower coverage, exogenously more differentiated products (lower σ) allow higher markups, increase profitability and therefore also coverage (s^C decreases). If competition is too tough and σ is close to one, the cable firm does not enter the market. In the next section I will compare these results with a situation where the regulator imposes a uniform pricing constraint on the incumbent.

4.2. *Duopoly under a uniform pricing constraint*[17]

If the regulator (or marketing reasons) imposes a uniform pricing constraint on the incumbent, a pure strategy equilibrium in prices does not exist for values of the product differentiation parameter σ close to one. If products are close substitutes, the incumbent's price would have to be rather low in order to gain market share against the cable entrant. As a consequence the incumbent might choose to serve only her captive area under tough price competition. This cannot be a Nash-equilibrium, however, since the cable firm would charge a high price in response, triggering again undercutting by the incumbent. In a related paper I describe in detail how the mixed strategy pricing equilibrium looks like.[18] Here, I briefly mention its characteristics and evaluate the implications for coverage and welfare.

[17] The details of the simulation used in this and the following sections are available as a Mathematica-file form the author on request. Here I restrict myself to the presentation and interpretation of the results.

[18] See Götz (2009)

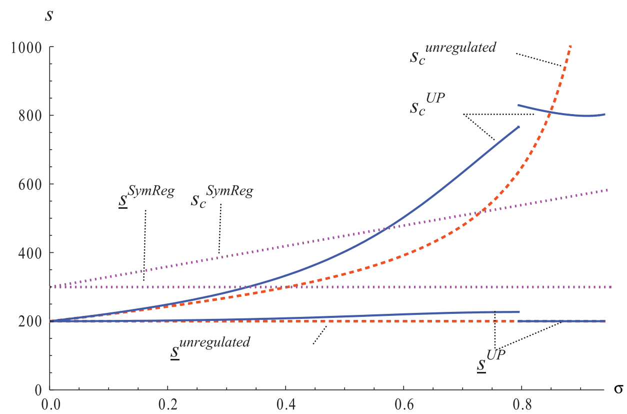

Fig. 9. Coverage of incumbent and cable firm and under various regulatory regimes.

Taking into account the coverage decision, a pure-strategy equilibrium in prices exists for $\sigma < .7958$. For values of σ in the interval [.7958, .94], a mixed strategy equilibrium exists, in which the cable firm charges a deterministic price and the incumbent randomizes between the monopoly price and the price, which is the best response to the cable firm's price. Note that this equilibrium has a nice interpretation in the tradition of papers such as Varian (1980): The probability with which the incumbent chooses the low price can be interpreted as the probability with which the incumbent serves all markets in a given period. The parameter region, in which the mixed strategy equilibrium applies, appears to be rather relevant. The different access technologies to the internet might not be too differentiated from the viewpoint of the consumers.

Fig. 9 compares the coverage decisions under various regulatory regimes. Apart from the uniform pricing constraint it considers the unregulated benchmark and symmetric price-regulation according to the welfare maximization scenario with only a telecoms incumbent. I turn to the latter case in the next section.

As is well known from the results Valletti et al. (2002) derive for the region of pure strategy equilibria, coverage of both the telecom incumbent and the cable firm is lower under a uniform pricing constraint (i.e., $\underline{s}^{UP} > \underline{s}^{unregulated}$ and $s_C^{UP} > s_C^{unregulated}$).[19] The result for the incumbent is straightforward as the uniform price is lower than the unconstrained monopoly price. The result concerning the entrant is somewhat surprising since the uniform pricing constraint leads to higher prices in the duopoly area compared to the unregulated benchmark. As Valletti et al. mention, the reason is a strategic effect: The entrant can induce soft behavior of the entrant by keeping the duopoly area small.

Fig. 9 shows that looking only at pure-strategy equilibria might miss an important point. If consumers regard the two products as close substitute, competition is fierce in an unregulated duopoly. As a consequence the entrant invests only in very large regions or not at all. In such a situation, a uniform pricing constraint might serve as a regulatory safeguard to secure competitive entry. For rather high values of σ (greater than about .85) coverage of the cable firm is higher (and even increasing in σ) under the uniform pricing constraint.[20] In Fig. 10, I examine the welfare consequences of the different scenarios.

If one compares welfare under facilities-based competition in the unregulated case ($W^{unregulated}$) with welfare under a uniform pricing constraint (W^{UP}) the first thing to note is that the two regimes hardly make a difference in terms of welfare unless goods are close substitutes. While coverage differs significantly in the range where pure-strategy equilibria exist, this hardly affects aggregate welfare even though it affects distribution in the sense that a uniform pricing constraint benefits people living in the covered monopoly regions.

Fig. 10 also shows that welfare decreases fast in the unregulated situation if the products become ever closer substitutes. Together with the result that welfare hardly differs between the unregulated regime and the regime with a uniform pricing constraint in the range where pure-strategy equilibria exist, Fig. 10 demonstrates the potential of the uniform pricing constraint to act as a regulatory safeguard. Of course, such a safeguard is important if consumers might consider the products as close substitutes.[21] In the next section I discuss how heavy-handed regulation such as a price-cap or access regulation compares to the two scenarios discussed above.

[19] Note that Valletti et al. (2002) claim the result for the entrant only in the case of a linear demand function, the case I consider in this paper.

[20] Note here an important peculiarity of the mixed strategy equilibria. In these equilibria the profit of the incumbent is by construction the same if she either serves only the monopoly segment or serves the whole market. Therefore, if she could recover its fixed investment, she might want to withdraw from the duopoly markets. As mentioned above, I assume that the incumbent has already irreversibly rolled-out broadband in the duopoly regions. This assumption seems to fit well with how DSL was actually rolled-out in many countries and where the telecoms incumbent was the first mover and in which where were pioneer profits in these regions. If the incumbent had not invested initially in these regions, we might end up with independent monopolies (see Hoernig, 2006). I will further discuss this topic below.

[21] A caveat with respect to the safeguard concerns situations such as new investments in FTTx. The uniform pricing constraint might lead to a situation, where the incumbent does not invest in regions, where she expects competition. See the discussion in footnote 18.

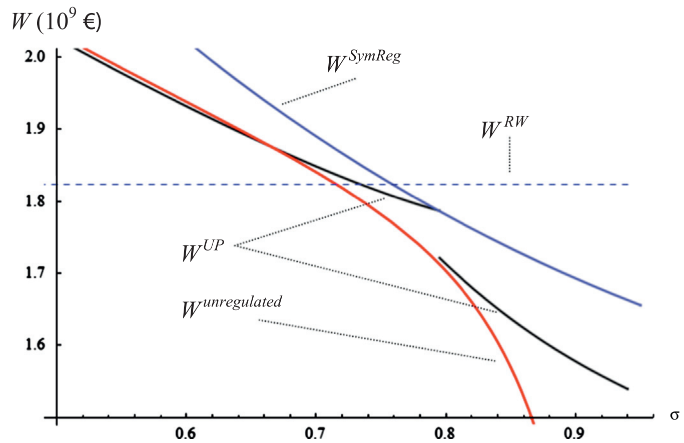

Fig. 10. Welfare *W* under facilities-based competition (various regulatory regimes).

4.3. Infrastructure-based competition with price-cap and access regulation

This section assumes that both the entrant and the incumbent face the same price cap and must provide access at the same conditions, respectively.[22] Furthermore, I assume that the regulator sets the welfare maximizing price from the regime with the regulated monopoly. The first assumption mainly serves to guarantee that in equilibrium the entrant does not charge a higher price than the incumbent.[23] Recent regulatory experience e.g. in the Netherlands concerning regulation of cable networks indicates that regulation might well be symmetric.

The second assumption allows easy comparison with the previous cases. Furthermore, it provides a reference case, which appears to match regulator's preoccupation with traditional incumbents as well as the consequences of the concept of significant market power (SMP) regulators in the EU apply. Figs. 9 and 10 (relevant are the curves with superscript *SymReg*) include as a further assumption that the firms are not allowed to set prices *below* the regulated price. The constraint that firms would like to set prices below p^{RW}, the price set by the regulator becomes binding for large values of the product differentiation parameter σ. Recent margin-squeeze cases indicate that regulators and antitrust authorities actually prevent network providers from reducing prices.[24] If one does not consider this constraint as relevant, the results from the cases without price regulation apply in the relevant range. If there were no further restriction, for instance, the unregulated duopoly case would apply for values of σ to the right of the intersection of s_C^{SymReg} with $s_C^{unregulated}$.

Note that Fig. 10 includes welfare in the case of a regulated monopoly. This case provides an interesting reference for two reasons: First, in some countries, e.g. in Germany and in Portugal, the telecoms incumbent owned and owns, resp., the cable network. These incumbents only invested in one broadband technology, not two. Therefore, comparison shows what is lost (or gained) in terms of welfare, if incumbents are not *horizontally* unbundled. Second, it might be an explicit policy goal to prevent duplication of infrastructure for the traditional reasons of either subadditivity or of sustainability of cross-subsidization.[25]

Fig. 10 demonstrates that the degree of product differentiation is a key variable with respect to the welfare effects of the different regimes. If products are almost identical (i.e., σ is close to one), an entry ban and horizontal bundling of the networks, respectively, may lead to higher welfare if the monopolistic incumbent faces an omniscient and benevolent regulator. Probably most interesting is that a significant range of σ values exists (σ around .75), for which even perfect and costless (price) regulation aimed at the telecoms incumbent cannot significantly improve welfare. If the networks are more differentiated a 'single network policy' is clearly inferior to unregulated competition, even if regulation is perfect.

Taking into account the inevitable costs associated with regulation and the imperfect information regulators face, Fig. 10 hardly supports heavy-handed (price and entry) regulation. The existence of a significant range where welfare under (costless and omniscient) heavy-handed regulation and welfare in an unregulated situation and light-handed regulation situation, respectively, hardly differs, lends support to less interventionist policies like that in the US with respect to next generation networks.

[22] For an analysis where only the incumbent provides access and a single entrant can choose in each region whether to enter based on own facilities or on access provided by the incumbent see Bender and Götz (2011).

[23] See Briglauer, Götz, and Schwarz (2011) for a discussion of the 'problem' that entrants might charge higher prices than the incumbent. They also provide a demand specification which leads to the same results as in our case.

[24] See Briglauer et al. (2011) for a discussion of this issue.

[25] See Höffler for arguments in favour of entry bans. The projects to subsidize Next Generation Network projects in Singapore and Australia appear to focus very much on a single infrastructure. See WIK (2008).

5. Public policy: subsidization of broadband investment and access

In this final policy section, I analyze the effects of both demand-side and supply-side subsidies on total welfare.[26] Both policy instruments are and were employed, respectively. In Austria, for instance, spending on broadband access was tax-deductible by final consumers. Supply-side subsidies to broadband are discussed in many countries, in particular under the headline of universal service obligations.[27] While some general results are available, I focus again on the results of the simulation to illustrate both magnitudes and global rather than local effects. An obvious, but nevertheless important general result is the welfare improving effect of a 'small' subsidy starting from the decentralized equilibrium. The reason is the consumer surplus effect: Firms cannot extract all consumer surplus created by upgrading an exchange. Therefore, the incentive to invest is downward biased and under-investment results.

In order to analyze the effects of the subsidies I extend the above simulation to allow for both a subsidization of the fixed investment costs (Fig. 11) and for a price subsidy received by the households (Fig. 12), respectively. In addition to the above assumptions on parameters, I assume that $\sigma = .65$, a value also employed by Valletti et al. Furthermore, I abstract from cost of funds due to distortionary taxation and keep on assuming equal weights of both consumers and firms in the social welfare function. I present here the results for the case where a uniform pricing constraint is in place, a case which seems to be relevant for most countries.

Fig. 11 allows for three conclusions beyond the general result that 'small' subsidies are welfare increasing. First, given that the subsidy is not too high in the sense that it does not capture the whole investment costs, subsidization of both firms is much more welfare increasing than only subsidizing 'rural' regions by paying subsidies to the incumbent. The reason is a competition effect of the subsidies. The subsidies to the entrant increase her coverage. Apart from the increase in availability this increases the duopoly region leading also to lower prices. This effect explains the difference in the welfare effects.

Second, the optimal subsidies are of significant size. They account for close to 50% of the investment costs. As a consequence of such subsidies the minimum size of regions covered would decrease by 50% from a population of 20,000 ($s = 200$) to about 10,000 ($s = 100$).

Third, and going back to the policy where only the incumbent receives subsidies, Fig. 11 shows that subsidies that pay for almost the total investment cost leading to an almost 100% coverage yield welfare levels similar to the situation without subsidies. This holds without accounting for potential network externalities. This result indicates that, at least as long as the social cost of funds is not too high, supply-side subsidies for reasons of regional policy should not do much harm to total welfare.[28]

Turning to demand-side subsidies and Fig. 12, one caveat is in order. Under imperfect competition with prices above marginal cost, (small) subsidies are always welfare increasing. These subsidies turn into profits at a large degree. In this case, both the fact that both profits and consumer surplus receive equal weights in the social welfare function and the fact that subsidies are financed by revenues from non-distortionary taxation lead to the high welfare gains apparent in Fig. 12. Accordingly, the underlying amount of subsidies would be huge. At the welfare maximum (*subsidy/household* ~36€), the price would be equal to the subsidy; consumers in covered regions would receive the service for free, i.e. at marginal costs.

Note that demand-side subsidies mainly benefit consumers in more densely populated regions, which would be covered anyway. While a subsidy of about 36€ would enable all consumers in covered regions to access broadband, however small their willingness to pay is, the smallest covered region would exhibit an s of about 125, a value significantly higher than with supply-side subsidies.

Taken together, supply-side subsidies can be seen as an effective instrument to increase coverage and to supply smaller regions with access. Demand-side subsidies appear to be an expensive instrument to predominantly increase penetration.[29]

6. Conclusions

This article has examined the effect of various regulatory regimes on firms' incentives to provide broadband access to the internet. Taking into account differences in the population density across the regions in an economy, the focus was on the trade-off between broadband penetration and broadband coverage. A rather stylized model revealed general patterns, which also yield insights for the evaluation of regulatory options with respect to new technologies such as Next Generation Networks. The analysis emphasized the Schumpeterian argument of market power as a prerequisite for investment. As far as regulation is concerned, the paper showed that even costless and well-informed heavy-handed regulation need not be able to improve much upon the unregulated benchmark in terms of welfare. Light-handed regulation such as uniform pricing

[26] Valletti et al. discuss coverage constraints, which are alternative policy instruments to increase coverage. However, they do not consider the respective policy effects in their discussion of universal service obligations. Coverage constraints without additional subsidies do not appear to be a relevant policy instrument with respect to next generation networks, for instance.

[27] See the Economist magazine supra note 2 for a policy discussion, and Picot & Wernick (2007) for an overview of activities in various countries.

[28] Note that this rather cautious statement does not imply that such a policy is some sort of ideal. In particular if for instance the quality of the service, i.e. the speed of the internet connections or the technology to be used is to be determined as well if asymmetric information about both willingness to pay and the costs of providing the service exists big problems might arise. However, the analysis could well provide guidance in more standard cases of providing a well-known technology such as basic broadband internet services based on copper.

[29] These conclusions are in line with the findings of (Goolsbee, 2003, chap.12), who also finds that supply-side subsidies are superior to usage subsidies.

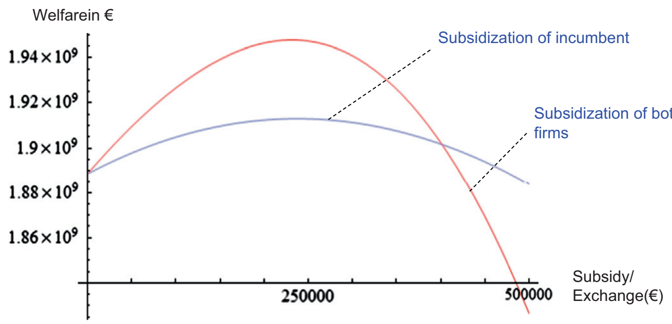

Fig. 11. Welfare W with supply-side broadband subsidies.

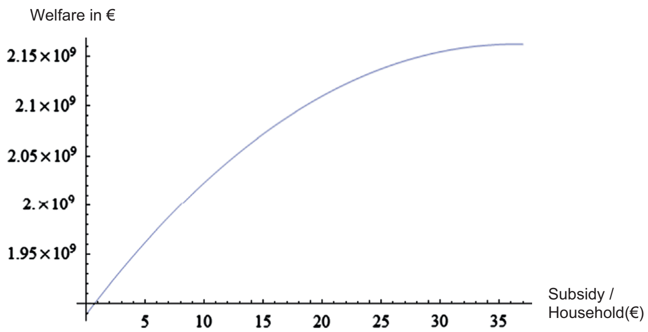

Fig. 12. Welfare W with demand-side broadband subsidies.

constraints might be preferable as a regulatory safeguard in a world where regulators lack knowledge of key parameters. Of particular importance for the evaluation of the different regulatory options is the question how differentiated products are from the viewpoint of consumers. It is an important task for empirical research to find out more about consumer's valuation of product variety in this specific case. However, even robust empirical results indicating a potential positive effect of heavy-handed regulation in the model would only constitute the best-case-scenario for regulatory intervention. Given the uncertainty surrounding investments in new technologies, in particular with respect to the demand side, regulatory commitment to either no or only light-handed regulation appears to be superior.[30]

The model makes a clearer case for policy action when it comes to supply-side subsidies. With this kind of potential state intervention rent-seeking by firms might lead to strategic withholding of investments in otherwise profitable regions by incumbents. It is a topic for future research, how subsidization schemes should look like if one takes strategic incentives of firms with respect to policy into account.

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[30] For a detailed discussion see Crandall and Aron (2008).

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