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Access Regulation with Asymmetric Termination Costs

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Abstract

In many telecommunications markets incumbent providers enjoy a demand-side advantage over any entrant. However, market entrants may enjoy a supply-side advantage over the incumbent, since they are more efficient or operate on innovative technologies. Considering both a supply-side and a demand-side asymmetry, the present model analyzes the effect of two regulatory regimes: An access markup for a low cost network and reciprocal charges below the costs of a high cost network. Both regimes may have adverse effects on subscribers, market shares, and profits. It can be shown that an access markup is not generally beneficial and an access deficit not generally detrimental for the respective networks. However, if providers discriminate between on-net and off-net prices a markup on the entrant's termination cost is generally to its benefit and to the incumbent's detriment.

Keywords: Termination charges; Interconnection; Asymmetric Regulation; Price Discrimination.

JEL-Classification: L13, L51, L96

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1 Introduction

The liberalization of European telecommunications markets can be regarded as a success at least with two respects. Former established incumbent fixed-line operators face competition from various new providers which sequentially entered the markets. Moreover, several new technologies such as mobile and IP-based telephony have emerged which additionally challenge to competitive position of former incumbent operators. This created an asymmetric market environment in various dimensions. Typically, in Europe, incumbent fixed-line operators still enjoy a demand-side advantage over any entrant in terms of subscriber base, both in the fixed-line and the mobile telecommunications markets. However, due to the later entry, entrants may had the opportunity to set up more recent technologies which may imply a cost-side advantage of service on their side. Especially, with IP-based networks, marginal costs of providing electronic communications are virtually zero, which, e.g., has been stated by the German Monopolies Commission (Monopolkommission, 2006).

Practitioners in regulatory authorities as well as academics have acknowledged the important role of interconnection charges, also labeled as termination or access charges, at the wholesale level to imped competition and foster entry at the retail level. The question arises, whether asymmetries of operators require an asymmetric regulation of interconnection charges. In the mobile telecommunications markets the European Commission (EU Commission 2009) proposes termination rates to be limited to the incremental costs of providing call termination, so called pure long-run incremental cost (pure LRIC). The costing model should reflect the fact that operators may have different cost structures, which can e.g. be linked to different technical conditions of their networks, e.g. spectrum licenses, can be a result of different economies of scale due to different market shares or due to the adoption of more efficient technologies. Such cost differences have rarely been considered in the theoretical literature on call termination, which serve as the starting point of the present analysis.

The German Bundesnetzagentur recently estimated lower termination costs for the later entrants in the mobile telecommunications market. For E-Plus, one of two smaller competitors, it estimated termination costs of 2,67 ct/min, whereas it estimated higher costs from 3,33-3,37 ct/min for the other operators. In February 2011, the Bundesnetzagentur has announced mobile termination rates (MTRs) for all operators for the years 2010-2012 between 3.36-3.39 ct/min.[1] Thus, it sets a markup on the cost of one of the smaller network E-Plus, whereas it adopts LRIC-regulation for all other operators.

This access markup on termination costs of the low cost network serves as a starting point of the present analysis. In a model with a demand-side asymmetry (and cost-side symmetry) between telecommunications providers, Peitz (2005a) shows that such an entrant's access markup indeed benefits entrants and, given entry, competition is more intense. In an accompanying paper (Peitz (2005b)) he further shows that this also holds if providers discriminate between prices for calls terminated on-net and off-net. The present model can generalize his results and show that this conclusion is sensitive to a symmetry of termination costs. By considering asymmetric termination costs it will be shown the an entrant's access markup can even be to the detriment of its profit and in turn, can reduce entry into the market. This result is due to a cost-saving effect for the incumbent. If termination costs are sufficiently asymmetric, the high cost incumbent has an incentive to terminate calls in the low cost network (off-net) and thereby attract rival customers. This (positive or negative) effect of regulation on providers' market share is new and basically determines the effect of regulation on providers' profits. If asymmetries in the demand- and supply-side are large it can be shown that both providers prefer cost-based regulation of termination charges.

The second part of the analysis covers another widely proposed regulatory regime. The British Ofcom recently announed a glide path of MTRs based on a maximum average rate calculated using the pure LRIC of providing call termination for their major operators from 4,18 pence per minute in 2011, moving towards 0,69 pence per minute in 2015.[2] Consequently, the cost of calling to mobile networks are set on a reciprocal basis and will steadily decrease. In line with Carter and Wright (1999, 2003) the second part of the paper deals with a reciprocal regulation and the sequential reduction of termination rates, given cost asymmetries between networks. In a model of pure demand-side asymmetry Carter and Wright (1999, 2003) show that

[1]Bundesnetzagentur, BK3a-10-098, BK3a-10-099, BK3a-10-100, and BK3a-10-101.
[2]http://stakeholders.ofcom.org.uk/consultations/wmctr/

a marginal reduction of a reciprocal termination charge leaves providers' market shares and profits unaffected. It will be shown that this no longer holds with asymmetric termination costs and both providers may benefit or suffer from a reduction of the reciprocal termination charge. It will be shown that if asymmetries in demand and supply are large, both providers prefer cost-based regulation of termination charges to the incumbent's costs.

Asymmetries in termination costs have also been addressed by Kocsis (2007) who focuses on a supply-side asymmetry with a linear demand for calls. Hoernig (2009) calibrates a model of competition between an arbitrary number of telecommunications networks in the presence of tariff-mediated network externalities, call externalities, and cost and surplus asymmetries. Harbord and Hoernig (2010) run simulations based on the model of Hoernig (2009) to show that a "bill-and-keep" regime increases social welfare, consumer surplus, and networks' profits.

The rest of the paper is organized as follows: Section 2 provides the base model. Section 3 allows for an access markup for the low cost network and analyzes the regimes of nondiscriminatory pricing and price discrimination between on-net and off-net calls. Similarly, section 4 discusses the effect of reciprocity of termination charges for both networks. Section 5 concludes.

2 The Model

Consider competition between an established provider (firm 1) and an entrant (firm 2) which are located at the opposite ends of a Hotelling-line. The base model follows the seminal model of Laffont et al. (1998). It assumes that both networks are interconnected and provide full local coverage.

For calls from to the rival's networks ("off-net") providers have to pay a termination charge of a_j. They incur a marginal cost c_i per minute for originating and terminating a call, so total marginal costs of a call are assumed to be $2c_i$, where the model abstracts from any additional costs, e.g. transmission costs. Specifically, we assume that $c_2 < c_1$, i.e. the entrant operates at lower termination cost which e.g. may be due to a more recent technology.[3]

[3]In practise, there is a discussion whether later entrants face lower or higher costs of

To mirror current market structures in many European countries it is assumed that the incumbent still captures a larger installed subscriber base than the entrant. To model the demand-side asymmetry the present model follows the framework of Carter and Wright (2003). The utility derived by a consumer for subscribing to either network i is given as

$$U_i = v_0 + \theta_i + u(q(p_i)), \tag{1}$$

where $q(p_i)$ is the number of calls placed on network i, depending on the per-minute price p_i. v_0 represents a fixed surplus ("option value") from being connected to either network and is assumed sufficiently large so that all subscribers choose to be connected to a network. Subscribers receive a network specific benefit of subscribing to network i of

$$\theta_1 = \frac{\beta}{2\sigma} + \frac{1-x}{2\sigma}$$

and

$$\theta_2 = \frac{x}{2\sigma}.$$

Customers are endowed with a value of x drawn from a uniform distribution on the $[0, 1]$ interval, with the networks 1 and 2 located at either end of the interval. The parameter σ expresses the degree of substitution between both providers. Hence, σ can be interpreted to reflect the degree of competition in the market, with higher values corresponding to more intense competition.

As in the models of Carter and Wright (1999, 2003) the present model introduces an incumbency advantage of $\beta > 0$. An incumbency advantage results from a variety of factors. It might capture reputation effects of an established network, whereas there is uncertainty about the quality and service of the entrant. Alternatively, it can proxy for switching costs (see De Bijl and Peitz (2002)) due to consumers' inertia or due to technical reasons.

Given that all consumers' marginal willingness to pay for calls is the same

termination than established incumbents. Due to the sequential allocation of frequencies in mobile telecommunications entrants in Germany sometimes claim to face higher coverage costs to cover the territory or to insure indoor coverage of its 1800 Mhz band compared to the 900/1800 Mhz band of T-Mobile and Vodafone. Otherwise, it may be stressed that the fact that a frequency band is only suitable for a more expensive technology should be compensated by a lower market price for this license.

and known, networks can do no better than offering two-part tariffs. Each network charges a per-minute price p_i and a fixed fee F_i. Therefore, the two-part tariff is given as $T_i(q) = F_i + p_i q(p_i)$.

The function

$$\upsilon(p_i) = \max_q \{u(q) - p_i q\}$$

denotes the indirect utility derived from making calls at a price p, so $\upsilon'(q) \equiv -q(p)$ gives the associated demand function. For example, a linear demand function of $q(p) = 1 - p$ is represented by an indirect utility of $\upsilon(p) = \frac{1}{2}(1-p)^2$. A consumer's net surplus of belonging to network i is $\omega_i = \upsilon(p_i) - F_i$. Subscribers are assumed to be identical in terms of their demand for calls to other subscribers.

Solving for the indifferent consumer with $U_1 = U_2$, the market share of the incumbent is

$$s_1 = \frac{1}{2} + \frac{\beta}{2} + \sigma(\omega_1 - \omega_2) \tag{2}$$

and $s_2 = 1 - s_1$ for the entrant.

3 Asymmetric Regulation

In the following we analyze to regulatory regimes. In the first part we analyze the impact of an entrant's access markup on cost, in the second part we analyze the impact of an incumbent's access deficit below cost. In either regulatory regime, we analyze the pricing strategies of non-discriminatory pricing and price-discrimination between on-net and off-net prices.

3.1 Non-discriminatory pricing

In the following analysis the entrant may charge a termination fee above marginal costs, i.e. $a_2 > c_2$, whereas the incumbent is regulated at costs, i.e. $a_1 = c_1$.[4] Since market shares s_i are directly determined by the net surplus ω_i, it is more convenient to consider networks to compete over p_i

[4]In a different model setup De Bijl and Peitz (2009) analyze the effects of charging termination fees a high cost fixed-line network, assuming bill-and-keep pricing at a VoIP network, which faces zero cost for call termination.

and ω_i rather than in p_i and F_i. Substituting $F_i = \upsilon(p_i) - \omega_i$ the profit function of provider i is denoted as

$$\Pi_i = s_i(p_i - 2c_i)q(p_i) + s_i(\upsilon(p_i) - \omega_i) + s_i s_j\big((a_i - c_i)q(p_j) - (a_j - c_i)q(p_i)\big). \quad (3)$$

The first two parts denote the profits in the retail market due to per-minute prices and fixed fees. Calling patterns are assumed to be balanced, with a share of $s_i s_j$ requiring interconnection.[5] The third part represents the profit in the interconnection market. Provider i charges a termination rate of a_i, but incurs costs of c_i for rival subscribers' calls terminated in its network. Otherwise, for off-net calls by fellow subscribers the provider has to pay a termination charge of a_j but saves the termination costs.

Equilibrium prices correspond to "the perceived marginal costs" of a call of

$$p_i^* = 2c_i + s_j^*(a_j - c_i), \quad (4)$$

which is the standard result in the symmetric setup of Laffont et al. (1998) and asymmetric setups of Carter and Wright (2003), Peitz (2005a), and Valletti and Cambini (2005). By setting per-minute prices equal to the perceived marginal costs the networks can extract consumers' surplus by the fixed fee. The providers incur costs of $2c_i$ for originating and terminating calls on-net but save costs of $s_j c_i$ for calls terminated off-net.

Rearranging $F_i = \upsilon(p_i) - \omega_i$, the fixed fee at the equilibrium per-minute price is given as

$$F_i^* = \frac{s_i^*}{\sigma} - s_i^*(a_j - c_i)q(p_i^*) + (s_i^* - s_j^*)(a_i - c_i)q(p_j^*). \quad (5)$$

Each provider sets its per-minute price equal to the perceived marginal cost and, thus, makes no profit from the amount of off-net and on-net traffic by fellow subscribers. The only source of income stems from subscription and

[5] This is the standard assumption in the literature (see, e.g., Laffont et al. (1998) or Valletti and Cambini (2005)). Gabrielsen and Vagstad (2008) instead assume that people tend to place more calls in "calling clubs" i.e. to family and friends, independent of the market share of the providers.

incoming calls from rival subscribers. Accordingly, each operator makes a profit in terms of net surplus of

$$\Pi_i^* = s_i^*(\upsilon(p_i^*) - \omega_i^*) + s_i^* s_j^*(a_i - c_i)q(p_j^*). \tag{6}$$

3.1.1 Subscribers' Net Surplus

According to equation (4) an entrant's access markup directly increases the incumbent's per-minute prices for given market shares. The total effect on subscribers' surplus is ambiguous, though, and depends on the extent of the asymmetries in the market.

Proposition 1. For symmetric termination costs subscribers of both networks benefit from a marginal increase of the entrant's termination charge. For asymmetric termination costs net utilities may increase or decrease. Subscribers of both networks will likely benefit if providers are not too differentiated and termination costs are not too asymmetric.

Proof: See Appendix.

The technical proof goes along the lines originated by Peitz (2005a) and relies on applying results on supermodular games and comparative static analysis. Technically, it will be shown that for symmetric termination costs ($c_1 = c_2$), the pseudo best-response functions are upward sloping, hence are strategic complements. The pseudo best-response functions are shifted outwards in response of a marginal increase in entrant's termination charge. This confirms the positive effect on subscribers of both providers, obtained in the model of demand-side asymmetry and supply-side symmetry by Peitz (2005a). However, for any $c_1 > c_2$ the pseudo best-response functions are either strategic complements are substitutes, since $\frac{\partial^2 \Pi_i^*}{\partial \omega_i \partial \omega_j} \lessgtr 0$, depending on the parameters. Subscribers of both providers may benefit or suffer from an entrant's access markup.

The intuition is as follows. Consider the incumbent operator. As already stated by Peitz (2005a) due to the larger termination charge is has to pay, it has an incentive to decrease the number of calls to the entrant in order to keep its perceived marginal costs low. The number is maximal for an equal split of the market, hence, the incumbent has an incentive to increase its subscribers' net surplus to increase its market share. However, to the contrary, it also has an incentive to increase the number calls to the rival's network. This is due to a cost-saving effect. The incumbent could save its higher costs by terminating calls in the entrant's network and thus, also has an incentive to increase the number of calls to the entrant's network.

The entrant has countervailing incentives as well. Clearly, on the one hand, the entrant has an incentive to increase the number of incoming calls to obtain higher revenues from incoming calls given rival's demand for calls and therefore offers a higher net surplus to its consumers. However, slightly reducing the net surplus reduces the amount of incoming calls and thereby, reduces the rival's cost-saving effect and increases rival's per-minute price. In turn, the net utility from calling on the incumbent's side decreases as well, competition on net surplus becomes less intense and the entrant may capture the remaining net surplus via the fixed fee.

3.1.2 Market Shares

The expression for equilibrium market shares are relegated to the appendix. Based on the previous effect on subscribers, we are interested in the effect of an entrant's access markup on provider's market shares. In his model of demand-side asymmetry and supply-side symmetry Peitz (2005a) concluded a neutral effect of an entrant's access markup on market shares locally around cost-based regulation. Total differentiation of the entrant's market share (locally around cost-based regulation of $a_i = c_i$) yields:

$$\frac{ds_2^*}{da_2}|_{a_i=c_i} = \frac{q' s_1^* s_2^* (c_2 - c_1)}{2(c_1 - c_2)(q(p_2^*) - q(p_1^*)) - (c_2 - c_1)^2 q' - \frac{3}{\sigma}} \tag{7}$$

and of $\frac{ds_1^*}{da_2}|_{a_i=c_i} = -\frac{ds_2^*}{da_2}|_{a_i=c_i}$ for the incumbent. Hence, there is a local effect on market shares for any asymmetry in termination costs ($c_1 \neq c_2$). Given that $c_2 < c_1$ the numerator is positive, as $q' < 0$. The sign of $\frac{ds_2}{da_2}$ is thus determined by the sign of the denominator. Otherwise, for a supply-side symmetry, the neutrality result by Peitz (2005a) is confirmed.

Proposition 2. For symmetric termination costs an entrant's access markup has no local effect on market shares. For asymmetric termination costs an entrant's access markup has a positive local effect on its market share if i) the degree of substitution between both networks is sufficiently low (i.e., σ is sufficiently large), ii) termination costs are sufficiently asymmetric, and iii) the demand for calls is sufficiently rigid.

Proof: See Appendix.

Example 1: To illustrate the above proposition assume an indirect utility of calls of $\upsilon(p_i) = \frac{1}{2}\frac{(A-p_i)^2}{b}$ for $A, b > 0$, which leads to a linear demand of calls of $q(p_i) = \frac{A-p_i}{b}$ and set $A = b = 1$. From evaluation of equation (7) at cost-based regulation it follows that there is a positive effect on the entrant's market share if

$$(c_1 - c_2)^2 > \frac{1}{\sigma}. \tag{8}$$

Given that providers are hardly differentiated, i.e., competition is intense, and given that termination costs are sufficiently asymmetric, an increase of the entrant's termination charge has a positive local effect on its market share. Otherwise, if competition is sufficiently soft, this may be reversed. The intuition behind the result follows the one given in the previous section since market shares are directly determined by subscribers' net surplus and providers face countervailing incentives to increase or decrease subscribers' net surplus depending on the incumbent's cost saving for off-net call termination. If the entrant's termination costs are sufficiently low the incumbent has an incentive to decrease net surplus of it's subscribers and in turn, to decrease its market shares, in order to increase the number of off-net calls.

3.1.3 Profits

Since providers set per-minute prices equal to perceived marginal costs, the equilibrium profits are denoted by equation (6). Since regulation affects market shares, it affects both the retail market (the first part of equation (6)), and the interconnection market (the second part of the equation). Differentiation of the profit functions with respect to a_2 (locally around cost-based regulation of $a_i = c_i$), yields

$$\frac{\partial \Pi_1^*}{\partial a_2}|_{a_i=c_i} = 2s_1^* \frac{ds_1^*}{da_2}\big(\frac{1}{\sigma} + (c_1 - c_2)q(p_1^*)\big) + s_1^{*2}\big((c_1 - c_2)q' \frac{dp_1^*}{da_2} - q(p_1^*)\big) \quad (9)$$

and

$$\frac{\partial \Pi_2^*}{\partial a_2}|_{a_i=c_i} = 2s_2^* \frac{ds_2^*}{da_2}\big(\frac{1}{\sigma} - (c_1 - c_2)q(p_2^*)\big) + s_2^{*2}\big(q(p_1^*) - (c_1 - c_2)q' \frac{dp_2^*}{da_2}\big). \quad (10)$$

Proposition 3. With symmetric termination costs an entrant's access markup positively (negatively) affects the entrant's (the incumbent's) profit locally around cost-based regulation. With asymmetric termination costs both providers may benefit or suffer from an entrant's access markup. If competition becomes too intense both providers prefer cost-based regulation of termination charges.

Given symmetric termination costs of $c_1 = c_2$ it has been shown in equation (7) that there is no local effect on market shares, hence $\frac{ds_i^*}{da_2}|_{a_i=c_i} = 0$. Applying the neutrality of market shares simplifies the effect of a marginal increase of the entrant's termination charge on providers' profits denoted as

$$\frac{\partial \Pi_1^*}{\partial a_2}|_{c_1=c_2} = -s_1^{*2} q(p_1) < 0$$

and

$$\frac{\partial \Pi_2^*}{\partial a_2}|_{c_1=c_2} = s_2^{*2} q(p_1) > 0.$$

This confirms the non-neutrality result on profits obtained by Peitz (2005a) in a model of demand-side asymmetry and by Kocsis (2007) in a model of supply-side asymmetry for symmetric termination costs. However, in the present model the cost asymmetry additionally affects calling patterns, so the effect on profits is less straightforward and the results given by Peitz (2005a) may be reversed. The entrant may suffer and the incumbent may benefit from a markup on the entrant's termination cost.

Entrant's profit

Decompose the effects on profits in the retail and in the interconnection market and assume the entrant captures market shares from the incumbent, i.e. $\frac{ds_2^*}{da_2} > 0$. An increase in the entrant's termination fee above marginal termination cost affects i) the per-minute profit of rival subscribers making off-net calls $(a_i - c_i)$, ii) the demand for off-net calls per rival subscriber $(q(p_j^*))$, and iii) the total amount of off-net calls $(s_i^* s_j^*)$. Obviously, a termination markup increases the per-minute profit per rival subscriber unit. Calling patterns are assumed to be balanced. Starting from the asymmetric situation of $s_2 < s_1$, an increase in s_2 increases the number of off-net calls, which is maximized at $s_1 = s_2$. Both effects benefit the entrant. Total interconnection profit is determined by $s_i^* s_j^*(a_i - c_i)q(p_j^*)$. Hence, it is further necessary to determine the impact on rival subscriber's demand, given as $\frac{dq(p_i^*)}{da_2} = q' \frac{dp_i^*}{da_2}$, with $q' < 0$. It holds that

$$\frac{\partial p_1^*}{\partial a_2}|_{a_i=c_i} = s_2^* - (c_1 - c_2)\frac{ds_2^*}{da_2} \lesseqgtr 0.$$

Thus the effect on rival subscribers' demand is ad hoc unclear. If the difference in termination costs is large the incumbent has an incentive to push the demand for off-net calls to save its termination costs and thereby, to decrease its per-minute price. Otherwise, if the entrant's subscriber base is too large, an entrant's access markup may be to the detriment of its termination profit. This is due to providers' perceived marginal costs. If the entrant's subscriber base is sufficiently large, there are many off-net calls. Now, an increase in a_2 has a larger impact on rival's per-minute prices for a larger entrant's market share. Given the difference in termination costs, the incumbent increases its per-minute prices for a larger entrant's market share, reducing the demand of the incumbent's subscribers which may overturn the cost-saving effect.

Consider the retail market. It follows from equation (6) that the effect of a termination markup on the entrant's retail profit is determined by market shares and the fixed fee, determined by subscribers' net surplus as $F_i = v(p_i) - \omega_i$. Assume again that the entrant's market share is increasing in a_2. Locally evaluating the derivative of the fixed fee with respect to the entrant's termination fee (around cost-based termination charges) yields

$$\frac{\partial F_2^*}{\partial a_2}|_{a_i=c_i} = \frac{ds_2^*}{da_2}\big(\frac{1}{\sigma} - (c_1 - c_2)q(p_2^*) - (c_1 - c_2)q'\big) - (s_1^* - s_2^*)q(p_1^*).$$

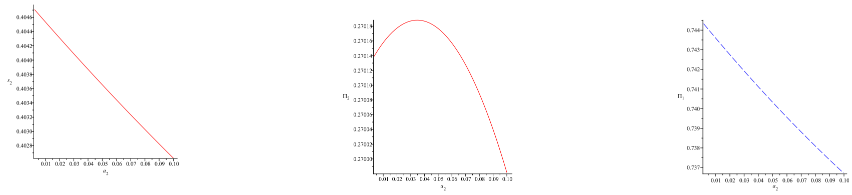
It has been stated above that for symmetric termination costs subscribers' net surplus increases in an entrant's access markup. Hence, since market share are locally unaffected for $c_i = c_j$, fixed fees decrease, leading to lower profits in the retail market. Otherwise, for asymmetric termination costs, the fixed fee may increase or decrease. The effects in the retail and interconnection market may be countervailing, leading to a non-monotone relationship between the termination charge and profits. This will be illustrated in example 2.

Incumbent's profit

Consider the effect of an entrant's access markup on the incumbent's profit. Notably, as per-minute prices are set equal to perceived marginal cost, an increase of a_2 does not affect the interconnection profit of equation (6) locally around $a_1 = c_1$. So the local effect on total profit is given as

$$\frac{\partial \Pi_1^*}{\partial a_2}|_{a_i=c_i} = \frac{ds_1^*}{da_2}F_1^* + s_1^*\frac{\partial F_1^*}{\partial a_2}.$$

Remember that the incumbent provider may offer a higher net surplus to its subscribers in response to an increase in a_2. In order to determine the effect on the fixed fee it is necessary to additionally determine the effect on the indirect utility from making calls, as $F_i = v(p_i) - \omega_i$. Given the indirect utility $v(p_i)$ the fixed fee is the lower the higher the net utility ω_i. The effect on the indirect utility from making calls is affected by the per-minute price, which may increase or decrease in a_2 as $\frac{\partial p_1^*}{\partial a_2}|_{a_i=c_i} = s_2^* - (c_1 - c_2)\frac{ds_2^*}{da_2} \gtreqless 0$. Now if competition is sufficiently soft, it follows that $\frac{ds_2^*}{da_2} > 0$, and the incumbent's per-minute price decreases. The incumbent saves the higher termination cost on its network for every call terminated in the entrant's network. For $s_2 < s_1$ an increase in the entrant's market share increases the number of off-net calls, which is maximized at $s_2 = s_1$. Now, the perceived marginal cost is the lower the higher the entrant's market share, and thus, the incumbent may benefit even if it gives up market shares to the entrant, due to a cost-saving effect. This positive effect holds if the share of off-net calls, determined by rival's market share is small, otherwise for large s_2 the total loss in market shares might become too large compared to the cost-saving effect. Thus, the effects on profits crucially depend on the demand- and supply-side asymmetry and on the degree of competition in the market. This positive effect on indirect utility vanishes if termination costs become more symmetric, and thus, in line with Peitz (2005a), the incumbent suffers from the rival's access markup, since the cost-saving effect is reduced.



Entrant's market share. | Entrant's profit. | Incumbent's profit.

Figure 1: Providers' market shares and profits depending on a_2.

Example 2: Consider a linear demand of $q(p) = 1 - p_i$ and set parameters at $a_1 = c_1 = 0.5, c_2 = 0, \beta = 1$, and $\sigma = 0.5$. Figure 1 plots the entrant's and the incumbent's profit functions for a larger deviation from cost-based regulation. For a small incumbent's advantage of $\beta = 1$ the demand-side is not too asymmetric. Here, the entrant prefers an above, but close to marginal cost termination charge, whereas the incumbent prefers the entrant to be regulated at marginal costs. Moreover, as stated above, an increase or decrease in market share is not sufficient for profits to go in the same direction.

Regulation of termination fees may have a non-monotone effect on profits for asymmetric termination costs, which contradicts the positive effect of an access markup for the respective provider in a model of a pure demand-side asymmetry (and a cost-side symmetry) by Peitz (2005a). The present model generalizes his result and shows that the positive effect only holds termination costs are relatively identical.

3.2 Price Discrimination

The following section allows providers to charge different prices for calls terminated on the subscriber's network ("on-net") and for those terminated on the rival's network ("off-net"). Denote provider $i's$ on-net price as p_i and its off-net price as $\hat{p}_i$. If a provider's market share is s_i, its subscribers make a fraction s_i of their calls on-net and the remaining $1 - s_i$ calls off-net. Then, subscribers' net surplus $\omega(p_i, \hat{p}_i)$ is

$$\omega(p_i, \hat{p}_i) = s_i \upsilon(p_i) + s_j \upsilon(\hat{p}_i) - F_i. \tag{11}$$

With price discrimination is follows that providers set per-minute prices equal to the true marginal costs, i.e.

$$p_i^* = 2c_i \tag{12}$$

and

$$\hat{p_i}^* = c_i + a_j. \tag{13}$$

Without price discrimination, the first-order conditions with respect to call prices weights the optimal per-minute prices with price discrimination of equations (12) and (13) by their market shares, which gives equation (4). Since termination costs differ for both providers, a uniform per-minute price is the average of marginal on-net and off-net costs, which reflects a weighted average of true marginal costs.

The equilibrium fixed fee is set to

$$F_i^* = \frac{s_i^*}{\sigma} + s_i^*(\upsilon(\hat{p_i}^*) - \upsilon(p_i^*)) + (s_i^* - s_j^*)(a_i - c_i)q(\hat{p_j}^*). \tag{14}$$

Proposition 4. If providers can discriminate between on-net and off-net prices for calls all subscribers benefit from an entrant's access markup.

Proof: See Appendix.

Without price discrimination subscribers may benefit or suffer from a marginal increase of the entrant's termination charge, depending on extent of the cost-saving effect. However, with price discrimination the per-minute prices are set to true marginal costs of on-net and off-net termination. Thus, there is no cost-saving opportunity and it directly follows that subscribers unambiguously benefit from an entrant's access markup. Due to the higher off-net costs, the incumbent has an incentive to reduce the number of off-net calls and due to the higher termination rate the entrant has an incentive to increase the number of off-net calls.

If providers are unable to discriminate between on-net and off-net prices, it has been shown that both providers' market shares are positively or negatively locally affected by a marginal increase in the entrant's termination charge a_2 above marginal costs. However, if providers can price discriminate it can be shown that market shares are locally unaffected, i.e.

$$\frac{ds_i^*}{da_2}|_{a_i=c_i} = 0. \tag{15}$$

This restores the result of Carter and Wright (2003) and Peitz (2005a) in a model with cost-asymmetries and price discrimination. At the point of cost-based regulation, equilibrium market shares do not respond to an entrant's access markup, independent of any asymmetry in size or termination costs. With price discrimination regulation of termination fees leaves on-net per-minute prices (locally) unaffected. As in the models of Carter and Wright (2003) and Peitz (2005a) the asymmetries only determine the decision to subscribe to either network, but once subscribed, the asymmetry does not affect subscribers' calling demand.

A termination markup generates income from inbound calls from rival subscribers for the entrant. Locally around cost-based regulation, the entrant benefits from a marginal increase in its termination charge. Otherwise, the incumbent has to pay a higher termination charge for outbound calls, and hence, it suffers from the increase. Technically,

$$\frac{\partial \Pi_1^*}{\partial a_2}|_{a_i=c_i} = -s_1^{*2} q(\hat{p_1}^*) < 0 \tag{16}$$

and

$$\frac{\partial \Pi_2^*}{\partial a_2}|_{a_i=c_i} = s_2^{*2} q(\hat{p_2}^*) > 0. \tag{17}$$

Proposition 5. A marginal increase in the entrant's termination charge does not affect equilibrium market shares. It gives rise to higher (lower) profits for the entrant (incumbent) provider. This holds independent of any demand- and supply-side asymmetry.

Proof: See Appendix.

Hence, price discrimination can restore the results of the previous literature in a model of asymmetric termination costs. Independent from any supply-side asymmetry, an entrant's access markup is unambiguously to the benefit of the entrant and to the detriment of the incumbent. In this sense, asymmetric regulation may serve as an instrument to encourage market entry in the long run. This holds generally if providers discriminate between on-net and off-net prices and does less generally hold, if asymmetric providers do not discriminate in pricing.

4 Reciprocal Regulation

4.1 Non-discriminatory Pricing

The EU Commission (2009) generally favors reciprocal termination charges, which in a long run should result in a "bill-and-keep" regime of zero termination charges. In line with the Ofcom's glide path reduction of termination costs and the analytical model by Carter and Wright (2003) the following section analyzes the effect of a reduction of a reciprocal termination rate ($a_1 = a_2 = a < c_1$) below the incumbent's cost.

For reciprocal termination charges equilibrium per-minute-prices are set to

$$p_i^* = 2c_i + s_j^*(a - c_i). \tag{18}$$

4.1.1 Subscribers' Net Surplus

Considering reciprocal termination fees it can be shown that subscribers may be again adversely affected by regulation. The technical proof goes along the line of section 3.1.1 and is relegated to the Appendix.

Proposition 6. For symmetric termination costs a marginal reduction of the reciprocal termination charge has no local effect on subscribers' net utilities. Otherwise, for asymmetric termination costs, a reduction of the reciprocal termination charge below the incumbent's cost is unambiguously beneficial for incumbent's subscribers. Entrant's subscribers benefit if termination costs are not too asymmetric, otherwise, they are harmed.

Proof: See Appendix.

Since (locally) the incumbent faces the same termination cost for on-net and off-net termination there is no cost-saving opportunity of off-net call termination any longer. The incumbent faces an access deficit, and thus, has an unambiguous incentive to reduce the number of off-net calls. As the number of off-net calls is determined by the market shares, the incumbent should increase the net utility to the subscribers in order to increase its market share and to reduce the number of off-net calls. The entrant still has countervailing incentives. On the one hand, since $a = c_1 > c_2$, it benefits from interconnection of rival customers, and thus has an incentive to increase the amount of incoming calls by increasing the net utility for its customers. On the other hand, it faces higher termination costs for off-net than for on-net calls, thus, it has an incentive to reduce the amount of off-net calls by decreasing the net utility for its customers. Hence, the effect on entrant's subscribers depends on the cost difference. If the entrant's termination costs are sufficiently low compared to the incumbent's cost, entrant's subscribers are harmed, otherwise, if costs become more symmetric they benefit.

4.1.2 Market Shares

The equilibrium market share equations are relegated to the Appendix. Total differentiation of the entrant's market share with respect to a locally around cost-based regulation of the incumbent network ($a = c_1$) yields that

$$\frac{ds_2^*}{da}|_{a=c_1} = \frac{(c_1 - c_2)(s_2^{*2} - 2s_1^* s_2^*)q'}{2(c_1 - c_2)(q(p_2^*) - q(p_1^*)) - (c_1 - c_2)^2 s_2^* q' - \frac{3}{\sigma}}. \qquad (19)$$

Proposition 7. For symmetric termination costs a marginal reduction of the reciprocal termination charge has no local effect on market shares. Otherwise, for asymmetric termination costs, a marginal decrease of the reciprocal termination charge below the incumbent's cost increases the entrant's market share if i) providers are sufficiently differentiated, ii) the difference in termination costs is not too large, and iii) the entrant's market share is not too large.

Proof: See Appendix.

The analysis shows that the "neutrality result" on market shares by Carter and Wright (2003) only holds for symmetric termination costs. Otherwise, there is a local effect of regulation on market shares, determined by the sign of the denominator, which is due to the previous effects on subscribers' net surplus.

Example 3: Consider a linear calling demand of $q(p_i) = 1 - p_i$ again. A reduction of the reciprocal termination charge increases the entrant's market shares, i.e. $\frac{ds_2^*}{da}|_{a=c_1} < 0$ if

$$(c_1 - c_2)^2 < \frac{3}{\sigma} \frac{1}{(2 + 3s_2^*)}. \tag{20}$$

This holds if the entrant's initial cost-advantage is sufficiently low, competition in the market is sufficiently soft, and the entrant's market share is sufficiently small. Consider from the per-minute price of the incumbent provider of $p_1^* = 2c_1 + s_2^*(a - c_1)$ that a reciprocal termination charge of $a < c_1$ decreases the price and thus increases the indirect utility of calls $\upsilon(p_1^*)$. Given a larger entrant's market share this effect is intensified and the entrant has to offset the increase of incumbent subscribers' net surplus in order not to lose market shares.

4.1.3 Profits

In a their model on asymmetric competition Carter and Wright (2003) concluded that for asymmetric market shares and symmetric termination costs a marginal reduction of the reciprocal termination charge does not affect providers' profits. This no longer holds for asymmetric termination costs. From the previous section it follows that providers can both gain or lose market shares in response to a marginal reduction of the reciprocal termination charge below the incumbent's costs. Then, both providers' profits may be positively or negatively affected. The effect on providers' profit crucially depends on the degree of competition in the market and the demand- and supply-side asymmetry.

Proposition 8. For symmetric termination costs a marginal reduction of the reciprocal termination charge does not affect providers' profits. For asymmetric termination costs providers may gain or suffer. If competition is sufficiently soft a marginal reduction of the reciprocal termination charge is generally to the detriment of the incumbent and to the benefit of the entrant. If competition is intense and the demand-side asymmetry is sufficiently large, the incumbent may benefit.

Proof: See Appendix.

Entrant's profit

Consider the effects on the entrant's profit in both the interconnection and the retail market. Marginally decreasing the reciprocal termination charge induces countervailing effects in the interconnection market, where the termination charge affects i) the per-minute profit per rival subscriber $(a - c_2)$, ii) the total off-net traffic by rival subscribers $(q(p_1^*))$, and iii) the amount of off-net traffic $(s_1^* s_2^*)$. The first effect is clearly negative. The second effect is positive. Marginally reducing the termination fee leads to a decrease in the incumbent's per-minute price, notably $\frac{\partial p_1^*}{\partial a}|_{a=c_1} = s_2^* > 0$. From $q' < 0$ it follows that off-net traffic per incumbent subscriber is increasing, which is to the entrant's benefit as long as $a > c_2$. Total off-net traffic $(s_1^* s_2^* q(p_1^*))$ depends on the sign of the market shares effect. Given soft competition, the entrant captures market shares, and thus, the number of off-net traffic is increasing for any $s_2 < s_1$. Hence, the total effect on interconnection profit may be ambiguous.

Consider the effects in the retail market. The effect on retail profit is determined by the fixed fee, given by

$$F_2^* = \upsilon(p_2^*) - \omega_2^*.$$

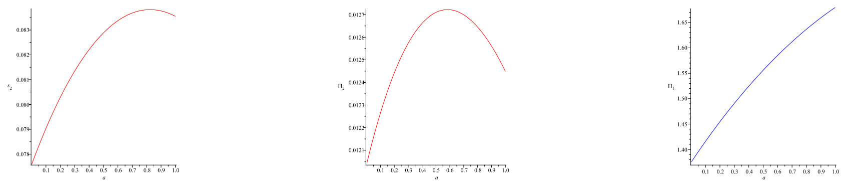
The effect on the fixed fee is determined by the indirect utility from making calls and the subscribers' net utility. Notice from section 4.1. that the incumbent provider offers a larger net surplus to its subscribers. This implies a tendency towards a lower fixed fee for the entrant, too, in order not to lose (too much) market share. However, a marginal reduction of the reciprocal termination charge decreases the entrant's per-minute price, if the provider gains market shares, as $\frac{\partial p_2^*}{\partial a} = -\frac{ds_2^*}{da}(c_1 - c_2) + s_1^* > 0$ for $\frac{ds_2^*}{da} < 0$. The per-minute price decreases, as, on the one hand, the termination charge decreases and, on the other, hand fewer calls are terminated off-net. This translates into a larger indirect utility from marking calls and, thus, to an opposing effect on the fixed fee. Finally, the total effect on profit is ambiguous again, which is illustrated in example 4 below.

Incumbent's profit

Consider the incumbent provider's profit. It will be shown in the Appendix that whenever its market share is decreasing, its total profit is decreasing. In the interconnection market it faces a loss per rival subscriber. If the incumbent gives away market shares, total entrant's off-net traffic increases, leading to a larger loss from interconnection. Moreover, since $\frac{\partial p_2^*}{\partial a}|_{a=c_1} = s_1^* + (c_1 - c_2)\frac{ds_1^*}{da} > 0$ for $\frac{ds_1^*}{da} > 0$ entrant's subscribers' calling demand increases, leading to loss in the interconnection market, too, which leads total profit to decrease.

Otherwise, for increasing markets shares the incumbent provider may benefit. Decompose the effects of the retail and the interconnection market. The effect in the interconnection market depends on the effects on the revenue per rival subscriber and total off-net traffic. Since termination fees are regulated below the incumbent's cost there is an unambiguous loss from interconnection of $s_1^* s_2^* q(p_2^*)$ per rival subscriber. Starting from the asymmetric situation of $s_1 > s_2$, off-net traffic to the incumbent is reduced. The effect on the demand for off-net calls depends on the incumbent provider's market share, as $\frac{\partial p_2^*}{\partial a}|_{a=c_1} = s_1^* + (c_1 - c_2)\frac{ds_1^*}{da} \lesseqgtr 0$. Consider incumbent gains market shares. The entrant's per-minute price will increase if s_1 is sufficiently low, i.e. the demand-side asymmetry is sufficiently low. This benefits the incumbent since the entrant's off-net traffic, and thus, the loss from interconnection is reduced. Otherwise, for higher s_1 the entrant's per-minute price might decrease, so subscribers' demand for calls increases, which in turn harms the incumbent. Now, the total effect on incumbent's profit depends on the demand-side asymmetry. For a large asymmetry it may be harmed, for lower values it benefits.

Example 4: Consider a linear demand of calls of $q(p_i) = \frac{A-p_i}{b}$ and set $A = 4, b = 5, \sigma = 0.5, c_1 = 1,\ \beta = 5.5$ and $c_2 = 0$. The following pictures illustrate the effects of a reduction of the reciprocal termination rate on provider's market shares and profits.



Entrant's market share for $\beta = 5.5$. Entrant's profit for $\beta = 5.5$. Incumbent's profit for $\beta = 5.5$.

Figure 2: Providers' market shares and profits depending on a.

Observe, as already stated above, market shares may increase or decrease. Moreover, a decrease or increase in market share is not sufficient for the profit to decrease or increase. Moreover, it may also be generally shown that both providers may be harmed from the reduction, if the entrant's market share is very low, i.e. the incumbent's demand-side advantage is large. This is in line with Carter and Wright (2003) who stated that both a larger incumbent and a smaller entrant may prefer cost-based regulation of the incumbent if the incumbent's advantage is sufficiently large. This does seem to hold even with cost-asymmetries and for larger deviations from cost-based regulation.

4.2 Price Discrimination

Now consider providers price discriminate in on-net and off-net prices again. It will be shown in the Appendix that independent of the opportunity to discrimination, incumbent subscribers will benefit from a marginal reduction of the reciprocal termination charge, whereas entrant's subscribers benefit or suffer. The incumbent unambiguously suffers from a termination deficit and thus, has an incentive to decrease the number of off-net calls by giving more surplus to its subscribers. The entrant, however, still benefits from interconnection of rival customers, thus on the hand has an incentive to increase the amount of incoming calls. On the other hand, though, it faces higher termination costs for off-net than for on-net calls, thus, it has an incentive to reduce the amount of off-net calls by decreasing the net utility for its customers accordingly.

This translates into a local effect on the entrant's market share of

$$\frac{ds_2^*}{da}|_{a=c_1} = \frac{(s_2^* - s_1^*)(c_1 - c_2)q(\hat{p_1})'}{2\big((c_2 - c_1)q(\hat{p_1^*}) - \upsilon(\hat{p_1}^*) - \upsilon(p_1^*) + \upsilon(\hat{p_2}^*) - \upsilon(p_2^*)\big) - \frac{3}{\sigma}}. \quad (21)$$

Hence, the effect on market shares depends on both the demand- and the supply-side asymmetry. For symmetric market shares or symmetric termination cost market shares do not locally respond to a marginal decrease of the reciprocal termination charge below the incumbent's termination cost. Otherwise, for both a demand- and supply side asymmetry, market shares do locally respond. With price discrimination the surplus from on-net calls remains unaffected by regulation. The marginal effect on surplus is determined by the effects surplus from off-net calls and the adjustment of the fixed fee. If providers can price discriminate, they can extract every extra surplus by adjusting the fixed fee accordingly. It holds that the marginal effect on net surplus is given by $\frac{\partial \omega(p_i,\hat{p_i})}{\partial a} = s_j \frac{\partial \upsilon(\hat{p_i}^*)}{\partial a} - s_i \frac{\partial \upsilon(\hat{p_i}^*)}{\partial a} - (s_i^* - s_j^*)(a - c_i)q(\hat{p_j}^*)'$. For symmetric market shares any extra surplus is perfectly passed-through into the fixed fee. Thus, there is no effect on net surplus and accordingly no effect on market shares, independent of any supply-side asymmetry. If market shares differ, the pass-through is imperfect, so also the net surplus of calls is affected. Then, again, the market share effect depends on the extent of the supply-side asymmetry. However, if providers are not able to discriminate in prices, they can not perfectly extract the surplus from on-net and off-net calls, they only extract an average surplus from calls in general and the pass-through into the fixed fee is only partial.

Proposition 9. If providers discriminate between on-net and off-net prices, incumbent's subscribers still benefit from a marginal reduction of the reciprocal termination charge, whereas entrant's subscribers benefit or suffer, depending on the supply-side asymmetry. This translates into a local effect on market shares and profits, thus, both providers may (locally) benefit or suffer from the reduction of the reciprocal termination charge.

Proof: See Appendix.

Given a supply-side symmetry of $c_1 = c_2$ providers' profits are locally unaffected by regulation, i.e. $\frac{\partial \Pi_i^*}{\partial a}|_{a=c_1} = 0$, which confirms the result of Carter and Wright (2003). This directly follows from the neutral market share effect and the fact that on-net and off-net prices are identical for both providers. Although, if both the demand- and supply-side are asymmetry, the effects on profits are ambiguous again and both providers may benefit or suffer from the reduction which holds independent of a price discrimination between on-net and off-net calls.

5 Conclusion

This paper has explored the ramification of regulating interconnection terms in asymmetric market environments. Typically, former established networks still enjoy a demand-side advantage over entrants. However, due to later entry, entrants may enjoy a cost-side advantage, because they may have adopted more efficient technologies. The present paper has discussed the effects of two widely proposed regulatory regimes of cost-based and reciprocal regulation.

With cost-based regulation, a low cost network will receive less for rival calls terminated in its network than it has to pay for calls by fellow subscribers terminated in a high cost network. This does not seem to be in line with efforts to encourage market entry of alternative telecommunications providers. Thus it is a relevant policy question, whether to deviate from the cost-based regulation in the presence of cost asymmetries and allow for an access markup on the low cost network. The paper has shown, though, that this even may hinder market entry. The total effect on provider' profits depends on the relative magnitude of a cost-saving and a market share effect. Otherwise, if providers discriminate between on-net and off-net prices for calls, market entry is unambiguously encouraged.

The European Commission widely favors reciprocal termination charges in the long run, which has been recently been put into practise by the British Ofcom. Hence, in a second step, the paper has analyzed the effects of reciprocity in termination charges. The model shows that incumbent subscribers benefit from a marginal reduction of the reciprocal termination fee, whereas the entrant's subscribers may or benefit or suffer, depending on the degree of substitution of providers and the difference in termination costs. This holds independent of the opportunity to discriminate between on-net and off-net prices. For larger deviations from cost-based regulation the incumbent provider generally suffers from a decrease of the reciprocal termination charge, whereas the entrant generally benefits.

To conclude, a regulatory authority has to consider (positive or negative) feedback effects on market shares and on the demand for calls, when determining the most adequate regulation in the presence of asymmetries in termination costs.

A Appendix

Asymmetric Regulation

Proof of Proposition 1:

Profit functions of both providers are given as

$$\Pi_1^* = s_1^*(p_1^* - 2c_1)q(p_1^*) + s_1(\upsilon(p_1^*) - \omega_1) + s_1^* s_2^* \left((a_1 - c_1)q(p_2^*) - (a_2 - c_1)q(p_1^*)\right)$$

and

$$\Pi_2^* = s_2^*(p_2^* - 2c_2)q(p_2^*) + s_2(\upsilon(p_2^*) - \omega_2^*) + s_1^* s_2^* \left((a_2 - c_2)q(p_1^*) - (a_1 - c_1)q(p_2^*)\right),$$

where market shares of $s_1 = \frac{1}{2} + \frac{\beta}{2} + \sigma(\omega_1 - \omega_2)$ and $s_2 = \frac{1}{2} - \frac{\beta}{2} + \sigma(\omega_2 - \omega_1)$ depend on subscriber' net surplus ω_i. Along its best-response function each operator sets per-minute prices to perceived marginal costs. Thus the only income source stems from subscription and off-net traffic, leading to profits in terms of net surplus of

$$\Pi_i^* = s_i^*(\upsilon(p_i^*) - \omega_i^*) + s_i^* s_j^*(a_i - c_i)q(p_j^*).$$

The first order condition of the incumbent provider with respect to subscribers' net surplus ω_1 is given as

$$\frac{\partial \Pi_1^*}{\partial \omega_1} = \sigma(\upsilon_1^* - \omega_1^*) + s_1^*(\frac{\partial \upsilon_1^*}{\partial p_1}\frac{\partial p_1^*}{\partial \omega_1} - 1) + (a_1 - c_1)(\sigma(s_2^* - s_1^*)q(p_2^*) + s_1^* s_2^* \frac{\partial q(p_2)}{\partial p_2}\frac{\partial p_2^*}{\partial \omega_1}).$$

For convenience label $\upsilon(p_i) = \upsilon_i$, $q(p_i) = q_i$, and $\frac{dq(p_i)}{dp_i} = q_i'$. Taking account for $\frac{\partial \upsilon i}{\partial pi} = -q_i$ and for per-minute prices of equation (4) it follows that

$$\frac{\partial \Pi_1^*}{\partial \omega_1} = \sigma(\upsilon_1^* - \omega_1^*) + s_1^*(\sigma q_1^*(a_2 - c_1) - 1) + \sigma(a_1 - c_1)\} \left((s_2^* - s_1^*)q_2^* + s_1^* s_2^* q'(a_1 - c_2)\right).$$

The cross-derivative is

$$\frac{\partial^2 \Pi_1^*}{\partial \omega_1 \partial \omega_2} = \sigma(\frac{\partial \upsilon_1^*}{\partial p_1}\frac{\partial p_1^*}{\partial \omega_2}) + \sigma(a_2 - c_1)(-\sigma q_1^* + s_1^* q' \frac{\partial p_1^*}{\partial \omega_2}) + \sigma$$

which around cost-based regulation of termination charges simplifies to

$$\frac{\partial^2 \Pi_1^*}{\partial \omega_1 \partial \omega_2}|_{a_i = c_i} = \sigma - \sigma^2(c_2 - c_1)q_1^* + \sigma^2(c_2 - c_1)^2 s_1^* q',$$

which implies that the incumbent network's pseudo best-response functions is upwards sloping if competition is not too weak and the difference in termination costs $(c_1 - c_2)$ is not too large. One obtains that an increase in the entrant's termination charge a_2 shifts the pseudo best-response function outwards, as

$$\frac{\partial^2 \Pi_1^*}{\partial \omega_1^* \partial a_2} = \sigma(\frac{\partial \upsilon_1^*}{\partial p_1}\frac{\partial p_1^*}{\partial a_2}) + s_1\sigma((a_2 - c_1)q' \frac{\partial p_1^*}{\partial a_2} + q_1)$$

which reduces to

$$\frac{\partial^2 \Pi_1^*}{\partial \omega_1^* \partial a_2}|_{a_i = c_i} = \sigma(s_1^* - s_2^*)q_1^* + s_1^* s_2^* \sigma(c_2 - c_1)q' > 0.$$

This term is strictly positive for $s_1 > s_2$ and $c_2 < c_1$, which has been assumed.

Consider the entrant's profit. Applying same technique, the marginal profit is

$$\frac{\partial \Pi_2^*}{\partial \omega_2} = \sigma(\upsilon_2^* - \omega_2^*) + s_2^*(\sigma q_2^*(a_1 - c_2) - 1) + \sigma(a_2 - c_2)\left((s_1^* - s_2^*)q_1^* + s_1^* s_2^* q'(a_2 - c_1)\right).$$

The cross derivative is denoted as

$$\frac{\partial^2 \Pi_2^*}{\partial \omega_2 \partial \omega_1}|_{a_i = c_i} = \sigma - 2\sigma^2(c_1 - c_2)q_2^* + \sigma^2(c_1 - c_2)^2 s_2^* q'.$$

The shift of the pseudo-best response in the entrant's termination charge is denoted as

$$\begin{aligned} \frac{\partial^2 \Pi_2^*}{\partial \omega_2 \partial a_2} &= \sigma(\frac{\partial \upsilon_1^*}{\partial p_2}\frac{\partial p_2^*}{\partial a_2}) + \sigma s_2^*(a_1 - c_2)q'\frac{\partial p_2^*}{\partial a_2} + \sigma(s_1^* - s_2^*)q_1^* + s_1^* s_2^* q' \sigma(a_2 - c_1) \\ &\quad + \sigma(a_2 - c_2)((s_1^* - s_2)^* q_1^* + s_1^* s_2^* q'). \end{aligned}$$

As per-minute prices are only affected by rival's termination charges it follows that $\frac{\partial p_2^*}{\partial a_2} = 0$ and thus

$$\frac{\partial^2 \Pi_2^*}{\partial \omega_2 \partial a_2}|_{a_i = c_i} = \sigma(s_1^* - s_2^*)q_1^* + s_1^* s_2^* \sigma(c_2 - c_1)q' > 0.$$

Hence, also the entrant's pseudo best-response is shifted outwards. For identical termination costs, effects of both providers' pseudo best-response function are positive. This confirms the neutrality result on market shares for symmetric termination costs.

Proof of Proposition 2:

The entrant's market share in equilibrium satisfies the equation

$$\begin{gathered} s_2^* = \tfrac{1}{2} - \tfrac{\beta}{6} - \tfrac{\sigma}{3}\big((\upsilon(p_1^*) - \upsilon(p_2^*) + s_2^* q(p_1^*)(a_2 - c_2) \\ + s_1^* q(p_1^*)(c_2 - c_1) - s_1^* q(p_2^*)(a_1 - c_1) + s_2^* q(p_2^*)(c_2 - c_1)\big). \end{gathered} \tag{22}$$

The incumbent's market share is accordingly given by $s_1 = 1 - s_2$.

Total differentiation of equation (22) locally around cost-based regulation of $a_i = c_i$ leads to

$$\frac{ds_2^*}{da_2}|_{a_i=c_i} = -\frac{\sigma}{3}\left\{\begin{array}{c} \frac{\partial \upsilon(p_1^*)}{\partial p_1}\frac{\partial p_1^*}{\partial a_2} - \frac{\partial \upsilon(p_2^*)}{\partial p_2}\frac{\partial p_2^*}{\partial a_2} + s_2^* q_1^* \\ +(c_2 - c_1)(\frac{\partial s_1^*}{\partial a_2}a_1 + s_1^* q' \frac{\partial p_1^*}{\partial a_2} + \frac{\partial s_2^*}{\partial a_2} q_2^* + s_2^* q' \frac{\partial p_2^*}{\partial a_2}) \end{array}\right\}.$$

Using $\frac{ds_1}{da_2} = -\frac{ds_2}{da_2}$, $\upsilon'(p_i) = -q_i$, inserting optimal per-minute prices and rearranging yields that

$$\frac{ds_2^*}{da_2}|_{a_i=c_i} = \frac{q' s_1^* s_2^* (c_2 - c_1)}{2(c_1 - c_2)(q_2^* - q_1^*) - (c_2 - c_1)^2(s_1^* q' + s_2^* q') - \frac{3}{\sigma}}.$$

Price Discrimination

Providers set optimal on-net prices, off-net prices, and the fixed fee by maximizing the profit function with respect to p_i, $\hat{p}_i$, and $\omega(p_i, \hat{p}_i)$.

From

$$\frac{\partial \Pi_i}{\partial p_i} = s_i\big(s_i q_i + s_i(p_i - 2c_i)q_i'\big) + s_i^2 \upsilon_i' = 0$$

and using $\upsilon_i' = -q_i$ follows that

$$p_i^* = 2c_i.$$

By solving

$$\frac{\partial \Pi_i}{\partial \hat{p}_i} = s_i s_j \hat{q}_i + s_i s_j(\hat{p}_i - c_i - a_j)\hat{q}_i{}' + s_i s_j \hat{\upsilon}_i{}' = 0$$

follows that

$$\hat{p}_i{}^* = c_i + a_j.$$

To derive the optimal fixed fee it is again convenient to consider providers to compete on net-surplus rather than on the fixed fee directly. From evaluation the FOC at equilibrium per-minute prices it follows that

$$\frac{\partial \Pi_i}{\partial \omega_i} = \sigma(s_i \upsilon_i + s_j \hat{\upsilon}_i - \omega_i) + s_i(\sigma(\upsilon_i - \hat{\upsilon}_i) - 1) + \sigma(a_i - c_i)\hat{q}_i(s_i - s_j).$$

From setting this equal to zero it follows that the optimal net-surplus is given as

$$\omega_i = 2s_i\upsilon_i + (s_i - s_j)\hat{\upsilon}_i - \frac{s_i}{\sigma} + (a_i - c_i)(s_j - s_i)\hat{q}_i.$$

After re-substituting $F_i = s_i\upsilon_i + s_j\hat{\upsilon}_i - \omega_i$ follows that

$$F_i^* = \frac{s_i^*}{\sigma} + s_i^*(\hat{\upsilon}_i{}^* - \upsilon_i^*) + (s_i^* - s_j^*)(a_i - c_i)\hat{q}_i{}^*.$$

Proof of proposition 4:

Along its best-response function each operator sets per-minute prices to the true marginal costs. Thus the only income source stems from subscription and off-net traffic, leading to profits in terms of net surplus of

$$\Pi_i^* = s_i^*(s_i^*\upsilon_i^* + s_j\hat{\upsilon}_i^* - \omega_i^*) + s_i^*s_j^*(a_i - c_i)\hat{q}_j^*.$$

The first order condition of the incumbent provider with respect to subscribers' net surplus ω_1 is given as

$$\frac{\partial \Pi_1^*}{\partial \omega_1} = \sigma(s_1\upsilon_1^* + s_2\hat{\upsilon}_1^* - \omega_1^*) + s_1(\sigma(\upsilon_1^* - \hat{\upsilon}_1^* - 1)) + \sigma(a_1 - c_1)\hat{q}_2(s_2^* - s_1^*).$$

The cross-derivative is

$$\frac{\partial^2 \Pi_1^*}{\partial \omega_1 \partial \omega_2}|_{a_i=c_i} = \sigma + 2\sigma^2(\hat{\upsilon}_1^* - \upsilon_1^*) > 0,$$

which implies that the incumbent network's pseudo best-response functions is upwards sloping for any $a_2 = c_2 < c_1$. One obtains that an increase in the entrant's termination charge a_2 shifts the pseudo best-response function outwards, since

$$\frac{\partial^2 \Pi_1^*}{\partial \omega_1^* \partial a_2}|_{a_i=c_i} = \sigma(s_1^* - s_2^*)\hat{q}_1^* > 0,$$

and hence, the incumbent's subscribers benefit from the entrant's access markup.

The first order condition of the entrant's profit with respect to subscribers' net surplus ω_2 is given as

$$\frac{\partial \Pi_2^*}{\partial \omega_2} = \sigma(s_2^* \upsilon_2^* + s_1^* \hat{\upsilon}_2^* - \omega_2^*) + s_2(\sigma(\hat{\upsilon}_2^* - \upsilon_2^* - 1) + \sigma(a_2 - c_2)\hat{q}_1^*(s_1^* - s_2^*).$$

The cross-derivative is given by

$$\frac{\partial^2 \Pi_2^*}{\partial \omega_2 \partial \omega_1}|_{a_i=c_i} = \sigma + 2\sigma^2(\upsilon_2^* - \hat{\upsilon}_2^*) = \sigma > 0,$$

which also implies that the entrant's pseudo best-response functions is upwards sloping. One obtains that an increase in the entrant's termination charge a_2 shifts the pseudo best-response function outwards, since

$$\frac{\partial^2 \Pi_2^*}{\partial \omega_2 \partial a_2}|_{a_i=c_i} = \sigma(s_1^* - s_2^*)\hat{q}_1^* > 0,$$

and thus, also entrant's subscribers benefit from the markup.

Proof of proposition 5:

The equilibrium market share of the incumbent provider is implicitly determined by

$$s_1^* = \frac{1}{2} + \frac{\beta}{6} + \frac{\sigma}{3}\big(2(s_1^* \upsilon_1^* - s_2 \upsilon_2^*) + (s_2^* - s_1^*)\big(\hat{\upsilon}_1{}^* + \hat{\upsilon}_2{}^* + (a_1 - c_1)\hat{q}_2{}^* + (a_2 - c_2)\hat{q}_1{}^*\big)\big)$$

and by $s_2 = 1 - s_1$ for the entrant.

Total differentiation locally around cost-based regulation yields

$$\frac{ds_1^*}{da_2}|_{a_i=c_i} = \frac{\sigma}{3}\big(2(\frac{ds_1^*}{da_2}\upsilon_1^* - \frac{ds_2^*}{da_2}\upsilon_2^*) + (\frac{ds_2^*}{da_2} - \frac{ds_1^*}{da_2})(\hat{\upsilon}_1{}^* + \hat{\upsilon}_2{}^*)$$
$$+ (s_2^* - s_1^*)(\frac{\partial \hat{\upsilon}_1{}^*}{\partial \hat{p}_1{}^*}\frac{\partial \hat{p}_1{}^*}{\partial a_2} + \hat{q}_1^*)\big).$$

After rearranging and using $\frac{d\upsilon_i}{dp_i} = -q_i$ follows that

$$\frac{ds_1^*}{da_2}|_{a_i=c_i} = \frac{(s_2^* - s_1^*)(\hat{q}_1{}^* - \hat{q}_1{}^*)}{\frac{3}{\sigma} - 2(\upsilon_1^* - \hat{\upsilon}_1{}^* + \upsilon_2^* - \hat{\upsilon}_2{}^*)}.$$

Hence, it follows that

$$\frac{ds_1^*}{da_2}|_{a_i=c_i} = -\frac{ds_2^*}{da_2}|_{a_i=c_i} = 0.$$

Since equilibrium per-minute prices are set equal to the marginal cost, providers earn profits from the fixed fee and inbound calls from rival subscribers, leading to profits of

$$\Pi_1^* = \frac{s_1^{2*}}{\sigma} + s_1^{2*}(\hat{v_1}^* - v_1^* + (a_1 - c_1)\hat{q_2}^*).$$

The FOC with respect to a_2 yields

$$\begin{aligned}\frac{\partial \Pi_1^*}{\partial a_2}|_{a_i=c_i} &= \frac{ds_1^*}{da_2}\big(\frac{2}{\sigma} + 2s_1^*(\hat{v_1}^* - v_1^* + (a_1 - c_1)\hat{q_2}^*)\big) \\ &+ s_1^2\big(\frac{\partial \hat{v}_1}{\partial \hat{p}_1}\frac{\partial \hat{p_1}^*}{\partial a_2} - \frac{\partial v_1}{\partial p_1}\frac{\partial p_1^*}{\partial a_2} + (a_1 - c_1)\frac{\partial q}{\partial p_2}\frac{\partial p_2^*}{\partial a_2}\big).\end{aligned}$$

Since $\frac{ds_i^*}{da_2} = 0$ and only the off-net price $\hat{p}_1$ responds to a_2 it follows that

$$\frac{\partial \Pi_1^*}{\partial a_2}|_{a_i=c_i} = -s_1^2\hat{q}_1 < 0.$$

The entrant's profit is denoted as

$$\Pi_2 = \frac{s_2^{2*}}{\sigma} + s_2^{2*}(\hat{v_2}^* - v_2^* + (a_2 - c_2)\hat{q_1}^*).$$

Since per-minute prices and market shares do not (locally) respond to a_2 it simply follows that

$$\frac{\partial \Pi_2^*}{\partial a_2}|_{a_i=c_i} = s_2^{*2}\hat{q}_1 > 0.$$

Reciprocal Regulation

Proof of Proposition 6:

To show that subscribers benefit from a marginal decrease of the reciprocal termination charge apply the same steps as in the proof of proposition 4.1. First consider the incumbent provider's marginal profit of

$$\frac{\partial \Pi_1^*}{\partial \omega_1} = \sigma(\upsilon_1^* - \omega_1^*) + s_1(\sigma q_1^*(a - c_1) - 1) + \sigma(a - c_1)((s_2^* - s_1^*)q_2^* + s_1^* s_2^* q'(a - c_2)).$$

The cross derivative is denoted as

$$\frac{\partial^2 \Pi_1^*}{\partial \omega_1 \partial \omega_2} = \sigma - \sigma^2(a - c_1)q_1^* - 2\sigma^2(a - c_1)(a - c_2)(s_2 - s_1),$$

where at $a = c_1$ it holds that

$$\frac{\partial^2 \Pi_1^*}{\partial \omega_1 \partial \omega_2}|_{a=c_1} = \sigma > 0.$$

A marginal decrease of the reciprocal termination charge shifts the incumbent network's pseudo best-response function outwards as

$$\frac{\partial^2 \Pi_1^*}{\partial \omega_1 \partial a}|_{a=c_1} = \sigma(s_1^* - s_2^*)(q_1^* - q_2^*) + \sigma(c_1 - c_2)s_1^* s_2^* q' < 0.$$

With symmetric termination costs and from

$$sign(q_2^* - q_1^*)|_{c_1=c_2} = sign(p_1^* - p_2^*)|_{a=c_1} = (c_1 - c_2)(2 - s_1^*) = 0$$

follows that $\frac{\partial^2 \Pi_1^*}{\partial \omega_1 \partial a} = 0$. Otherwise, for $c_1 > c_2$ the second part is negative, since $q_i' < 0$. The sign of the first part is determined by $sign(q_1^* - q_2^*) = sign(p_2^* - p_1^*)$. At $a = c_1$ it holds that $sign(p_2^* - p_1^*) = (c_2 - c_1)(2 + s_2^*) < 0$. From this it follows that the term is clearly negative and the pseudo best-response functions shifts outwards.

Applying same technique for the entrant it follows that

$$\frac{\partial \Pi_2^*}{\partial \omega_2} = \sigma(\upsilon_2^* - \omega_2^*) + s_2^*(\sigma q_2^*(a - c_2) - 1) + \sigma(a - c_2)((s_1^* - s_2^*)q_1^* + s_1^* s_2^* q'(a - c_1)).$$

The cross derivative is given as

$$\frac{\partial \Pi_2^*}{\partial \omega_2 \partial \omega_1}|_{a=c_1} = \sigma - 2\sigma^2(c_1 - c_2)q_2^* + \sigma^2 + (c_1 - c_2)^2 s_2 q' \lesseqgtr 0.$$

The shift of the pseudo best-response function is given by

$$\frac{\partial^2 \Pi_2^*}{\partial \omega_2 \partial a}|_{a=c_1} = \sigma(s_1^* - s_2^*)(q_1^* - q_2^*) + 2\sigma s_1 s_2 (c_1 - c_2)q' + \sigma(c_1 - c_2)(s_1 - s_2)q'.$$

Again, from $sign(q_1^* - q_2^*)|_{a=c_1} = (c_2 - c_1)(2 + s_2^*) < 0$ follows that this is negative and the pseudo best-response function shifts outwards.

Proof of Proposition 7:

The entrant's market share with reciprocal access regulation is given as

$$s_2^* = \frac{1}{2} - \frac{\beta}{6} - \frac{\sigma}{3}(\upsilon_1^* - \upsilon_2^* + s_2^* q_1^*(a - c_2) - s_1^* q_2^*(a - c_1) + (c_2 - c_1)(s_1^* q_1^* + s_2^* q_2^*)).$$

Total differentiation of $\frac{ds_2^*}{da}$ yields

$$\frac{ds_2^*}{da}|_{a=c_1} = -\frac{\sigma}{3}\left\{ \begin{array}{c} \frac{d\upsilon_1^*}{dp_1}\frac{dp_1^*}{da} - \frac{d\upsilon_2^*}{dp_2}\frac{dp_2^*}{da} + (a - c_2)(s_2^{*\prime} q_1^* + s_2^* q' \frac{dp_1^*}{da}) + s_2^* q_1^* - \\ (a - c_1)(s_1^{*\prime} q_2 + s_1^* q_2^*) - s_1^* q_2^* + (c_2 - c_1)(s_1^{*\prime} q_1^* + s_1^* q' \frac{dp_1^*}{da} \\ + s_2^{*\prime} q_2^* + s_2^* q' \frac{dp_2^*}{da}) \end{array} \right\}.$$

Using $\upsilon'(p) \equiv -q(p)$, $\frac{ds_i}{da} = -\frac{ds_j}{da}$ and evaluation locally around $a = c_1$, this reduces to

$$\frac{ds_2^*}{da} = \frac{(c_1 - c_2)q'(s_2^{*2} - 2s_1^* s_2^*)}{2(c_1 - c_2)(q_2^* - q_1^*) - (c_1 - c_2)^2 s_2^* q') - \frac{3}{\sigma}}.$$

As $c_1 > c_2$, $s_1 > s_2$ and $q' < 0$ the numerator is always positive, so the sign of $\frac{ds_2^*}{da}$ is determined by the denominator.

Proof of proposition 8:

The effect on total profits is decomposed in effects in the retail market and in the interconnection market as

$$\Pi_i^* = s_i^* F_i^* + s_i^* s_j^* (a - c_i) q(p_j^*).$$

Total resulting effects on profits are depicted by evaluating the derivatives of the profit functions with respect to a marginal change in the reciprocal termination charge locally around $a = c_1$. Consider the marginal change of the incumbent's profit of

$$\frac{\partial \Pi_1^*}{\partial a}|_{a=c_1} = s_1^*(\frac{2}{\sigma}\frac{ds_1^*}{da} + s_1^*(q(p_2^*) - q(p_1^*)))$$

and of

$$\frac{\partial \Pi_2^*}{\partial a}|_{a=c_1} = \begin{array}{c} 2s_2^*\frac{ds_2^*}{da}(\frac{1}{\sigma} + (c_1 - c_2)(q(p_1^*) - q(p(p_2^*)))) \\ +s_2^{*2}(q(p_1^*) - q(p_2^*) + (c_1 - c_2)(q's_2^* - q's_1^*) + (c_1 - c_2)^2\frac{ds_2^*}{da}) \end{array}$$

for the entrant.

Remind from equation (8) that there is no local effect on market shares for symmetric termination cost. Secondly notice that $(q_2^* - q_1^*)|_{a=c_1} = sign(p_1^* - p_2^*) = (c_1 - c_2)(2 - s_1^*) = 0$ for $c_1 = c_2$. From both follows that

$$\frac{\partial \Pi_i^*}{\partial a}|_{c_1=c_2} = 0.$$

Proof of proposition 9:

Consider the first order condition of the incumbent provider with respect to subscribers' net surplus ω_1 which is denoted as

$$\frac{\partial \Pi_1^*}{\partial \omega_1} = \sigma(s_1 \upsilon_1^* + s_2 \hat{\upsilon}_1^* - \omega_1^*) + s_1(\sigma(\upsilon_1^* - \hat{\upsilon_1}^* - 1)) + \sigma(a - c_1)\hat{q}_2(s_2^* - s_1^*).$$

The cross-derivative is

$$\frac{\partial^2 \Pi_1^*}{\partial \omega_1 \partial \omega_2}|_{a=c_1} = \sigma + 2\sigma^2(\hat{\upsilon}_1^* - \upsilon_1^*) = \sigma > 0,$$

which implies that the incumbent network's pseudo best-response functions is upwards sloping. One obtains that a decrease in the reciprocal termination charge a shifts the pseudo best-response function outwards, since

$$\frac{\partial^2 \Pi_1^*}{\partial \omega_1 \partial a_2}|_{a=c_1} = \sigma(s_1^* - s_2^*)(\hat{q}_1^* - \hat{q}_2^*) < 0$$

for any $c_2 < c_1$ and hence, the incumbent's subscribers benefit from the reduction of the reciprocal termination charge.

The first order condition of the entrant's profit with respect to subscribers' net surplus ω_2 is given as

$$\frac{\partial \Pi_2^*}{\partial \omega_2} = \sigma(s_2^* \upsilon_2^* + s_1^* \hat{\upsilon}_2^* - \omega_2^*) + s_2(\sigma(\upsilon_2^* - \hat{\upsilon}_2^* - 1) + \sigma(a - c_2)\hat{q}_1^*(s_1^* - s_2^*).$$

The cross-derivative is given by

$$\frac{\partial^2 \Pi_2^*}{\partial \omega_2 \partial \omega_1}|_{a=c_1} = \sigma + 2\sigma^2(\hat{\upsilon}_2^* - \upsilon_2^*) \lesseqgtr 0$$

since the price for on-net calls is lower than for off-net calls and so the second part is negative. This implies that the entrant's pseudo best-response functions is upwards or downwards sloping. One obtains that a reduction of a shifts the pseudo best-response function outwards, since

$$\frac{\partial^2 \Pi_2^*}{\partial \omega_2 \partial a_2}|_{a=c_i} = \sigma(s_1^* - s_2^*)(\hat{q}_1^* - \hat{q}_2^*) + (c_1 - c_2)\sigma(s_1 - s_2)\hat{q}_1' < 0.$$

The first order conditions of the profit functions with respect to a marginal decrease of the reciprocal termination charge are denoted as

$$\frac{\partial \Pi_1^*}{\partial a}|_{a=c_1} = 2\frac{ds_1^*}{da}s_1^*\big(\frac{1}{\sigma} + \upsilon(\hat{p_1}^*) - \upsilon(p_1^*)\big) + s_1^{*2}\big(q(\hat{p_2}^*) - q(\hat{p_1}^*)\big)$$

and

$$\frac{\partial \Pi_2^*}{\partial a}|_{a=c_1} = 2\frac{ds_2^*}{da}s_2^*\big(\frac{1}{\sigma} + \upsilon(\hat{p_2}^*) - \upsilon(p_2^*) + (c_1 - c_2)q(\hat{p_1}^*)\big) \\ + s_2^{*2}\big(q(\hat{p_1}^*) - q(\hat{p_2}^*) - (c_1 - c_2)q'\big).$$

Thus, for any supply-side symmetry the neutrality result by Carter and Wright (2003) can be confirmed, otherwise, for a supply-side asymmetry, effects are ambiguous.

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