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By

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Dynamic regulation and entry in telecommunications markets: A policy framework*

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Abstract

We analyze a repeated setting of an asymmetric, differentiated telecommunications market with an incumbent and an entrant. The entrant may roll out its own network or use parts of the incumbent's network. The incumbent is established in the market, while the entrant gradually builds up a track record for quality. We investigate different entry strategies and regulatory policies and discuss entrants' incentives to invest in network depending on regulatory choices.

JEL-Classification: L96, L51, L13

Keywords: Telecommunication, Access Price, Interconnection Charge, Network, Regulation

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1 Introduction

Liberalizing fixed telecommunications markets in Europe and elsewhere is proving to be a difficult task. In particular, the current situation is far from resembling a level-playing field, in which incumbent and entrants compete on the same terms. This makes regulation a complicated task because there do not exist a priori reasons to impose the same regulatory regime on both types of players, incumbent and entrants.

Policy makers have recognized the importance of the terms of access to the competitors' networks for shaping competition in the market. In this paper, we present a formal model which allows us to address the following questions: How will different access price regimes affect competition between operators? What are the consequences of this for consumers surplus and welfare in the short and the long term? What are the effects of retail price regulation? Which access price rules are appropriate for different entry modes? What are the likely consequences of different forms of regulation for investment decisions?

Our model is based on the assumption that initially the networks of entrants do not satisfy the same quality standards as the incumbent's network. Over time, they improve the quality of infrastructure. We also provide some discussion about an alternative specification, based on the assumption that consumers' fixed utility levels are linear in previous-period market shares, capturing that utility is derived from positive, operator-dependent network externalities.

This paper is connected to an existing and growing body of literature on access pricing for competing operators. The initial articles on network interconnection (Armstrong, 1998; Laffont, Rey and Tirole, 1998; Carter and Wright, 1999) focused on access pricing in a symmetric setting.[1] A recent paper on asymmetric competition is Carter and Wright (2003), who explore operators' preferences for different types of reciprocal access pricing rules if there is asymmetric brand loyalty. Peitz (2003) analyzes the effects of asymmetric access price regulation in such a setting. Armstrong (2002a) also studies asymmetric access prices and focuses on the role of heterogeneous calling pattern in a model with unit demand and regulated retail prices.

In De Bijl and Peitz (2002a, b) we develop models that address asymmetries between an incumbent and an entrant, which allowed us to derive policy implications on asymmetric access pricing as well as asymmetric regulation of retail prices. This paper, is different to our earlier work in the following respects. Compared to De Bijl and Peitz (2002b), we obtain results by using a model more closely related to those in the literature. We also provide new insights, for example on cost asymmetries. Compared to our (2002a) paper, we provide a broader picture, including the analysis of local-loop unbundling and carrier-select. This makes it, furthermore, possible to elaborate on the dynamic interaction between regulation and new operators' incentives to invest in networks.[2] The resulting observations and insights are highly relevant for policy

[1] For extensive reviews of the literature on access pricing and competition in telecommunications, see Laffont and Tirole (2000) and Armstrong (2002b).

[2] On the effect of reciprocal access prices on investment incentives see Valletti and Cambini

concerned with the choice between competition in network versus competition in services. For easy comparison between different types of regulatory regimes, the current paper sometimes borrows from our earlier work.

The structure of this paper is as follows. Section 2 presents a model of facilities-based entry, and analyzes both regulation of terminating access prices and retail prices. Section 3 looks at alternative entry modes, based on local loop unbundling and carrier select, and discusses entrants' incentives to choose a particular way of entering the market in relationship to the regulatory regime. Section 4 concludes the paper.

2 Facilities-based entry

2.1 The model

There are two operators, an incumbent (operator 1) and an entrant (operator 2); each operator has a full-coverage network consisting of a long-distance backbone and a local access network.[3] In each period $t = 1, ..., T$, each operator i chooses a per-minute price p_i^t and a subscription fee m_i^t. The market shares resulting from competition and consumers' choices are denoted by $s_1^t = s_1[p_1, p_2, m_1, m_2; t, s_1^{t-1}]$ and $s_2^t = s_2[p_1, p_2, m_1, m_2; t, s_2^{t-1}]$. Notice in particular that they depend on market shares in the previous period. In period 1, initial market shares are given and denoted by s_1^0 and s_2^0, satisfying $s_1^0 = 1$ and $s_2^0 = 0$, that is, operator 1 initially covers the whole market.

In each period, the operators maximize profits of that period only. This assumption is justified in several situations, for instance if firms ignore the effects of current market share on future profits (see De Bijl and Peitz, 2002b, for an elaborate motivation). Although assuming that operators are "myopic" is restrictive, it nevertheless provides a useful benchmark, while making the analysis tractable. Furthermore, in reality, investors may implement incentive contracts that aim at fast recovery of fixed costs, and a quick turnover of personnel involved in strategic pricing may make it hard to implement a long-term pricing strategy.

There is a continuum of consumers with mass n who all are subscribed to either one network. The networks are horizontally differentiated. Consumers are assumed to be uniformly distributed on the $[0, 1]$-interval. Operator 1 is located at $l_1 = 0$, and operator 2 at $l_2 = 1$. Consumer $z \in [0, 1]$ incurs a disutility $-\theta|l_i - z|$, which is linear in the distance between consumer location and the location of the operator. If $\theta = 0$ networks are perfect substitutes; the larger θ the more differentiated the networks.

Each consumer subscribes to only one network. In period t, the consumer identified by its location z subscribes to operator 1 if

(2002).

[3] The model in this section is based on De Bijl and Peitz (2002a), which was inspired by Armstrong (1998) and Laffont, Rey and Tirole (1998). See also De Bijl and Peitz (2002b) for a different specification and more background information.

$$v_1[p_1, m_1; t, s_1^{t-1}] - \theta z > v_2[p_2, m_2; t, s_2^{t-1}] - \theta(1 - z),$$

where $v_i[p_i, m_i; t, s_i^{t-1}]$ denotes the conditional indirect utility of a network at the ideal location z. The realized market share of operator i in period t is equal to:

$$s_i^t = \frac{1}{2} + \frac{v_i[p_i^t, m_i^t; t, s_i^{t-1}] - v_j[p_j, m_j; t, s_j^{t-1}]}{2\theta}.$$

Intuitively, an operator's market share increases if the operator offers a relatively larger level of net utility to consumers, and decreases otherwise. Larger values of θ make it more difficult to gain market share.

Assuming that utility levels are expressed in monetary units and can be added up, conditional indirect utility for a network at an ideal location can be written as:

$$v_i[p_i, m_i; t, s_i^{t-1}] = U_i[t, s_i^{t-1}] - m_i + u[x[p_i]] - p_i x[p_i].$$

This indirect utility consists of a traffic-independent part and a traffic-dependent part. Firstly, given a price per-minute equal to p_i, each consumer has an individual demand of $x[p_i]$ call minutes, and derives utility $u[x]$ from calling x minutes. Individual demand for call minutes follows from maximizing $u[x] - xp_i$. Secondly, a consumer derives a fixed utility $U_i[t, s_i^{t-1}]$ from subscribing to network i. This utility may come from, for example, brand preference; services offered in addition to voice telephony, and having a telephone connection to be reached by others. We assume that the total net utility of each network is positive for all consumers, that is, $v_i - \theta > 0$.

Throughout the analysis and simulations we assume that the utility from calling x minutes takes the form

$$u[x] = ax - \frac{1}{2}bx^2, \text{ where } a, b > 0,$$

which gives rise to a linear demand function for call minutes $x[p_i] = (a - p_i)/b$.

Entrants may be quick to roll out networks to offer voice telephony and gain market share, but initially, their networks may not satisfy the same quality standards as the incumbent's network. Over time, they improve the quality of their infrastructure. Hence we postulate that the fixed utility level offered by the incumbent is constant, $U_1[t, s_1^{t-1}] = u^0$, while the entrant offers a fixed utility that increases over time according to:

$$U_2[t, s_2^{t-1}] = u^0 q_2[t].$$

Thus the incumbent is already established in the market but the entrant has to build up a track record so that q_2 is initially less than one and increasing over time. In particular, we assume that $q_2[t] = \min\{t - 1, (t^* - 1)\}/(t^* - 1)$, that is, the fixed utility offered by the entrant increases linearly over time, up to a given period t^*, at which point it reaches the incumbent's level. We will refer to this assumption as the *track-record specification*.

A more general specification of the fixed utility function is

$$U_i[t, s_i^{t-1}] = u^0(\alpha_i + \beta_i q_i[t] + \gamma s_i^{t-1}),$$

where α_i, β_i and γ are positive constants. In the above specification, $\alpha_1 = 1, \alpha_2 = 0, \beta_1 = 0, \beta_2 = 1$, and $\gamma = 0$. An alternative specification, which may be called the *network-externalities specification*, is to assume that $\alpha_1 = \alpha_2 = 1$, $\beta_1 = \beta_2 = 0$, and $\gamma = 1$, resulting in $U_i[t, s_i^{t-1}] = u^0(1 + s_i^{t-1})$. Hence, fixed utility levels are linear in previous-period market shares, capturing that utility is derived from positive, operator-dependent network externalities.[4]

We distinguish between fixed costs (independent of traffic and the number of consumers served), connection-dependent but traffic-independent costs, and traffic-dependent costs. Fixed costs do not affect the pricing decisions and are only relevant for investment decisions. Such costs may be incurred initially, for instance the costs of building a backbone, and are possibly sunk when pricing decisions are taken. We abstract from this type of costs. Connection-dependent but traffic-independent will also be denoted as the fixed cost of the local loop. This cost captures, for instance, the maintenance cost of the local loop, and may also include the investment cost that has to be recovered. Operator i's fixed cost of the local loop is denoted by f_i. Connection-dependent but traffic independent costs affect the gain per consumer and therefore operators' pricing decisions. Traffic-dependent costs include marginal cost and charges paid to other operators for interconnection.

Period-t terminating access fees paid to operator i are denoted by τ_i^t. These access prices are set by a regulator, and hence exogenous for the operators. Whether access charges are incurred depends on the type of call. One can distinguish three types of telephone calls and associated traffic-dependent (i.e., marginal) cost levels:

- on-net calls: calls that originate and terminate on a single operator's network ($k = 1$) with associated cost c_{i1} for operator i;
- off-net calls: calls that terminate on another operator's network ($k = 2$) with associated cost $c_{i2} + \tau_j^t$ for operator i;
- incoming calls: calls that originate from another operator's network ($k = 3$) with associated cost $c_{i3} - \tau_i^t$ for operator i.

Observe that only in the case of off-net calls and incoming calls, the operator of the network where the call originates pays a per-minute terminating access fee to the operator of the network where the call terminates. We assume that the marginal cost of the local loop is the same for originating and terminating traffic, that is, $c_{i1} - c_{i2} = c_{i3}$.

[4] In our discussion paper version (De Bijl and Peitz, 2001) we provide an extensive comparison of simulation results in the two specifications. In the present paper we focus on the first specification and report only results which, qualitatively, are also obtained in the other specification.

With respect to calling patterns, we assume that when a consumer makes a telephone call, the receiver of the call is any other consumer with equal probability, independent of the network she is subscribed to. In the aggregate, the share of on-net and off-net calls of an operator are equal to its and its competitor's market share. For instance, given prices and realized market shares, the total volume of call minutes that originates on network 1 is equal to $n\, s_1 x[p_1]$. Then a fraction s_1 of this volume, that is, $n\, s_1 s_1 x[p_1]$, terminates on network 1. Similarly, the traffic volume terminating on network 2 is $n\, s_2 s_1 x[p_1]$.

Operator i's period-t profits $\Pi_i[p_1^t, p_2^t, m_1^t, m_2^t; t, s_i^{t-1}]$ are equal to:

$$\begin{aligned}\Pi_i[p_1^t, p_2^t, m_1^t, m_2^t; t, s_i^{t-1}] &= n\, s_i^t s_i^t x[p_i^t](p_i^t - c_{i1}) + \\ &\quad n\, s_i^t s_j^t x[p_i^t](p_i^t - c_{i2} - \tau_j^t) + \\ &\quad n\, s_i^t s_j^t x[p_j^t](\tau_i^t - c_{i3}) + \\ &\quad n\, s_i^t (m_i^t - f_i).\end{aligned}$$

To conclude the description of the model, we recapitulate the structure of the game. Initial market shares s_1^{t-1} and s_2^{t-1} are the only relevant initial conditions of the market in period t. Operators take terminating access prices τ_1^t and τ_2^t as given. They simultaneously choose per-minute prices p_1^t and p_2^t, and subscription fees m_1^t and m_2^t. Consumers observe these prices, choose where to subscribe and make their telephone calls in period t. Market shares s_1^t and s_2^t are realized; operators receive profits $\Pi_1[p_1, p_2, m_1, m_2; t, s_1^{t-1}]$ and $\Pi_2[p_1, p_2, m_1, m_2; t, s_2^{t-1}]$ in period t.

Operators chooses prices to maximize period profits while taking the prices chosen by its rival firm as given. Equilibrium values of functions and variables will be marked with superscript $*$. For example, in equilibrium in period t, operator 1's per-minute price is denoted by p_1^{t*}.

A Nash equilibrium in period t, which is characterized by prices $(p_1^{t*}, p_2^{t*}, m_1^{t*}, m_2^{t*})$, satisfies the following conditions:

1. Given s_i^{t-1}, each operator's prices p_i^{t*} and m_i^{t*} maximize its profits given the other operator's prices p_j^{t*} and m_j^{t*}, for $i = 1, 2$, where $i \neq j$.

2. Consumers choose a network and a quantity of call minutes to maximize net utility, and the operators take this behavior into account when choosing prices.

In equilibrium in period t, given s_i^{t-1}, none of the operators has an incentive to deviate from its pricing strategy (p_i^{t*}, m_i^{t*}), if

$$\begin{aligned}\Pi_1^t[p_1^{t*}, p_2^{t*}, m_1^{t*}, m_2^{t*}; t, s_i^{t-1}] &\geq \Pi_1[p_1, p_2^{t*}, m_1, m_2^{t*}; t, s_i^{t-1}] \text{ and} \\ \Pi_2^t[p_1^{t*}, p_2^{t*}, m_1^{t*}, m_2^{t*}; t, s_j^{t-1}] &\geq \Pi_2[p_1^{t*}, p_2, m_1^{t*}, m_2; t, s_j^{t-1}]\end{aligned}$$

for all admissible p_1, p_2, m_1, m_2. Necessary conditions for an interior equilibrium are

$$\begin{aligned}\partial\Pi_i[p_1^t, p_2^t, m_1^t, m_2^t; t, s_i^{t-1}]/\partial p_i^t &= 0, \\ \partial\Pi_i[p_1^t, p_2^t, m_1^t, m_2^t; t, s_j^{t-1}]/\partial m_i^t &= 0,\ i, j = 1, 2,\ j \neq i.\end{aligned}$$

In our simulations we check that the solutions to the system of first-order condition, (p_i^{t*}, m_i^{t*}), are a global maximizer of $\Pi_i[\cdot,\cdot,p_j^{t*},m_j^{t*};t,s_i^{t-1}]$.

Producers surplus in period t, PS^t, is equal as the sum of profits in the industry, that is,

$$PS^t = \Pi_1[p_1^t, p_2^t, m_1^t, m_2^t; t, s_1^{t-1}] + \Pi_2[p_1, p_2, m_1, m_2; t, s_2^{t-1}],$$

and consumers surplus in period t, CS^t, defined as the consumers' aggregate net utility, is equal to

$$\begin{aligned} CS^t &= n\, s_1[p_1^t, m_1^t; t, s_1^{t-1}] v_1[p_1^t, m_1^t; t, s_1^{t-1}] + n\, s_2[p_2^t, m_2^t; t, s_2^{t-1}] v_2[p_2^t, m_2^t; t, s_1^{t-1}] \\ & \quad -\frac{n\,\theta}{2}\left(\left(s_1[p_1^t, m_1^t; t, s_1^{t-1}]\right)^2 + \left(s_2[p_2^t, m_2^t; t, s_2^{t-1}]\right)^2\right). \end{aligned}$$

The last term in the expression for consumer surplus is explained by the disutility that consumers incur owing to the subscription to a network that does not possess ideal characteristics. The welfare level in period t, W^t, is equal to the total surplus that is realized in the market, that is, $W^t = PS^t + CS^t$. In the case that operators are symmetric with respect to costs (in particular $c_{ij} \equiv c_j$, $i = 1,2$, $j = 1,2,3$) and that per-minute prices are equal to marginal costs the expression for welfare becomes

$$W^t = n\left(s_1 U_1 + s_2 U_2 - f + u[x[c_1]] - c_1 x[c_1] - \frac{\theta}{2}(s_1^2 + s_2^2)\right) \qquad (1)$$

Throughout this paper, we use numerical methods to derive results. The parameter values on which the simulations are based can be found in the appendix. The numerical methods are discussed in De Bijl and Peitz (2002b).

2.2 Analysis

2.2.1 Welfare: monopoly versus duopoly; first-best

Before analyzing equilibrium outcomes, we want to discuss considerations of a planner who deregulates the telecommunications market. We consider two technologically symmetric networks, that is, with identical cost structures. Is a duopoly with cost-based retail prices superior to a cost-based monopoly in terms of welfare? Note that first-best pricing involves per-minute prices equal to marginal costs, that is, $p_i = c_1$. Since we assume that all consumers participate in the market, the level of the subscription fee is arbitrary. (Clearly, for high subscription fees some consumers eventually no longer subscribe; the assumption of full participation only makes sense for sufficiently low subscription fees.) What matters for welfare is the market share of operators, which is determined by the difference in subscription fees $\Delta \equiv m_1 - m_2$. Substituting the expressions for market share into the equation for welfare (1) and maximizing with respect to Δ one obtains that $\Delta = 0$ in the social optimum. This implies that the socially optimal market shares under duopoly satisfy $s_i = 1/2 + (U_i - U_j)/(2\theta)$. We observe that subscription fees that are equal to the fixed costs of a connection, that is, $m_i = f_i \equiv f$, (together with cost-based per-minute prices) implement the social optimum.

Compared to a monopoly, a duopoly creates certain inefficiencies:

1. connection-independent fixed costs, C_i^t, are duplicated;
2. the entrant initially lacks a track record of quality compared to the incumbent (in the track-record specification of the model);
3. network externalities are not fully exploited (in the network-externalities specification).

On the other hand, a duopoly leads to social benefits: a differentiated duopoly better fits a consumer population with heterogeneous tastes. Other social benefits that are not incorporated into the model are those associated to competition reducing the X-inefficiency of the incumbent, that is, socially wasteful expenditures can be avoided. Such expenditures were possibly included in the profits of the incumbent. Also, mature competition creates a level-playing field, and this possibly reduces the social costs of regulation, which were not introduced into the model. Last but not least, it is often claimed that a protected monopoly leads to dynamic inefficiencies by not providing the right incentives to invest.

We will discuss further discuss welfare in terms of the two model specifications. First, consider the track-record specification of the model. If fixed costs C_i^t are negligible in the long run duopoly is welfare improving upon monopoly (at cost-based prices). This is so because in the long run the entrant has built up a track record of quality and offers the same utility v_i as the incumbent at prices $p_1^t = p_2^t$, $m_1 = m_2$. Because of the initial lack of a quality track record, the entrant's network offers lower fixed utility in early periods so that duopoly is welfare improving upon monopoly in the short run if the better average fit owing to product differentiation overcompensates the lower utility associated to the lack of track record in the short run. Considering intertemporal welfare, if the discount factor is sufficiently close to 1 and the time horizon T sufficiently long a cost-based duopoly dominates a cost-based monopoly in terms of welfare for sufficiently low fixed costs C_i^t.

Next, consider the network-externalities specification. Welfare per consumer (gross of fixed costs C_i^t) in period t under monopoly is on average $(\alpha + \gamma)u^0 - f_1 - \theta/2$. Corresponding welfare per consumer under duopoly is on average $\alpha u^0 - f_1 + (\gamma u^0 s_1^{t-1} - (\theta/2)s_1^t)s_1^t + (\gamma u^0 s_2^{t-1} - (\theta/2)s_2^t)s_2^t$. At T large, market share hardly changes over time so that $s_i^{t-1} \approx s_i^t$ and we can approximate welfare per consumer by $\alpha u^0 - f_1 + (\gamma u^0 - \theta/2)((s_1^t)^2 + (s_2^t)^2)$. Hence if $\gamma u^0 - \theta/2 \leq \varepsilon < 0$ a cost-based duopoly is welfare improving upon a cost-based monopoly in the long run for a sufficiently small fixed costs C_i^t.

Even if a cost-based duopoly leads to lower welfare in our model, one can still make the case for competition by referring to unmodelled advantages of competition such as those mentioned above. Below, we take the decision to introduce competition as given. Nevertheless, before the introduction of competition it is interesting to ask whether competition (regulated or not) indeed improves upon a regulated monopoly.

While we have analyzed when a regulated duopoly performs better than a regulated monopoly, it remains an open question whether an unregulated or only partially regulated duopoly performs better than a regulated monopoly. A duopoly which is not or only partially regulated can generate two distortions compared to the first-best: (1) a deadweight loss due to per-minute prices different from marginal costs; (2) a market share distortion.

2.2.2 Regulation of access prices

In this subsection, we analyze the regulation of access prices when the operators are free to choose their retail prices. We consider various access regimes, in particular, reciprocal and asymmetric access pricing.

A first observation, which was made by Laffont, Rey, and Tirole (1998), is that, in each period, each operator has two instruments at its disposal, the per-minute price and the subscription fee. Therefore an operator can split the building of market share from generating call volume. By manipulating an operator's first-order conditions, given any prices of the competitor, one can show that:

$$p_i^{t*} = s_i^t c_{i1} + s_j^t (c_{i2} + \tau_j^t) \text{ in each period } t.$$

That is, profit-maximization leads to per-minute prices that equal "perceived" marginal costs. Each operator uses the subscription fee to extract consumer surplus and sets usage price equal to marginal costs. This is because the subscription fee is more effective in capturing market share than the per-minute price; the gain in consumers surplus from a cut in the per-minute price (below perceived marginal costs) is less than the associated cost that the operator incurs, whereas a reduction in the subscription fee translates one-to-one into the surplus offered to consumers.

One can easily check that an operator that sets per-minute price equal to perceived marginal costs makes zero profits from the total amount of on-net and off-net traffic. Consequently, the only sources of profits are revenues from subscription and revenues from incoming traffic. Furthermore, in equilibrium, the product differentiation parameter θ has no direct effect on per-minute prices. An increase in the product differentiation parameter directly pushes the subscription fees upward (apart from indirect effects through market shares). These pricing principles hold in the symmetric setup of Laffont, Rey, and Tirole (1998) and asymmetric setups as in this paper, as well as in Carter and Wright (2003) and De Bijl and Peitz (2002a, b).

In our simulations we consider the following regulatory regimes: cost-based access price regulation, reciprocal access price regulation, and asymmetric access price regulation. Under cost-based regulation, the (reciprocal) access price is set equal to 0.5 Euro-cents in all periods. For the reciprocal access markup we take the access price equal to 1 in all periods. Asymmetric access price regulation is invoked for a limited number of periods and replaced afterwards by cost-based

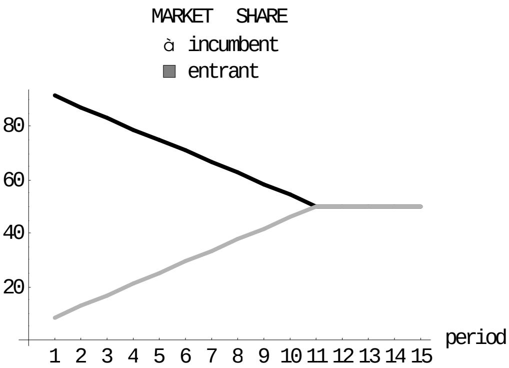

Figure 1: Cost-based regulation: market shares

regulation. We consider asymmetric access prices for six and for nine periods. In the former case we speak of short-lived asymmetric regulation, in the latter of long-lived asymmetric regulation. In the asymmetric regime the price to access the entrant's network is set equal to 1 Euro-cent. Under price cap regulation we consider a price cap on the incumbent's subscription fee of 45 Euros over a two-month period.

Cost-based access prices

In the track-record specification of the model, the fixed utility disadvantage of the entrant decreases linearly over time up to period t^*, which in the simulations is set equal to 11 (see the appendix for all parameter values used in the simulations). In the results, this is fully reflected in the subscription fees under cost-based regulation: for instance, in period 2 the fixed utility difference is equal to 45 Euros and the difference in subscription fees is equal to 30 Euros (period 5: 30 Euros and 20 Euros, respectively; period 8: 15 Euros and 10 Euros respectively). Under cost-based regulation all variables can easily be expressed analytically and it is possible to dispose of numerical methods. However, to illustrate the evolution of the industry, we use our numerical example.

Similar to subscription fees, also market shares evolve linearly over time until the entrant has fully built up its track record of quality (see Figure 1). With our parameter values the entrant first gains a market share of around 8.3% which is augmented by around 4.2% each period.

Under cost-based regulation, none of the operators obtains profits from incoming calls and profits in equilibrium are $\Pi_i^t = ns_i^t(m_i^t - f_i) - C_i^t$. In our simulations we do not include connection independent fixed costs C_i^t; this corresponds to $C_i^t = 0$. Since the entrant's market share and subscription fee increase linearly over time profits are increasing and convex over time until the entrant has caught up with the incumbent. Correspondingly, the incumbent's profits are decreasing and convex over time (compare Figure 2).

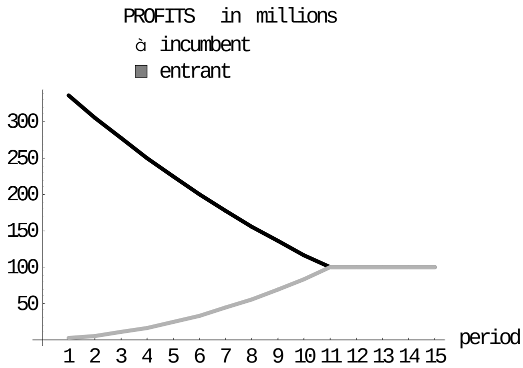

Figure 2: Cost-based regulation: profits

As explained in the previous section, welfare in a mature duopoly dominates welfare under monopoly for C_i^t sufficiently small because of beneficial product differentiation. This can also be seen by looking at Figure 3: the initial point of the trajectory for welfare (which is close to the monopoly situation) corresponds to lower welfare than the end point of the trajectory. In a mature market both operators set the same subscription fee so that the market splits equally between them. Hence, competition with cost-based access prices implements the first-best. In initial periods, there is a social cost to duopoly given the lack of the entrant's track record. If those social costs are high, welfare can be significantly improved by a regulatory policy which makes it harder for the entrant to gain market share in early periods. The reason is that, in each initial period, operator 2 prices lower than operator 1 so that, in equilibrium, $\Delta > 0$. Consequently, the socially optimal market share of operator 1 is greater than its market share under competition with cost-based access prices. The trade-off between the gradual build-up of a track record, which makes the entrant more attractive to consumers, and the gain in market share explains why welfare can be initially decreasing, as demonstrated in Figure 3.

As competition matures, the incumbent's profits decline and this is only partially offset by the increase of the entrant's profits so that producers surplus is declining over time. At the same time consumers gain from more mature competition, which is reflected by the increasing trajectory of consumers surplus (see Figure 3).

Reciprocal access prices (with markups)
In our simulations, introducing a reciprocal access markup does not change the picture much in terms of the slopes of the trajectories of the variables. The only notable exception is the per-minute price which was constant under cost-based regulation. Since per-minute price equals perceived marginal costs, the entrant's per-minute price is decreasing over time as it builds up a track record

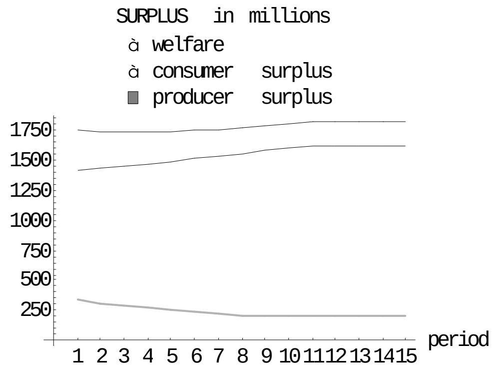

Figure 3: Cost-based regulation: surplus

of quality. The reason is that it has a small market share in early periods leading to relatively high perceived marginal costs. These costs are significantly higher than those of the incumbent because a call originating on the incumbent's network is likely to terminate on the incumbent's network when the incumbent's market share is large. Under a positive reciprocal access markup, the entrant has a lower market share than under cost-based access pricing because of its higher perceived marginal costs.

Operators have two sources of profits: profits from subscription and profits from incoming traffic. Initially, the entrant has to compete hard for consumers leading to small or even negative profits from subscription in early periods (as can be checked in our simulations). Whether or not the entrant is doing better under reciprocal access price regulations in a period in which it has not yet fully built up its track record cannot be said unambiguously (for a detailed answer see Carter and Wright, 2003). Aggregated over time both operators receive lower profits under reciprocal access price regulation than under cost-based regulation. In the long run, profits are not affected by a symmetric access markup: in a symmetric market losses in profits from subscription are exactly offset by gains in profits from incoming calls when comparing a positive access markup to access price equal the marginal cost of the local loop. This is the profit neutrality result under two-part tariffs, shown by Laffont, Rey, and Tirole (1998).

Clearly, a positive reciprocal access markup reduces welfare and consumers surplus in the long run because perceived marginal costs deviate from true marginal costs giving rise to a deadweight loss.

Asymmetric access prices

Asymmetric access price regulation treats entrant and incumbent differently. We consider regulation which favors the entrant in early periods of competition by fixing an access price above marginal costs for calls terminating on the entrant's

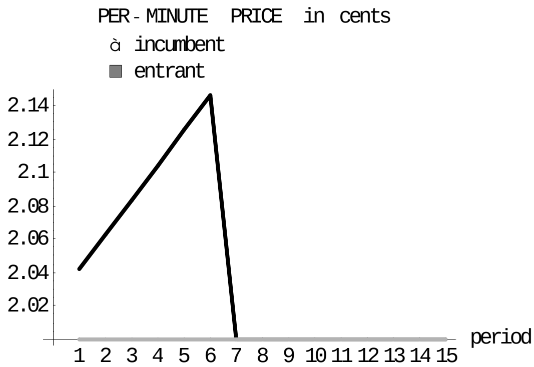

Figure 4: Asymmetric access price regulation: per minute prices

network. In our simulations reported here, this access markup prevails for six periods. This asymmetric regulation generates positive profits from incoming calls for the entrant. The incumbent is subject to cost-based regulation.

The incumbent has perceived marginal costs which are increasing over time as long as the entrant is allowed to charge an access markup because the entrant's market share is also increasing (compare Figure 4). Consequently, the incumbent sets a higher per-minute price than under cost-based regulation. The more aggressive behavior of the entrant can be explained as follows: an additional consumer not only generates profits for the entrant through its subscription but also generates additional incoming calls, which are valuable to the entrant. This makes the entrant to compete more aggressively for given prices of the incumbent. Similarly, the incumbent prices more aggressively than in the absence of an access markup which is reflected by a lower subscription fee. It turns out that both operator offer a higher net utility to consumers under an access markup for the entrant given the net utility offered by the competing operator. With upward sloping best responses this implies that both operators price more aggressively than under reciprocal access price regulation.[5]

The difference between true and perceived marginal costs is quite small initially due to the small market share of the entrant. Nevertheless, competition is strongly affected because the entrant gains from incoming traffic. In our simulation, the evolution of market share is only slightly better for the entrant under asymmetric regulation than under cost-based regulation but its profits in early periods are much larger in relative terms. Trajectories of profits are depicted in Figure 5. Using our parameter constellation, profits in period 1 are 3.2 in-

[5] This result appears to be robust in our simulations. It would be desirable to have this as a general result within the analytical framework. We are not able to derive such a result because in our model (as well as in the Laffont, Rey, Tirole and Armstrong model) it cannot be shown that best responses (in net condititional indirect utilities) are everywhere upward sloping. However, it can be shown that this result holds locally around cost-based access prices (see Peitz, 2003).

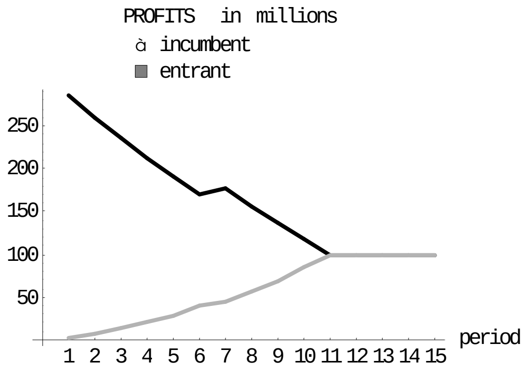

Figure 5: Asymmetric access price regulation: profits

stead of 2.8 million Euros and, in period 2, they are 7.2 instead of 6.3 million Euros. This makes asymmetric access price regulation a powerful instrument to improve entrant's profits in early periods. Entrants whose fate depends on the short-run profits evaluation of financial markets may need such an initial regulatory stimulus to become or remain active in the market. While regulators may appreciate the additional instrument asymmetric access prices offer them for fine-tuning, the down-side is the risk of discretion and abuse. Furthermore, since fine-tuning implies a changing policy over time regulation may become less transparent for market participants. For additional remarks see Peitz (2003).

More intense competition in early periods works in favor of consumers so that consumers surplus is higher under asymmetric regulation than under cost-based regulation. Welfare is lower for two reasons: first, a small number of consumers subscribe to the entrant's network who would have subscribed to the incumbent under cost-based regulation. Owing to the initial lack of the entrant's track record this constitutes a loss in social surplus – recall that the socially optimal market share of the entrant is even less than its market share resulting from competition under cost-based access price regulation. Second, the deviation of the incumbent's per-minute price from true marginal costs creates a deadweight loss. Both these effects are rather negligible in our simulation ($\Delta W^t \approx 1$ to 2% times $\Delta\Pi_2^t$ for those periods in which asymmetric access prices are in place).

Cost asymmetries

So far, we assumed that the incumbent and entrant have identical marginal cost levels. In reality, though, costs may be asymmetric. It is therefore interesting to consider if the conclusions on access prices should be adapted in case of asymmetries. We will informally discuss results that can be verified in a straightforward way, using simulations with our model.

As a first example of a cost asymmetry, consider marginal costs, and suppose that the entrant's marginal cost of the local loop, c_{23}, is lower than the incumbent's cost c_{13}.[6] For instance, it may be the case that the entrant was able to roll out a local network based on a more recent technology, that has benefitted from cost-reducing innovations. As a point of reference, consider cost-based access regulation, that is, $\tau_1 = c_{13}$ and $\tau_2 = c_{23}$.

Compared with the case of identical marginal cost levels, the cost advantage makes the entrant gain market share faster, finally ending up with a larger share than the incumbent. The incumbent, facing a stronger competitor, sees its profits reduced, while the reverse holds for the entrant.

Consider a temporary access markup for the entrant only, for instance $\tau_2 = c_{13}$ during the first six periods. The incumbent, facing a higher perceived marginal cost, increases its per-minute price. Since market share is more valuable for the entrant, price competition in subscription fees becomes more intense. The incumbent's profits are reduced, and *vice versa* for the entrant. Consumers surplus is increased during the periods with an asymmetric access markup and the speed at which the entrant gains market share is slightly reduced.

Alternatively, suppose that the regulator enforces a reciprocal access price equal to the lowest cost level, that is, $\tau = c_{23}$ for both operators. Such a policy may be motivated by a notion of 'best practice', or benchmarking.[7] Alternatively, the idea may be to implement cost-based access pricing by using a forward-looking instead of historical cost definition. A consequence of this regulation is that the incumbent is not fully compensated for the traffic-dependent costs it incurs for incoming calls. Compared to cost-based access prices, the entrant reduces its per-minute price to reflect a lower perceived marginal cost. In general, competition for market share (by setting subscription fees) becomes less intense, as the incumbent loses money on providing access, making market share less valuable. There is an exception to this intuition though, since a counteracting effect is that the smaller the entrant's market share, the less costs of incoming traffic the incumbent incurs. Therefore, in an infant market the incumbent becomes more aggressive (compared to a regime of cost-based access pricing), instead of less. In a more mature market, both operators become less aggressive (still compared to cost-based access pricing). Consumers surplus in an infant market increases, while it decreases in a mature market.

How do the examples of access policy compare in terms of consumers surplus? In an infant market, access pricing based on best practice is better for consumers than a temporary access markup for the entrant. As the market matures and the temporary markup in the first access regime is no longer allowed, cost-based access pricing yields the highest level of consumers surplus.

Finally a few remarks about another example of a cost asymmetry. Suppose that the entrant's fixed cost of the local loop is lower, that is, $f_2 < f_1$. Similar to

[6] Note that if c_{23} is reduced, by definition also c_{21} and c_{22} decrease accordingly. An alternative assumption, that yields the same qualitative results as those discussed here, is that all of the entrant's marginal cost levels decrease (while satisfying $c_{21} = c_{22} + c_{23}$).

[7] See European Commission (2000a), and also the underlying Recommendation, for more on best-practice interconnection pricing. A difference with the idea as applied by the Commission is that they compare operators in different countries, while we consider benchmarking between competing operators.

the case above, the entrant may have been able to roll out a local network based on newer technology, but now with a different type of cost-reducing innovation. Compared with identical costs, the entrant gains market share at a quicker pace, at some point overtaking the incumbent. While per-minute prices are not affected, subscription fees are reduced. Hence, this type of cost asymmetry reduces the need to stimulate entry through asymmetric access prices.

Competition in flat fees
It is interesting to consider alternative pricing strategies. In particular, suppose that the operators compete in flat fees (see also De Bijl and Peitz (2002b, section 6.3). That is, they choose subscription fees m_1 and m_2 while per-minute prices satisfy $p_1 = p_2 = 0$.[8] Similarly, the starting point of the analysis in De Bijl and Peitz (2002a) is the case in which per-minute prices are fixed at marginal cost levels, which, in a similar way, greatly facilitates the analysis. In general, these model specifications provide a useful starting point for formal analysis. Each subscriber demands a fixed number of call minutes $x[0]$. This assumption may also correspond to an inelastic demand for call minutes, or to regulatory intervention with regard to retail tariffs. In reality, some operators offer free national calls on certain days (Deutsche Telekom, Germany, in 2001), or on off-peak calls up to a certain limit (Lince Telecommunications, Spain, in 2001).

A first observation is that the operators compete only for subscribers, while anticipating losses from network usage $x[0]c_{i1}$, when they choose subscription fees. It is straightforward to show that in a mature market (with symmetric operators), reciprocal access prices cancel out of the operators' profit functions. The reason is that each operator has identical demand for call minutes per customer. Therefore, the gains from incoming traffic at a higher access price are cancelled out by losses from off-net calls. Moreover, also if operators are asymmetric, that is, the entrant is still building up its track record, reciprocal access prices do not affect profit levels. The reason is that call volumes do not respond to changes in the level of the reciprocal access price. However, profit-neutrality does not hold if access prices are asymmetric.

A general observation is that with fixed per-minute prices, market shares in an interior equilibrium do not depend on access prices (De Bijl and Peitz, 2002a). Therefore, total surplus is also independent of access prices. A change in access prices does, however, lead to a redistribution of surplus between operators and consumers.

As in the model with two-part tariffs, asymmetric access prices can be used to stimulate entry. In particular, entry is facilitated if $\tau_1 < \tau_2$ (and $\tau_1 = c_3$). Then, only the entrant makes profits on incoming calls, while competition intensifies, leading to higher consumers surplus. Thus, the policy implications related to access regulation are similar to those under competition in two-part tariffs.

[8] To study heterogenous calling patterns, Armstrong (2002a) uses a similar set-up (assuming that subscribers have inelastic demand for calls), since it has the advantage that the volume of incoming calls for a given subscriber does not depend on market shares, nor on contracts offered by operators. See also Armstrong (2002b).

2.2.3 Regulation of retail prices

In the early stages of competition, it may make sense to control the incumbent's retail prices so that consumers do not have to wait for lower tariffs until the entrant has built up a track record and gained sufficient market share. In this subsection, we consider price cap regulation in different access price regimes.

If the incumbent is subject to price cap regulation the price cap is likely to be binding in early periods when the incumbent still enjoys substantial market power. In these periods the forces of competition may be insufficient from the viewpoint of the regulatory authority to guarantee "reasonable" prices for consumers. We will consider a price cap that is only applied to retail prices; the wholesale price (that is the access price) is separately regulated. A positive aspect of price cap regulation is that a moderate price cap becomes obsolete once competitors gain strength and hence can remain in place without inflicting any harm.

Concerning retail prices the regulator may have different concerns. To eliminate a deadweight loss he may force the incumbent to set its per-minute price equal to true marginal costs. To avoid that consumers have to pay an "excessive" subscription fee he may separately impose a maximal retail price. Only one of these two prices may be fixed or both of them. The regulator may alternatively impose a joint retail price cap so as to make a connection together with a certain number of call minutes available at a certain price.

A price cap on subscription fees

In the current paper, we discuss most elaborately a price cap on subscription fees (for more on price cap regulation see de Bijl and Peitz, 2002b; see also below). This reflects the importance that a regulator may attach to universal service provision, which is typically embodied in a low subscription fee. For example in the Netherlands, telecommunications authority Opta has made sure that the former incumbent KPN Telecom offers a budget subscription (among other contracts). The aim of this contract is that every customer is able to be connected, can be reached, and can make phone calls if needed, although the per-minute price is usually higher for budget contracts (see Opta, 1998). We consider a price cap on subscription fees together with asymmetric access price regulation. We report simulation results for asymmetric access price regulation in place for 9 periods.

As argued above, a subscription fee is binding in those periods in which the incumbent enjoys a considerable degree of market power. Because the incumbent is not restricted in its per-minute price, it increases the per-minute price above perceived marginal costs in those periods in which the price cap is binding for the subscription fee. As time passes, the market power of the incumbent declines; this implies that the shadow price on the price cap restriction decreases and the per-minute price decreases ceteris paribus. This tendency of a lower per-minute price is only partially offset by an increase in perceived marginal costs (see Figure 6).

The per-minute price is an imperfect instrument for the incumbent to make

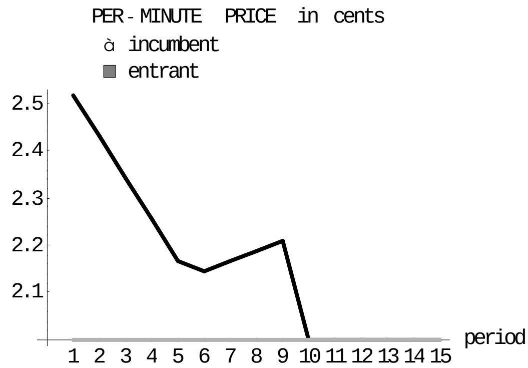

Figure 6: Price cap regulation: per minute prices

profits compared to the subscription fee. In equilibrium, both operators make lower profits than in the absence of price cap regulation because the incumbent prices more aggressively.[9] Consumers on the other hand gain from price cap regulation (see Table 5).

Tables 3 to 5 report profits and consumer surplus under three different regulatory regimes: cost-based access price regulation, asymmetric access price regulation, and the combination of price cap and asymmetric access price regulation.

	cost-based access prices	asymmetric access price regulation (9 periods)	asymmetric access price regulation (9 periods) and price cap
Π_1^1	335.4	285.8	282.6
Π_1^2	305.7	260.5	258.3
Π_1^3	277.3	236.3	234.9
$\sum_{t=1}^{15} \Pi_1^t$	2681.2	2375.71	2368.1

Table 3: Incumbent's profits: Comparison across different access regimes

	cost-based access prices	asymmetric access price regulation (9 periods)	asymmetric access price regulation (9 periods) and price cap
Π_2^1	2.8	3.2	2.6
Π_2^2	6.3	7.2	6.5
Π_2^3	11.1	12.8	12.2
$\sum_{t=1}^{15} \Pi_1^t$	850.6	890.5	888.1

Table 4: Entrant's profits: Comparison across different access regimes

[9]There is however an effect on the effectiveness of asymmetric access price regulation; see Section 4.

	cost-based access prices	asymmetric access price regulation (9 periods)	asymmetric access price regulation (9 periods) and price cap
CS^1	1415.6	1464.6	1470.1
CS^2	1433.8	1478.0	1482.0
CS^3	1452.7	1492.0	1494.7
$\sum_{t=1}^{15} CS^t$	23209.8	23476.8	23490.8

Table 5: Consumers surplus: Comparison across different access regimes

Compared to cost-based regulation, the entrant may do better than under combined price cap and asymmetric access price regulation, as can be seen from our simulation result (see Table 4). This is not necessarily so: a tough price cap regime may even inflict losses on the entrant so that it may refrain from entering in the first place. This makes price cap regulation a difficult policy instrument because one has to balance consumer interests with the goal to stimulate entry. Furthermore, price cap regulation such as pure subscription fee regulation can lead to strong distortions in the incumbent's pricing structure away from true marginal costs, and such pricing implies a welfare loss.

The distortion in the incumbent's per-minute prices induced by a price cap on subscription fees can be avoided by separately regulating the incumbent's per-minute price. Under such a more intrusive regulation the regulator can fix the incumbent's per-minute price at its socially efficient level, that is, at true marginal costs. A binding price cap on the subscription fee then makes the incumbent compete more aggressively than under cost-based regulation (as well as under regulation that only fixes the subscription fee). This affects the entrant's profits negatively. A temporary access markup for the entrant generates positive profits from incoming calls thus enabling the entrant to approach or reach profit levels that would be realized under cost-based regulation. To summarize, also when imposing separate price caps on both retail prices of the incumbent, the regulator can ameliorate the prospects of the entrant by complementing the price cap with asymmetric access price regulation.

Discussion

Concerning cost asymmetries, we note that if the entrant has lower cost levels, marginal or fixed (see the previous subsection), typically the need for price caps becomes less. This is due to the fact that lower cost levels for the entrant increase the intensity of price competition. Nevertheless, a certain type of access regime may reduce the intensity of price competition. As an example, recall the 'best practice' access policy if the entrant has a lower marginal cost of the local loop, which led to increased subscription fees in the long run. But here one should observe that, in an infant market, the incumbent becomes more aggressive, so that a price cap on subscription fees becomes less called for.

As in the previous subsection, we briefly discuss competition in flat fees. Suppose that the operators choose subscription fees m_1 and m_2 while per-minute prices satisfy $p_1 = p_2 = 0$. A binding price cap on the incumbent's subscription fee forces the entrant to reduce its subscription fee as well, due to increased competitive pressure. A lower price cap allows the incumbent to preserve more market share. As a result, welfare in the early stages of competition is higher. Nevertheless, retail price regulation may make entry unprofitable, and should therefore be carefully applied.

3 Other modes of entry and investment

The previous section focused on facilities-based entry, that is, the entrant rolls out a network with complete facilities, including a local access network. In reality though, not all entrants do so, or at least it takes substantial time before a complete network is in place. In particular, the local access network is typically the most costly component of a network, both in money and time. Nevertheless, entry may be possible, if entrants not only get terminating access to the incumbent's local network (as in the previous model), but also originating access. In this section, we consider two different ways of this type of combined access: local loop unbundling (3.1) and carrier select (3.2).[10] In the former case, the entrant leases local lines from the incumbent at a monthly rental fee. In the latter case, the entrant purchases originating access to end-users on a per-minute basis. This section concludes with a comparison of different entry modes, that allows one to draw conclusions related to an entrant's investments in a network (section 3.3).

3.1 Local loop unbundling

Unbundling of the local loop means that an entrant can (more or less) directly plug into the incumbent's network by creating a connection from its switch to the incumbent's local access network. The entrant pays a monthly fee, the line rental, to the incumbent, and can use the leased local lines to directly connect to end-users. The entrant incurs the traffic-dependent cost of the leased connections.

>From a regulatory viewpoint, the lease price of the incumbent's local loop is the central issue, in combination (and interaction) with terminating access prices. In addition, a regulator may consider to apply price caps on the incumbent's retail prices.

Although we do not provide a formal analysis here, it is useful to discuss the model adaptations that are needed for local loop unbundling. In the model, both operators still charge per-minute prices and subscription fees, since consumers have the possibility to subscribe to the entrant. The main difference with facilities-based competition is that the entrant pays a monthly fee to the incumbent. We denote this line rental, in a given period t, by L^t. In addition, the traffic-independent fixed cost of a connection of the incumbent, denoted by f_1, is split between the operators. The reason is that a connection comprises two components, the "local line" and the "line card", with associated costs f_i^{ll} and

[10] Based on De Bijl and Peitz (2002b), sections 5.2 and 5.3.

f_i^{lc}, respectively. Under local loop unbundling, the entrant provides its own line card, while using the incumbent's local line. Therefore, in period t, the incumbent's traffic-independent revenues are equal to $n\, s_1^t(m_1^t - f_1) + n\, s_2^t(L^t - f_1^{ll})$ and the entrant's traffic-independent revenues are equal to $n\, s_2^t(m_2^t - L^t - f_2^{lc})$. Operators' profit functions have to be adapted accordingly. The rest of the model remains as described in section 2.

Compared to facilities-based entry, what does competition look like under local loop unbundling? In the entrant's perception, the lease price of the local line is just another component of its traffic-independent cost of a connection, replacing the fixed cost of the local line. A higher lease price directly inflates the entrant's fixed cost per connection, and hence its subscription fee. Assuming that the whole market remains covered, an increase of the lease price has three consequences. Firstly, it increases the entrant's fixed cost of a connection and its subscription fee. Its profits are not affected, since the entrant is able to pass on the higher fixed cost to consumers through the subscription fee. Secondly, the incumbent is able to increase its subscription fee in response to the entrant's adapted subscription fee. Equivalently, the intensity of competition is reduced. Contrary to the entrant, the incumbent's costs remain unchanged, so that its profit level increases. Thirdly, consumers surplus is reduced. Total welfare remains constant, though. Overall, a higher lease price creates a transfer of surplus from consumers to the incumbent.

In the discussion above, our assumption that the market remains covered is realistic because a regulator will not allow price to be raised to an extent that leads to consumer drop-out. In most countries, telecommunications law specifies that universal service obligations – usually implying that subscriptions are available at reasonable tariffs – must be met; regulators have to implement these specifications.

More generally, the exact regulatory implications of our discussion of the model depend on the policy goals. Suppose, for instance, that the incumbent has other possibilities than the lease price and subscription fee to recoup its connection-dependent fixed costs. This may be the case when retail prices have not yet been rebalanced, so that markups in per-minute prices should contribute as well to cost recovery. Consumers surplus can be increased by imposing that the lease price is below the cost of the local line f_1^{ll}. The reason is that, while welfare is unaffected, consumers benefit from lower subscription fees. The exact level of the lease price should not be too low, taking into account that the incumbent must be able to finance investments in maintenance and upgrading of the local access network. In reality, due to tariff rebalancing, incumbents are typically supposed to recoup fixed costs through fixed charges. Given this constraint, consumers surplus is maximized by imposing a cost-based lease price, that is, a price equal to the cost of the local line f_1^{ll}. To the extent that the lease price should also cover other fixed costs, such as connection-independent investments made by the incumbent, a markup in the lease price may be called for.

Interestingly, the negative effect of a lease price markup on consumers surplus can be alleviated by putting a price cap on the incumbent's subscription fee.

Such a price cap affects competition in a similar way as in a situation of facilities-based entry (see section 2.2.3), but has the additional effect that consumers are compensated for the utility reduction caused by the markup in the lease price.

With such a compensation scheme, the competitive pressure is increased so that the entrant makes lower profits. Hence, while in the interest of consumers, entry becomes less attractive. This implies that trying to "fine-tune" regulatory policy in a way that consumers do not loose in the short term, may prolong the need for regulatory interventions.

3.2 Carrier select

In a situation of carrier-select-based entry, an entrant purchases originating access to end-users from the incumbent on a call-by-ball basis, in addition to terminating access. Consumers who wish to make calls through the entrant's long-distance network either dial a prefix (usually consisting of four digits) before a phone number or register once for all calls that they make. In both cases, the incumbent's switches direct such calls to the entrant's backbone.[11]

In contrast to facilities-based entry and local loop unbundling, which can both be seen as situations of two-way access, under carrier select the entrant needs access to a bottleneck facility owned by the incumbent, but not vice versa. Hence, carrier select is a situation of one-way access. A regulator will primarily be interested in both the originating and the terminating access price that the entrant has to pay to the incumbent. Moreover, a regulator may consider the use of price caps on the incumbent's retail prices.

It is instructive to discuss how the model needs to be adapted for carrier select. Consumers who use carrier select do this on a per-call basis, so they keep their subscriptions to the incumbent, and continue to derive a fixed utility of having a connection to the incumbent's network $U_1[t, s_1^{t-1}]$. The entrant only charges a retail price p_2^t, and no subscription fee. The incumbent's originating access price in period t is denoted by δ_1^t. The entrant incurs a traffic-dependent cost of its long-distance network, denoted by c_{24}. If one adapts the operators' profit functions accordingly, it is straightforward to see that only the sum $\delta_1^t + \tau_1^t$ is relevant for the outcomes of the model; not its separate components. The entrant's traffic-dependent cost per minute is equal to $\delta_1^t + c_{24} + \tau_1^t$, while the incumbent, for whom each call is on-net, faces a cost of c_{11}. Hence, the entrant heavily depends on the incumbent, while the reverse is not the case. This is an important difference with facilities-based entry and local loop unbundling, where the incumbent incurs a termination fee τ_2^t for off-net calls.

Competition under carrier select is different than under facilities-based entry and local loop unbundling, because of the one-way nature of access prices. Because of this asymmetry, the entrant does not receive any access revenues. Without regulation, one-way access may, for instance, lead to a "price squeeze,"

[11] In reality, it may also happen that an entrant does not have a network at all, and also needs to purchase long-distance transmission from the incumbent. Our model can easily be adapted to apply to such situations of pure resale. The results in this paper are robust to such an adaptation of the model.

that is, the incumbent could increase the entrant's cost of access $\delta_1^t + \tau_1^t$ and reduce its retail price p_1^t. By doing so, the entrant's profit margin can be reduced, or even eliminated. The risk of a price squeeze is especially large if the regulator has difficulties in observing the incumbent's marginal cost levels. The regulator needs this type of information to judge whether access prices are reasonably close to marginal costs, and whether the retail price is not too low compared to the traffic-dependent cost.

Markups in the originating or terminating access price charged by the incumbent raise the entrant's costs, and therefore soften competition in the retail market. However, only the incumbent benefits; its market share and profit level increase, while the reverse holds for the entrant. Consumers surplus and total welfare decrease. To maximize consumers surplus and welfare, given carrier select, access prices should be cost-based, provided that the incumbent should at least recover its traffic-dependent costs. This observation holds both in an infant as in a mature market.

Since all consumers, also the entrant's customers, keep their subscription to the incumbent, the latter faces no competitive pressure on its subscription fee. A price cap on this retail price is therefore needed to prevent the incumbent from charging the monopoly price.

Suppose the incumbent's subscription fee is fixed by the regulator. Then the incumbent uses the per-minute price to extract additional profits from its market power. The regulator may therefore consider also the regulation of the incumbent's per-minute price. A drawback of such a price cap is that, although the direct gains for consumers can be substantial, the entrant's profits decrease. In addition, the entrant's build-up of market share is slowed down, resulting in a lower market share in the long run. Nevertheless, capping the per-minute price can remedy the reduced intensity of competition caused by access markups. Given the drawbacks of a price cap, though, it seems better to prevent access markups in the first place, rather than trying to dampen its side effects with another regulatory instrument.

In practice, there often exist several entrants, using different entry modes in a given market segment. As long as some entrants use local loop unbundling or facilities-based entry, the incumbent does face competition for subscribers so that retail price regulation is less likely to be needed.

3.3 Dynamic regulation and investments in networks

Although an analysis of each of the entry modes discussed above is interesting in its own respect, additional insights can be obtained by making comparisons across the entry strategies. For instance, given a certain regulatory regime, will an entrant roll out its own network, lease local lines from the incumbent, or opt for the "minimalistic" entry mode of carrier select? For incumbents and entrants alike, this is a crucial issue. See, for instance a policy document by the Ministry of Economic Affairs (2000) in the Netherlands, referring to the benefits of competition in infrastructures (compared to competition in services on a single infrastructure), which has become a possibility because the natural-monopoly argument no longer applies, as argued in the document (p. 22). The Dutch incumbent operator KPN argues on its website: "An important choice facing a regulator is whether to give priority to competition based on services or that based on the infrastructure. [...] Opta [the regulator] can determine whether there is any incentive for these providers to invest in their own networks, or whether they will prefer to use KPN's network (at no financial or commercial risk). The higher the permissible charges, the less incentive there will be for other providers to use KPN's network. They would then be more likely to invest in their own networks."[12]

However, as for example the Economist writes in a recent survey, it is not clear which entry mode is to be preferred: "How best to promote competition over the local loop is by far the most controversial topic in telecoms regulation. Ideally, competitors would put an end to the incumbents' local-loop monopoly by building their own networks. But building a competing network with the same reach is hugely expensive and time-consuming. Cable networks generally provide coverage only in some areas, and mobile-phone networks cannot yet offer broadband internet access. So, over the past few years, most of the developed world has been asking incumbents to share their networks with rivals-technically known as "local loop unbundling" (LLU). This means treating the incumbents as a special case and regulating them in an "asymmetric" way, at least until competing networks have been constructed. By allowing competitors to lease or resell lines, regulators have been able to foster competition in both telephony and broadband access." (The Economist, Survey: Telecoms, October 9, 2003)

The notion that the market for fixed telecoms is no longer a natural monopoly does not necessarily apply to all segments of the market, as casual observation in various countries suggests (e.g. for the Netherlands see Ministry of Economic Affairs, 2000). For instance, in most parts of the Netherlands, consumers can only subscribe to KPN's network; no alternative networks that reach them have been rolled out. Opta, while recognizing the relationship between regulation and incentives to invest in infrastructure, correctly argues that it faces the challenge of striking the right balance between competition in services and infrastructures (Opta, 2003, p. 13).

Although consumers observe competing offers with entry, there remains an asymmetry between incumbent and entrant under local loop unbundling. One response by regulators is to enforce unbundling requirements for "old" installed technology but not to mandate unbundling or other forms of access at regulated prices for new technology. For instance, in the U.S. the FCC recently ruled that if the Bells build a new fibre-optic local loop, it will not enforce access rules which apply to "old" technology. The reason is that the FCC wants to encourage investments in "new" technology.

Within the framework of our models, let us look first of the effect of the lease price of the local loop, L^t, on an entrant's incentives to invest in local lines itself. While a low (e.g. cost-based) lease price is best for consumers surplus,

[12] http://www.kpn-corporate.com/eng/mij/index.php?id=5.02&taal=eng (consulted July 2003).

a consequence may be that the entrant refrains from rolling out its own local access network. Thus, from a dynamic perspective, it may be recommendable to allow the incumbent to charge a lease price above cost. The "best of both worlds" can be obtained by imposing an increasing series of lease prices L^1, L^2, L^3,..., in combination with a specific form of retail regulation. By starting with a low, cost-based lease price, the entrant can build up market share, gain a reputation and track record, while consumers benefit from competition right from the start of market liberalization. In time, though, it should become less and less attractive for the entrant to lease local lines from the incumbent, which provides incentives to invest in its own local access network. As discussed in section 3.1, without retail regulation, the entrant can pass on the increased lease price to consumers through its subscription fee, so that its profits remain unaffected. A price cap on the incumbent's subscription fee, however, prevents this. Accordingly, a combination of wholesale and retail regulation is needed to tilt the balance towards facilities-based entry.

Alternatively, the entrant may have to pay a fixed fee independent of the number of subscribers. Then an increase in this fee strengthens the incentives to invest (for a dynamic analysis, see Bourreau and Dogan, 2003).

Next, consider the effect of access prices on the entrant's incentives to invest. In case of carrier select, a high originating access δ_1^t price directly hurts the entrant, giving it incentives to bypass the incumbent's local access network. The same is true for the incumbent's terminating access price τ_1^t; also here an access markup negatively affects a carrier select entrant, more than in case of facilities-based entry or local loop unbundling (because of the one-way dependency; see section 3.2). In order to gradually reduce the attractiveness of carrier-select-based entry compared to the other two entry modes, an increasing series of access prices δ_1^1, δ_1^2, δ_1^3,..., can be used. This corresponds to a "ladder" approach according to which entrants are first helped to climb the ladder, after which they should face their own risks. Terminating access prices τ_1^t could, in principle, fulfill a similar function. However, since they apply in any entry situation (and possibly cannot be made conditional on the entry mode), distortions can be avoided by setting them at cost-based levels (as argued in section 2.2.2).

In our view, carrier select can be very useful to stimulate entry (and build-up of market share by entrants) in an infant market, so that consumers directly benefit from increased service variety and downward pressure on retail tariffs. Nevertheless, one can argue about the long-term benefits of this type of entry. Firstly, carrier-select entrants are limited in the quality options that they can offer, since they heavily depend on the incumbent's facilities. Secondly, to function properly it requires continued regulatory intervention, which is costly in itself.

The limitations of carrier select are, although to a lesser extent, also true for local loop unbundling. A difference is that leasing local lines results in "ownership" of end-users (through subscriptions) as well as more possibilities for enhanced services, such as fast Internet access (e.g. by using a digital technology such as ADSL). Regulatory oversight with regard to lease prices and contractual conditions of using the incumbent's premises, remains required, though.

The associated cost of continued regulatory oversight may be worthwhile if the prospects for facilities-based entry are dim, which is currently still the case for certain types of consumers. In certain market segments, one hardly observes that entrants connect end-users to their backbones, as already mentioned above. Facilities-based entrants are primarily interested in large corporate customers and densely populated, metropolitan areas. Other types of customers remain stuck with the existing local access networks of the incumbent (although this is not necessarily unfavorable). Hence, depending on the population density and nature of customer demand, the local access network may lead to a natural monopoly in the market for fixed telecoms. In those cases, local loop unbundling may remain an effective way of exposing incumbents and consumers to competition in the longer run. Because of the increased possibilities for offering new services, unbundled access seems superior to carrier select.

Now suppose that a regulator wants to encourage facilities-based entry where possible (i.e., profitable from an entrant's viewpoint) without discouraging local loop unbundling in segments where the local access network leads to a natural monopoly. Can these goals be obtained at the same time? Clearly, if the regulator has sufficient information to identify the segments of the market which constitute a natural monopoly, then it can design – provided that competition and telecommunications laws allow for it – its regulatory policy conditional on these finding (see chapter 8 in De Bijl and Peitz, 2002b). Otherwise, as also our analysis has shown, there exists a conflict which remains unsolved.

To conclude this section, a remark on our assumption about the track-record specification (see section 2). Related to our results is an interesting modification by Valletti and Cambini (2002), who postulate that a higher quality not only affects the fixed utility part of net utility, but also increases the demand for call minutes. In a two-stage model in which both operators first invest in quality they show that a high reciprocal access price can be seen as a collusive device to avoid investment costs. Consequently, a high reciprocal access price leads to underinvestment from a social point of view. Their findings are particularly relevant in segments of the market in which a new technology has to be used by all firms.

4 Conclusion

This paper has presented a formal framework, which allows to address regulatory policy under different entry scenarios in a telecommunications market. In particular, we have analyzed the effects of access price policy in an infant and a mature market. Our framework allows to describe the evolution of the industry, something which a one-shot model cannot achieve. However, we have done this in an admittedly restrictive way. More work is needed, to include further considerations about the dynamics of the industry. In particular, the analysis of dynamic business strategy and investments in relationship to regulation is an important topic for further research. Since regulation affects investment decisions, regulators have to be concerned about the impact of regulation on infrastructure investments. Entry decisions not only depend on regulation in force at the moment of the decision, but also on the expected future regulatory policy and regulators' views about economies of scale in local access networks in different segments of the market. The controversy about natural monopolies and how to deal with them in various segments in the market for fixed telecommunications has not yet been resolved.

Appendix 1: Parameter constellation used in numerical simulations

demand parameters	a	20 Euro-cents
	b	0.015 Euro-cents
	θ	20 Euros
	u^0	50 Euros
	$\alpha_1 = \alpha_2$	1
	β	1
	γ	0
	t^*	11
	n	10,000,000
	s_1^0	1
cost parameters	$c_{11} = c_{21}$	2 Euro-cents
	$c_{12} = c_{22}$	1.5 Euro-cents
	$c_{13} = c_{23}$	0.5 Euro-cents
	$f_1 = f_2$	20 Euros

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