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PRICE DISCRIMINATION, ENTRY, AND SWITCHING COSTS IN NETWORK COMPETITION

ABSTRACT: *This paper reviews theoretical models of network competition in telecommunications. We will discuss two alternative approaches. The first approach assumes Hoteling's horizontal differentiation and the second approach is based on switching costs. We will first analyse spatial competition with linear prices and continue with price discrimination between on-net and off-net calls. Price discrimination can also be used to deter entry to the market. We will also deal with the regulator's optimal choice of access price, which should be designed to induce entry of new firms. Furthermore, pricing of roaming services and the switching cost approach to network competition will be considered. Finally, we will illustrate the theoretical results with data from the Serbian mobile and fixed telephony market.*

KEY WORDS: *telecommunications, spatial competition; access pricing; price discrimination; entry; predatory behaviour; switching costs.*

JEL CLASSIFICATION: L14, L96

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1. INTRODUCTION

Network effects are a specific form of externality that has become an important field of research with the rapid development of telecommunications and the internet. With network externality the utility of one user increases with the number of users using the same service[1]. Individual users do not consider these additional benefits that they generate to others by joining the network, and for that reason the network could fail to exist, even though it is socially optimal for the network to operate[2]. The first paper to analyse monopoly provision of telecommunication services was Rolf's (1974). In order to avoid network failure with a monopoly provider a critical mass of users must be reached, and after that point network effects govern the number of users towards a stable equilibrium. The critical mass can be reached by providing free service for a certain period or by providing service below cost. When the critical mass is reached, the provider increases its price. This pricing pattern might seem to be entry-deterring (or predatory if there are other rivals in the market), but to avoid market failure this behaviour is necessary. The monopolist should set the price such that two-thirds of the population is subscribed and this equilibrium is not welfare-maximising. The market that is not served by the monopolist represents residual demand facing the entrant. Entry to the monopolised market might be welfare-improving, since the utility of existing users is increased due to a higher level of network externalities, the utility of new users is non-negative, and the entrant's profit is positive. If there is more than one provider in the market, access pricing becomes an important issue when one network uses another network's infrastructure, thus avoiding redundant investment. In telecommunications the access price is the price that network A pays to network B for the service of conveying and terminating a call originating from network A.

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1 Daganoglu and Grzybowski (2007) studied the effects of network externalities in the German mobile telephony market and identified a large increase in the number of subscribers, with a 700% growth rate from January 1998 to June 2003. It remains puzzling how such an increase was achieved when prices of mobile phone communication services only fell by 41%. Without network effects and based only on price decline, the number of subscribers would be twice as low. In other words, in order to achieve this growth rate only by price reduction and without network effects, prices would have to become negative.

2 A nice example of such market failure is presented in Pepall, Richards, and Norman (2011).

In general, networks can charge two-part tariffs: subscription fee and per-minute price. Per-minute price can be the same, regardless of the network where the call terminates or the network's price discrimination, charging a higher price for calls terminating on the rival's network. Price discrimination could also be the incumbent's instrument to deter entry, as the entrant has a small number of subscribers and its users pay more to make more off-net calls compared to users of the incumbent's network. In order to induce entry to the market, the regulator may use an asymmetric access-pricing policy, where the entrant is allowed to charge a higher access price than the incumbent.

The second form of externality in telecommunications is call externality, when the user of one network receives free calls from users of other networks. In roaming service the user pays a reception charge for incoming calls.

Users may be locked in to their operator, who can exploit this situation by extracting the consumer's surplus. One source of switching costs stems is when the user of one network makes a higher proportion of calls to friends and family that belong to the same network and by changing operator the switching user would be faced with higher per-minute prices for off-net calls. The other source of switching costs is when the user has to inform all his contacts that he has changed his number.

The rest of the paper is organised as follows. In the second part we present the model of horizontal differentiation in telecommunication services with linear prices. The second section reviews price discrimination in the same setup. The following two sections deal with entry. The fifth section studies the 'receiver pays' principle, and the last section presents the switching cost approach.

2. SPATIAL COMPETITION WITH LINEAR PRICES AND DIFFERENT CALLING PATTERNS

The dominant approach in the literature on network competition in telecommunications is to use Hoteling's model of horizontal differentiation, where two operators are located at the opposite ends of the unit interval and users are uniformly distributed on the interval according to their network preferences. For example, if the user is located at the left end of the unit interval, where operator 1 is also located, his utility is not reduced because his ideal operator is at the same location. The further the user is from the left end of the interval, the lower his utility from subscribing to operator 1's network. The most common assumption is that outgoing calls are completely random and that the user calls other users with equal probability. We will start our survey with the paper that established the standard approach of horizontal differentiation in network competition, by Laffont, Rey, and Tirole (1998*a*). They assume reciprocal access charges when access charges are the same for all operators and model the competition in linear per-minute prices without price discrimination. The marginal cost of originating a call is c_0, the marginal cost of terminating a call is also c_0, and the marginal cost of conveying a call is c_1. The total marginal cost of an on-net call is $c = 2c_0 + c_1$. The first operator is located at the left side of the interval $x_1 = 0$ and the second operator on the right side $x_2 = 1$. The user located at *x*, making *q* minutes of outgoing calls, having income *y*, and unit disutility *t* from subscribing to a network that is not his favourite has utility:

$$y + u(q) + v_0 - t|x - x_i|, \tag{1}$$

where v_0 is a fixed utility from subscription and $t|x - x_i|$ is disutility from using a network that is not his favourite. If $t = 0$, in the user's view, networks are perfect substitutes, and as *t* increases networks are more differentiated. The term v_0 measures the utility from connecting to any network. In the absence of this term, when the substitutability is low (*t* is high), it might happen that some users in the middle of the Hoteling line who are the furthest from the operators might decide not to subscribe to avoid obtaining negative utility, and this term is needed to ensure full coverage. The user's utility from *q* minutes of outgoing calls is:

$$u(q) = \frac{q^{1-(1/\eta)}}{1-(1/\eta)}. \tag{2}$$

The maximisation of user's utility, subject to budget constraint, yields a constant elasticity demand function:

$$q = p^{-\eta}, \tag{3}$$

where p is the price of per-minute call. Substituting this result in the direct utility function, we obtain the indirect utility function:

$$v(p)=\frac{q^{1-(1/\eta)}}{1-(1/\eta)}-pq=\frac{\frac{q}{q^{1/\eta}}}{\frac{\eta-1}{\eta}}-pq=\frac{p^{-(\eta-1)}\eta}{\eta-1}-\frac{(\eta-1)\,p^{-(\eta-1)}}{\eta-1}=\frac{p^{-(\eta-1)}}{\eta-1}\,. \tag{4}$$

We will use the logic of Hoteling's model to determine the location of the user who is indifferent between subscribing to network 1 or 2, which charge prices p_1 and p_2:

$$v(p_1)-t\alpha=v(p_2)-t(1-\alpha)\,, \tag{5}$$

$$\alpha=\frac{1}{2}+\sigma[v(p_1)-v(p_2)]\,, \tag{6}$$

where $\sigma=1/2t$ represents the index of competition or index of substitution between two networks and, as usual, α measures location and network's share due to uniform distribution. When the 'transport cost' is high, networks are highly differentiated and substitutability is low. By using the last equation and Roy's identity, it could be inferred that:

$$\frac{\partial\alpha}{\partial p_1}=-\sigma q_1\ ,\ \frac{\partial\alpha}{\partial p_2}=\sigma q_2\,. \tag{7}$$

The first case studied by Laffont, Rey, and Tirole (1998*a*) is when the access charge is the same for both operators and is determined exogenously by the regulator. The first part of the profit of operator *i* stems from outgoing calls:

$$\alpha_i[(p_i-c)q(p_i)-f]\,. \tag{8}$$

The second part of the profit function is access revenue:

$$\alpha_i\alpha_j[a-c_0][q(p_j)-q(p_i)]\,, \tag{9}$$

where a is the access charge. The last equation shows that operator i has positive access revenue if it has more incoming than outgoing calls, which implies that operator i is more expensive than operator j. The entire market is covered and we can denote the market share of operator 1 by α and its profit function is:

$$\alpha(p_1, p_2)[(p_1 - c)q(p_1) - f] + \alpha(p_1, p_2)(1 - \alpha(p_1, p_2))(a - c_0)[q(p_2) - q(p_1)]\,. \tag{10}$$

Symmetry implies $\alpha = 1/2$ and the first-order condition with respect to p_1 gives:

$$\frac{1}{2}[(p_1 - c)q'(p_1) + q(p_1)] + \frac{\partial \alpha}{\partial p_1}[(p_1 - c)q(p_1) - f] - \frac{1}{4}(a - c_0)q'(p_1) = 0\,. \tag{11}$$

There is no partial derivative of market share in the second term since $d[\alpha(1-\alpha)]/d\alpha = 0$. We can use the symmetry assumption that implies $p_1 = p_2 = p$ and substitution such that $\pi(p) = (p - c)q(p) - f$. From $q(p) = p^{-\eta}$ it follows that $q'(p) = -\eta\, p^{-\eta-1} = -\eta q / p$ and the first-order condition becomes:

$$-\eta(p - c)\frac{q}{p} + q - 2\sigma q \pi(p) + \frac{\eta}{2}(a - c_0)\frac{q}{p} = 0\,, \tag{12}$$

$$\frac{p - \left(c + \dfrac{a - c_0}{2}\right)}{p} = \frac{1}{\eta}\left[1 - 2\sigma\pi(p)\right]. \tag{13}$$

The equilibrium described above exists if neither the access charge nor the substitutability of the two networks is too high. To understand the intuition of the existence result, suppose that both access charge and substitutability are high. In that case each network has an incentive to lower its per-minute price to expel the competitor from the market. But this situation is not equilibrium either, since the other operator could adopt the same strategy and obtain half of the profit.

The other possibility studied by Laffont, Rey, and Tirole (1998*a*) is that access charges are market-determined and could be asymmetric. This environment could be modelled with a two-stage game, where operators first choose access charges and then choose per-minute prices. We will solve the game by backward induction, first determining equilibrium per-minute prices for the given market shares. The profit function of operator 1 is:

$$\alpha(p_1,p_2)[(p_1-c)q(p_1)-f]+\alpha(p_1,p_2)(1-\alpha(p_1,p_2))[(a_1-c_0)q(p_2)-(a_2-c_0)q(p_1)]\,. \tag{14}$$

In the symmetric equilibrium when $\alpha=1/2$, the profit function becomes:

$$\frac{1}{2}[(p_1-c)q(p_1)-f]+\frac{1}{4}(a_1-c_0)q(p_2)-\frac{1}{4}(a_2-c_0)q(p_1)\,. \tag{15}$$

The first-order condition with respect to p_1 gives:

$$\frac{1}{2}[(p_1-c)q'(p_1)+q(p_1)]-\frac{1}{4}(a_2-c_0)q'(p_1)=0\,. \tag{16}$$

By using the fact that $q(p_1)=p_1^{-\eta}$ and $q'(p_1)=-\eta\, p_1^{-\eta-1}$ the first-order condition is:

$$p_1=\frac{\eta}{\eta-1}\left[c+\frac{(a_2-c_0)}{2}\right]. \tag{17}$$

We now return to the first stage and maximise profit with respect to access price a_1. The first-order condition implies:

$$\frac{1}{4}q(p_2(a_1))+\frac{1}{4}(a_1-c_0)\frac{dq(p_2)}{d\,p_2}\frac{d\,p_2}{d\,a_1}=0\,. \tag{18}$$

By using the analogy with (17):

$$\frac{d\,p_2}{d\,a_1}=\frac{1}{2}\frac{\eta}{\eta-1}\,. \tag{19}$$

Using the fact that $\frac{dq(p_2)}{d\,p_2}=-\eta\frac{q_2}{p_2}$, the first-order condition becomes:

$$\frac{1}{4}q(p_2(a_1))+\frac{1}{4}(a_1-c_0)\left[-\eta\frac{q_2}{p_2}\frac{1}{2}\frac{\eta}{\eta-1}\right]=0, \tag{20}$$

$$\frac{1}{4}q(p_2(a_1))\left[1-\frac{(a_1-c_0)}{2\,p_2(a_1)}\frac{\eta^2}{\eta-1}\right]=0. \tag{21}$$

The last condition implies that in symmetric equilibrium when $p_1 = p_2 = p$ and $a_1 = a_2 = a$:

$$\frac{(a-c_0)}{2}=p\frac{\eta-1}{\eta^2}. \tag{22}$$

Substituting this result in (17), we obtain:

$$p=\frac{\eta}{\eta-1}\left[c+p\frac{\eta-1}{\eta^2}\right], \tag{23}$$

$$p=\frac{\eta^2}{(\eta-1)^2}c. \tag{24}$$

The marginal cost for the network is:

$$c+\frac{(a-c_0)}{2}=c+\frac{\eta^2}{(\eta-1)^2}c\frac{(\eta-1)}{\eta^2}=c+\frac{c}{\eta-1}=\frac{\eta c}{\eta-1}. \tag{25}$$

Therefore, this equilibrium is characterised by double mark-up and the equilibrium price is higher than the monopoly price since the relevant marginal cost is exactly equal to the monopoly price.

Finally, LRT (1998*a*) compare linear prices with two-part tariffs when networks charge fixed subscription fee *F* and per minute price *p*. They determine that with two-part tariffs the equilibrium profit is independent of the access charge, in contrast to the case with linear prices. The intuition for this result is that if both operators increase their access charge by the same amount their per-minute prices must increase, and, to maintain the same level of consumer's surplus and the same market share, networks must reduce their subscription fee by the same amount. The two effects offset each other, and the profit is independent of the access charge.

Dessein (2004) modified the assumption of a random calling pattern, which implies that all users make and receive the same number of calls, and distinguished between light and heavy users. Heavy users make more calls than light users and the calling pattern need not be balanced. If light (heavy) users receive more calls than they make, this is a light- (heavy-) biased calling pattern. With an unbalanced calling pattern, operators also need to consider the opportunity costs of certain clients. Users that receive more calls increase access revenue for the operator and are very valuable, and if they subscribe to the competitor's network they are very costly since the operator has to pay access charges to its rival. Therefore, the value of these users is twice the access revenue that the operator earns on calls received by these users. Users that make more calls than they receive produce an access deficit and the operator needs to pay more to its competitor than it receives, and the cost of this user is twice the value of the access deficit because by subscribing to the competitor's network this user produces access revenue.

The third approach for modelling calling patterns is to assume that the user's calling pattern is biased and that he makes more calls to friends and family than to other users. This approach is the key assumption in switching-cost literature, where the presence of calling groups creates high barriers to changing network. We will discuss this issue in more detail later on.

3. PRICE DISCRIMINATION

In the case of price discrimination, operators charge different prices for calls terminating on their own network and for calls terminating on a rival network. Laffont, Rey, and Tirole (1998*b*) discussed this issue in the following setup. Network i charges price p_i for on-net calls and price $\hat{p}_i$ for off-net calls, and it has market share α_i . Access charge a is common to both networks and, with two operators in the market, the vector of prices is $\mathbf{p} = (p_1, \hat{p}_1, p_2, \hat{p}_2)$, the market share of operator 1 is $\alpha(\mathbf{p})$, and the market share of operator 2 is

$1-\alpha(\mathbf{p})$. Users are uniformly distributed along the unit interval according to their network preference. The first network is located at 0 and the second at 1. The utility with network effects of the user subscribing to network *i* is:

$$w_i(p_i, \hat{p}_i) = \alpha_i v(p_i) + \alpha_j v(\hat{p}_i), \tag{26}$$

where $v(\cdot)$ is indirect utility. The user located at $x = \alpha$ is indifferent between two networks if:

$$w(p_1, \hat{p}_1) - t\alpha = w(p_2, \hat{p}_2) - t(1-\alpha). \tag{27}$$

This gives us the location of the indifferent user and the market share of operator 1:

$$\alpha = \frac{1}{2} + \sigma[w(p_1, \hat{p}_1) - w(p_2, \hat{p}_2)]. \tag{28}$$

Substituting (26) in (27) and using full coverage assumption, we obtain:

$$\alpha = \frac{1}{2} + (1-\alpha)\sigma[v(\hat{p}_1) - v(p_2)] - \alpha\sigma[v(\hat{p}_2) - v(p_1)]. \tag{29}$$

After determining market shares, Laffont, Rey, and Tirole (1998*b*) determine equilibrium prices. They define access markup as the difference between access price and the cost of that service divided by total cost:

$$m = \frac{a - c_0}{c}. \tag{30}$$

If we use this definition, the total profit of operator *i* can be written as:

$$\pi_i = \alpha_i[\alpha_i(p_i - c)q(p_i) + (1-\alpha_i)(\hat{p}_i - c(1+m))q(\hat{p}_i) - f] + \alpha_i(1-\alpha_i)mcq(\hat{p}_j), \tag{31}$$

where *f* is traffic-independent fixed cost. The first term is profit from on-net calls, the second is profit from off-net calls, and the last is access revenue.

To determine equilibrium on-net and off-net price with stable market shares of two operators, Laffont, Rey, and Tirole (1998*b*) maximise the profit of operator *i* holding the user's utility constant. This constraint implies that the market share is constant as well.

$$\max_{p_i, \hat{p}_i} \overline{\alpha}_i (p_i - c) q(p_i) + (1 - \overline{\alpha}_i)(\hat{p}_i - c(1+m)) q(\hat{p}_i)\,, \tag{32}$$

where the last term in the previous profit function and the fixed cost do not affect the maximisation and are neglected. The constraint of constant utility is:

$$\overline{\alpha}_i v(p_i) + (1 - \overline{\alpha}_i) v(\hat{p}_i) = \overline{w}_i\,. \tag{33}$$

By using the fact that $q = p^{-\eta}$ and $v(p) = \dfrac{p^{-(\eta-1)}}{\eta - 1}$ and forming the Lagrangian function with multiplier μ on the constraint, the maximisation problem with respect to on-net price becomes:

$$\max_p [p^{-\eta+1} - c\, p^{-\eta}] - \mu \frac{p^{-(\eta-1)}}{\eta - 1}\,, \tag{34}$$

$$(1-\eta)\, p^{-\eta} + c\eta\, p^{-\eta-1} + \mu\, p^{-\eta} = 0\,, \tag{35}$$

$$\frac{p - c}{p} = \frac{\mu + 1}{\eta}\,. \tag{36}$$

In the same fashion, the maximisation problem with respect to off-net price is:

$$\max_{\hat{p}} [\hat{p}^{-\eta+1} - c(1+m)\, \hat{p}^{-\eta}] - \mu \frac{\hat{p}^{-(\eta-1)}}{\eta - 1}\,, \tag{37}$$

$$\frac{\hat{p} - c(1+m)}{\hat{p}} = \frac{\mu + 1}{\eta}\,. \tag{38}$$

The right hand sides of (43) and (45) are equal and we can equalise the left-hand sides, which gives the relationship between on-net and off-net prices:

$$\hat{p} = p(1+m)\,. \tag{39}$$

Birke and Swann (2006) empirically analyse the effect of price discrimination on the volume of on-net and off-net calls. Based on a sample from the British market, they identify that the volume of on-net calls is much larger than the volume of off-net calls. They use the following regression that accounts for possible autocorrelation to explain this phenomenon:

$$\Delta q_t = \log\left(\frac{\hat{q}}{q}\right)^{Actual} - \log\left(\frac{\hat{q}}{q}\right)^{Expected} = \alpha - \beta_1 \log\left(\frac{\hat{p}}{p}\right) - \beta_2 \Delta q_{t-1}\,, \tag{40}$$

where q, $\hat{q}$ and p, $\hat{p}$ represent the quantity and price of on-net and off-net calls, respectively. Parameter β_1 measures price elasticity of demand. If there is no price discrimination, the right-hand side of the last equation is equal to α and this parameter should be equal to 0 if the difference in volume stems only from price discrimination. On the other hand, if $\alpha < 0$ in the absence of price discrimination, the difference in volume is a consequence of the coordinated choice of network among groups of family and friends. The price elasticity is estimated as $\beta_1 = 0{,}46$ and α is negative, indicating coordinated network choice. This effect is so strong that the user is indifferent between the network having 9.2 million additional users and one additional member from his friends and family group.

4. ENTRY DETERRENCE AND CALL EXTERNALITIES

Entry in both mobile and fixed telephony has become increasingly easier with the development of new technologies. In mobile telephony, improvements in the use of spectrum have permitted issuing more licenses, which are sold at spectrum auctions[3]. Spectrum auctions have become the main tool for allocation of spectrum rights on market principles.

Entry costs and price discrimination are the main aspects of the strategic interaction between incumbents and entrants, according to Calzada and Valletti (2008). If entry costs are low, such that entry could occur, incumbents can set

3 See for example Trifunović (2011) and Trifunović and Ristić (2013).

low access charges and accommodate entry or they can increase access charges and price discrimination to deter entry because then off-net calls become more expensive for the entrant. If entry costs are high, incumbents set the access charge at a low level and the degree of price discrimination is reduced.

The cost structure of Calzada and Valletti's (2008) model is similar to previous models, with the marginal cost of an on-net call $c = c_0 + 2c_1$. The cost of an off-net call for the originating network is $c_1 + c_0 + a$ and the access charge is defined as $a = mc + c_0$, where m is a markup over marginal cost and the total marginal cost of the off-net call can be written as $c_1 + c_0 + a = c(1+m)$. Users of network *i* pay a subscription fee F_i and per-minute prices p_i and $\hat{p}_i$ for on-net and off-net calls, respectively.

An increased access charge increases the operator's profit and to compensate users the operator lowers the subscription fee, which reduces profit. In equilibrium the second effect dominates, and an increase of m lowers profit. To avoid this outcome, operators set the markup to zero in equilibrium, resulting in efficient pricing.

The analysis is more involved if the possibility exists for the entry of new firms. If the markup is zero, operators maximise their profits. However, this markup attracts the entry of new firms into the industry. In order to deter entry, incumbents might conduct predatory behaviour by increasing the markup over an efficient level. This strategy is based on sacrificing part of the current profit, which could be compensated by higher profit if entry is successfully blocked.

The entry game is modelled in the following fashion. In the first stage the incumbents decide on a level of access charge that cannot be changed in the second stage. This assumption can be justified by the fact that in practice access charges are set in advance and are changed infrequently. If an entrant decides to enter the market in the second stage, it pays a fixed entry cost *K*. This cost might be interpreted as the price of buying a license at auction. In the next stage the operators compete in prices and subscription fees.

The profit function of each firm depends on the number of firms in the market, *N*, and on the access markup, $\pi(N, m)$. As the number of firms increases the profit of each firm falls due to higher competition. A firm will enter the market if its profit is higher than the entry cost $\pi(N,m) > K$.

Suppose that there are two incumbents in the market that set an efficient markup of zero $m(0)$ and earn profit $\pi(2,m(0))$. If the entry cost is such that $K > \pi(3,m(0))$, the entry of a third firm is unprofitable and the incumbents do not need to set a higher mark-up than the efficient level $m(0)$. On the other hand, if $K < \pi(3,m(0))$ the entry of the third firm is profitable. Two incumbents can prevent entry by increasing the mark-up to $m(1)$, which represents the markup preventing entry of one entrant and is defined as the highest level of m that makes entry unprofitable $\pi(3,m(1)) = K$. Denote by $\pi(3,m(0)) = K_2^b$. Then for K that is close to K_2^b, $m(1) \to m(0)$ and $\pi(2,m(0)) > \pi(3,m(0))$, which implies that for $K \to K_2^b$ $\pi(2,m(1)) > \pi(3,m(0))$ and entry deterrence is profitable. Nevertheless, even when entry is profitable the incumbents might decide to accommodate entry if they need to sacrifice a significant part of their profit. The limiting value of m such that incumbents are indifferent between deterring and accommodating entry is $\pi(3,m(0)) = \pi(2,m^*)$.

Furthermore, Calzada and Valletti (2008) assume that instead of random calling patterns there might be a bias as users direct the majority of their calls to family and friends. In fact, a fraction β_i of calls are directed to family and friends and $1-\beta_i$ are directed to other users completely randomly. This assumption induces members of this group to coordinate their choice and choose the same network. Suppose that there are two incumbents and one entrant and that the incumbent's users have a larger friends and family circle than the entrant's users, $\beta_I > \beta_E$. Operators are asymmetric and the higher mark-up gives a competitive advantage to incumbents and has a negative effect on the entrant who has a larger share of off-net calls. In other words, the difference in profit between incumbents and entrants increases with $\beta_I - \beta_E$ and the entrant's market share is lower for larger values of $\beta_I - \beta_E$.

According to Hoering (2007), in markets with asymmetric firms, the fact that large firms (incumbents) have a higher on-net off-net price differential than small firms might not reflect predatory behaviour but could represent the incumbent's attempt at reducing the level of call externalities for users of a small network. In this model the direct utility of q minutes of outgoing calls is $u(q)$ and the indirect utility is $v(p)$. Users that receive calls are not charged for that service and call externalities are represented by the externality parameter $0 \le \beta \le 1$, such that the utility of receiving calls is $\beta u(q)$. There are two operators in the market with market shares $\alpha_1 + \alpha_2 = 1$, where operator 1 is the incumbent and operator 2 the entrant, with the incumbent having the larger market share $\alpha_1 > \alpha_2$. Users are distributed uniformly on the unit interval and the user located at *x* has utility from joining networks 1 and 2:

$$u_1(x) = w_1 + A - tx\,,\ u_2(x) = w_2 - (1-x)t\,, \tag{41}$$

where the parameter A captures the asymmetry effect because the user gets larger utility by joining the incumbent's network. The term w_i measures network externalities and call externalities:

$$w_i = \alpha_i[v(p_i) + \beta u(q_i)] + \alpha_j[v(\hat{p}_i) + \beta u(q(\hat{p}_j)]\,, \tag{42}$$

where the first term captures utility from making and receiving on-net calls and the second term captures utility from making and receiving off-net calls.

The presence of call externalities motivates operators to raise their off-net prices to internalise call externalities. This effect is more important for the incumbent that has more calls directed to the entrant than vice versa, and for that reason the large network has a higher off-net price than the small network. However, this difference does not reflect predatory behaviour if we take into consideration call externalities.

Hahn (2003) analyses one more aspect of call externalities, when the values of the user's outgoing and incoming calls are positively correlated. The first assumption in the model is that the probability of calling other subscribers is completely random. The second assumption is that the user's utility is the same, regardless of the identity of the other users he is calling or receiving calls from, and users benefit from network and call externalities.

The value of the user's outgoing calls v is distributed according to the probability distribution $F(v)$ on the interval $[\underline{v}, \bar{v}]$. In equilibrium, users with call value less than or equal to v^* do not make outgoing calls, but they are not excluded from the market and they pay a fixed fee for receiving calls. However, the 'no distortion' on the top result does not hold here because users, including the highest-value user, make an inefficiently low quantity of outgoing calls. This result stems from the positive correlation of the values of users' outgoing and incoming calls.

Even though there are some low-value users who only receive calls, the operator decides to serve these users and charge them a fixed fee for this service. This strategy is rational because the presence of call-receiving subscribers increases the utility of call-making users due to network externalities and the operator can increase its profit with higher prices for outgoing calls. Moreover, the operator serves low-value users even if it is making a loss on this subset if this loss could be more than offset by increased profit from the subset of high-value users.

5. ENTRY AND ACCESS PRICE REGULATION

If the access charge is regulatory-determined, the regulator might set the same access charge for all operators in the market. However, depending on the market shares of operators, the regulator might decide to use asymmetric access charges in order to enhance entry to the market and higher competition. According to Peitz (2005), incumbents that have a large market share should set their access price to equal cost, while entrants are allowed to set an access price above cost. This strategy makes entry more attractive and can increase the consumer's surplus at the cost of marginally reducing the total welfare. Thus, the application of this strategy depends on the relative weight that the regulator attaches to the entrant's profit, the consumer's surplus, and the total welfare. It is natural to assume that users subscribing to the incumbent's network have a higher utility than users subscribed to the entrant's network due to the higher coverage of the incumbent's network and the additional services that are still not provided by the entrant. This difference in utilities is expected to vanish over time.

Peitz (2005) proceeds by relying on the theory of super-modular games[4], which represent the situation when best response functions are strategic complements, in the terminology of Bulow, Geanakoplos, and Klemperer (1985). Peitz (2005) shows that starting from cost-based access pricing for the entrant, increasing the entrant's access price moves the incumbent's best response function outward. Technically, when best response functions move outward the indirect utilities of users increase. The intuition behind Peitz's obtained result is that when the entrant's access charge contains a mark-up the incumbent aims to reduce the number of off-net calls to lower its costs and this strategy translates into a reduction of the entrant's market share. To achieve this objective, the incumbent has to lower its subscription fee and increase the user's indirect utility. By analogy, the entrant aims to increase its market share and its strategy to achieve this objective is to reduce its subscription fee and to provide higher utility for users. Therefore, the main conclusion is that starting from cost-based regulation for the entrant, increasing the entrant's access price increases users' utilities. This mark-up on the entrant's access price translates into its higher profit. Therefore, both users and entrant benefit from an asymmetric access pricing policy. At the same time, this policy reduces total welfare due to the markup that the incumbent now imposes for per-minute prices above the marginal cost of the outgoing call. However, Peitz (2005) shows that for the small entrant the reduction of the total surplus is also small. This asymmetric access-pricing regulation should be temporary in nature and when the entrant reaches a market share similar to that of the incumbent the regulator should use symmetric access-pricing.

Using the same framework, de Bijl and Peitz (2004) consider a dynamic setting where the entrant lags behind the incumbent in quality of service but improves it gradually and catches up with the incumbent's quality of service at time t^*. They use simulation analysis, and assume that demand for outgoing calls is linear. The fixed cost per user of the local network for operator i is f_i. The access charge may vary over time, and in period t it is a_i^t. Traffic-dependent costs can be classified into 3 groups: the marginal cost of an on-net call for

[4] The theory of supermodular games was developed by Milgrom and Roberts (1990) and Vives (1990).

operator *i* is c_{i1}, the marginal cost of an off-net call is $c_{i2}+a_j^t$, and the marginal cost of an incoming off-net call is $c_{i3}-a_i^t$.

As a benchmark case, they consider the welfare-maximising choice of per-minute prices and subscription fee. When per-minute prices are equal to respective marginal costs and the subscription fee is equal to the fixed cost per user of the local network, the social optimum is achieved.

De Bijl and Peitz (2004) consider three types of access price regulation. Under cost-based regulation the access charge is set to the marginal cost of call termination. With symmetric access markup, operators earn profit on the access charge, while with asymmetric access charge the entrant is allowed to set the access charge over cost and the incumbent sets an access price equal to cost.

With cost-based access pricing the entrant increases its market share and profit, while the incumbent's market share and profit are reduced up to the point where they become equal. Total industry profit decreases in time but the consumer's surplus increases, and as a net result welfare also increases. This policy implements the first-best solution such that per minute price and subscription fee are equal to costs. When a symmetric access mark-up policy is used, operators earn revenue from the subscription fee and also have access revenue and the incumbent and the entrant earn higher profit than under the previous policy. However, this policy reduces the consumer's surplus because per-minute prices are higher than costs. The latter effect dominates, and the welfare is also lower. In the case of asymmetric access pricing the pattern of the entrant's market share is similar to that of cost-based regulation but its profit is much higher. The competition is fiercer, and the consumer's surplus is higher than under cost-based access pricing. The welfare is slightly lower due to the fact that the incumbent sets its per-minute price at an inefficient level.

In further analysis, de Bijl and Peitz (2004) assume that the entrant might have a lower marginal cost then the incumbent due to the use of new technology, $c_{23}<c_{13}$. In the case of cost-based access pricing, the entrant's market share in the last period becomes higher than the incumbent's. The second possibility is an asymmetric access charge such that the entrant earns a mark-up, $a_2=c_{13}$. In that case, the incumbent's profit is lower, the entrant's is higher, and the

consumer's surplus increases. The third possibility is that the regulator imposes cost-based regulation according to the lowest cost $a_1 = a_2 = c_{23}$, when the incumbent has a loss on each minute of call received from the entrant's network. At first the incumbent becomes more aggressive, aiming to reduce the entrant's market share, but as the entrant gains in market share it becomes less aggressive. The consumer's surplus increases in the beginning and decreases thereafter.

The previous discussion was based on the assumption that the entrant builds its own network upon entry. There are two other possibilities mentioned in de Bijl and Peitz (2004). Local-loop unbundling is when the incumbent leases its network to the entrant for a fixed monthly fee and the carrier selects when the entrant pays a per-minute fee to the incumbent for outgoing calls as a compensation for using its network. In the leasing arrangement when the incumbent increases the monthly leasing fee, the entrant responds by increasing its subscription fee and this enables the incumbent to also increase the subscription fee and soften the competition. The incumbent's profit is increased at the expense of the users. From a dynamic perspective, the regulator could impose an increasing sequence of monthly leasing prices. This policy aims to facilitate entry in periods with low leasing fees and in later periods it should induce the entrant to build its own network.

In the carrier-select arrangement the entrant does not gain access revenues from incoming calls, pays the usual access charge to the incumbent for calls terminating on his network, and on top of this pays an access charge for outgoing calls regardless of their final destination. If the incumbent raises a fee for carrying the entrant's outgoing calls on its network, its profit and market share increase at the expense of the entrant. The consumer's surplus and total welfare are reduced. The regulator should use a policy of cost-based access pricing to avoid these negative effects when the entrant depends heavily on the incumbent. Moreover, from a dynamic perspective the regulator should adopt a policy of increasing the sequence of access charges for using the incumbent's network for outgoing calls. As in the previous case, this policy should induce the entrant to build its own network.

6. THE 'RECEIVER PAYS' PRINICPLE

Technology standardisation is an important aspect of the mobile phone telecommunications market. In the EU, operators are regulatory constrained to use the same standard (GSM), while in the US this requirement is not imposed and the market operates with incompatible standards. Koski and Kretschamer (2005) find that incompatible standards result in intensive price competition to achieve a critical mass of users, while standardisation produces an economy of scale that results in lower prices. However, price competition is less intensive with standardised technology.

In the models that we have analysed so far, only outgoing calls are charged and the receiver benefits from positive call externalities. In some circumstances the receiver is also charged for receiving calls and thus experiences negative call externalities. That is the practice in the US for national traffic and for roaming services worldwide. Jeon, Laffont, and Tirole (2004) analyse this situation where the receiver is also charged. They assume that the caller's utility from q minutes of outgoing call is $u(q)$ and the receiver's utility is $\tilde{u}(q)$, where $\tilde{u}(q) = \beta u(q)$, with $0 < \beta < 1$. There are two operators charging three-part tariffs: subscription fee F_i, per-minute price for outgoing calls p_i, and per-minute price for incoming calls r_i.

The marginal cost of originating and terminating a call is c_0, the common access charge is a, and the total marginal cost of a call is $c = 2c_0 + c_1$, where c_1 is the marginal transportation cost. The marginal cost of an off-net call for the network where the call originates is $c + (a - c_0)$ and is $(c_0 - a)$ for the network where it terminates. The assumption is that the whole market is covered: $\alpha_1 + \alpha_2 = 1$.

The reception charge might be regulatory- or market-determined. Jeon, Laffont, and Tirole (2004) analyse competition in two-part tariffs (F_i, p_i) when it is regulatory-determined at the level (r_1, r_2). The subscription fee determines the operator's market share by influencing the user's utility. Users are uniformly distributed along the unit interval: operator 1 is located at $x_1 = 0$ and operator 2 at $x_2 = 1$. The utility of the user located at x and subscribed to the network located at x_i is:

$$y + v_0 - t\left|x - x_i\right| + u(q) + \widetilde{u}(\widetilde{q}) \text{ ,} \tag{43}$$

where $u(q)$ is the utility from outgoing calls and $\widetilde{u}(\widetilde{q})$ is the utility from incoming calls. Operators can use a three-part tariff (F_i, p_i, r_i) or five-part tariff when they price discriminate $(F_i, p_i, \hat{p}_i, r_i, \hat{r}_i)$. The reception charge for on-net calls is r_i and for off-net calls is $\hat{r}_i$. The user's demand for outgoing calls is $u'(q) = p$ and demand for incoming calls is $\widetilde{u}'(\widetilde{q}(r)) = r$. The length of a call is determined by both caller and receiver and with linear prices the volume is $\min\{q(p_i), \widetilde{q}(r_j)\}$. When operators use price discrimination we distinguish between two sub-cases. If the caller and receiver belong to the same network the length of a call is $\min\{q(p_i), \widetilde{q}(r_i)\}$ and if the caller is subscribed to network *i* and the receiver to network *j* the length of a call is $\min\{q(\hat{p}_i), \widetilde{q}(\hat{r}_j)\}$.

We will first analyse the case with linear prices and regulatory-determined access charges. If we neglect the user's disutility from subscribing to a network that is not ideal, the user's utility is:

$$w_i = v(p_i) + \alpha_i \widetilde{u}(q(p_i)) + \alpha_j \widetilde{u}(q(p_j)) - r_i[\alpha_i q(p_i) + \alpha_j q(p_j)] - F_i \text{ ,} \tag{44}$$

where the first term is indirect utility from outgoing calls, the next two terms represent the utility from receiving on-net and off-net calls respectively, and the fourth term measures total reception charges for receiving on-net and off-net calls. By using the previously described logic, the location of the user who is indifferent between subscribing to network *i* and network *j* and equivalently the market share of operator *i* is:

$$\alpha_i = \frac{1}{2} + \frac{1}{2t}[v(p_i) - v(p_j) - (F_i - F_j) - (r_i - r_j)(\alpha_i q(p_i) + \alpha_j q(p_j))] \text{ .} \tag{45}$$

Finally, the profit of operator *i* is:

$$\pi_i = \alpha_i \{[p_i - c - \alpha_j (a - c_0) + \alpha_i r_i] q(p_i) + (r_i + a - c_0)\alpha_j q(p_j) + F_i - f\} \text{ ,} \tag{46}$$

where the term $[p_i - c - \alpha_j(a - c_0) + \alpha_i r_i]q(p_i)$ is profit from outgoing and from incoming on-net calls, the term $(r_i + a - c_0)\alpha_j q(p_j)$ is profit from incoming off-net calls, and *f* is fixed traffic-insensitive cost per user.

The operator maximises its profit with respect to p_i and F_i. We have argued previously that the choice of F_i directly determines the market share, and the problem is isomorphic to the problem of first maximising profit with respect to p_i and then with respect to α_i.

The first-order condition with respect to p_i reveals that the optimal price should be equal to the strategic marginal cost:

$$p_i = c + \alpha_j(a - c_0) - \alpha_i r_j \,. \tag{47}$$

The intuition behind this pricing strategy is that when the length of outgoing calls from network *i* to network *j* increases, the users of network *j* experience direct (positive) externalities by receiving more calls but are also subject to pecuniary (negative) externalities due to the fact that they have to pay more for incoming calls. The operators' market shares depend on the users' utility and to keep the market share constant operator *i* should increase the subscription fee by $\alpha_i r_j$; that is, equal to the level of negative externalities that users of network *j* experience. In another interpretation the reception charge r_j is equivalent to a reduction of operator *i*'s marginal cost by $\alpha_i r_j$.

The second first-order condition is obtained by maximising the profit function with respect to α_i in symmetric equilibrium with $r_i = r_j = r$ and it gives the optimal subscription fee:

$$F = f + \frac{1}{2\sigma} - (p + r - c)q(p) \,. \tag{48}$$

The previous analysis was based on the assumption that call length is determined by the caller, but in reality it is possible that the receiver hangs up. Nevertheless, the above results are still valid when $r \le \tilde{u}'(q(p))$.

In order to study the case with market-determined reception charges, Jeon, Laffont, and Tirole (2004) assume that the receiver's marginal utility is random and that it depends on the time of the day or other activities that the receiver performs when receiving a call. In this environment the length of a call might be determined by the caller as well as by the receiver. Formally, the receiver's utility is:

$$\tilde{u}(q) + \varepsilon q = \beta u(q) + \varepsilon q\,, \tag{49}$$

where ε is distributed according to probability distribution $F(\cdot)$ on interval $[\underline{\varepsilon}, \overline{\varepsilon}]$ and $1 > \beta > 0$. The receiver equalises the marginal utility of receiving a call with the marginal cost of receiving a call $\beta u'(q) + \varepsilon = r_j$. The length of a call from network *i* to network *j* of one user is $q(\max(p_i, (r_j - \varepsilon)/\beta)$, and the total length of calls from network *i* to network *j* is $\alpha_i \alpha_j D(p_i, r_j)$:

$$D(p_i, r_j) = [1 - F(r_j - \beta\, p_i)]q(p_i) + \int_{\underline{\varepsilon}}^{r_j - \beta p_i} q\left(\frac{r_j - \varepsilon}{\beta}\right) f(\varepsilon) d\varepsilon\,, \tag{50}$$

where the first term represents the case where $\varepsilon > r_j - \beta\, p_i$ and the length of a call is determined by the caller, and the second term applies when $\varepsilon < r_j - \beta\, p_i$ and the length of a call is determined by the receiver.

By using the analogy with strategic marginal cost pricing for outgoing calls in (47), the operator equalises the reception charge with the strategic marginal cost of receiving a call:

$$r_i = \alpha_i c + \alpha_j (a - c_0) - \alpha_i p_j\,. \tag{51}$$

The intuition behind this result is that share α_i of calls received by the user of network *i* are on-net calls and the cost of this call is *c*, and share α_j of calls received by the user of network *i* are off-net calls and the cost of this call is $a - c_0$. The term $\alpha_i p_j$ measures the positive pecuniary externalities experienced by users of network *j* (when users of network *j* receive calls they save $\alpha_i p_j$ on calls that they would otherwise have to make) and network *i* has to reduce its subscription fee by $\alpha_i p_j$ to maintain a constant market share. The solution of (51) and (47) yields:

$$p = c + (a - c_0)\,, \tag{52}$$

$$r = c_0 - a\,. \tag{53}$$

The prices of outgoing and incoming calls equal their off-net costs. This result does not depend on symmetry and is robust to any division of market shares.

The last case studied by Jeon, Laffont, and Tirole (2004) is when networks discriminate between on-net and off-net calls. Without reception charges, large call externalities ($\beta \to 1$) might lead to connectivity breakdown as networks charge an infinite price for off-net calls in an attempt to internalise call externalities.

This result imposes the necessity of regulatory determination of reception charges based on the competitor's off-net price, $\hat{r}_j = g(\hat{p}_i)$, to prevent connectivity break down.

7. SWITCHING COSTS

All the previous models are based on Hoteling-type competition. In this part we will deal with the second approach, which assumes that users pay switching costs when they change networks. This is the main idea of the network competition model of Gabrielsen and Vagstad (2008), who claim that networks are becoming less differentiated. They assume that calling patterns are not completely random and that more calls are directed to friends and family. If the members of this circle belong to the same network, this creates user's lock-in and the individual user incurs switching costs in the form of a higher off-net price if he decides to change network. Price discrimination increases switching costs and if operators use two-part tariffs they can extract the consumer's surplus with a subscription fee.

The main assumption of Gabrielsen and Vagstad's (2008) model is that switching costs are uniformly distributed on the interval $[0, \bar{s}]$, where

$1/4 \leq \bar{s} \leq 1/2$. All operator costs are neglected to simplify the discussion. Operators set access charge *a* and they use two-part tariffs. The per-minute prices of on-net and off-net calls for operator *i* are p_i and $\hat{p}_i$, respectively, and the subscription fee is *F*. The calling pattern is biased such that with probability $\lambda \geq 0{,}5$ the user makes a call to friends and family and with probability $1-\lambda \leq 0{,}5$ she makes calls randomly.

In order to determine the equilibrium, it is necessary to suppose that firm *j* does not have an incentive to undercut firm *i* and take all its users. This strategy by firm *j* could be achieved if firm *j* sets $p = \hat{p} = 0$ and gains a market share of 1. In order to induce the user with the highest switching cost to change network, operator *j* has to pay his switching cost $\bar{s}$. It turns out that operator *j*'s incentive to undercut decreases in λ (for higher on-net traffic). The second possibility for undercutting a rival is to induce a subset of users with the lowest switching costs to change their operator. Recall that $\bar{s} = 0{,}5$ and Gabrielsen and Vagstat (2008) show that the no undercutting equilibrium is characterised by high values of switching costs in the range [0.3, 0.5].

When we analyse the sources of switching costs, the highest switching cost for the user is the necessity to inform all his contacts about the new number in the other network. In order to reduce this switching cost, regulators have adopted the policy of mobile phone number portability (MPNP), when users are allowed to keep their number after changing their operator. This policy aims to increase competition and should provide small operators with an additional opportunity to gain market share. Based on evidence from the Hong Kong market, Shi, Chiang, and Rhee (2006) determine that the price of per-minute call dropped by 60% after the adoption of MPNP. Contrary to expectations, this policy increased the market share of large networks at the expense of small networks. This implies that somehow paradoxically this policy was anti-competitive. In order to resolve this puzzle, Shi, Chiang, and Rhee (2006) constructed a model in the switching cost tradition with operators having asymmetric market shares.

In the model of Shi, Chiang, and Rhee (2006) there are *N* users and two operators, A and B. The market shares of the operators are $\hat{\alpha}_A$ and $\hat{\alpha}_B$, where $\hat{\alpha}_A + \hat{\alpha}_B = 1$ and operator A is larger, $\hat{\alpha}_A \geq \hat{\alpha}_B$. The cost of an on-net call is *c*, the cost of an off-net call is ϕc, and the access charge is $a = (\phi - 1)c$. Operators practice price discrimination with two-part tariffs where for operator *i*, p_{ii} is the price of an on-net call, p_{ij} is the price of an off-net call, F_i is the subscription fee, and q_{ii} and q_{ij} are the volumes of on-net and off-net calls, respectively. We will denote the user's indirect utility from on-net and off-net calls by $v_{ii} = v(q_{ii})$ and $v_{ij} = v(q_{ij})$, respectively.

The value of the subscription for the user is calculated according to a uniform calling pattern such that the user has an equal probability of calling *n* other users that may belong either to network A or to network B. The user has contact with $n\alpha_A$ users of network A and $n\alpha_B$ users of network B. The user of network *i* values the network as:

$$w_i = n\alpha_i v_{ii} + n\alpha_j v_{ij} - F_i . \tag{54}$$

The key assumption is that the user has a switching cost ψ_{ij} when he leaves network *i* and subscribes to network *j*. If he decides to switch from network *i* to network *j*, his valuation of network *j* is $w_j - \psi_{ij}$. This switching cost is uniformly distributed on $[0, \Psi]$ and reduction of switching costs is represented by a lower value of Ψ. When some users switch their network, updated market shares need to be calculated. For the network that attracts users the updated market share is larger than the initial market share and for the network that loses market share the reverse holds.

The first-order conditions, with respect to on-net and off-net price, yield equilibrium prices that are equal to respective costs $p_{ii} = c$ and $p_{ij} = \phi c$. This implies that $\Delta v = v_{ii} - v_{ij} = v(c) - v(\phi c) > 0$ is the user's valuation of the on-net price discount. The last result implies that prices are equal to marginal costs and the operator's profit stems from the subscription fee $\pi_i = n\alpha_i F_i$, where α_i is updated market share. By maximizing the profit of each operator with respect to the subscription fee and solving the system of the two first-order conditions, we obtain the equilibrium value of the subscription fee:

$$F_i = \frac{1 + \hat{\alpha}_i}{3\hat{\alpha}_l}\Psi - n\Delta v , \tag{55}$$

where $\hat{\alpha}_l$ is the initial market share of the network the switching user subscribed to (l could be A or B).

We can see that the larger network charges a higher subscription fee, with the intention to exploit locked-in users rather than to attract new users. The difference in subscription fees is:

$$F_A - F_B = \frac{\hat{\alpha}_A - \hat{\alpha}_B}{3\hat{\alpha}_l}\Psi \, . \tag{56}$$

These results show that the subscription fee increases with switching costs. The intuition is that higher switching costs lower competition and enable higher surplus extraction from users. Moreover, the difference in subscription fees also increases with an increase in switching costs. The subscription fee is lower when the user's valuation of the on-net discount is higher because the lower subscription fee attracts new users and existing subscribers can benefit from cheaper on-net calls.

To analyse this condition, note that the large network charges a higher subscription fee to extract consumers' surplus due to lock-in, but at the same time users of the large network benefit from on-net discounts. Therefore, the ratio $\Psi / n\Delta v$ measures the negative lock-in effect to positive on-net discount effect. When negative lock-in effect dominates, the large network loses its share. On the other hand, when the positive on-net discount effect dominates, the small network loses market share.

Reduction of switching costs lowers the ratio $\Psi / n\Delta v$, and if it falls below a certain threshold, MPNP increases market concentration. At the same time, this policy increases users' value to the networks. Finally, the small operator's profit is $\pi_B = N\alpha_B * F_B$. The reduction of switching costs is more likely to reduce both a small network's market share and its subscription fee. Therefore, the prediction of Shi, Chiang, and Rhee (2006) is that a small network's profit should decline with lower switching costs, with the further implication that entry to the market becomes less profitable.

8. THE SERBIAN TELECOMMUNICATIONS MARKET

In this section we will illustrate the previous theoretical results in the Serbian mobile and fixed telephony market[5]. There are three operators of mobile telephony in Serbia: MTS, Telenor, and VIP. MTS and Telenor were incumbents, and VIP entered in 2007. The entrant used carrier-select type of entry until 2009, when it developed its own infrastructure. MTS has the largest number of users, while Telenor has the highest revenue. The HHI index declined, and in 2014 it was 3.584 based on the number of users and 3.501 based on revenue. Until 2008 market growth was very dynamic, but from 2009-2014 the number of users only increased by 2.44%. In the same period MTS lost 23.54% of its users, while Telenor increased its number of users by 18.75%, and VIP by 95.79%. Upon entry, VIP had a larger share of pre-paying users, which implies that its users benefited the most from call externalities. But the situation has changed, and in 2014 MTS had the largest share of pre-paying users and the lowest level of outgoing traffic per user, implying the unexpected conclusion that users of MTS benefit the most from call externalities.

In 2011, mobile phone number portability (MPNP) was enforced and users' switching costs were considerably reduced. In Serbia this policy was pro-competitive and the market share of MTS, which had the largest number of users, shrunk from 53.1% to 44.56% in four years. On the other hand, the entrant, VIP, benefited from this policy by increasing its market share (from 16.13% to 22.17%). Moreover, the profitability of MTS was lower after 2011, and VIP's profitability was higher. Therefore, the conclusions are quite different from those of Shi, Chiang, and Rhee (2006), possibly due to the fact that currently the subscription fee mainly covers all the outgoing calls that the user makes and at the time the model was constructed two-part tariffs were used.

After the entry of VIP the incumbents did not increase price discrimination to deter entry. They wanted to extract the consumer's surplus through high on-net prices. On the other hand, MPNP resulted in lower on-net prices. However, MTS only lowered the on-net price significantly in 2014. Off-net prices

[5] Detailed analysis of this issue is presented in our previous paper, Trifunović and Mitrović (2016).

remained almost constant from 2011, and clearly MPNP increased the consumer's surplus.

Finally, concerning the receiver-pays principle, Telenor and MTS charge higher prices for outgoing than for incoming roaming calls and VIP does not price discriminate and its users have the highest level of pecuniary externalities. However, the widespread use of WhatsApp and Viber has contributed to a steady decline in operators' revenues from roaming.

Fixed telephony is becoming an outdated technology but is still used by businesses, and operators earn revenue by bundling internet with fixed telephony. Telekom Serbia was in a monopoly position until 2010 when a second operator, Orion, entered the market. In the next year the entry of Telenor followed and in 2012 SBB started fixed telephony services. Nevertheless, the incumbent, Telekom Serbia, maintained more than 99% of the market until 2012. Telekom Serbia did not react to entry and maintained the same per-minute prices for local, national, and fixed-to-mobile calls. The entrants also maintained almost the same prices from the year of entry until 2014. Competition was based on a larger spectrum of calls, including international calls that were included in the free minutes covered by the subscription fee. In April 2014 fixed phone number portability (FPNP) was introduced and 1.45% of all users took up this option in 2014. This policy was also pro-competitive, and the market share of Telekom fell from 97.6% in 2013 to 91.86% in 2014. An additional consequence of FPNP was that the incumbent reduced the per-minute price of national calls by 29% and the per-minute price of mobile-to-fixed telephony calls by 26.7%. Thus, this policy increased the consumer's surplus, as in the mobile telephony market.

9. CONCLUSION

We have presented different models of network competition in telecommunications. We have seen how this market can be modelled by using methodology from industrial organisation, such as price discrimination and entry. The most important contribution in this field was made by Nobel Prize Winner Jean Tirole. We have also illustrated some conclusions from the theoretical models with data from the Serbian market.

The dominant approach in the literature is to use spatial competition. The model of vertical differentiation can also be applied if one network provides a higher quality of service than another, which can be the case if an incumbent has a higher quality of service than an entrant. In recent years networks have become less differentiated and the switching-cost approach is probably becoming more relevant. The methodology that we have described in this paper could be applied to other markets with network externalities, such as the internet or computer software.

REFERENCES

Birke, D., and Swann, P. (2006). Network Effects and the Choice of Mobile Phone Operator. *Journal of Evolutionary Economics*, 16, 65-84.

Bulow, J., Geanakoplos, J., and Klemperer, P. (1985). Multimarket Oligopoly: Strategic Substitutes and Complements. *Journal of Political Economy*, 93(3), 485-511.

Calzada, J., and Valletti, T. (2008). Network Competition and Entry Deterrence. *Economic Journal*, 118, 1223-1244.

De Bijl, P., and Peitz, M. (2004). Dynamic Regulation and Entry in the Telecommunications Market: A Policy Framework. *Information Economics and Policy*, 16, 411-437.

Dessein, W. (2004). Network Competition with Heterogeneous Customers and Calling Patterns. *Information Economics and Policy*, 16, 323-345.

Doganoglu, T., and Grzybowski, L. (2007). Estimating Network Effects in Mobile Telephony in Germany. *Information Economics and Policy*, 19, 65-79.

Gabrielsen, T., and Vagastad, S. (2008). Why is On-net Traffic Cheaper than Off-net Traffic? Access Markup as a Collusive Device. *European Economic Review*, 52, 99-115.

Hahn, J-H. (2003). Nonlinear Pricing of Telecommunications with Call and Network Externalities. *International Journal of Industrial Organization*, 21, 949-967.

Hoering, S. (2008). On-net and Off-net Pricing in Asymmetric Telecommunications Networks. *Information Economics and Policy*, 19, 171-188.

Jeon, D.-S., Laffont, J.-J., and Tirole, J. (2004). On the Receiver-Pays Principle. *Rand Journal of Economics*, 35(1), 85-110.

Klemperer, P. (1995). Competition when Consumers Have Switching Costs: An Overview with Applications to Industrial Organization, Macroeconomics and International Trade. *Review of Economic Studies*, 62(4), 515-539.

Koski, H., and Kretschemer, T. (2005). Entry, Standards and Competition: Firm Strategies and the Diffusion of Mobile Telephony. *Review of Industrial Organization*, 26, 89-113.

Laffont, J.-J., and Tirole, J. (1994). Access Pricing and Competition. *European Economic Review*, 38, 1673-1710.

Laffont, J.-J., Rey, P., and Tirole, J. (1998*a*). Network Competition: Overview and Non-discriminatory Pricing. *Rand Journal of Economics*, 29(1), 1-37.

Laffont, J.-J., Rey, P., and Tirole, J. (1998*b*). Network Competition: Price Discrimination. *Rand Journal of Economics*, 29(1), 38-56.

Milgrom, P. and Roberts, J. (1990). Rationalizability and Learning in Games with Strategic Complementarities. *Econometrica*, 58, 1255-1278.

Peitz, M. (2005). Asymmetric Access Price Regulation in Telecommunications Markets. *European Economic Review*, 49, 341-358.

Peitz, M., Valletti, T., and Wright, J. (2004). Competition in Telecommunications: An Introduction. *Information Economics and Policy*, 16, 315-321.

Pepall, L., Richards D. and Norman, G. (2011). *Contemporary Industrial Organization: A Quantitative Approach*. Hoboken, New Jersey: John Wiley & Sons.

Rohlfs, J. (1974). A Theory of Interdependent Demand for a Communication Service. *Bell Journal of Economics*, 5, 16-37.

Shi, M., Chiang J., and Rhee, B.-D. (2006). Price Competition with Reduced Switching Costs: The Case of "Wireless Number Portability" in the Cellular Phone Industry. *Management Science*, 52(1), 27-38.

Shy, O. (2001). *The Economics of Network Industries*. Cambridge MA: Cambridge University Press.

Trifunović, D. (2011). Single Object Auctions with Interdependent Values. *Economic Annals*, 56(188), 125-170.

Trifunović, D., and Ristić, B. (2013). Multi-unit Auctions in the Procurement of Electricity. *Economic Annals*, *58*(197), 47-78.

Trifunović, D., and Mitrović, Đ. (2016). Network Externalities in Telecommunications Industry: An Analysis of Serbian Market. *Industrija*, 44(1), 63-87.

Vives, X. (1990). Nash Equilibrium with Strategic Complementarities. *Journal of Mathematical Economics*, 19, 305-321.

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