STOCKHOLM UNIVERSITY

Department of Economics
MScThesis
2004-01-15

Regulation and Welfare in the Mobile Market

Welfare Effects of Regulating Termination Charges

in Mobile Networks

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Abstract

The study investigates the welfare effects of regulating the so-called termination charges paid to mobile network operators when fixed phone subscribers make calls to mobiles. If left unregulated, these termination charges are set at monopoly level since the fixed line subscriber has no choice of mobile operator, but has to place the call via the mobile operator the called mobile happens to use. The charging of termination charges above cost has sometimes been justified by that it enables mobile operators to cross-subsidize handsets for new mobile subscribers. Subsidized handsets would stimulate growth and provide positive network externalities. The present study looks at the welfare of different theoretical scenarios which cover situations with and without network externalities. It also briefly investigates the growth stimulating effect of handset subsidies empirically. The study concludes that the arguments for regulation of termination charges are strong, and that it is questionable if the special case of network externalities is enough to justify an exception from this general rule.

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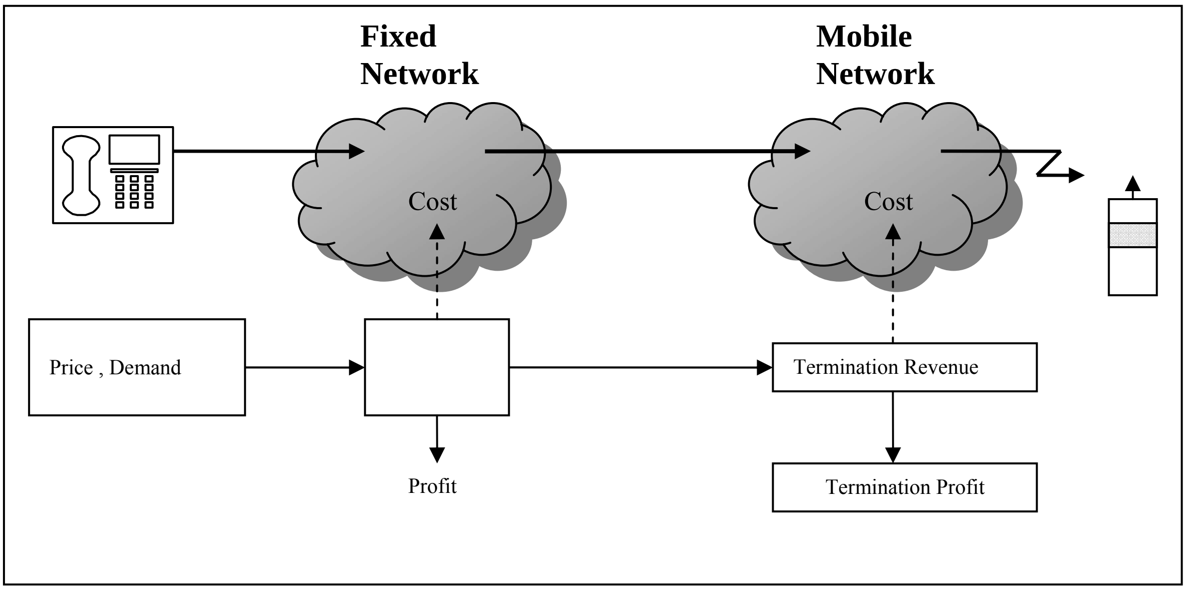
1. Introduction

This study will look at the welfare effects of regulating the so-called termination charges paid to mobile network operators when fixed phone subscribers make calls to mobiles.[1]

All telephone network, fixed and mobile, are legally obliged to allow interconnection with each other. This enables all phone users to communicate regardless of their network operators. For calls from the fixed network to a mobile subscriber, a special termination charge is charged by the operator where the call terminates. This fee is paid to the mobile operator by the fixed network operator but is ultimately borne by the calling customer (*Figure 1*). The mobile operator will collect a termination revenue and after deduction of its cost, get a termination profit.

Figure 1 Payment flows for calls from fixed to mobile phones (*mobile terminating calls*)



Source: Authors own illustration.

The problem is that the mobile market suffers from an asymmetry. While the mobile network operators compete for the mobile customers putting pressure on the prices these customers pay, prices for calling *to* a mobile phone are less exposed to competition. The reason is that the calling party, e.g. a fixed line subscriber, has no choice of mobile operator. She has to place the call via the mobile operator the called party happens to be a customer

[1] A similar situation is mobile-to-mobile calls but the study will focus on the fixed-to-mobile case since that call volume is normally much larger.

with. This is different from the situation of the mobile subscriber who can choose a competing mobile operator if she thinks calling *from* the mobile is too expensive.

Because of this asymmetry, there will be no incentives for the mobile operators to reduce their termination charges. If left unregulated, they would theoretically be set at monopoly levels (Wright [2002]).

The charging of termination charges above cost has sometimes been justified by that it enables mobile operators to cross-subsidize handsets for new mobile subscribers. Handset subsidies would internalize the network externality of that additional mobile subscribers benefit the fixed subscribers since they would have more mobile subscribers to communicate with.

A number of theoretical reports have pointed out a link between termination charges and subsidies for mobile customers, including handset subsidies (e.g. Armstrong [2002]). With higher competitive pressure for these customers, profits from call termination will be utilized for cross-subsidization.

Regulating the termination charges could therefore indirectly cause negative effects, if the termination profits were used to subsidize handsets and thereby stimulated mobile subscriber growth. An investigation of this scenario is included in the scope of the present study.

The second generation networks (e.g. GSM) in industrialized countries are now mature and the argument may be less valid since most people already have mobile phones. However, the issue may still be of interest for second generation networks in developing countries or the emerging third generation networks (e.g. image communication from fixed computers to 3G handsets).

2. Scope and Structure of Study

Scope

The scope of the study is to investigate, in principle, the welfare effects of introducing a regulation of termination charges to make them cost-based. Different theoretical scenarios will be studied to cover situations both without and with network externalities due to handset subsidies stimulating subscriber growth. It will also briefly investigate if there are any empirical indications of such stimulation. The study tries to answer the question in which situations regulation of termination charges is beneficial from a welfare perspective and in which situations it might have a negative effect.

Structure of the study

The study will be structured in the following way. In Section 3, the selected oligopoly model is presented. It is a circular-city model of markets where mobile operators compete with horizontally differentiated services.

The market equilibria in this model falls in two categories. First, there are equilibria in mature markets, where handset subsidies would not stimulate subscriber growth. Secondly, there are equilibria in growing markets where such stimulation may occur.

Then the effects on these equilibria of regulating the termination charges are studied. The states after regulation are defined as reference cases, which will be used in the welfare comparisons.

Section 4 deals with these welfare comparisons. First a generic welfare function is specified consisting of consumer surplus for various subscriber categories as well as operator profits. The calculation of consumer surplus in the circular-city model is covered in some detail. Then the complete welfare functions for the identified market equilibria and regulated cases are specified and welfare comparisons are made between them. In all cases except one special case, regulation improves welfare.

Section 5 is dedicated to a short empirical study comparing the subscriber growth in the Swedish GSM market, a market with extensive handset subsidies, and the Finnish, were a ban on subsidies was introduced. The comparison indicate that the Swedish handset subsidies seem to have stimulated subscriber growth during a short period in the early growth phase, but thereafter stimulated handset replacement rather than subscriber growth.

The conclusion in Section 6 is that the arguments for regulation of termination charges are strong, and that it is questionable if the special case is enough to justify an exception given that it is surrounded by a number of theoretical prerequisites and given empirical indications of a short period of validity.

Finally some areas for future studies are suggested in Section 7.

3. Model and Market Equilibria

The study will use a model from Bezzina-Pénard [2000] and also utilize the market equilibria found by them and Werner [2002] for the different welfare comparisons. For these comparisons, special reference cases will be defined to model the policy of the Swedish regulator (Post & Telestyrelsen, PTS).

The model assumes that mobile operators tries to create horizontal differentiation through marketing, advertising and service offering rather than vertical through network coverage and quality. This seems to be a reasonable assumption for the application of the model to new technologies like 3G, where regulator requirements must be fulfilled while the network size is constrained by financial limitations due to, e.g., licence fees.[2] It may be more questionable in other situation, like GSM networks in developing countries. However, even in those situations, the vast majority of customers will be in areas where they have sufficient coverage from most operators (i.e. in cities or areas with more dense population)

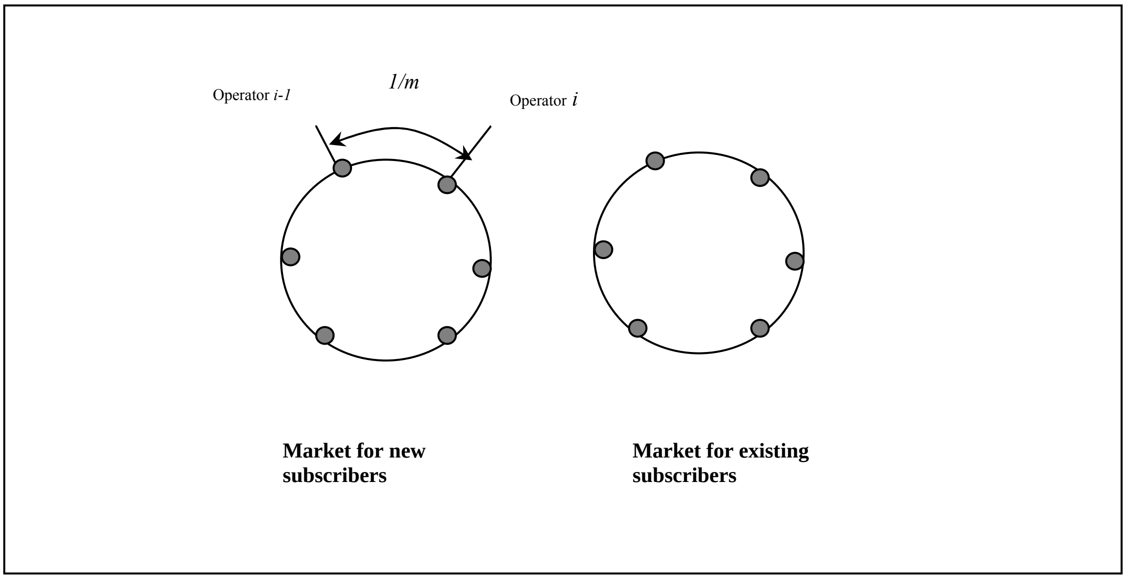
Model principles

The competition in the model takes place in two separate markets, the market for new subscribers and the market for existing ones (Bezzina-Pénard [2000]). These two markets, with their horizontally differentiated services, are modelled using "location" based circular-city models. Each market is modelled by a unit-circle with potential subscribers evenly distributed on the periphery. The m mobile operators are also located in different locations along the periphery of each circle. The word "location" in this context refers to a concept of ideal preferences. If a potential subscriber is located in exactly the same place as one of the mobile operators, that operators offering corresponds perfectly to the subscribers ideal. Any distance between the potential subscriber and the mobile operator implies that the operators offering does not fully correspond to the subscribers ideal. The distance causes a disutility proportional to the distance with a 'distance-cost' parameter k.

The mobile operators are placed symmetrically around each circle. The distance between two operators is consequently $1/m$, since the periphery is of unit length and there are m operators (*Figure 2*). It is assumed that the operators are located in the same places on both circles. It is also assumed that all potential subscribers along the circles are actually signing up to an operator, both markets are *fully covered* by the m operators.

[2] The situation in Sweden is different since the 3G operators have committed themselves to very extensive coverage at at given date. The conclusion regarding the type of differentiation is the same, though.

Figure 2 The markets for new and existing subscribers modelled as unit-circles with operator locations. Potential subscribers are evenly distributed along the circles peripheries.



Source: Tirole [1988 Fig 7.1, 7.2 p.283], Bezzina-Pénard [2000].

This leads to that each operator will capture a certain market share and consequently a certain number of subscribers. The total number of mobile subscribers develops over time. In each period t, n_t new subscribers are added. The total number of existing subscribers in period t reflects the accumulation of new subscribers in the previous periods: $N_{t-1} = \sum_{j=0}^{t-1} n_j$.

In the market for new subscribers the market share will be $\alpha_{i,t}$ (in period t for operator i) and the number of new subscribers for operator i will therefore be $n_t \cdot \alpha_{i,t}$. In the market for existing subscribers the market share is $\beta_{i,t}$, and the number of existing subscribers will consequently be $N_{t-1} \cdot \beta_{i,t}$.

Each operator sets a subscription price for its service in each period. The period length may be interpreted as a *lock-in period* of the subscription before it is possible to change operator (typically 12-18 months). The fixed price of the subscription, corresponding the monthly fees, is put together with a given number of call-minutes to a *rental package* for each period. So the operators compete with the price of identical rental packages. The price of such a package is $f_{i,t}$ for operator i in period t.

However, a new subscriber must first buy a handset and sign up for a subscription. The handset and handling service for the subscription are lumped together in an *access package*, provided at the price $a_{i,t}$. A new subscriber buys one access package and one rental package in the first period and pays ($a_{i,t}$ + $f_{i,t}$). For subsequent periods she only buys rental packages and pays $f_{i,t}$ if she renews the subscription with operator *i*. The handsets are assumed to be compatible between operators so if she would prefer to switch to another operator she would only pay the rental package price of the new operator.

Profit function

There are three sources of profit for the operator, the profit from access packages, from rental packages and from call termination. The profit, or margin, for operator *i* when selling one access package in period *t* is $M_{a,\,i,\,t} = a_{i,t} - c_0$, where c_0 is the handset cost and any ancillary costs, e.g. advertising. In a similar way, c_1 is the cost of providing a rental package and $M_{f,\,i,\,t} = f_{i,t} - c_1$ is the corresponding margin for one rental package.

In this study it will be assumed that the mobile operator sets the termination charge and that the fixed operator just add its own cost (c_3) for the call. The price that the fixed subscriber pays when calling a mobile is e_t. If the mobile operators cost for the call termination is c_2, the mobile operators profit from fixed-to-mobile call termination becomes $\pi(e_t) = (e_t - c_3 - c_2)\cdot D(e_t)$, were $D(e_t)$ is the demand for fixed-to-mobile calls. The demand and the profit is defined *per mobile subscriber* to simplify calculations.

The operators profit function consists of the profit from the market for new subscribers and the profit from the market for existing subscribers. The market for new subscribers generates profit from all three sources while the market for existing subscribers only generates profit from rental packages and termination.

The profit function for mobile operator *i* in period *t* can therefore be written (Bezzina-Pénard [2000 Eq.6, p.7])

$$\Pi_{i,t}(a_{i,t}, f_{i,t}, e_t) = \alpha_{i,t}\, n_t[\, M_{a,\,i,\,t} + M_{f,\,i,\,t} + \pi(e_t)\,] + \beta_{i,t} N_{t-1}[\, M_{f,\,i,\,t} + \pi(e_t)\,] \qquad (1)$$

Equilibria in a mature market

In a market without subscriber growth, the market equilibria are given by the first order conditions for $a_{i,t}$, $f_{i,t}$ *and* e_t derived from the profit function. The subscriber growth and number of subscribers can be regarded as exogenous and independent of prices. The operators maximize their profits and choose prices under the assumption that the other operators prices are given. In equilibrium, they will all choose the same price. Since the operators are symmetrically located in the unit-circles for the two markets, Nash equilibrium prices and markets shares will be the same for all operators. The market shares will be $\alpha^*_{i,t} = \alpha^*_t = 1/m$ and $\beta^*_{i,t} = \beta^*_t = 1/m$.

The first order condition for e_t is independent of the conditions for $a_{i,t}$ *and* $f_{i,t}$ and the equilibrium price for the fixed-to-mobile calls can be determined independently from the equilibrium prices for access and rental packages. The price of terminating calls will, in the absence of regulation, be set to the monopoly level due to the asymmetry discussed in the Section 1. It can therefore be taken to be identical in all periods, so the termination profit becomes $\pi(e_t) = \pi(e) \neq 0$. Two solutions can be found from the first order conditions (Bezzina-Pénard [2000 Proposition 1, p.8]):

Case I: Unregulated price for mobile terminating calls (*e*) and $\pi(e) < c_1 + k/m$

$$a^*_{I,t} = c_0$$
$$f^*_{I,t} = \frac{k}{m} + c_1 - \pi(e)$$
$$\Pi^*_{I,t} = N_t \frac{k}{m^2}$$

In this case, access packages (handsets) are sold at cost and are not subsidized by the mobile operators. Termination profits are used to subsidize the rental packages.

Case II: Unregulated price for mobile terminating calls ($\pi(e) \neq 0$) and $\pi(e) \geq c_1 + k/m$

$$a^*_{II,t} = c_0 + c_1 + \frac{k}{m} - \pi(e)$$
$$f^*_{II,t} = 0$$
$$\Pi^*_{II,t} = n_t \frac{k}{m^2} + N_{t-1} \frac{\pi(e) - c_1}{m}$$

In this case, access packages will also be subsidized and the rental packages will be free. Note that this situation arises as a corner solution to Case I when the termination profit $\pi(e)$ becomes large enough. It is assumed that operators do not pay subscribers for their calls and f_t is therefore not allowed to be negative.

To evaluate the welfare effects of these two cases, a special Reference Case is designed to mimic the policy of the Swedish regulator (PTS).[3] In this case the termination charge is regulated to be set at cost (c_2). The price of calling to mobiles e is then also cost based since we earlier defined that $e=c_2 + c_3$. The termination profit $\pi(e)$ consequently becomes zero. The equilibrium prices in the Reference Case therefore corresponds to the Case I solution with $\pi(e)=0$ since $0 < c_1+k/m$. The other prices are unregulated.

Reference Case R: Regulated cost-based price for mobile terminating calls, $e=c_2+c_3$ and $\pi(e)=0$

$$a^*_{R,t} = c_0$$

$$f^*_{R,t} = \frac{k}{m} + c_1$$

$$\Pi^*_{R,t} = N_t \frac{k}{m^2}$$

This policy is slightly different from a strict regulation, which would also imply that $f=c_1$. However, that would limit incentives for the creation of new services and other differentiation that bring value to customers. Rather, the regulator tries to encourage competition through encouraging virtual operators[4] and awarding additional licences (which corresponds to an increased m). But also by discouraging less beneficial differentiation like complex presentations of tariff schemes making it difficult for customers to compare prices between operators (i.e. decreased k). Note that if no beneficial differentiation were present and these measure were totally efficient, then $k/m \rightarrow 0$ and $f_t \rightarrow c_1$ as in the strictly regulated case.

Equilibria in a growing market

The situation in a growing market may lead to another equilibrium (Werner [2002]). This would be the case if the use of extensive handset subsidies (i.e. subsidization of access packages) would lead to an increased subscriber growth. Then, the number of new subscribers would not be exogenous but a function of the price of access packages, with a higher number of new subscribers at lower prices. This corresponds to a subscriber uptake function $n_t(a_{i,t})$

[3] Or at least its intentions since the regulation of termination charges for two of the major GSM operators is currently pending court decision. The termination charges of the dominant operator Telia were regulated in 1999. PTS [2003a Section 2.4.3].

[4] Virtual operators are buying network capacity from the licensed operators, but do not have their own network.

such that $\delta\, n_t / \delta\, a_{i,t} < 0$. In this situation, the best all firms could do is to set $a_{i,t}=0$. Increasing $a_{i,t}$ would not only decrease the market share of firm i but also decrease the number of new subscribers. This leads to a Nash-equilibrium where $a_{i,t}=0$ and the optimal $f_{i,t}$ is given by the first order condition $\partial \Pi_{i,t}/\partial f_{i,t}=0$. Note, however, that as soon as the stimulating effect of handset subsidies on subscriber growth vanishes, this particular equilibrium becomes unstable and is abandoned.

A third case, Case III, is defined below for the equilibrium. (Werner [2002][5]):

Case III: Unregulated price for mobile terminating calls ($\pi(e) \neq 0$) and $n_t=n_t(a_{i,t})$, $\partial\, n_t(a_{i,t})/\partial\, a_{i,t}<0$

$$a^*_{III,t} = 0$$

$$f^*_{III,t} = \frac{n_t}{N_t} c_0 + \frac{k}{m} + c_1 - \pi(e)$$

$$\Pi^*_{III,t} = N_t \frac{k}{m^2}$$

It can be seen in Case III that in the absence of termination profits, the mobile subscribers are financing the handset subsidies by paying more for the rental packages (the term $n_t/N_t \cdot c_0$). But in the presence of termination profits the increase in rental package price is counteracted by termination profits (especially if $\pi(e) \geq n_t/N_t \cdot c_0$).

This means that regulation of termination charges can result in two different outcomes. If, when $\pi(e)$ becomes zero, customers are rational and consider their total cost of subscription (i.e. both access and rental package prices in a long term perspective), there would be no competitive advantage for operators to set $a_{i,t}=0$. The Case III equilibrium would therefore be abandoned in favour of the 'ordinary' equilibria Case I, II or R. Since the regulation implies that $\pi(e)=0$, only Case R is realistic.

But if customers are non-rational and only consider the price of the access package and not the subsequent costs of rental packages, then the outcome would be Case III with $\pi(e)=0$. The latter situation will be defined as a second Reference Case Q.

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[5] Werner did not include termination profits in his model. This has been added in Case III. That can be done since $\pi(e)$ is exogenous to the operators game of setting $a_{i,t}$ and $f_{i,t}$ to maximize profits.
The case when termination profits are so large that f^* would become negative and therefore has to be limited to zero, in analogy with Case II, will not be explicitly evaluated.

Reference Case Q: Regulated price for mobile terminating calls $e=c_2+c_3$, $\pi(e)=0$ and $n_t=n_t(a_{i,t})$, $\partial n_t(a_{i,t})/\partial a_{i,t}<0$

$$a^*_{Q,t} = 0$$

$$f^*_{Q,t} = \frac{n_t}{N_t}c_0 + \frac{k}{m} + c_1$$

$$\Pi^*_{Q,t} = N_t \frac{k}{m^2}$$

Table 1 summarizes the unregulated and regulated Cases presented in this section. The respective welfare gains will be calculated next, in Section 4.

Table 1 Equilibria Cases for evaluation of welfare effects of regulating termination charges.

Without regulation	With regulation
Case I	Case R
Case II	Case R
Case III	Rational consumers - Case R
	Non-rational consumers - Case Q

Source: Section 3.

4. Welfare Analysis

This section will provide expressions for the welfare gain in the different situation specified in Table 1. First a generic welfare function is defined. A part of that function consists of the consumer surplus in the circular-city markets, so the calculation principles for this is covered in some detail. Then the complete welfare functions for the Cases are specified and the different welfare comparisons are made.

Generic welfare function

The welfare function used is the standard sum of consumer surplus (*CS*) and firm profits. This function will be defined for each period *t*. The n_t new subscribers in period *t* gain their surplus from the market for new subscribers while the N_{t-1} existing subscribers in period *t* gain surplus from the market for existing subscribers.

The consumer surplus for the fixed subscribers who make calls to mobiles ("*Callers to mobiles*") is, as before, defined per *mobile* subscriber to simplify the analysis. An increase in the number of mobile subscribers will increase the total surplus of the fixed subscribers since there would be more mobile subscribers who receive calls from the fixed network.

The profit per operator is multiplied by the number of operators m, and the fixed cost of the m operators is deducted. The fixed cost is regarded as common between the two markets, i.e. the same network infrastructure is used for both new and existing subscribers. The fixed cost F has been specified as a capital cost per period and assumed to be the same in all periods and for all operators.

The welfare function can now be written

$$W_t = n_t \cdot CS_{Newsubscribers,t} + N_{t-1} \cdot CS_{Existingsubscribers,t} + N_t \cdot CS_{Callerstomobiles} + m \cdot \Pi_t^* - m \cdot F \qquad (2)$$

where n_t is the number of new subscribers in period t, N_{t-1} is the number of existing subscribers in period t ($N_{t-1} = \sum_{j=0}^{t-1} n_j$) and N_t is the total number of subscribers in period t

$(N_t = N_{t-1} + n_t)$.

The consumer surplus (per mobile subscriber) for *Callers to mobiles* can be approximated using the price integral of the Marshallian demand curve for calls to mobiles[6]:

$$CS_{Callerstomobiles} = \int_{e_0}^{\infty} D(e)de \qquad (3)$$

The starting point of this integral for the regulated case is equal to the cost based price for calls to mobiles, $e_0 = c_2 + c_3$. For the unregulated cases, it equals the monopoly level $e_0 = e^m$ since the mobile operators are free to choose the price . The calculation of the consumer surplus in the two circular-city markets, $CS_{Newsubscribers}$ and $CS_{Existingsubscribers}$, will be described in the next section.

Consumer surplus in the circular-city model

As described in Section 3, there are m mobile operators offering their differentiated services in each of the two unit-circle markets. The operators are evenly spaced around the periphery of each circle at the distance $1/m$ and the potential subscribers are evenly spread around the

[6] Assuming the income effect is negligible.

circles. The subscribers along the periphery of a circle choose the operator *i* to maximize their utility *U* minus the price charged by the different operators (Salop [1979 p.142-145 and 149-151], Tirole [1988 p.97-99 and 282-284]).

$$\max_i \left[U\left(l_i, l^*\right) - p_i\right] \geq \bar{s} \tag{4}$$

where l_i is the location of operator *i* and l^* the location of an ideal operator according to the subscribers preferences, which would be an operator co-located with her own position. The price p_i set by each operator represents $(a_i + f_i)$ or f_i for the respective markets. The parameter $\bar{s}$ is the utility of consumption of *outside goods* different from the goods considered in the model, i.e. other goods than mobile handsets and subscriptions.

The utility level *U* falls with the distance to the ideal operator position in proportion to the distance due to the "distance cost" *k*. The maximum utility u_0 is experienced by potential subscribers co-located with their ideal operator.

$$U(l_i, l^*) = u_0 - k\left|l_i - l^*\right| \tag{5}$$

Since it is assumed that the market always is fully covered, the utility selected by subscribers must be positive regardless of the subscriber position. Equation 4 can therefore be rewritten

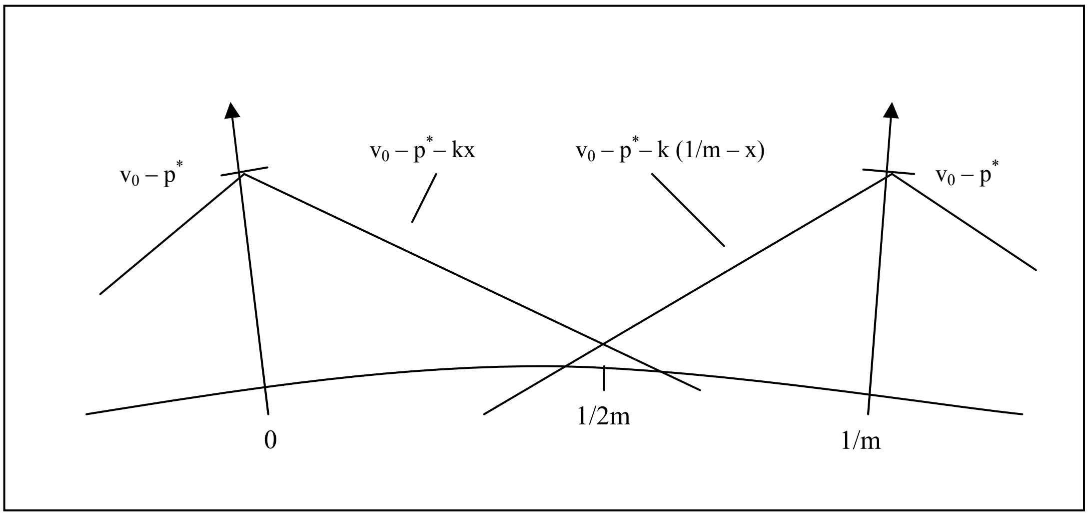
$$\max_i \left[v_0 - k\left|l_i - l^*\right| - p_i\right] \geq 0 \tag{6}$$

where v_0 can be regarded as a reservation price for consuming the goods inside the model, handsets and subscriptions.

$$v_0 = u_0 - \bar{s} > 0 \tag{7}$$

The consumer surplus for the subscribers choosing operator *i* can now be aggregated by integrating over the part of the circle where operator *i* provides the highest utility. This part of the circle is limited by the subscribers on each side of operator *i* who are indifferent between operator *i* and its nearest neighbours. The operators maximize their profits and choose prices under the assumption that the other operators prices are given. In equilibrium, they will choose the same price p^* and the distance $x=|l_i - l^*|$ from each operator to a subscriber indifferent between neighbouring operators will be $x^* = 1/2m$ (*Figure 3*).

Figure 3 Utility functions in the circular-city model.



Source: Based on Tirole [1988 Figure 2.2 p 98]

Since the situation is symmetrical on both sides, the integration can be done for one side and multiplied by two. The total surplus for all *m* operators subscribers on the unit-circle is then

$$CS = m \cdot 2 \int_{0}^{1/2m} (v_0 - kx - p^*)dx = m \cdot 2\left[\frac{v_0}{2m} - \frac{p^*}{2m} - \frac{k}{8m^2}\right] = \left\{w_0 = v_0 - \frac{k}{4m}\right\} = (w_0 - p^*) \qquad (8)$$

where the parameter w_0 has been introduced to simplify the notation and p^* represents the equilibrium prices in the respective markets, $\left(a^* + f^*\right)$ or f^*. This type of consumer surplus calculation will be used to calculate the consumer surplus for new and existing subscribers ($CS_{Newsubscribers}$ and $CS_{Existingsubscribers}$) in the welfare function.

Welfare functions for Cases

The welfare functions for the cases R, I and II, respectively, in period *t* can be written by combining Equation 2 and the result in Equation 8 with the equilibrium prices and profits in the three cases. The three welfare functions become

$$W_{R,t} = n_t(w_0 - (a^*_{R,t} + f^*_{R,t})) + N_{t-1}(w_0 - f^*_{R,t}) + N_t \cdot CS_R + m \cdot \Pi^*_{R,t} - m \cdot F \qquad (9)$$

$$W_{I,t} = n_t(w_0 - (a^*_{I,t} + f^*_{I,t})) + N_{t-1}(w_0 - f^*_{I,t}) + N_t \cdot CS_I + m \cdot \Pi^*_{I,t} - m \cdot F \qquad (10)$$

$$W_{II,t} = n_t(w_0 - (a^*_{II,t} + f^*_{II.t})) + N_{t-1}(w_0 - f^*_{II,t}) + N_t \cdot CS_{II} + m \cdot \Pi^*_{II,t} - m \cdot F \qquad (11)$$

Comparisons between Case I, II and Case R

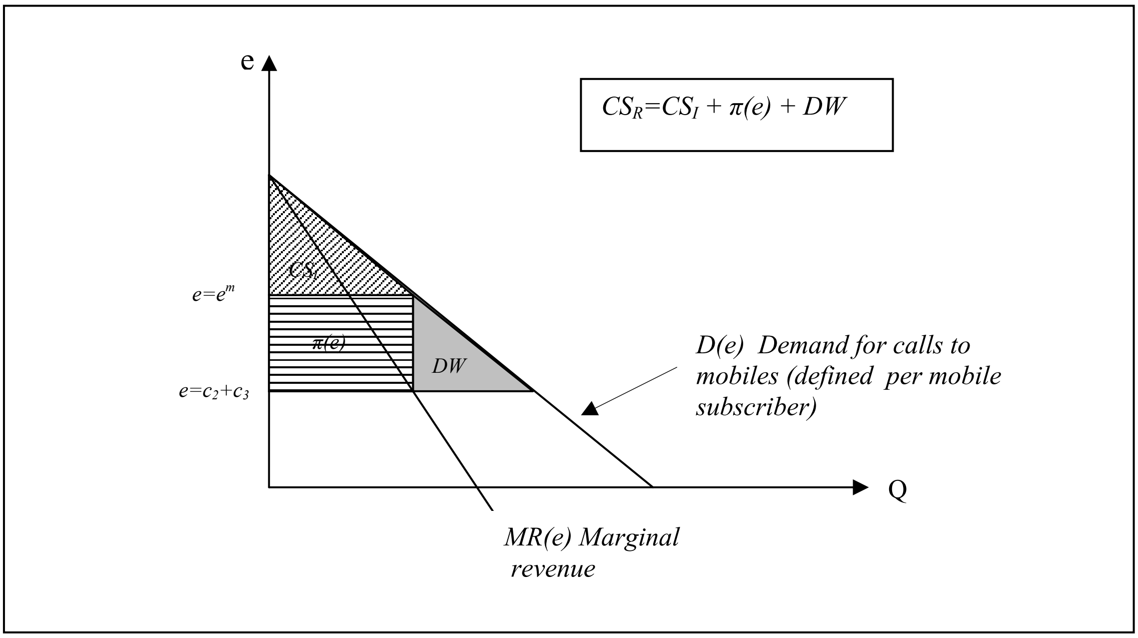
Welfare comparisons between the different Cases can now be made using the welfare functions defined. The comparisons assume that termination charges have been unregulated up to period *t*. Then there are two scenarios. Regulation can be enforced just at the beginning of period *t*. Alternatively, the unregulated state can continue throughout period *t.* When the starting point before period *t* is Case I and the state in period *t* is either Case R (regulated) or Case I (unregulated), the welfare gain of regulating can be expressed as the difference in welfare between the two scenarios in period *t*, $W_{R,t} - W_{I,t}$,which will be positive if the welfare in the regulated case is greater than the welfare in Case I.

$$W_{R,t} - W_{I,t} = n_t((a^*_{I,t} + f^*_{I,t}) - (a^*_{R,t} + f^*_{R,t})) + N_{t-1}(f^*_{I,t} - f^*_{R,t}) + N_t(CS_R - CS_I) + m(\Pi^*_{R,t} - \Pi^*_{I,t}) =$$

$$= N_t\left((CS_R - CS_I) - \pi(e)\right) \qquad (12)$$

To interpret the result in Equation 12, a graphical illustration is useful. Such an illustration for a linear demand curve is given in *Figure 4*. The consumer surplus (per mobile subscriber) in the regulated case equals the triangle between the cost-based price for mobile terminating calls and the demand curve so $CS_R = CS_I + \pi(e) + DW$.

Figure 4. Graphical illustration of the welfare difference between the regulated and unregulated prices for calls to mobiles.



Source: Equation 12.

The area CS_I under the demand curve is limited by the monopoly price level $e = e^m$.

A similar welfare comparison between the Reference Case and Case II yields a similar result $W_{R,t} - W_{II,t} = N_t\big((CS_R - CS_{II}) - \pi(e)\big)$ which equals $N_t \cdot DW$ since $CS_{II} = CS_I$ (e are in both cases the monopoly level).

The conclusion of the comparisons is that the regulated Reference Case provides higher social welfare than the unregulated equilibrium solutions in Cases I and II. In both Case I and II, the termination profit $\pi(e)$ is used to subsidize mobile subscribers. There is consequently a wealth transfer from fixed to mobile subscribers. This transfer causes an inefficiency, the deadweight loss $N_t \cdot DW$, which is similar in character to a transfer through taxation.[7] If the demand for calls to mobiles is very inelastic, DW becomes small, and vice versa.

Comparison between Case III and Case Q

As was discussed in Section 3, both Case III and Case Q have an enhanced subscriber growth due to the stimulating effect of handset subsidies. Case III will therefore be compared with Case Q in a similar way as before, but with some modification to cater for the extra subscriber growth.

The welfare comparison is made assuming a common history up to period t, i.e. the welfare expressions for the Reference Case ($W_{Q,t}$) and for Case III ($W_{III,t}$) have the same number of subscribers (N_{t-1}) at the beginning of period t. The welfare comparison then takes place in period t. In period t, the number of new subscriber will, in both cases, be $(n_t + \delta_t)$ which is higher than the uptake without stimulation (n_t) by an amount δ_t. The total number of subscribers in period t is then $N_{t-1} + n_t + \delta_t = N_t + \delta_t$. The welfare function for Case III is therefore

$$W_{III,t} = (n_t + \delta_t)\big(w_0 - (a^*_{III,t} + f^*_{III,t})\big) + N_{t-1}(w_0 - f^*_{III,t}) + (N_t + \delta_t)\cdot CS_{III} + m\cdot\Pi^*_{III,t} - m\cdot F \quad (13)$$

where

$$a^*_{III,t} = 0$$

$$f^*_{III,t} = \frac{n_t + \delta_t}{N_t + \delta_t}c_0 + \frac{k}{m} + c_1 - \pi(e)$$

$$\Pi^*_{III,t} = (N_t + \delta_t)\frac{k}{m^2}$$

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[7] The reason why there is no deadweight loss in the two circular-city markets is that their demand functions in equilibrium are perfectly inelastic due to the assumption of full market coverage.

If the enhanced subscriber growth is incorporated into the welfare function for Case Q in a similar way, the difference between the Reference Case Q and Case III after some algebra becomes

$$W_{Q,t} - W_{III,t} = (N_t + \delta_t) \cdot DW \tag{14}$$

DW in this expression is $((CS_Q - CS_{III}) - \pi(e))$, which is the same deadweight loss as in *Figure 4* before since $CS_{III}=CS_I$ due to *e* being at the monopoly level. So, also in this situation there is a clear welfare gain by regulating the termination charges.

Comparison between Case III and Case R

The comparison between Case III and Case R is different from the previous comparisons. Recall from Section 3 that the transition from Case III to Case R arose from a situation where the regulation of termination charges caused the rational and forward-looking subscribers to abandon the Case III equilibrium with its enhanced subscriber growth. Being in the Case R equilibrium therefore implies that the subscriber uptake is the unstimulated 'normal' growth. The welfare comparison in period *t* will therefore be between the Case III welfare function *with* enhanced growth as given by Equation 13 (and its attached $a^*_{III,t}, f^*_{III,t}$ and $\Pi^*_{III,t}$) and the *original* welfare function of Case R as given by Equation 9 (and its *original* $a^*_{R,t}, f^*_{R,t}$ and $\Pi^*_{R,t}$). As before, a common history before period *t* is assumed so that N_{t-1} is the same in both welfare functions. The difference between the Reference Case R and Case III in period *t* then becomes

$$W_{R,t} - W_{III,t} = N_t \cdot DW - \delta_t \cdot CS_{III} - \delta_t \cdot X \tag{15}$$

where $X = w_0 - (c_0 + c_1 - \pi(e))$.

The first term in Equation 15 is N_t times the deadweight loss *DW* in *Figure 4* in the same way as before since $CS_{III} = CS_I$ (*e* is the monopoly level in both cases). The second term, however, is extra surplus for the fixed subscribers calling to mobiles. The δ_t extra new subscribers attract calls from fixed subscribers which enhance the fixed subscribers welfare. This implies that these subscribers are receiving something in return for their paying a monopoly price for mobile terminating calls. It is the positive effect of the network externality. The third term in Equation 15 is less easily interpreted but will work in the same direction as $\delta_t CS_{III}$ as long as X is positive. This is the case if it is assumed that w_0 is constant in all periods and fulfils the assumption of full market coverage.[8]

It is obvious, that under some circumstances, the right hand side of Equation 15 may become negative. That would mean that the welfare *with* regulation would be less than the welfare *without* regulation, i.e. the regulation of termination charges would lead to a welfare loss. The condition for this is

$$N_t \cdot DW < \delta_t \cdot CS_{III} + \delta_t \cdot X \tag{16}$$

If this condition is fulfilled or not depends on the magnitude of the parameters involved.
By taking a conservative approach and setting $X=0$, Equation 16 can be rewritten as a stricter, but simpler, rule-of-thumb for when regulation of termination charges may lead to a welfare loss due to loss of network externalities:

$$\frac{\delta_t}{N_t} > \frac{DW}{CS} \tag{17}$$

where δ_t is the extra number of new subscribers in period t attributable to the handset subsidies, N_t is the total number of subscribers in the period, DW is the deadweight loss area shown in *Figure 4* and CS is the consumer surplus area called CS_{III} in Equation 16 and CS_I in *Figure 4* ($CS_{III}=CS_I$ since $e=e^m$ in both cases).

It is clear from *Figure 4* that an inelastic demand for calls to mobiles makes it easier to fulfil the condition in Equation 17 (smaller DW and larger CS), while a more elastic demand makes it more difficult. Also, as N_t becomes larger, the condition becomes harder to fulfil.

Overall, the risk for a welfare loss when regulating is higher in the early part of the network growth phase (low N_t) and when the demand for mobile terminating calls is inelastic.

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[8] The requirement for full market coverage in Case III´s market for new subscribers is $v_0 - (a^*_{III,t} + f^*_{III,t}) - k\frac{1}{2m} \geq 0$. Using Equation 6, the definition of w_0 in Eq.8 and the equilibrium prices attached to Eq.13 a requirement on w_0 can be derived. The highest lower bound of this w_0 expression is in period 1 when $n_0=N_0$ and $w_0 = 5k/4m + c_0 + c_1 - \pi(e)$. If this w_0-level is applied to all periods, then $X>0$ in all periods.

In summary, it can be concluded that the special case when a regulation of termination charges could harm welfare depends on a number of prerequisites identified above and earlier in Section 3:

1. Subscriber growth must be stimulated by the handset subsidies.
2. Customers must be rational and forward-looking.
3. Case III must have been stable before regulation, i.e. the unregulated termination profits must to a sufficient degree have covered the term $\frac{n_t}{N_t}c_0$ in the Case III rental package price expression ($f^*_{III,t}$).
4. The condition in Equation 16 must be fulfilled, or approximately $\frac{\delta_t}{N_t} > \frac{DW}{CS}$, which puts requirements on the elasticity of demand for calls to mobiles (through *DW/CS*), on the effectiveness of the handset subsidies (through δ_t) and on the networks degree of maturity (through N_t).

Summary of welfare effects

The results in this section can now be used to complete the table from Section 3. The completed Table 2 below shows that in all situations, except in one special case, regulation of termination charges leads to welfare gain. Regulation in the grey-shaded special case may in some situations cause a welfare loss, particularly in the early part of the network growth process and with inelastic demand for calls to mobiles, but may in other situations lead to a welfare gain.

Table 2 Welfare effects of regulating termination charges.

Without regulation	With regulation	Welfare gain
Case I	Case R	$N_t \cdot DW$
Case II	Case R	$N_t \cdot DW$
Case III	Rational consumers - Case R	$N_t \cdot DW - \delta_t CS - \delta_t X$
	Non-rational consumers - Case Q	$(N_t+\delta_t) \cdot DW$

Source: Table 1, Equation 12, 14, 15.

Since the existence of this special case depends on a stimulation of the subscriber growth through handset subsidies, the next section will investigate if there are any evidence of such behaviour in empirical data.

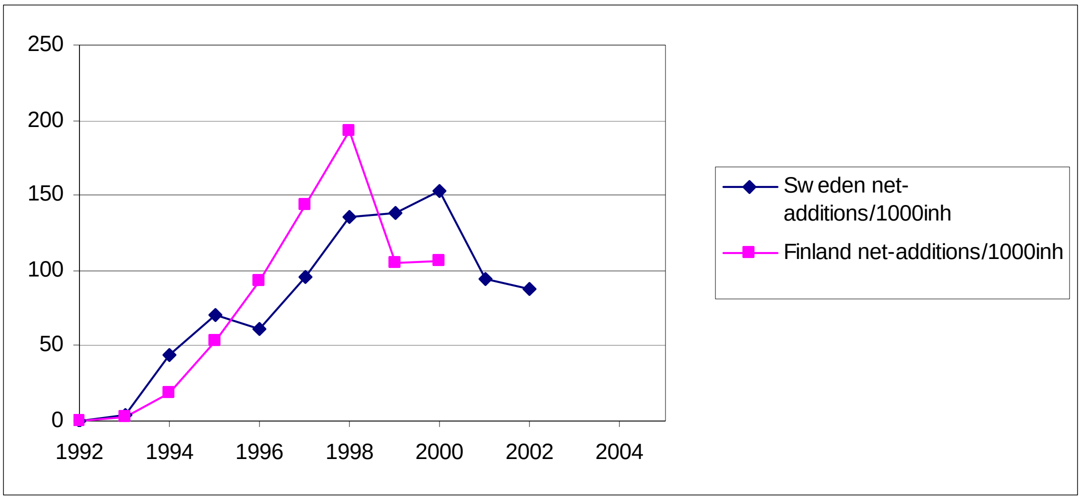
5. Stimulation of Subscriber Growth – Empirical Indications

This section will briefly look at the effectiveness of handset subsidies on subscriber growth. It is of course difficult to establish an exact empirical relation that links the number of new subscribers to the level of handset subsidies. However, a way to get an indication could be to use a comparison between the subscriber development in Sweden, where there have been extensive subsidization, and in another country where there were no handset subsidies. Finland would be a suitable candidate for such a comparison. Sweden and Finland have similarities in terms of their mobile markets. Both were early starters in GSM and they were both using the analogue NMT system extensively before the launch of GSM.

In Sweden, the amount of subsidy per handset varied considerably over the last decade. After a rapid increase in subsidization, a peak was reached in the end of 1994, with subsidies in the order of SEK 5000-6000 per handset (ComputerSweden [2003]). The subsidies then fell gradually to a level around SEK 2000 per handset (PTS et al. [1999 p.24]). However, during this period, the price charged by handset manufacturers fell as well so the consumer price did not mirror the change in subsidies. At the highest subsidy levels, the customer paid a couple of thousand SEK herself since the handset were very expensive at that time. Since then, there have been plenty of instances when the handsets have been given away for free ($a_t=0$). The SEK 2000 subsidy level was approximately maintained until the year 2000 (PTS [2000 Section 4.5]). After that the operators removed subsidies to some extent, but there still exist some offers with subsidies of up to SEK 1000 (Ny Teknik [2003]).

In Finland, handset subsidies were banned in 1996 (Europe Economics [2001 p.17]). There may have been some subsidies before that, it has not been possible to quantify the extent, but looking at the yearly subscriber growth in Finland (*Figure 5*) there is no change in the shape of the curve around 1996 which would have been expected if the ban changed the situation markedly. On the other hand, the effect of the extensive Swedish subsidies is clearly visible before 1996 while the growth in Finland at that time is much smoother. It seems reasonable to attribute the differences to the effect of handset subsidies.

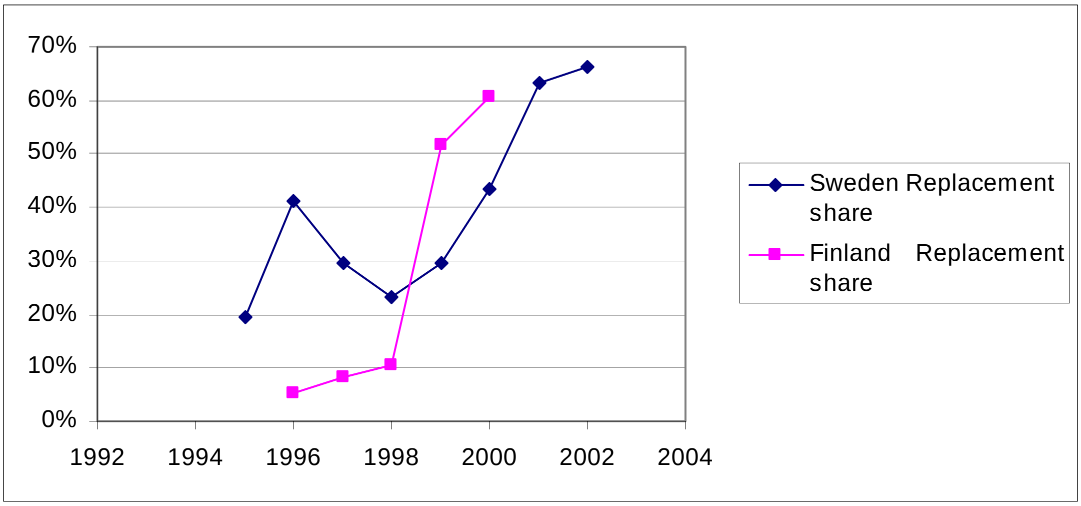
Figure 5 Number of new subscribers (net additions) per 1000 inhabitants per year for Finland (1991-2000) and Sweden (1992-2002).



Sources: Number of subscribers: PTS [2003b Tabell 14, s.52] (Number of net additions in Sweden in 1993 assumed to be equal to number of sold phones MTB [2003]), Kommunikationsministeriet [2003]. Population: SCB [2003], Statistics Finland [2003].

Swedens sudden lag in net additions of subscribers in 1996 may look peculiar, but is partly explained by an increased replacement of phones. That is shown in *Figure 6* which shows the share of the handsets sold each year that cannot be attributed to net additions of subscribers, here called the *replacement share*.

Figure 6 Replacement share of sold mobile phones per year for Finland (1996-2000) and Sweden (1995-2002).



Source: Number of sold phones: Mobiltelebranschen [2003], Mobile CommerceNet [2003]. Number of subscribers: PTS [2003b Tabell 14, s.52], Kommunikationsministeriet [2003].

Note: Replacement share is defined as the share of the handsets sold each year that cannot be attributed to net additions of subscribers.

Again, the picture is different in Finland and Sweden. Finland exhibits a pattern which is more what one would expect, that the replacement gradually increases as the subscriber stock grows. Sweden, on the other hand, has an extreme peak in replacements in 1996 and has a higher replacement rate than Finland until 1998. From 1998, the two countries have similar replacements rates with the Swedish curve being a couple of years shifted, probably due to the previous upgrading of the phone stock. However, in terms of *phones sold /1000 inhabitants*, i.e. both for new subscribers and for replacement, Sweden was lower than Finland between 1996 and 2000, so replacement is not the whole explanation.

To conclude, there seems to have been a stimulating effect of handset subsidies on subscriber growth during 1994-1995. Thereafter, the stimulating effect disappears and the subsidies instead stimulate replacements of phones. Since the Swedish regulator has indicated that the demand for calls to mobiles is rather inelastic (PTS [2002 p.4]) and given that the unregulated termination charges were high at the time (PTS [2003a Section 2.4.3]), a welfare loss *may* potentially have occurred had a regulation been enforced in this two year period.

6. Conclusions

Based on the theoretical and empirical results of this study, a number of tentative conclusions can be drawn, keeping the limitations of both theory and empirical results in mind:

1. Regulation of termination charges to be cost-based is generally beneficial from welfare perspective. In all studied situations, except one special case, regulation brings improved welfare.

2. The only situation found when regulation of termination charges potentially (but not necessarily) could be harmful, is a special case when the subscriber growth can be stimulated by subsidizing the mobile handsets and termination profits are used to cross-subsidize these. In that situation, network externalities creates welfare for the fixed subscribers calling to mobiles, the same subscribers who have to pay a monopoly price for their calls if the termination charges are unregulated. In this situation regulation may cause a welfare loss under certain circumstances, particularly

in the early part of the network growth process and with inelastic demand for calls to mobiles. But under other circumstances it could lead to a welfare gain.

3. An empirical comparison between the Swedish GSM market, with extensive handset subsidies, and the Finnish, where a ban on subsidies was introduced, indicate that the Swedish handset subsidies seem to have stimulated subscriber growth during the period 1994-1995. In the subsequent period, the subsidies seem to have stimulated handset replacement rather than subscriber growth. Since the Swedish regulator has indicated that the demand for calls to mobiles is rather inelastic and given the high unregulated termination charges at the time, the conditions for a welfare loss of regulation *may* have been fulfilled during the brief period of 1994-1995.

To conclude, the arguments for regulation of termination charges are strong. It is questionable if the special case, with all its theoretical prerequisites and with empirical indications of just a brief period of effective handset subsidies, is enough to justify an exception from the general rule.

7. Future studies

The following two areas have been perceived as shortcomings of the present study and should be included in further studies:

1. A reliable estimation of the demand curve for mobile terminated calls in the Swedish market. This would enable a more precise conclusion about the welfare effects.
2. The circular-city model with full market coverage gives an inelastic demand for mobile originating calls. Future studies should cater for incomplete market coverage or cater for elastic demand in some other way.

In addition, comparisons with GSM markets in, e.g., developing countries, and the emerging 3G markets, would be interesting.

Figures

Tables

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