On the profit neutrality of access charges in network competition*

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Abstract

This note demonstrates that the puzzling profit neutrality of access charges, i.e. network profit is independent of the access charge with two-part call tariffs, depends on a specific property of subscription demand. Profit neutrality is equivalent to the subscription elasticity being proportional to consumer net surplus at symmetric prices. Standard formulations of subscription demand - the Hotelling, the circular city and the random utility model – all have this proportionality. Small transformations of subscription demand may yield a profit maximising access charge far from the social optimum. Thus, policy conclusions drawn on the basis of profit neutrality are not robust.

Keywords: network competition, two-way access, two-part tariffs, profit neutrality.
JEL classification: L510, L960

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1 Introduction

In their seminal contribution on network competition, Laffont, Rey and Tirole (1998a) derive a profit neutrality result which has drawn considerable attention. The profits of two interconnected networks are independent of the access charge they pay for call termination in the competitor's network, provided the networks use two-part call tariffs, do not price discriminate between calls inside and outside the network, and have symmetric access charges and symmetric costs.

This profit neutrality is puzzling. A monopoly network would set a call price equal to marginal cost so as to maximise the social surplus and use a fixed subscription fee to fully extract this surplus (Oi 1971). An access charge different from the marginal cost of call termination yields a call price different from marginal cost, thereby generating a loss in social surplus.

Why is it not costly for the industry to deviate from marginal cost pricing when it is always costly for a monopolist to do so? When is profit neutrality likely to hold; when is it not? What happens to the networks' optimal access charge and welfare if profit neutrality fails? The answers to these questions are important because profit neutrality is a desirable property of network competition. Under profit neutrality the determination of the access charge can be delegated to the networks. The networks have no incentive for setting an access charge other than the socially optimal one if their profits are independent of the access charge. Delegation relieves the regulator of the burden of trying to calculate what the socially optimal access charge actually is. The difficulty stems from the hard fact that the regulator generally tends to not know what the networks' production cost are.

I demonstrate in this note that profit neutrality is a knife-edge result. The networks by their choice of access charge affect the social surplus, as well as the intensity of competition for subscribers through the effect on call tariffs. The social surplus is divided between the industry and the consumers in proportion to the price sensitivity of subscription demand - the subscription elasticity. When subscription demand is elastic, competition for subscribers is intense. With intense competition the equilibrium subscription fees are low and consequently most of the surplus goes to the consumers. When demand is inelastic, competition is weak and most of the surplus goes to the industry. Network profit is independent of the access charge if and only if the subscription elasticity is proportional to consumer net surplus at symmetric prices. In this specific case any change in social surplus resulting from a change in the access charge is exactly offset by a corresponding change in the intensity of competition for subscribers. The reason the literature has focused on the special case of profit neutrality is because all of the standard formulations of subscription demand - Hotelling, the circular city and the random utility model - happen to have proportional subscription elasticity. One can eliminate the proportionality by a straightforward generalization of subscription demand also within the existing class of models. Thus, profit neutrality is an extreme result (as claimed by Laffont and Tirole 2000).

For policy purposes the interesting question is not whether profit neutrality itself is robust but rather whether the policy implications stemming from profit neutrality are robust. After all, if small changes to the model would lead to a profit maximising access charges only slightly different from the socially optimal access charge, the policy conclusions would be robust. Unfortunately, small perturbations to the economic model underlying profit neutrality can have large discontinuous effects on the networks' preferred access charge and therefore on welfare. Instead of being a profit maximising access charge (as under profit neutrality) the socially optimal access charge becomes the profit minimising access charge. A corner solution arises whereby the networks' preferred access charge is either very high or very low. Suddenly, there is a very strong case for access charge regulation. It follows that policy conclusions drawn on the basis of profit neutrality are not robust.

The present paper contributes to the literature investigating the robustness of profit neutrality by generalizing subscription demand. Dessein (2003) and Hahn (2004) examine heterogeneous calling patterns and find that profit neutrality still holds. Also, one can include call externalities without affecting the result (Jeon, Laffont and Tirole 2004, Berger 2005).

There are a number of circumstances under which profit neutrality fails; see Armstrong (2002) for an elaborate discussion. First, if networks price discriminate between calls terminated inside (on-net) and outside (off-net) one's network (Laffont, Rey and Tirole 1998b) the networks may jointly benefit from an access price below (Gans and King 2001), at (Calzada and Valletti 2008) or above (Gabrielsen and Vagstad 2008) the marginal cost of termination, depending on the mode of competition and subscription demand. Second, profit neutrality fails if the networks set asymmetric access charges (De Bijl and Peitz 2002). It is clear that in these first two cases a policy maker could restore profit neutrality by banning call price discrimination and imposing symmetric access charges on the networks. Third, when the total market size is growing the networks will generally profit from an access charge below termination cost (Dessein 2003, Armstrong and Wright 2008). Fourth, the access charge affects profit if the networks are asymmetric (De Bijl and Peitz 2002, Carter and Wright 2003, Armstrong and Wright 2008). In fact, asymmetric networks may fail altogether in reaching an agreement. The problem associated with a growing market is of limited relevance for those lead countries approaching full market coverage. In the UK, for example, there are now more mobile subscriptions than inhabitants (Armstrong and Wright 2008). As the industry matures and challengers gain market share at the expense of the incumbent, one might expect problems associated with asymmetric networks to fade. Finally, if networks compete in dimensions other than price, for example quality, they might benefit from a high access charge in order to curb investments (Valletti and Cambini 2005). With uniform coverage obligations and a regulatory focus on reducing switching costs, it appears that in the future networks will compete even more intensely in prices than quality.

The policy maker cannot affect the properties of subscription demand in any predictable manner. Thus, regulatory problems associated with non-neutral access charges may be persistent even in an otherwise ideal market where retail competition is limited entirely to prices, call price discrimination is forbidden, the market is fully covered, and the networks have symmetric access charges and symmetric costs.

2 Analysis

The model is essentially the one by Laffont, Rey and Tirole (1998a and b), henceforth LRT, except I use general functional forms to describe subscription and call demand and allow more than two networks. There is a continuum of consumers of unit measure, each of whom subscribes to one of $n \geq 2$ networks. Every subscriber to network i makes q_i calls at the (non-discriminatory) price p_i per call to every other subscriber (i.e., the call pattern is balanced) so as to maximise the quasi-linear utility $U(q_i) - p_i q_i + I$, where U is well-behaved, and I is exogenous income. Income is assumed sufficiently high to render demand D interior at all prices: $D(p_i) \equiv U'^{-1}(p_i)$ for all $p_i \geq 0$. The consumer net surplus in network i is

$$v_i \equiv V(p_i, R_i) \equiv U(D(p_i)) - p_i D(p_i) - R_i, \tag{1}$$

where R_i is the subscription fee. Since the focus is on symmetric equilibria, assume that all networks except possibly i charge the same call price $p(a)$ and subscription fee $R(a)$ as a function of the symmetric access charge a, i.e., all networks face the same access charge. The consumer net surplus in any network other than i is $v(a) \equiv V(p(a), R(a))$. The customer base of network i is $s(v_i, v(a))$. It is continuous and differentiable, increasing in v_i and symmetric in the sense that $s(v(a), v(a)) = n^{-1}$. Let $\sigma(v(a)) \equiv (\partial s/\partial v_i|_{v_i=v(a)})nv(a)$ be the subscription elasticity at symmetric prices.

The profit of network i is

$$\Pi(p_i, R_i) \equiv s(v_i, v(a)) [(p_i - c) D(p_i) + (1 - s(v_i, v(a))) (a - c_t) (D(p(a)) - D(p_i)) + R_i - f], \tag{2}$$

where c_t (c_o) is the marginal cost of call termination (origination), $c = c_t + c_o$, and $f \geq 0$ is the per-subscriber cost. Differentiating the profit with respect to the call price and the subscription fee, respectively, gives the following two first-order conditions for a symmetric equilibrium:

$$v(a)[1 + (p(a) - c - \tfrac{n-1}{n}(a - c_t))\tfrac{D'(p(a))}{D(p(a))}] - \sigma(v(a)) [(p(a) - c) D(p(a)) + R(a) - f] = 0, \tag{3}$$

$$v(a) - \sigma(v(a)) [(p(a) - c) D(p(a)) + R(a) - f] = 0. \tag{4}$$

Subtracting (4) from (3) gives the equilibrium call price:

$$p(a) = c + \tfrac{n-1}{n}(a - c_t). \tag{5}$$

Plugging $p(a)$ back into (4) one can solve for the equilibrium subscription fee:

$$R(a) = f + \tfrac{v(a)}{\sigma(v(a))} - \tfrac{n-1}{n}(a - c_t) D\left(c + \tfrac{n-1}{n}(a - c_t)\right). \tag{6}$$

The call price is set equal to the effective marginal cost so as to maximise the social surplus inside the network. The network then uses the subscription fee to balance the customer base against surplus extraction of the subscribers.

Substituting (5) and (6) in (1) and (2), respectively, one can solve for the equilibrium consumer net surplus and the equilibrium profit, respectively:

$$v(a) = \frac{\sigma(v(a))}{1+\sigma(v(a))} W(a), \tag{7}$$

$$\pi(a) \equiv \Pi(p(a), R(a)) = \frac{1}{n} \frac{v(a)}{\sigma(v(a))} = \frac{1}{n} \frac{1}{1+\sigma(v(a))} W(a), \tag{8}$$

where

$$W(a) \equiv U(D\left(c + \tfrac{n-1}{n}(a - c_t)\right)) - cD\left(c + \tfrac{n-1}{n}(a - c_t)\right) - f$$

is the social surplus and equal to the sum of consumer net surplus and producer surplus. Social surplus is divided between the consumers and the industry in proportion to the subscription elasticity. If the subscription demand is elastic, competition for subscribers is intense and most of the surplus goes to the consumers. If the subscription demand is inelastic, the networks extract most of the surplus. The networks affect by their choice of the access charge a their profit through two channels. First, by distorting the access charge away from the marginal cost of termination they reduce the size of the pie to be distributed since the social surplus then goes down. Second, they affect their share of the pie if the intensity of competition is sensitive to changes in the call tariffs. Changing the access price is profitable if and only if competition deteriorates faster than the social surplus. Profit neutrality means that the two effects cancel: the networks get a larger share of a smaller pie, holding the piece of the pie constant. Formally, profit neutrality is equivalent to $\pi(a) = k$ for all a and some constant $k > 0$. Using (8), the following result is immediate:

Proposition 1 *Network profit is independent of the access charge in symmetric equilibrium if and only if the subscription elasticity is proportional to the consumer net surplus (i.e.* $\sigma(v(a)) = v(a)/k \ \forall a$ *and for some* $k > 0$*).*

Profit neutrality can be pinned down to a particular proportionality feature of the subscription demand. This makes it easy to check whether profit neutrality holds. I illustrate the usefulness of this result by means of a few examples. As the two first examples show, proportionality holds for the most commonly used models of horizontal differentiation.

The "standard" circular city Assume that the consumers are uniformly distributed on the unit circle. The utility of belonging to a network located at i is $v_i - 2t|l - i|$ for a consumer located at l, where $t > 0$ is a (virtual) transportation cost and a measure of horizontal differentiation. When all networks are equidistant the subscription demand of network i is

$$s(v_i, v(a)) = \frac{1}{n} + \frac{v_i - v(a)}{2t}.$$

The circular city model was explored by Armstrong and Wright (2008); see also Calzada and Valletti (2008) for a discussion. The duopoly Hotelling models first used by Armstrong (1998) and LRT are special cases of this circular city model, with $n = 2$. As is easily calculated, the subscription elasticity is indeed proportional, $\sigma(v(a)) = v(a)n/2t$, and profit neutrality immediately follows: $\pi(a) = 2t/n^2$.

The "standard" random utility model Assume that the utility of belonging to network i is $v_i + \varepsilon$, where ε has a double exponential distribution, i.i.d. across consumers and networks. With a continuum of consumers, network i's subscription demand is

$$s(v_i, v(a)) = \frac{\exp\{\frac{1}{\gamma}v_i\}}{\exp\{\frac{1}{\gamma}v_i\}+(n-1)\exp\{\frac{1}{\gamma}v(a)\}},$$

where $\gamma > 0$ is a measure of horizontal differentiation. This random utility model was first used by Dessein (2003) in the duopoly case and recently extended by Calzada and Valletti (2008) to the general n network case; see also Anderson, de Palma and Thisse (1992). Even in this case the subscription elasticity is proportional, $\sigma(v(a)) = \frac{1}{\gamma}\frac{n-1}{n}v(a)$, which implies profit neutrality: $\pi(a) = \gamma/(n-1)$.[1]

In the standard models the networks have no incentive for distorting the access charge away from the social optimum since network profit is independent of the access charge. The question is whether this conclusion is robust to perturbations in the underlying model. To address this question, I consider a slight generalization of subscription demand.

The "general" circular city Assume that everything is as in the circular city above, except now the utility of belonging to a network at i is $h(v_i) - 2t|l-i|$, where $h(\cdot)$ is twice continuously differentiable and strictly increasing. Network i's subscription demand is

$$s(v_i, v(a)) = \frac{1}{n} + \frac{h(v_i)-h(v(a))}{2t}.$$

The subscription elasticity is $\sigma(v(a)) = kh'(v(a))v(a)$ at symmetric prices, where $k = n/2t$. If h is concave, the marginal effect on the network's subscription demand of offering consumer net surplus is decreasing, i.e., $\partial^2 s/\partial v_i^2 < 0$. In this sense, there are decreasing returns to price reductions. Conversely, convexity of h can be interpreted as increasing returns to price reductions.

The "general" random utility model Assume that everything is as in the random utility model above, except the utility of belonging to network i is $h(v_i) + \varepsilon$. Network i's subscription demand is

$$s(v_i, v(a)) = \frac{\exp\{\frac{1}{\gamma}h(v_i)\}}{\exp\{\frac{1}{\gamma}h(v_i)\}+(n-1)\exp\{\frac{1}{\gamma}h(v(a))\}}.$$

[1] Subscription demand is a function of the differences in consumer net surplus both in the circular city and the random utility model. How is this property related to profit neutrality? Assume that $s(v_i, v(a)) = g(v_i - v(a))$, where $g(0) = 1/n$. In this case $\sigma(v(a)) = g'(0)nv(a)$. It follows from Proposition 1 that profit is independent of the access price. The converse is not true, i.e., profit neutrality does not imply that subscription demand is a function of the differences in consumer net surplus. For example, $s(v_i, v(a)) = g((v_i/v(a))^{v(a)} - 1)$ does not have this property, but still is proportional: $\sigma(v(a)) = g'(0)nv(a)$.

A variant of this random utility model where $h(v_i) \equiv \ln v_i$ was introduced by Doganoglu and Tauman (2002) who studied duopoy competition, but without two-part tariffs. Stennek and Tangerås (2008) considered a model with n symmetric networks. Again, the subscription elasticity can be written on the form $\sigma(v(a)) = kh'(v(a))v(a)$, where now $k = (n-1)/n\gamma$.

Consider the implications of a general subscription elasticity for the profit maximizing access charge. Substitute $\sigma(v(a)) = kh'(v(a))v(a)$, where $k > 0$, into (7) and (8) and rearrange consumer net surplus and network profit as

$$v(a) + \tfrac{1}{kh'(v(a))} = W(a),\ \pi(a) = \tfrac{1}{nkh'(v(a))}.$$

The marginal effect

$$\pi'(a) = -\tfrac{h''(v(a))v'(a)}{nk(h'(v(a)))^2} = \tfrac{h''(v(a))}{h''(v(a))-k(h'(v(a)))^2}\tfrac{1}{n}W'(a)$$

on network profit of an increase in the access charge is ambiguous and depends, among other things, on the properties of h.

Profit is independent of the access charge only in the knife-edge case $h'' = 0$. However, this does not mean that profit non-neutrality by itself is a cause for alarm. In case $h'' < 0$, $\pi'(a)$ has the same sign as $W'(a)$. It follows that the profit maximising access charge is the same as the one that maximises social welfare, namely $a = c_t$. The implication remains the same as under profit neutrality, even though profit neutrality actually fails here: if the networks face decreasing returns to price reductions, they have no incentive for distorting the access charge away from the social optimum.[2]

The problem arises when there are small, but positive returns to price reductions, i.e., when $h'' \in (0, k(h')^2)$. In this case, the socially optimal access charge would actually *minimise* network profit. The profit function now is strictly quasi-convex in the access charge, and the networks would optimally set a very high or a very low access charge in the absence of regulation. Indeed, the optimal access charge from the networks' viewpoint could well be the welfare minimising access charge. This dramatic swing in the network's incentives occurs even for infinitely small perturbations ($h'' \gtrsim 0$) away from the profit neutral environment.[3] The policy conclusions obtained from the profit-neutral setting are not robust.

3 Conclusion

I have demonstrated that the profit neutrality of network competition is a knife-edge result and depends crucially on a particular proportionality feature of subscription demand. Nonetheless,

[2] This is true also if there are strong and increasing returns to price reductions, i.e., if $h''(v) > k(h'(v))^2 > 0$.

[3] Consider the following parametric example, where $h(v) = v + yv^2/2$ and $y < k$. Note that $h''(v)/(h'(v))^2 = y/(1+yv)^2 < y < k$ for all $v > 0$ and $y > 0$. Let $\overline{a}$ ($\underline{a}$) be the maximal (minimal) feasible access charge. The networks' most preferred access charge $a^*(y)$ is $a^*(y) = c_t$ for all $y < 0$, and $a^*(y) \in \{\underline{a}, \overline{a}\}$ for all $y \in (0, k)$, which renders the optimal access charge discontinuous at $y = 0$ - precisely where network profit is independent of the access charge.

for policy purposes the interesting question is whether the policy implications stemming from profit neutrality are robust, and not whether profit neutrality itself is robust. The policy implications are non-robust. Small perturbations to the economic model underlying profit neutrality can have large discontinuous effects on the networks' optimal access charge and therefore on welfare.

Profit neutrality arises even in the economic analysis of payments systems. In a discussion of the research, Gans and King (2003) note that profit neutrality holds if the card issuing, acquiring and merchant segments of the market all are differentiated a la Hotelling. Whether the demand proportionality discussed here can be applied to payment systems is an issue for future research.

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