Access Pricing, Quality Degradation, and Foreclosure in the Internet

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Abstract: Access to both a local and a global network is needed in order to get complete connection to the Internet. The purpose of this article is to examine the interplay between those two networks and how it affects the domestic public policy towards a domestic provider of local access. We find that a cost-oriented regulation is detrimental to domestic welfare, because it shifts profit to the foreign provider of global access. The optimal policy is that the regulator commits itself to set an access price above costs, possibly the same price as in an unregulated market economy. A regulation of the global access price has a non-monotonic effect on domestic welfare, and there is a potential conflict between international and domestic regulation policy.

1 Introduction

During the last decade the Internet has become an important industry, for example measured in the number of people using services such as email and web-browsing. Although we can learn a lot about this new industry by applying standard results from economics, there are some idiosyncratic characteristics of the Internet industry that call for a closer examination. For example, Internet connectivity may be seen as a composite good that is produced by the complementary inputs local access and global access. The local access network is typically dominated by a domestic telecommunication company, and the global access network - called the Internet backbone - is dominated by a limited number of US companies. While the providers of local access have historically been regulated both on price and quality in their home country, the providers of global access have so far not been regulated.

The purpose of this paper is to examine the interplay between the firms in the global and the local network concerning price and quality setting, and analyze possible implications of this interplay for the public regulation policy. We show that a strict regulation of the access prices may be detrimental to welfare, and in particular we demonstrate that the price of local access should be set above cost if foreign firms have market power.

Since the Internet is rather new, there are relatively few studies in the literature of this particular industry. Inspired by Mackie-Mason and Varian (1994, 1995a, 1995b), there exists some analyse of the congestion problem in the Internet and price setting to end users without market power. Neither access pricing nor the quality of interconnection between networks are important topics in those studies. More in line with our focus, though, are Cremer *et al.* (2000), Milgrom *et al.* (2000), Economides (1998a, 1998b) and Sibley and Weisman (1998). The two former study the Internet backbone market, while Economides and Sibley and Weisman focus on an upstream monopolist's incentives to foreclose rival downstream firms through quality degradation. An important distinction between our study and theirs, is that we are concerned about the interplay between the local and global access network.

In our model a dominant firm provides access to the global network, while the incumbent telecommunication firm provides local access in a particular country. The end-users are served by two Internet service providers, and one of them is owned by the domestic telecommunication firm in charge of the local access network. In the first version of our model we assume that the second end-user provider is an independent firm. We show that in this case the integrated local telecommunication firm would find it profitable to set a high local access price to the independent end-user provider and thereby to monopolize the end-user market (foreclosure). If the global access provider's price setting is exogenously determined, we find that a regulator maximizing domestic welfare should set the local access price equal to long run marginal costs. In such a way it triggers competition in the end-user market. This reproduces the well known cost-oriented price regulation paradigm, and serves as a benchmark for our analysis.[1]

Results change dramatically if the global access price is endogenous. A restrictive regulation policy, as described above, is now detrimental to domestic welfare. The same is true if the regulator cannot credibly commit itself to a certain access price, and ends up by setting price equal to marginal costs. Such a low local access price would imply that the provider of global access could gain a larger share of the market's profit potential by setting a high access price. Hence, a reduction of the local access price is partly replaced by an increase in the global access price and thereby a profit shift out of the country. If the regulator could commit himself to a public policy, often denoted ex ante regulation, the best he could do would possibly be to not intervene. By doing so, it prevents any profit shift out of the country.

Next, we consider the case where the provider of global access has acquired the independent end-user provider. Now the end-user providers are in a symmetric position, since each of them controls an essential input both of them need. Not surprisingly, we find that foreclosure will not take place in equilibrium. More surprisingly, we find that if the regulator could behave credibly it would set an access price below the one it would prefer if the provider of global access had not acquired the end-user. Hence, an end-user provider owned by the foreign global access

[1]Our main results will not be altered if we allow for a regulated price on local access below marginal costs (see section 3). See also Laffont and Tirole (2000) for a discussion.

provider should be given more favourable terms than an independent and locally owned end-user provider. The reason is that the global access provider's response to a lower local access price is now distinctly different, because its main response to a lower access price is to act more aggressively in the end-user market. Thereby consumer surplus increases.

We extend the model further by assuming that the provider of global access has the ability to degrade the quality of the input sold to the locally-owned end-user provider. If there is no regulation of access prices, we find that the global access provider decides not to practice quality degradation. The reason is that any quality degradation would harm the global access provider's potential for profit extraction from the end-user provider who is integrated with the provider of local access.

However, there might be a price cap on the global access price, for example due to WTO-agreements that reduce the scope for firms to abuse their international market power. If such a price cap is sufficiently restrictive, the global access provider's profits from serving the locally-owned end-user provider are limited. Then the global access provider may have incentives to foreclose it by practicing quality degradation. The domestic regulator, though, would rather have both end-user providers active in the market to ensure rivalry in the output market. The regulator's best choice may then be to set a higher local access price than the provider of local access itself would have done. By doing so it encourages the global access provider not to practice foreclosure. However, for a sufficiently low global access price it is not possible for the regulator to prevent the global access provider from practicing foreclosure.

Finally, note that there is a potential conflict between international and domestic public policy. First, a restrictive price cap on global access would, as noted above, result in foreclosure even if the local access price is regulated. This is detrimental to domestic welfare, and the country would have been better off without any regulation of the global access price. Second, a price cap on the global access price may result in a less restrictive price cap on the local access price, and may even in some cases result in a higher end-user price. Such a response from the domestic regulator would shift profits from the providers of global access to the providers of local access.

2 The Internet

For our purpose, Internet connectivity sold to end-users in Europe can be seen as a composite good that consists of one domestic input (local access into homes) and one global input (access to the Internet backbone in the US). These inputs are supplied by Local Access Providers (LAPs) and Internet Backbone Providers (IBPs), respectively. Internet connectivity is sold to the end-users from a regional Internet Service Provider (ISP), who needs to buy local access to consumers from the LAP and global Internet access from an IBP.[2]

The market structure is dominated by a few firms in both the local and the global access network. Regarding local access, the "last mile into homes", the local telephone lines and the cable-tv lines are the alternatives for private users (Clark, 1999). Obviously, local access has to be offered locally. Due to their dominant position, the LAPs are typically subject to regulation of price and quality for local access as an input component. In the EU, for instance, the evolution of the regulatory regime has led to commitment to a restrictive practice, often denoted ex ante regulation, towards the LAPs.

In contrast, there has so far been no regulation of the global access input supplied by the IBPs. A few US firms provide connection to the global backbone to regional ISPs all over the world.[3] It should be noted that global access is much more essential for Internet connectivity than for conventional telephone services. While only a relatively small portion of world wide telephone calls go to or from the US, the majority of the Internet traffic has to go through the US. For the location of Internet facilities we thus have a clear asymmetry between the US and the rest of the world.

Even if no IBP separately is in position to use market power, a group of co-

[2]Between the bottleneck components local access and core backbone access there is a chain of intermediates. We do not consider these intermedites segments, since their potential for using market power seems to be limited.

[3]Access to the top-level of global infrastructure is controlled by US firms such as MCI WorldCom, Sprint, Genuity (formerly GTE), and AT&T. The only non-American firm operating a top-level backbone is Cable &Wireless, who bought MCI's backbone operation before the MCI-WorldCom merger. See Cremer *et al.* (2000) and Kende (2000) for an overview.

operating IBPs may be in position to do so (Cremer et al, 2000, Milgrom et al, 2000). In addition to giving access to information located on servers in the US, the input from the IBPs also secures access to the core routing structure and access to all Internet addresses in the world (Milgrom et al, 2000). A limited number of core IBPs co-operate in creation of a consistent routing structure. The full routing tables are a part of the input sold to regional ISPs, and they define the addresses that can be reached. When the IBPs co-operate in coordination their core routers, it would be a temptation to use it as a collusive device (Varian, 1999). The control over the core routers (with full routing tables) distincts the IBPs from other ISPs that are controlling regional backbones.

Recently, we have witnessed a more active role played by the core IBPs. While they still have cost-free interconnection among themselves, they now charge smaller regional ISPs for access to their global infrastructure and core routing services. In other words, the smaller regional ISPs have become customers (or resellers) of the core IBPs facilities and services.[4] We have also observed that IBPs have integrated vertically into the retail market for Internet connectivity (the ISP segment) in Europe.

3 Some preliminaries

Let us consider the stylized market contexts illustrated in Figures 1a and 1b. The ISPs buy local access and global access as inputs from the LAP and the IBP, respectively. Throughout the paper we assume that (i) one IBP provides global access and one LAP provides local access, (ii) ISP A and ISP B compete in the market for Internet connectivity sold to end-users, and (iii) the LAP is vertically integrated and operates ISP A as its subsidiary. Since the ISPs have to choose capacity in the regional backbone network as well as in the transatlantic transport network we

[4] An example of this is UUNET (an MCI WorldCom subsidiary), who ended the cost-free interconnection regime in 1997 and started to charge smaller ISPs for access to their backbone. See Mackie-Mason and Varian (1997) and Werbach (1997) for a summary of the internet's history.

will model downstream competition as a Cournot game.[5] For simplicity, we further assume that there is no horizontal differentiation between the two services offered by the ISPs. However, it should be noted that neither of these assumptions are essential for our main results (see discussion in Section 7).

In section 4 we assume that the non-integrated IBP sells global access as an input to both ISP A and ISP B. This market structure is denoted VS (vertical separation), and it is illustrated by Figure 1a. In section 5 we assume that the IBP vertically integrates into the retail market and operates ISP B as its subsidiary, see Figure 1b. This market structure is denoted VI (vertical integration). In section 6 we apply the same structure as in section 5, but we allow the IBP to engage in non-price discrimination (quality reduction) towards ISP A.

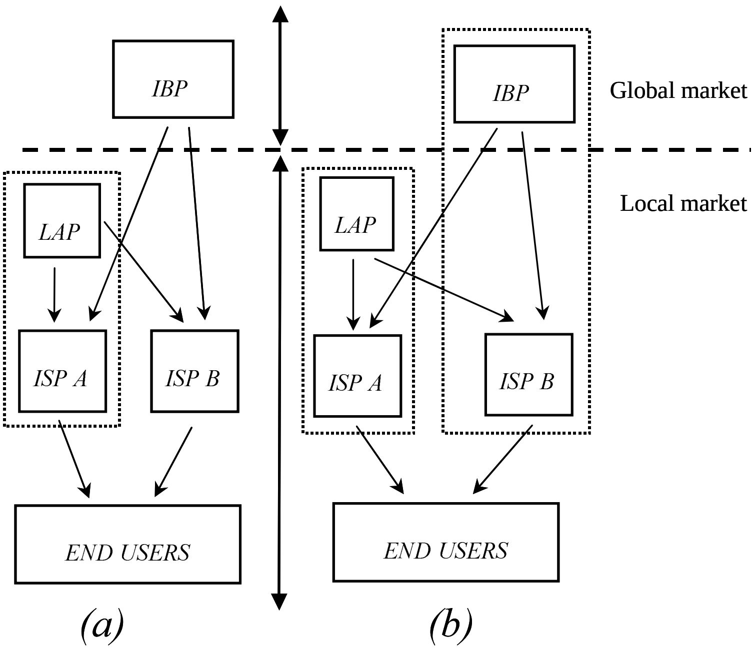

Figure 1: The market structure.

[5]Downstream ISPs usually operate their own regional backbones in the territories they serve, while they sign long-term contracts for transatlantic capacity. Hence, it seems appropriate to see the competition between the ISPs as a capacity constrained price game.

Demand side

Let consumer demand for Internet services be given by

$$p = \alpha - \beta(q_A + q_B), \tag{1}$$

where p is the price, and q_A and q_B denote the quantities from ISP A and ISP B, respectively. The consumer surplus may consequently be written as

$$CS = (\alpha - p)(q_A + q_B)/2. \tag{2}$$

Supply side

The profits for the downstream firms (the ISPs) are

$$\pi_i = (p - w_l - w_g)q_i. \qquad (i = A, B) \tag{3}$$

where w_l and w_g are the prices charged by the LAP and the IBP, respectively. Upstream profits for the LAP and the IBP are given by

$$\pi_{LAP} = (w_l - c_l)(q_A + q_B) \tag{4}$$

and

$$\pi_{IBP} = (w_g - c_g)(q_A + q_B), \tag{5}$$

where c_l and c_g are the respective long run marginal costs.

Since the LAP is vertically integrated, it is useful to express its aggregate profit level as

$$\pi^I_{LAP} = \pi_{LAP} + \pi_A. \tag{6}$$

If the IBP is vertically integrated, the market structure denoted VI, we have

$$\pi^I_{IBP} = \pi_{IBP} + \pi_B. \tag{7}$$

Domestic welfare

Domestic welfare is measured as the sum of consumer surplus and domestic profits (π_D);

$$W = CS + \pi_D. \tag{8}$$

In the case where ISP B is a domestic independent firm we have $\pi_D = \pi^I_{LAP} + \pi_B$, while $\pi_D = \pi^I_{LAP}$ if ISP B is owned by the foreign IBP.

A benchmark: VS with exogenously given global access price

As a benchmark, let us consider the model illustrated in Figure 1a (VS). For the moment, we will assume that the IBP charges an exogenously given price w_g. If it is normalized to zero, it can be interpreted as the old regime where the IBPs did not charge the regional ISPs for global access (see Chapter 2).

Rewriting equation (6) we can express the profit level of the integrated LAP as

$$\pi^I_{LAP} = (p - w_g - c_l)q_A + (w_l - c_l)q_B. \tag{9}$$

We assume that the LAP first chooses w_l, and that ISP A and ISP B subsequently compete in quantities. Solving the game by backward induction, we start with the quantity setting by the ISPs. Using equations (1), (3) and (9) we find that the first order conditions $\partial\pi^I_{LAP}/\partial q_A = 0$ and $\partial\pi_B/\partial q_B = 0$ imply

$$q^*_A = (\alpha + w_l - 2c_l - w_g) / (3\beta) \tag{10}$$

and

$$q^*_B = (\alpha + c_l - 2w_l - w_g) / (3\beta). \tag{11}$$

At stage 1 the LAP determines the price w_l that it will charge from ISP B. Differentiating (9) with respect to w_l we find that

$$w^*_l = (\alpha + c_l - w_g) / 2. \tag{12}$$

From equations (11) and (12) it is thus clear that the LAP chooses an access price w_l such that $q^*_B = 0$ (and $\pi^*_B = 0$), and is thereby able to act as a monopolist in the downstream market. Hence, it exploits its control over the local access to deter the rival downstream firm from being active.

The fact that the LAP becomes a monopolist may obviously have negative welfare effects, and indicates that there is a role for public policy. The government maximizes welfare with respect to w_l subject to the constraints

$$\pi^{I*}_{LAP} \geq 0, \pi^*_B \geq 0,\ w_l \geq c_l. \tag{13}$$

The first two constraints state that each domestic firm should have a non-negative profit, and the last inequality says that the LAP must have a non-negative price-cost margin on its sale to ISP B.

Imperfect downstream competition is the only distortion when the global access price is exogenous. Hence, the domestic regulator can achieve a first-best outcome through a restrictive regulation of the local access price (and possibly subsidize the local access provider). The first-best outcome is one where the consumer price for Internet connectivity is equal to long-run marginal costs, $p = c_l + w_g$, and with a corresponding industry output equal to $\alpha - \beta(c_l + w_g)$. Since the ISPs use a positive mark-up, the regulator thus needs to set the local access price below marginal costs ($w_l < c_l$) in order to reach this equilibrium. However, the restriction $w_l \geq c_l$ seems appropriate in our context, since the regulation policy in both the EU and the US typically allows firms to set prices such that their long-run marginal costs are covered. This implies that the local access price should be set equal to marginal cost, since $dW/dw_l < 0$ for $w_l = c_l$. It should be noted that the restriction $w_l \geq c_l$ does not affect any of the results qualitatively. In fact, a central message of this article is that in some cases it may be optimal for the regulator to set the access price strictly above marginal costs ($w_l > c_l$).

By regulating the local access price the regulator prevents the LAP from achieving a monopoly position. It is straight forward to show that the welfare level is now higher than the one without regulation.

Our results so far can be summarized in the following lemma:

Lemma 1: *Let us assume a VS market structure and that w_g is exogenous. If no regulation, then the LAP sets the local access price so high that ISP B is foreclosed. If regulation, a regulator that maximizes domestic welfare sets $w_l = c_l$, and both ISPs are active.*

In the benchmark w_g has been exogenous, which is consistent with the fact that w_g has been equal to zero until recently. Lately, however, the IBPs have begun to charge the ISPs for connectivity to the backbone, and presumably this pricing behaviour will become more widespread along with the increased commercialization of the Internet [see, e.g., Frieden (1999) and Cremer *et al.* (2000)]. In the following sections we analyze the effect of an endogenously determined price w_g from the IBP.

4 Vertical separation

Also in this section we have a market structure as illustrated in Figure 1a, where the IBP is vertically separated from the ISPs. The only difference from the benchmark presented in the previous section is that the IBP acts as a monopolist that sets the global access price w_g endogenously. In the benchmark case a lower price w_l of local access reduced the marginal cost of ISP B, and thus led to increased competition and higher output. Therefore it was optimal for the domestic regulator to set a restrictive price cap on local access. Below, we show that this need not be the case when w_g is endogenous. The reason is that in addition to the direct effect on ISP B's costs, a reduction of w_l allows the IBP to charge a higher price w_g of access to the backbone. In this case the regulator therefore faces a trade-off between stimulating to downstream competition and preventing profit shifting from the domestic market to the foreign upstream firm. The problem of the domestic regulator is that there are now two distortions, but only one policy instrument available (the local access price). Not surprisingly, domestic price regulation is therefore possibly less effective than when w_g is exogenous. To show this, we will first analyze the outcome in an unregulated market economy.

Equilibrium

We will assume that prices and quantities are determined in a non-cooperative two-stage game. At stage one the LAP and the foreign IBP simultaneously set the access prices w_l and w_g, respectively, while there is Cournot competition in quantities between ISP A and ISP B at stage 2. The latter assumption implies that q_A^* and q_B^* are still given by equations (10) and (11).

To find the equilibrium value of w_g, we insert q_A^* and q_B^* into (5) and differentiate with respect to w_g. Taking w_l as given, we have

$$w_g(w_l) = (2\alpha + 2c_g - w_l - c_l)/4. \tag{14}$$

In a similar way, we find that

$$w_l(w_g) = (\alpha + c_l - w_g)/2. \tag{15}$$

In the appendix we prove the following Proposition:

Proposition 1: *Let us assume a VS market structure and no regulation. Then the LAP sets w_l such that $q_B^* = 0$.*

The LAP thus uses its control over the essential domestic input (access to the local network) to practice foreclosure against the competing downstream firm, ISP B. Thereby the LAP is able to retain its monopoly power over the consumers. Note that this result is identical to the result found when the global access price was exogenous (see Lemma 1). It thus illustrates that strategic behaviour by the global access provider does not change the LAP's strategy of monopolization.

Domestic public policy

In principle, the government can act as a first mover when it regulates the local access price w_l. This means that it sets w_l *before* IBP sets w_g. However, such a commitment to ex ante regulation may not be credible. If it is not a credible commitment, we can model public policy as if w_l and w_g were set *simultaneously.* In the following we analyze both cases, and we start with the latter.

No credible commitment

In this case we have a two-stage game, where the regulator and the IBP choose w_l and w_g at stage one and the integrated LAP and ISP B choose quantities at stage two. We then have the following results (see the Appendix):

Proposition 2: *Let us assume a VS market structure and that the regulator and the IBP set w_l and w_g simultaneously.*

(i)The regulator then sets $w_l = c_l$, and

(ii) the welfare level is lower with than without regulation.

Since the regulator and the IBP act simultaneously, the regulator is not able to influence the IBP's choice of w_g. For any given choice of w_g, the regulator's best choice is to set access price equal to marginal costs and thereby eliminate the dead weight loss following from a local access price above marginal costs. The regulated price of local access is thus equal to long-run marginal costs, as is the case when w_g is exogenous (see Lemma 1).

It can be shown that consumers are better off and domestic producers worse off following regulation. Since part (ii) in Proposition 2 states that regulation is detrimental to domestic welfare, then the reduction in domestic profits is only partially passed on to the domestic consumers. The reason is that part of the initial domestic profit is shifted to the IBP. The IBP anticipates that the regulator sets access price equal to marginal costs, and its best choice is then to set a higher access price to the backbone than what is the case without regulation. Put differently, regulation lowers domestic profits and permits the IBP to extract more profits from the domestic market.

Credible commitment

Let us now take for granted that the government succeeds with ex ante regulation. Then we have the following game:

· *Stage 1:* The regulator determines the price w_l

· *Stage 2:* The IBP determines the price w_g

· *Stage 3:* The LAP and ISP B set the quantities q_A and q_B

We have the following result (see the Appendix):

Proposition 3: *Let us assume a VS market structure and that the regulator can set w_l in a credible way. It would then choose not to regulate w_l.*

We see that if the regulator can credibly commit itself, it prefers not to regulate at all. The result in Proposition 3 follows from our result reported in Proposition 2. A binding price cap on w_l would imply that the IBP raises its access price w_g, thereby shifting profits from the domestic producers to the foreign producer. To avoid such a profit shift, the regulator is better off by not intervening in the market and thus by allowing the domestic producers to capture a large portion of the total profit in the domestic market.

5 Vertical integration

Let us now focus on the market structure illustrated in Figure 1b. We assume that both the LAP and the IBP have integrated vertically into the ISP segment, and that ISP B is a subsidiary of the IBP (while ISP A is still owned by the LAP).

In the previous section the domestic regulator face a trade-off in setting the local access price, since a lower w_l not only reduces the costs of ISP B but also increases w_g. The higher w_g in turn increases the costs of both ISP A and ISP B. So what changes when the IBP integrates into the downstream market? The main difference is that an increase in w_g affects only ISP A's costs. Hence, the problem that a reduction of w_l increases w_g becomes less serious.

If the IBP is vertically integrated, we may write its profit level as [c.f. equation (7)]

$$\pi^I_{IBP} = (p - w_l - c_g)q_B + (w_g - c_g)q_A. \tag{16}$$

The profit level of the integrated LAP is still given by (9), and Cournot competition generates the following equilibrium quantities:

$$q^*_A = (\alpha + w_l - 2c_l + c_g - 2w_g)/(3\beta), \tag{17}$$

and

$$q^*_B = (\alpha + w_g - 2c_g + c_l - 2w_l)/(3\beta). \tag{18}$$

Equilibrium

In the first stage of this game the integrated LAP and the integrated IBP set the prices w_l and w_g. Inserting for (17) and (18) into (9) and (16), we find that $d\pi^I_{LAP}/dw_l = 0$ and $d\pi^I_{IBP}/dw_g = 0$ imply that

$$w_l(w_g) = [5(\alpha + c_l) - w_g - 4c_g]/10 \tag{19}$$

and

$$w_g(w_l) = [5(\alpha + c_g) - w_l - 4c_l]/10. \tag{20}$$

Then we have the following result (see the Appendix):

Proposition 4: *Let us assume a VI market structure and no regulation. Then w_l and w_g are set such that $q_i^* > 0$, where $i = A, B$.*

We see that in this case both ISPs offer positive quantities. This is in contrast to the result stated in Lemma 2, where only the LAP was assumed to be vertically integrated and it foreclosed the ISP B. To understand the distinction between these two outcomes, note that now both the ISPs have access to an essential facility and in that respect they are symmetric. From the LAP's point of view, the ISP B is now a low cost producer. It faces a low marginal cost, since $c_g < w_g$. The LAP then finds it beneficial to serve the low cost producer rather than foreclose it.

Domestic public policy

If regulation is not a credible commitment, it follows from the previous analysis that the regulator would end up with a regulated local access price equal to marginal costs in this case as well. More interestingly, though, is the case where regulation is a credible commitment. In that case the regulator sets w_l at stage 1, the integrated IBP sets w_g at stage 2 and q_A and q_B are set at stage 3.

Proposition 5: *Let us assume a VI market structure and that the regulator can set w_l in a credible way. Then it sets $w_l < w_l^*$, and domestic welfare increases.*

At first glance, this may come as a surprise. A low local access price is beneficial for the IBP, the foreign owner of the ISP B, and may thus shift profits out of the country. However, the IBP's response to a lower local access price is now distinctly different from what was the case with vertical separation. First, the detrimental effect on the IBP's access price, w_g, is now more limited. The reason is that this access price is now only affecting the ISP A's sale, while under vertical separation it affected both ISPs' sales. Second, the integrated IBP now responds to lower local access price by acting more aggressively in the output market. This is beneficial for the consumers, and explains why the regulator decides to set a lower local access price than what the domestic LAP would have set.

6 Quality reduction

Above we have seen that it may not be optimal for the regulator to use cost-based prices on local access, because that may lead to higher prices on global access and increased profit shifting. This raises the question of whether there is a need for a global price regulation.

So far we have assumed that the bottleneck owners' only choice variable is price. However, a price regulation of the access price may induce foreclosure through non-price discrimination (see Laffont and Tirole, 2000). In particular, if the integrated IBP meets a price cap on w_g it may engage in non-price discrimination by reducing the quality of the input sold to the local incumbent's subsidiary ISP A. As shown in Economides (1998a, 1998b), it can be profitable to do so, and thereby put its rival in a disadvantageous position.[6] An LAP who meets a price cap on local access, may also have incentives to practise foreclosure through non-price discrimination.[7] Since the prevailing regulation regime in Europe typically has an ambition to regulate both price and quality on local access, we will, however, not consider this possibility. On the other hand, it seems difficult to implement quality requirements on the backbone providers. For example, it is almost impossible for an international regulatory authority to decide whether an integrated firm such as MCI Worldcom offers new functionality based on technological advantage to its own retail subsidiaries or practices quality degradation on input sold to the rivals.[8]

In line with Economides (1998a, 1998b), we let $f \geq 0$ be a "quality reduction parameter" which is such that one unit increase in f reduces the consumers' willingness to pay by one unit. In this case ISP A faces a parallel downward shift in its demand curve.

By including the quality reduction parameter we can write the profit level of the

[6] See also Bergman (2000) and Economides (2000) for a note and comment on Economides (1998a).

[7] For further discussions and examples, see Laffont and Tirole (2000) and Economides (1998b).

[8] The Microsoft case gives an illustration of the problems in such a context, see, e.g., Economides (1998b)

LAP as

$$\pi^I_{LAP} = (p - w_g - c_l - f)q_A + (w_l - c_l)q_B. \tag{21}$$

Without any loss of insight we will assume that no costs are incurred for the integrated IBP when it reduces the quality of the input to ISP A. Therefore π^I_{IBP} is still given by (16), and with Cournot competition in quantities at the last stage of the game we have

$$q^*_A = (\alpha + w_l + c_g - 2c_l - 2\,w_g - 2f)\,/(3\beta), \tag{22}$$

and

$$q^*_B = (\alpha + c_l + w_g + f - 2w_l - 2c_g)\,/(3\beta). \tag{23}$$

Differentiating (16) with respect to f we find

$$d\pi^I_{IBP}/df = \frac{2}{9\beta}\left[f + \alpha + c_l + c_g - 2(w_g + w_l)\right], \tag{24}$$

which means that $d^2\pi^I_{IBP}/df^2 > 0$ for any given values of w_l and w_g. Setting $d\pi^I_{IBP}/df = 0$ thus gives us a minimum value of π^I_{IBP}, and therefore we must look at extreme values of f to find the IBP's best choice.

There are two extreme values of f. It cannot be negative, so there is a lower bound at $f^{lb} = 0$. The upper bound is given by

$$f^{ub} = (\alpha + w_l + c_g - 2c_l - 2\,w_g)\,/2, \tag{25}$$

because then $q_A = 0$ from equation (22). There is no reason to set $f > f^{ub}$, because ISP A is deterred from entering the market already at $f = f^{ub}$. Moreover, note that if w_g is unregulated, the IBP does not need the non-price foreclosure instrument f; it can always use w_g as a substitute.

Equilibrium

From the above, it follows that the IBP either sets $f = 0$ and imposes no quality reduction at all, or sets $f = f^{ub}$ and deters ISP A from entering the market. In the former case, we have the vertical integration equilibrium reported in the previous section. In the latter case, the LAP maximizes $\pi^I_{LAP} = (w_l - c_l)q_B$ with respect to

w_l at stage 1 and the integrated IBP maximizes $\pi^I_{IBP} = (p - w_l - c_g)q_B$ with respect to q_B at stage 2. By comparing these two outcomes, we find that the IBP chooses to impose quality reduction if and only if the access price to the backbone is set below some critical value w^c_g.[9] Letting w^*_g denote the access price that the IBP would have chosen in an unregulated market, we have the following result (see the Appendix):

Proposition 6: *Let us assume a VI market structure, that there is no regulation, and the IBP has the option to reduce quality when serving ISP A. Then the IBP will choose*

(i) not to impose quality reduction if $w^c_g \leq w_g \leq w^*_g$,

(ii) to impose quality reduction if $w_g < w^c_g$ *and thereby foreclose ISP A.*

Note that for endogenously determined w_g our result is in contrast to the result found in Economides (1998a, 1998b). He found that quality reduction would always be used to foreclose its downstream rivals. In his model, there is only one provider of an essential facility. Obviously, then, the provider of the essential facility can benefit from putting its downstream rival at a disadvantage by reducing the quality of its input. In our setting, though, quality reduction will not exclude the rival from being partly active in the market, since the rival provides the integrated IBP with local access. Then the integrated IBP is better off by providing the rival with high quality input and extracting profits from the rival through its access price w_g than by foreclosing the LAP's subsidiary ISP A if $w_g > w^c_g$.

As indicated, one important reason why foreclosure through quality reduction would not be profitable is that it would prevent the IBP from extracting profits from the integrated LAP. If so, it could be of interest to examine how any regulation of w_g, for example as a result of international public policy, may affect the IBP's choice of quality reduction. As shown in part (ii) of the Proposition, the IBP will prefer

[9] Weisman (1995) and Sibley and Weisman (1998), who analyze whether a monopolist subject to price-cap regulation has incentives to increase the costs of rivals to its vertically related affiliate, finds a similar result. They argue that these incentives may be weak unless the affiliate makes a sufficiently large share of the firm's total profit. See also Reiffen (1998) and Weisman (1998) for further discussions.

foreclosure if w_g is sufficiently low. A low global access price implies that the IBP earns only a limited price-cost margin on its deliveries to ISP A, and therefore the IBP is better off by foreclosing ISP A. Note that exclusion of ISP A is not a goal *per se*, but only a means to transfer market power from the regulated global bottleneck to the retail segment.

Domestic public policy

In line with the previous sections, we assume that the regulator can credibly commit itself to a certain local access price. Then we have that the regulator sets w_l at stage 1, the IBP sets f at stage 2, and ISP B (and ISP A if no foreclosure) sets quantities at stage 3.

Proposition 7: *Let us assume a VI market structure, the IBP has the option to reduce quality when serving ISP A, and the regulator can set w_l in a credible way. Then*

(i) if $w_g < w_g^l$, the regulator sets $w_l < w_l^*$ and there is foreclosure,

(ii) if $w_g^l < w_g < w_g^h$, the regulator sets $w_l > w_l^*$ and there is no foreclosure, and

(ii) if $w_g^h < w_g \leq w_g^*$, the regulator sets $w_l < w_l^*$ and there is no foreclosure.

Due to the IBP's ability to practice foreclosure the public policy becomes relatively complex. On the one hand, the regulator prefers a low access price w_l in order to increase consumer surplus. On the other hand, a low value of w_l implies that the IBP earns a large price-cost margin on its own sales. This tends to make it more profitable for the IBP to practice foreclosure, and thereby to dampen the rivalry in the end-user market. In Figure 2 we have illustrated our results with a numerical example. The dotted lines show how the regulator's choice of w_l is affected by the global access price w_g, while the solid lines show how the choice of the LAP is affected.

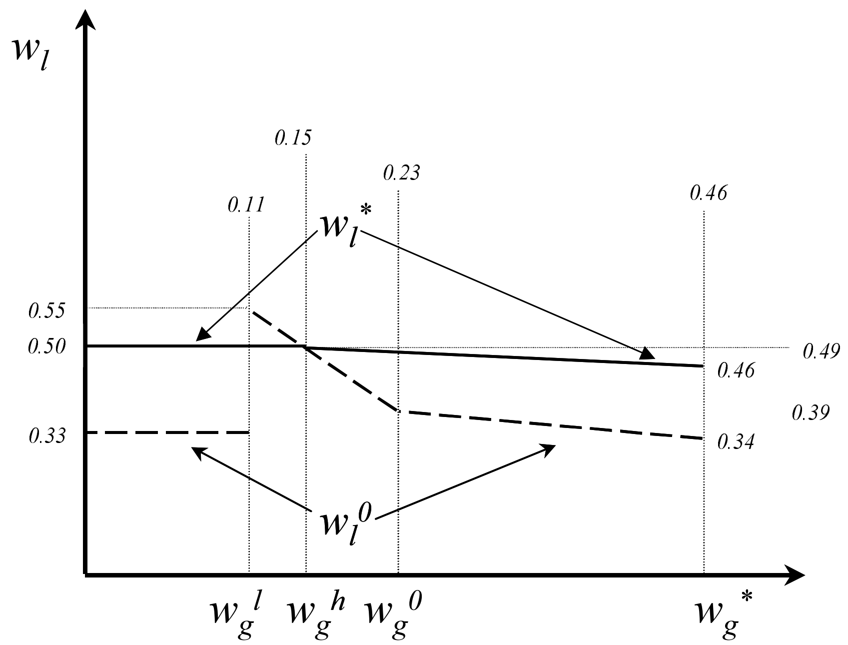

Figure 2: Regulator's or the LAP's choice of w_l (with $\alpha = 1$, $c_l = c_g = 0$).

By setting a high local access price the regulator makes the alternative to foreclosure less attractive for the IBP. If w_g is sufficiently low, the IBP earns such a small profit on its sale to the ISP A that it is not possible for the regulator to prevent the IBP from engaging in foreclosure. However, for an intermediate value of w_g the regulator sets such a high local access price that the IBP decides to switch from foreclosure to no foreclosure. In fact, for some values of w_g the regulator sets a *higher* local access price than the one the LAP would have chosen. Finally, if w_g is high the IBP would have chosen no foreclosure anyway. Then the regulator sets a lower access price than the LAP would have done, as was the case in the previous section where foreclosure was not an option.

It may seem as a surprise that for intermediate values of w_g the regulator sets a higher local access price than the LAP would set, since a high local access price would, all else equal, result in a high price in the output market. However, the welfare gain from a high access price is that it prevents foreclosure of ISP A and thereby ensures rivalry between the ISPs in the output market.

International versus domestic public policy

An exogenously determined w_g can, as argued above, be interpreted as a price cap enforced due to international coordination of public policy. A natural question, then, is how international and domestic public policy interact. Let w_l^o denote the regulator's choice of local access price. We have the following result:

Proposition 8: *Let us assume a VI market structure, the IBP has the option to reduce quality when serving ISP A, and the domestic regulator can set w_l^o in a credible way.*

(i) A price cap on w_g would reduce domestic welfare if $w_g \leq w_g^l$, and otherwise increase domestic welfare.

(ii) $\partial w_l^o / \partial w_g = 0$ if $w_g < w_g^l$, and $\partial w_l^o / \partial w_g < 0$ if $w_g > w_g^l$.

(iii) $\partial p / \partial w_g = 0$ *if* $w_g < w_g^l$, $\partial p / \partial w_g < 0$ *if* $w_g^l < w_g < w_g^o$, *and* $\partial p / \partial w_g > 0$ *if* $w_g > w_g^o$.

A restriction on the global access price would limit the IBP's ability to extract profits from the market in question, and thus be beneficial for the domestic country. We see that this is true if $w_g \geq w_g^l$. However, an even more restrictive price cap than that on global access would result in foreclosure and thereby higher price in the output market. In such a case the domestic country would be worse off than what would have been the case if there was no price cap on global access. Hence, an international regulation of global access price increases domestic welfare only if the global access price is not set below a certain threshold level. See Figure 3, where we use a numerical example to illustrate how the global access price affects prices and domestic welfare.

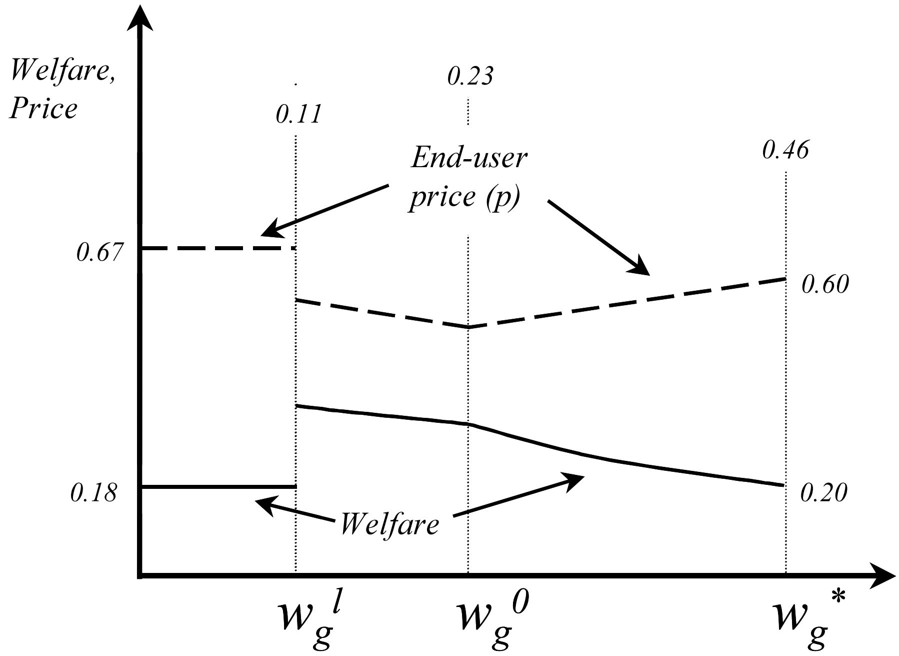

Figure 3: Welfare and end-user price (with $\alpha = 1$, $c_l = c_g = 0$).

Finally, note the potential conflict between international and domestic public policy. First, for high values of w_g a more restrictive price cap on global access results in a less restrictive price cap on local access, but end-user price falls. To understand this, note that a lower global access price shifts profits from the global access providers to the domestic country. The regulator maximizing domestic welfare finds it profitable to let both domestic consumers and domestic producers benefit from the profit shift. It partly offsets the reduction in w_g by increasing w_l. Second, and even more detrimental to the interest of the global access provider, for intermediate levels of w_g a more restrictive global access price increases both the local access price and the end-user price. The reason is that the domestic regulator now responds to a reduction in w_g by increasing w_l substantially, thereby preventing the IBP from practicing foreclosure. This suggests that more restrictive international regulation may be partly offset, and in some cases even more than offset, by less restrictive domestic regulation.

7 Discussion of results and conclusion

Domestic telecommunication firms have historically had a very dominant position in many countries. No surprise, then, that many of these firms have been facing a restrictive regulatory regime in their home country. In particular, some countries have enforced a cost-oriented price regulation for access sold to rivals in the downstream market. In this article we have shown that such a public policy might be misguided in a situation where inputs are provided by both local and foreign firms, which is the case in, for example, the market for Internet. A restrictive policy towards domestic firms may result in a larger profit potential for foreign firms and thereby a profit shift out of the country. The reverse may also be true, where a more restrictive international regulation may trigger a less restrictive domestic public policy and thereby a profit shift to the domestic country.

In this paper we have assumed that there is Cournot competition between the ISPs, and that there is no horizontal product differentiation. We have tested the robustness of our results with respect to these assumptions by analyzing Bertrand competition and differentiated products under vertical separation and vertical integration. The main results are still valid, except for some minor differences in the case of vertical separation. First, with horizontally differentiated products the local access provider will obviously not want a complete foreclosure of the rival, since there are some extra profits that can be extracted from the market by serving the rival. Second, recall that in the case with Cournot competition and identical products the local access provider would prefer to foreclose its downstream rival, and the regulator would choose not to regulate. With Bertrand competition and differentiated products the regulator may interfere. When products are close substitutes the regulator would set a higher access price than the local access provider would prefer. By doing so it would force the backbone provider to reduce its global access price. If the products are very differentiated, on the other hand, the regulator would set a lower local access price than the local access provider would prefer. The reason for this is that the downstream market is less competitive the larger the extent of product differentiation, and therfore a lower local access price is needed to avoid excessively high consumer prices.

We have not analyzed the implications of Betrand competition and horizontal product differentiation in the context where the integrated backbone provider can use quality reduction as an alternative foreclosure tool, so this may be an interesting extension. However, we would expect that the main results survive also in this case. The reason is that the IBP's trade-off between reducing its upstream profit and increasing its downstream profit when degrading the rival's quality on global backbone access will be the same. Our conjecture is that the key difference is that the rival will be only partly foreclosed if the ISPs supply differentiated services.

In the last section of the paper we assumed that the price of access to the global backbone is regulated, but we did not provide any discussion of how this is done. An interesting extension of the model would thus be to analyze a regulation game between a domestic and a foreign government. We have shown that a too restrictive price cap is detrimental to welfare, a case that both governments should have incentives to avoid. For a less restrictive price cap, however, there is likely to be a conflict of interests between the governments. In particular, the domestic government may prefer a relatively low global access price and a relatively high local access price, while the preferences of the foreign government are the opposite. It is therefore not obvious what will be the outcome of a regulation game. In fact, it is possible that we end up with a prisoner's dilemma, where both the local access price and the global access price are high.

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9 Appendix

Proof of Proposition 1

We can use equations (14) and (15) to find that $w_l^* = (2\alpha + 5c_l - 2c_g)/7$ and $w_g^* = [3(\alpha - c_l) + 4c_g]/7$. Inserting this into equations (10) and (11) it follows that $q_A^* = Q^* = 2(\alpha - c_l - c_g)/(7\beta)$ and $q_B^* = 0$. Q.E.D.

Proof of Proposition 2

(i) The quantities q_A^* and q_B^* are given by equations (10) and (11). Differentiating national welfare W from equation (8) with respect to w_l implies that $w_l = 2c_l + w_g - \alpha$ when $dW/dw_l = 0$. But this value of w_l is a violation of the constraint that $w_l \geq c_l$, c.f. equation (13). The regulator will therefore set $w_l = c_l$.

(ii) Inserting $w_l = c_l$ into equation (14) we have that $w_g^* = (\alpha + c_g - c_l)/2$. From equations (10) and (11) it thus follows that $q_A^* = q_B^* = (\alpha - c_l - c_g)/(6\beta)$ and $Q^* = (\alpha - c_l - c_g)/(3\beta)$. Inserting for the equilibrium values of w_l^*, w_g^* and Q^* from the proof of Proposition 1 into the welfare function (8) we find that with no regulation welfare is the following:

$$W^* = \frac{6}{49\beta}(\alpha - c_l - c_g)^2. \tag{26}$$

In a similar way, we find that with regulation welfare is the following:

$$W^{SO} = \frac{6}{54\beta}(\alpha - c_l - c_g)^2. \tag{27}$$

It is thus evident from equations (26) and (27) that $W^* > W^{SO}$. Q.E.D.

Proof of Proposition 3

The equilibrium quantities q_A^* and q_B^* are still given by (10) and (11). At the second stage of this game the IBP takes w_l as given, and maximizes π_{IBP} with respect to w_g. This generates the same reaction function $w_g(w_l)$ as in equation (14). Inserting this into the welfare function, equation (8), and differentiating with respect to w_l we find that

$$w_l^o = (\alpha + c_l - c_g)/2 \tag{28}$$

when $dW/dw_l = 0$. By comparing equations (15) and (28), and noting that $w_g > c_g$, we see that the regulator prefers a *higher price* than the domestic monopolist.

However, $w_l > w_l^*$ is not feasible since it would imply that ISP B sells a negative quantity. Hence, the regulator decides not to regulate w_l. Q.E.D.

Proof of Proposition 4

We can use equations (19) and (20) to find that $w_l^* = [45(\alpha - c_g) + 54c_l]/99$ and $w_g^* = [45(\alpha - c_l) + 54c_g]/99$, respectively. Inserting into (17) and (18) we thus find $Q^* = 4(\alpha - c_l - c_g)/(11\beta)$ and $q_A^* = q_B^* = 0.5Q^*$ if $c_l = c_g$. Q.E.D.

Proof of Proposition 5

The reaction function $w_g(w_l)$ and the equilibrium quantities q_A^* and q_B^* are given from equations (20), (17) and (18), respectively. The regulator maximizes $W = CS + \pi_{LAP}^I$ [c.f. equation (8)] with respect to w_l. Solving this maximization problem we find that

$$w_l^o = [35(\alpha - c_g) + 64c_l]/99. \tag{29}$$

This price chosen by the regulator is smaller than the one preferred by the LAP (provided that $a - c_l - c_g > 0$, which is the only interesting case). Q.E.D.

Proof of Proposition 6

Let us first examine the case where w_g is endogenous, such that $w_g = w_g^*$. If no foreclosure, we have the equilibrium values reported in the proof of Proposition 4. Inserting those into the IBP's profit function we have that

$$\pi_{IBP}^{f=0} = \frac{14}{121\beta}(\alpha - c_l - c_g)^2. \tag{30}$$

If foreclosure, $q_A = 0$ and w_g is non-existing since there are no deliveries from IBP to ISP A. Then it can be shown that $w_l^* = (\alpha - c_g + c_l)/2$ and $q_B = (\alpha - c_g - c_l)/(4\beta)$. Inserting the equilibrium values into the IBP's profit function, we have that

$$\pi_{IBP}^{f>0} = \frac{1}{16\beta}(\alpha - c_l - c_g)^2. \tag{31}$$

Then it can easily be checked that $\pi_{IBP}^{f=0} > \pi_{IBP}^{f>0}$, which implies that quality reduction is not profitable for the IBP.

Let us now assume that w_g is exogenous, *i.e.*, $w_g < w_g^*$. If foreclosure, w_g plays no role. Hence, $\pi_{IBP}^{f>0}$ is as stated above. If no foreclosure, the IBP's profit for a given w_g is now as follows:

$$\pi_{IBP}^{f=0} = (w_g - c_g)(25(\alpha - c_l) + 2c_g - 27w_g)/(50\beta) \tag{32}$$

Now it can be shown that $\pi_{IBP}^{f=0} > \pi_{IBP}^{f>0}$ if $w_g^c < w_g < w_g^t$. Furthermore, it can be shown that $w_g^t > w_g^*$. Then we have that $\pi_{IBP}^{f=0} > \pi_{IBP}^{f>0}$ if

$$w_g < \left[50(\alpha - c_l) + 58c_g - 5\sqrt{46}(\alpha - c_l - c_g)\right]/108 \equiv w_g^c \tag{33}$$

Foreclosure is then profitable for the IBP if $w_g < w_g^c$. Q.E.D.

Proof of Proposition 7

Suppose that the IBP practices foreclosure ($f > 0$). For a given level of w_l, the IBP's profit is as follows:

$$\pi_{IBP}^{f>0}(w_l) = \frac{1}{4\beta}(\alpha - w_l - c_g)^2. \tag{34}$$

If no foreclosure, for exogenous w_g and w_l the IBP's profit is as follows:

$$\pi_{IBP}^{f=0} = \frac{1}{9\beta}\left[(\alpha + 5w_g + 2c_l - 7c_g - 4w_l)\alpha - (5w_g - 4c_l + 5c_g - w_l)w_g + Y\right] \tag{35}$$

where $Y = (c_l - 4w_l)c_l + (c_g + 2c_l)c_g + (4w_l - 5c_g)w_l$. Now it can be shown that $\pi_{IBP}^{f=0} > \pi_{IBP}^{f>0}$ if $w_g^0 < w_g < w_g^1$, and that $w_g^1 > w_g^*$. Then the relevant value of w_g, where the IBP is indifferent between foreclosure and no foreclosure for a given level of w_l, is the following:

$$w_g^0 = \left[5(\alpha + c_g) + 2c_l - 7w_l\right]/10 \equiv w_g^c(w_l). \tag{36}$$

Solving with respect to w_l, we have that the IBP is indifferent if the regulator sets the following local access price:

$$w_l = \left[5(\alpha + c_g) + 2c_l - 10w_g\right]/7 \equiv w_l^c(w_g). \tag{37}$$

However, for sufficiently high w_l the IBP decides not to serve its own subsidiary ISP B in the no foreclosure situation (no foreclosure of ISP A). From (18) we find that $q_b \leq 0$ if

$$w_l \geq (\alpha + w_g - 2c_g + c_l)/2 \equiv w_l^0(w_g). \tag{38}$$

Hence, if foreclosure is not possible at $w_l = w_l^0$, then it is not possible at all. By comparison, we find that $w_l^c(w_g) \leq w_l^0(w_g)$ if:

$$w_g \geq (\alpha - c_l + 8c_g)/9 \equiv w_g^l. \tag{39}$$

For $w_g < w_g^l$, it is thus not possible by setting a high w_l to force the IBP not to foreclosure.

Let us now consider the case where $w_g^l < w_g < w_g^c(w_l)$. We know from Proposition 6 that in such a case the IBP would prefer foreclosure. Given foreclosure, the regulator maximizes welfare by setting $w_l^o = (\alpha - c_g + 2c_l)/3$. The welfare is in this case equal to:

$$W^{f>0} = \frac{1}{6\beta}(\alpha - c_l - c_g)^2. \tag{40}$$

Alternatively, the regulator could set w_l so that the IBP prefers no foreclosure rather than foreclosure. If no foreclosure, we have the welfare specified in (8). If we now plug in equilibrium quantities from (17) and (18), as well as the critical value of the local access price to ensure no foreclosure, $w_l^c(w_g)$, we have the following welfare:

$$W^{f=0} = \frac{1}{98\beta}\left[31\alpha^2 - 62\alpha c_l - 12\alpha w_g + 31c_l^2 + 12c_l w_g - 51w_g^2 + X\right] \tag{41}$$

where $X = -50\alpha c_g - 32c_g^2 + 50c_g c_l + 114c_g w_g$. Then we have that $W^{f=0} > W^{f>0}$ if:

$$[22(\alpha - c_l) - 51w_g + 29c_g][2(\alpha - c_l) + 3w_g - 5c_g] > 0, \tag{42}$$

and it can be shown that $W^{f=0} > W^{f>0}$ if :

$$w_g < [22(\alpha - c_l) + 29c_g]/51 \equiv w_g^u, \tag{43}$$

where w_g^u denotes the value of w_g for which the regulator is indifferent between foreclosure and no foreclosure. Let us compare this critical value with the value where the IBP is indifferent between foreclosure and no foreclosure, given that the regulator sets the optimal w_l for the case of no foreclosure. We plug the regulator's choice of w_l in the case of no foreclosure into $w_g^c(w_l)$. It can be shown that in such a case it is unprofitable for the IBP to engage in foreclosure if

$$w_g > (\alpha - c_l + 2c_g)/3 \equiv w_g^o. \tag{44}$$

By comparison, we have that $w_g^u > w_g^o$. It implies that when w_g is close to w_g^u, the regulator would prefer to set a local access price such that the IBP's best choice is no foreclosure. Then we have shown that the regulator sets w_l so that no foreclosure occurs for $w_g^l < w_g < w_g^o$.

Let us now consider the case when w_g is close to w_g^*. In this case it can be shown that if the regulator sets its optimal access price in the case of no foreclosure, the IBP would choose no foreclosure. Could the regulator then prefer to set w_l so low that the IBP chooses foreclosure? We check for $w_g = w_g^*$. We plug in for the equilibrium values of q_A and q_B, the regulator's choice of w_l and the IBP's choice of w_g. We find that the welfare is the following if no foreclosure:

$$W^{f=0} = \frac{37}{198}(\alpha - c_l - c_g)^2. \tag{45}$$

Alternatively, the regulator could set w_l so that the IBP prefers foreclosure rather than no foreclosure. If foreclosure, we have the welfare specified in (8) for a given w_l. In this case the critical value of the local access price to ensure no foreclosure, w_l^c, is equal to c_l. Then we have the following welfare if foreclosure:

$$W^{f>0} = \frac{1}{8}(\alpha - c_l - c_g)^2. \tag{46}$$

Now it can easily be shown that $W^{f=0} > W^{f>0}$. This implies that the regulator will not prefer foreclosure if no regulation of w_g, and it follows straightforward that it would neither prefer foreclosure for lower w_g.

Finally, let us check how w_g affects the regulator's choice of w_l. First, let us find the value of w_g where the regulator would set w_l identical to the one chosen by the LAP. $w_l^c(w_g)$ denotes the price the regulator has to set to make the IBP indifferent between foreclosure and no foreclosure, while $w_l(w_g)$ shown in (19) is the LAP's choice of access price given no foreclosure. We have that $w_l^c(w_g) = w_l(w_g)$ if

$$w_g = \left[(\alpha - c_l)5 + 26c_g\right]/31 \equiv w_g^{h1} \tag{47}$$

However, the LAP's local access price may increase following a shift from no foreclosure to foreclosure. Comparing (19), the LAP's price for a given w_g and no foreclosure, with the LAP's price if foreclosure ($w_l = (\alpha - c_l - c_g)/2$), we have that the LAP sets a higher price if foreclosure than if no foreclosure if:

$$w_g > 10c_l + c_g \equiv w_g^n \tag{48}$$

It can be shown that $w_g^{h1} \lesseqgtr w_g^n$. If $w_g^{h1} > w_g^n$, then the LAP's price would increase as a result of a shift from no foreclosure to foreclosure. If so, we have to compare $w_l^c(w_g)$ with LAP's price if foreclosure. We have that those two prices are identical when:

$$w_g = (3\alpha + 11c_l + 17c_g)/20 \equiv w_g^{h2}. \tag{49}$$

Then we have the following definition of the critical value where the regulator and the LAP would set identical price:

$$w_g^h = \begin{cases} w_g^{h1} & \text{if} \quad w_g < 10c_l + c_g \\ w_g^{h2} & \text{otherwise} \end{cases} \tag{50}$$

It can easily be checked that $w_l^o < w_l^*$ if $w_g > w_g^h$ and that $w_l^o < w_l^*$ if $w_g^l < w_g < w_g^h$. If $w_g < w_g^l$, the IBP practices foreclosure and the LAP would set $w_l^* = (\alpha - c_g - c_l)/2$ and the regulator would set $w_l^o = (\alpha - c_g + 2c_l)/3$. Then we have that $w_l^* > w_l^o$ if $\alpha - c_g - c_l > 0$, the only interesting case. Q.E.D.

Proof of Proposition 8

From Proposition 7 we know that $W = \frac{1}{6\beta}(\alpha - c_l - c_g)^2$ when $w_g < w_g^l$. If $w_g = w_g^*$, then for $w_l = w_l^o$ it can be shown that $W = \frac{37}{198\beta}(\alpha - c_l - c_g)^2$, which is higher that the welfare when $w_g < w_g^l$.

If $w_g < w_g^l$, then the IBP chooses foreclosure and the regulator's choice of w_l is unaffected by w_g. If $w_g^l < w_g < w_g^o$, then we have that

$$\partial w_l^c(w_g)/\partial w_g = -10/7. \tag{51}$$

If $w_g^o < w_g \leq w_g^*$, then it can be shown that the regulator's choice of w_l for a given w_g is the following:

$$w_l^o(w_g) = [135\alpha - 75c_g + 178c_l - 60w_g]/313, \tag{52}$$

and it follows straight forward that:

$$\partial w_l^o(w_g)/\partial w_g = -60/313. \tag{53}$$

Finally, let us check how w_g affects end-user price. If $w_g < w_g^l$, then w_g has no effect on end-user price. If $w_g^l < w_g < w_g^o$, then we plug w_l^c into (17) and (18) into (1) and find that

$$\partial p/\partial w_g = -1/7. \tag{54}$$

If $w_g^o < w_g \leq w_g^*$, then we plug w_l^o from the proof of Proposition 5 into (17) and (18) and (17) and (18) into (1) and find that

$$\partial p/\partial w_g = 1/3. \tag{55}$$

Q.E.D.