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Access Price Regulation, Competition and Broadband Investment

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ABSTRACT

A vertically integrated firm invests in network quality and provides bottleneck access to its own downstream subsidiary and an independent firm, which offer differentiated value-added services. We consider two model variants, one in which the regulator commits to an access price before quality investment, and one in which there are first-mover advantages, such as consumer switching costs. We find that, contrary to common wisdom, in both variants access regulation may simultaneously promote consumer welfare and foster investment incentives.

Keywords: Access regulation, Broadband investment, Switching costs.
JEL Classification: L51; L96; O31.

1. Introduction

One of the most important conflicting priorities in telecommunications is how to foster investment in very fast broadband access networks (the so-called Next Generation Access networks, or NGA),[1] while simultaneously promoting sustainable competition in value-added services. On the one hand, there is a wide consensus that light-handed regulation (or even no regulation at all) is essential to ensure a fair return on infrastructure investment, and thereby provide firms with sufficient incentives to invest. On the other hand, since NGA are not easily replicable, then the regulator should monitor that the bottleneck owner sells local access to competitors at reasonable and non-discriminatory terms.

The purpose of this paper is to show that, in some relevant cases, access price regulation may improve long-run welfare (i.e., including NGA investment) as compared to the case without regulation. Indeed, we find that, in the considered cases, access price regulation may increase consumer surplus, and simultaneously encourage investment in network quality.

We study an industry where the bottleneck owner provides local access to two competing downstream firms, one of which is its own subsidiary. Both firms benefit from investment in network quality, but they have a different ability to offer value-added services to end users (e.g., in terms of content provision).

In the first model variant, the regulator commits to an access price before the incumbent carries out NGA investment. In practice, certainty and stability of regulation are key elements to foster investment. Since investment is an irreversible long-term decision, it may be argued that the regulator cannot commit to a given policy over the whole economic life of the assets. To reinforce the credibility of regulation, the

[1] NGA deployment is recognized as a key factor to foster job creation and economic growth (see, for instance, the ‘Digital Agenda for Europe’; http://ec.europa.eu/information_society/digital-agenda). In particular, NGA enable operators to offer a variety of high quality innovative services (see Avenali *et al*., 2013, for a study on the welfare effects of bundling strategies).

EU Commission issued a Recommendation[2] that provides investors with information on the future regulation of NGA. Moreover, in the EU, regulators' decisions are constrained in the period between two successive analyses of relevant markets. Since the regulator and the incumbent repeatedly interact on a number of occasions, then, if the regulator reneges on its decisions today, it loses future credibility (Nitsche and Wiethaus, 2011).

The literature is mixed on the presence and the effects of regulatory commitment. Foros (2004) assumes that the regulator sets the access price discretionary after the investment stage. He shows that access regulation reduces investment, and possibly consumer surplus. Mizuno and Yoshino (2012) also assume regulatory discretion, but they find conditions for which the vertically integrated firm invests high. In a different framework, Bourreau and Dogan (2006) find that access regulation may foster investment when the regulator can commit. Some papers show how the regulator can use two-part access tariffs (Brito *et al*., 2010) or multi-period access pricing schemes (Avenali *et al*., 2010) to ensure dynamic consistency. On the other hand, Cambini and Silvestri (2012) assume that the regulator can commit to a given regime, but not to the level of the access price.

In our model, an unregulated access price dampens competition, and often leads to market foreclosure of the independent downstream firm. Thus, we argue that the commitment issue affects the case without regulation at least as much as the case where the regulator decides first. Indeed, in the former case, the regulator should necessarily intervene *ex post* (i.e., when investment is already sunk) to strengthen competition, thereby reneging on its initial decision to rely on market forces alone.

In the second model variant, we assume that there are first-mover advantages, such as consumer switching costs. Since the incumbent has already built the customer base, switching costs adversely affect the rival firm's market share. We predict the worst possible outcome in the absence of access regulation. Actually, the incumbent may have the incentive to under-invest to deter entry, particularly when the rival could in principle provide better services. Thus, with switching costs, the incumbent's conduct may reduce quality, and thereby lead to market foreclosure. Access price regulation can correct these distortions, even if the regulator does not have commitment ability.

This paper is organized as follows. Section 2 presents the basic assumptions. Section 3 deals with regulatory commitment. Section 4 considers switching costs. Section 5 concludes.

2. Basic Assumptions

Our basic model follows Foros (2004). A vertically integrated firm (firm 1) sells wholesale access to two competing downstream firms, its subsidiary and an independent rival (firm 2). Downstream firms benefit from the upstream firm's investment *x* improving the local access input quality. However, they have a different ability β_i (i=1,2) to transform input into output, that is, to offer value-added services to end users (e.g., in terms of content provision).

Consumers' valuation of firm *i*'s services is expressed as $s+\beta_i x$, where *s* is the willingness to pay (hereafter, wtp) for basic services,[3] and $\beta_i x$ is the wtp for value-added services that use the enhanced input quality. Thus, $\beta_1, \beta_2 \in [0,1]$ measure the demand-side spillover from the bottleneck owner's investment, respectively to its subsidiary and the rival.[4]

A consumer of type *s* buys from firm *i* if $s+\beta_i x-p_i > s+\beta_j x-p_j$ ($i \neq j$), where p_i and p_j are retail prices, unless both expressions are negative (in which case *s* will not buy). Consumers have unit demands. If both firms are active then quality-adjusted prices are such that $p_1 - \beta_1 x = p_2 - \beta_2 x = P$, so as types $s \geq P$ enter the market. Given uniform distribution, there are $a-P$ active consumers. Hence, $Q=a-P$ must hold, where $Q=q_1+q_2$ is the quantity sold. Thus, the inverse demand curves faced by the two firms are $p_1=a_1-q_1-q_2$ and $p_2=a_2-q_1-q_2$, where $a_1=a+\beta_1 x$ and $a_2=a+\beta_2 x$ include demand-side spillovers from investment.[5]

Firm 1 has a constant upstream marginal (per user) cost *c*. It also has an investment cost in network quality $C(x)=$□□$x^2/2$, where *x* is for every potential user. Downstream firms' costs other than local access are normalized to zero. Hence, firms' profit functions are respectively

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[2] Commission Recommendation 2010/572/EU of 20 September 2010 on regulated access to Next Generation Access Networks (http://europa.eu/legislation_summaries/information_society/strategies/si0018_en.htm).

[3] To avoid corner solutions with full participation, *s* is taken to be uniformly distributed between $-\infty$ and a>0.

[4] The demand structure is also similar to Katz and Shapiro (1985) and (since then) several other authors.

[5] An increase in *x* implies parallel upward shifts in demand curves. If $\beta_1=\beta_2$, value-added services (e.g. video and interactive gaming) are homogeneous. If $\beta_i>\beta_j$ (i, j=1,2; $i \neq j$) then firm *i* offers higher quality than firm *j*.

$\pi_1 = (p_1 - c)q_1 + (w - c)q_2 - \varphi x^2/2$ and $\pi_2 = (p_2 - w)q_2$, where *w* is the access price.[6] Social welfare is $W = CS + \pi_1 + \pi_2$, where $CS = (a_1 - p_1)q_1/2 + (a_2 - p_2)q_2/2$ is consumer surplus.

In the next sections, we solve a pair of relevant model variants.

3. Regulatory Commitment

In this section, we assume that the regulator maximizes welfare *ex ante*. Thus, it can credibly commit to an access price before the facility-based firm invests in network quality. We consider the following three-stage game. At the first stage, the regulator (or firm 1) chooses the access price *w*. At the second stage, firm 1 chooses the investment level *x*. At the third stage, downstream firms compete *à la* Cournot.[7] We solve the game backwards.

First, we solve the third stage and obtain the equilibrium quantities resulting from Cournot competition, which can be interpreted as the number of retail subscriptions:

$$q_1^* = [(a-c) + (w-c) + x(2\beta_1 - \beta_2)]/3; \quad q_2^* = [(a-c) - 2(w-c) + x(2\beta_2 - \beta_1)]/3;$$

$$Q^* = [2(a-c) - (w-c) + x(\beta_1 + \beta_2)]/3.$$

If $2\beta_i - \beta_j \geq 0$ $(i, j = 1,2;\ i \neq j)$, then downstream firms' value-added services are not too different, and retail quantities are non-decreasing in quality *x* (for a given access price). Unless otherwise stated, we maintain this assumption throughout the paper.

At the second stage, the facility-based firm chooses the investment level *x* that maximizes its profit. The first order condition (FOC) on firm 1's profit with respect to (wrt) *x* gives:

$$x^* = \frac{(w-c)(\beta_1 + 4\beta_2) + 2(a-c)(2\beta_1 - \beta_2)}{A},$$

where $A = 9\varphi - 2(2\beta_1 - \beta_2)^2$, and the second order condition (SOC) holds as long as $A>0$.[8]

3.1. Unregulated Access Price

At the first stage, firm 1 sets the access price that maximizes its profit, while anticipating quantities (third stage) and quality (second stage). The FOC on firm 1's profit wrt *w* gives:

$$w^* = \frac{1}{2}\left[(a+c) + \frac{\beta_1(a-c)(\beta_1 + 4\beta_2)}{A^*}\right],$$

where $A^* = 10\varphi - 9\beta_1^2 + 8\beta_1\beta_2 - 4\beta_2^2$, and the SOC holds as long as $A^*>0$.

Inserting for w^* into the equilibrium investment level and retail quantities, we have:

$$x^* = \frac{5\beta_1(a-c)}{A^*};\ q_1^* = \frac{(a-c)(5\varphi - \beta_1^2 + 3\beta_1\beta_2 - 2\beta_2^2)}{A^*};\ q_2^* = \frac{2\beta_1(\beta_2 - \beta_1)(a-c)}{A^*};$$

$$Q^* = \frac{(a-c)(5\varphi - 3\beta_1^2 + 5\beta_1\beta_2 - 2\beta_2^2)}{A^*}.$$

When $\beta_1 \geq \beta_2$, firm 1 forecloses the rival and achieves downstream monopoly. In such a case, firm 1 sets the investment level x^m and retail quantity q_1^m under monopoly as follows:

$$x^m = \frac{(a-c)\beta_1}{2\varphi - \beta_1^2}; \qquad q_1^m = \frac{(a-c)\varphi}{2\varphi - \beta_1^2},$$

where the SOC holds as long as $2\varphi - \beta_1^2 > 0$. To summarize:

Result 1. If the access price is unregulated, then $\beta_2 > \beta_1$ is a necessary and sufficient condition for the rival downstream firm to be active.

Result 2. If the access price is unregulated, then quality is higher with market sharing (i.e., when $\beta_2 > \beta_1$) than under foreclosure. Both quality and the rival firm's quantity increase in β_2.

The results obtained here are the same as in Foros (2004). Indeed, when firm 1 freely sets the access price, reversing the order of moves in the first two stages of the game has no bite. When firm 2 has

[6] This is interpreted as a fee for each subscriber served by firm 2 by using the local access input sold by firm 1.

[7] Indeed, they face capacity constraints in regional and global backbones, which are shared facilities. Thus, the quantity game recalls a capacity-price game where firms set the backbone capacity and then compete in prices.

[8] This implies that the cost parameter φ is high enough that firm 1 does not make an arbitrarily high investment.

higher ability, firm 1 invests and thereby allows the rival firm to gain market share, because firm 1 can capture some of the rival's rents through the access price.

3.2. Regulated Access Price

If the regulator (rather than firm 1) sets the access price at the first stage, then the objective function to be maximized is social welfare. The FOC on social welfare wrt *w* gives:

$$w^r = c-(a-c)\cdot B,$$

where $B = D/E$, with $D = 2(\beta_1-\beta_2)(2\beta_1-\beta_2)(5\beta_1^2-5\beta_1\beta_2+8\beta_2^2)+\varphi(9\varphi-32\beta_1^2+38\beta_1\beta_2-38\beta_2^2)$, and $E=(\beta_1-2\beta_2)(13\beta_1^3+16\beta_1^2\beta_2-19\beta_1\beta_2^2+14\beta_2^3)+\varphi(9\varphi-23\beta_1^2+2\beta_1\beta_2+52\beta_2^2)$. The SOC on w^r holds as long as *E*>0. Furthermore, $B \le 0$ must hold to avoid that w^r falls below firm 1's marginal cost.[9] We can prove that *E*>0 and $B \le 0$ simultaneously hold when the investment cost is sufficiently convex, but not too much (see the following sections).

Inserting for w^r into the equilibrium investment level, we obtain:

$$x^r = (a-c)\left[\frac{3\varphi(\beta_1-2\beta_2)-4(\beta_1+\beta_2)(\beta_1^2-3\beta_1\beta_2-\beta_2^2)}{E}\right].$$

3.3. Comparison of Results with and without Access Price Regulation

Let us compare the results obtained with and without access regulation. To fix ideas, we focus on the case where, absent regulation, there is downstream competition.

For simplicity, assume that $\beta_1 < \beta_2 \equiv 1$, so that $\beta_1 \in [1/2, 1)$. Then, firm 2 is active even if the access price is not regulated (Result 1), and the SOC on x^* holds as long as $\varphi > 1/2$. On the other hand, we can find that w^r is the optimal regulated access price as long as □>0.65 (to ensure $w^r \ge c$, φ should also be lower than a critical value that rises with β_1, which, however, is not essential to our analysis). Thus, for comparison purposes, we require □>0.65.

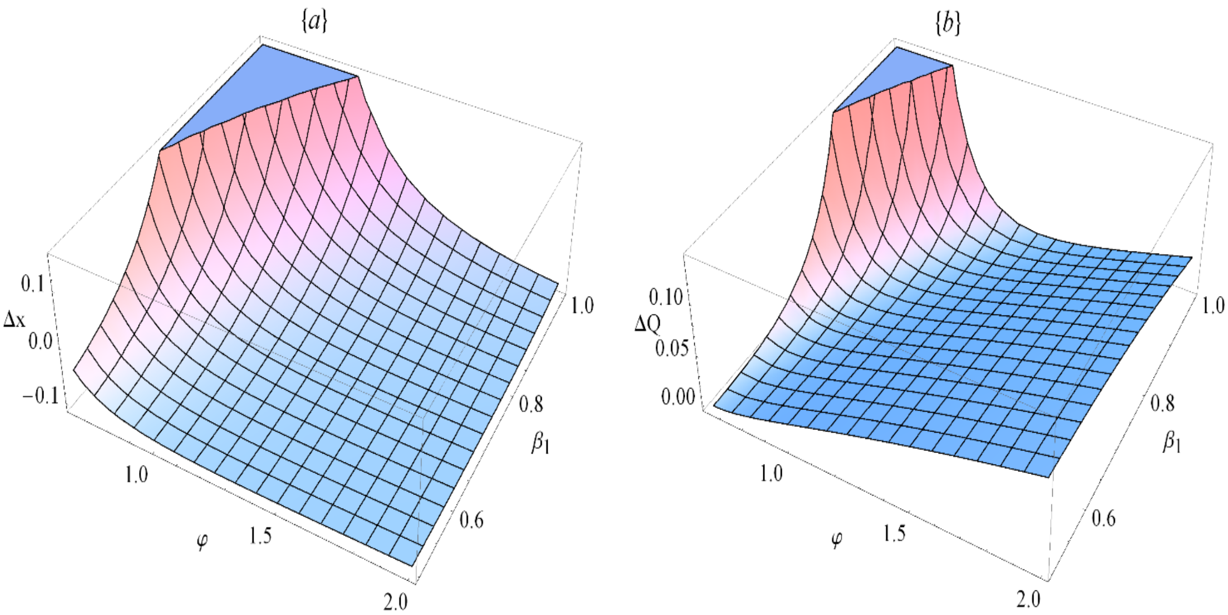

Figure-1. (a) Quality investment, and: (b) Total quantity, with and without regulation.

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[9] Under regulatory commitment, having $w^r \ge c$ is essential to preserve firm 1's investment incentives. Thus, if *B*>0 then the regulator sets $w^r = c$, and the results with regulatory commitment replicate those with discretion.

First, we compare investment levels. We analyse the sign of $\Delta x = x^r - x^*$ in the range of feasible values of φ. Figure 1, panel (a), shows that $\Delta x > 0$, that is, quality is higher with than without access price regulation, as long as the investment cost is not too convex. For a given φ, Δx rises with the facility-based firm's ability to offer value-added services.[10]

As to consumer surplus, we analyse the sign of $\Delta Q = Q^r - Q^*$. Figure 1, panel (b), shows that $\Delta Q > 0$ in almost the entire feasible space.[11] Thus, access regulation may raise consumer surplus for relatively low values of □□ that is, when it also raises investment. To sum up:[12]

Result 3. If $\beta_1 < \beta_2 \equiv 1$ then: (*i*) quality is higher with than without access regulation as long as the investment cost is not too convex; (*ii*) consumer surplus is almost always higher with than without access regulation.

3.4. Comparison of Results with Regulatory Commitment Versus Discretion

Absent commitment ability, the regulator sets the access price at marginal cost, given that investment is already sunk. Hence, access regulation reduces quality, but raises consumer surplus as long as the investment cost is sufficiently convex (see Foros, 2004).

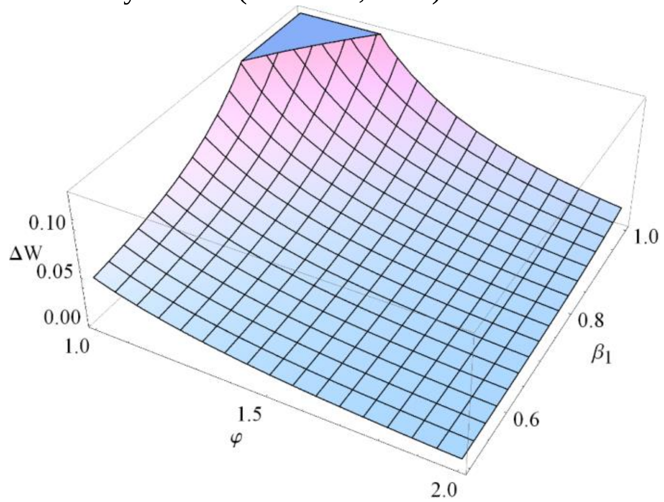

Figure-2. Social welfare under regulatory commitment versus discretion.

Let us briefly compare the alternative cases of regulatory commitment and discretion. We find a clear-cut result in terms of social welfare. When the regulator moves first and sets $w^r = c - (a-c)\cdot B$, calculation yields that the associated welfare level W_1 is:

$$W_1 = \frac{(a-c)^2\left(4(4\beta_1 - 5\beta_2)(\beta_1 - \beta_2)^2(\beta_1 + \beta_2) - 12(2\beta_1 - 3\beta_2)(\beta_1 + \beta_2)\varphi + 9\varphi^2\right)}{2\left(13\beta_1^4 - 10\beta_1^3\beta_2 - 28\beta_2^4 + 52\beta_2^2\varphi + 9\varphi^2 + 21\beta_1\beta_2\left(26\beta_2^2 + \varphi\right) - \beta_1^2\left(51\beta_2^2 + 23\varphi\right)\right)},$$

while, when firm 1 moves first and thus $w^r = c$, the associated welfare level W_2 is:

$$W_2 = \frac{2(a-c)^2\left[3\left(2\beta_1^2 - 3\beta_1\beta_2 + \beta_2^2\right)^2 - (14\beta_1 - 13\beta_2)(2\beta_1 - \beta_2)\varphi + 18\varphi^2\right]}{\left[9\varphi - 2(2\beta_1 - \beta_2)^2\right]^2}.$$

Given that $1 \equiv \beta_2 > \beta_1$, Figure 2 shows that $\Delta W = W_1 - W_2 > 0$ in the relevant parameter space,[13] particularly if the investment cost is not too convex.

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[10] If φ is slightly above the minimum value (0.65), then regulation increases investment when $\beta_1 \geq 0.59$. As φ grows, $\Delta x > 0$ only holds for higher β_1 values. If $\beta_1 \to 1$, then regulation increases investment when $\varphi \leq 4/3$.

[11] Generally, ΔQ rises with □, but has a peak when $\varphi \to 0.65$ and $\beta_1 \to 1$. If □□=1/2, then $\Delta Q > 0$ when □>0.75. As □□ rises, the range of □ values for which $\Delta Q < 0$ gets smaller (if $\beta_1 \to 1$, it collapses to □□□□□□.

[12] Consider the alternative case where, absent regulation, firm 1 monopolizes the retail market (i.e., $1 \equiv \beta_1 > \beta_2$). In this case, quality is lower with than without access regulation. Since access regulation promotes competition, consumer surplus is higher with than without regulation as long as the investment cost is sufficiently convex.

[13] In the alternative case where $1 \equiv \beta_1 \geq \beta_2$, the qualitative results are not affected.

Result 4. Social welfare is higher under regulatory commitment than discretion.

4. First-Mover Advantages: Consumer Switching Costs

Consider the case where consumers have a switching cost *k* of changing service provider from firm 1 to firm 2. In a third-stage Cournot equilibrium, for both firms to be active, the (quality-adjusted) price that consumers pay to firm 2 should be *k* per unit lower than the price paid to firm 1. This case is formally equivalent to the alternative case where there are no switching costs, but firm 2 has an additional unit (i.e., per user) production cost of *k*. Thus, firms' profit functions can be written as $\pi_1 = (p_1 - c)q_1 + (w - c)q_2 - \varphi x^2/2$ and $\pi_2 = (p_2 - k - w)q_2$.

Consider the following three-stage game. At stage one, firm 1 sets *x*. At stage two, firm 1 (or the regulator) sets *w*. At stage three, downstream firms compete in quantities. We focus on the unregulated case, and find that switching costs may harm quality and competition. We then show how access price regulation can avoid these adverse effects.

Before solving the game, for our purposes, it is worth considering the benchmark case without investment. We can easily prove the following result.

Result 5. If firm 1 does not invest in quality, then it sets an access price that forecloses firm 2 from the market, while the regulator would set the access price at marginal cost. Therefore, consumer surplus and social welfare are higher with than without access price regulation.

Consider now the case with investment. By solving the third stage of the game, we obtain the Cournot equilibrium quantities:

$$q_1^* = [(a-c) + (w-c) + k + x(2\beta_1 - \beta_2)]/3; \quad q_2^* = [(a-c) - 2(w-c) - 2k + x(2\beta_2 - \beta_1)]/3;$$

$$Q^* = [2(a-c) - (w-c) - k + x(\beta_1 + \beta_2)]/3.$$

For a given access price, switching costs negatively (positively) affect firm 2's (firm 1's) market share. The net effect is that switching costs reduce the total quantity sold.

4.1. Unregulated Access Price

At the second stage, firm 1's profit maximization gives the optimal unregulated access price:

$$w^* = c + \left[\frac{(a-c)}{2} + \frac{x(\beta_1 + 4\beta_2)}{10} - \frac{2}{5}k\right].$$

Inserting for w^* into the equilibrium retail quantities, we obtain:

$$q_1^* = \frac{(a-c)}{2} + x\frac{(7\beta_1 - 2\beta_2)}{10} + \frac{1}{5}k; \quad q_2^* = \frac{2}{5}(x(\beta_2 - \beta_1) - k); \quad Q^* = \frac{(a+c)}{2} + x\frac{(3\beta_1 + 2\beta_2)}{10} - \frac{1}{5}k.$$

Therefore, we find that: $q_2^* > 0 \Leftrightarrow k < x(\beta_2 - \beta_1) \Leftrightarrow \beta_2 > \beta_1 + k/x$.

Result 6. In the presence of consumer switching costs, if the access price is unregulated then $\beta_2 > \beta_1 + k/x$ is a necessary and sufficient condition for firm 2 to be active.

It follows that, albeit firm 2 has higher ability than firm 1 ($\beta_2 > \beta_1$), firm 2 is foreclosed as long as investment is low, that is, $x \le k/(\beta_2 - \beta_1)$. For a given quality, firm 2 is active if and only if it has a high enough efficiency advantage, which has to rise when investment declines. Thus, switching costs lead to easier monopolization of the retail market by firm 1.

4.2. Investment Level

At the first stage, firm 1 sets the investment level that maximizes its profit, while anticipating retail quantities and the access price. The FOC on firm 1's profit wrt *x* gives:

$$x^* = \frac{5\beta_1(a-c) + 4k(\beta_1 - \beta_2)}{A^*},$$

and the SOC is fulfilled as long as $A^* = 10\varphi - 9\beta_1^2 + 8\beta_1\beta_2 - 4\beta_2^2 > 0$.

Since $dx^*/dk < 0$ then switching costs reduce investment (recall that firm 2 is active when it has much higher ability to use the improved input). We also find that $dx^*/d\beta_2$ is the sum of two terms: the first one is positive (as without switching costs), while the second one is negative and proportional to switching costs. In contrast to Result 2, we find what follows.

Result 7. In the presence of switching costs, an increase in the rival firm's ability to offer value-added services may reduce firm 1's investment, even if the access price is unregulated. Inserting for x^*, we find $q_2^* = \left(2\beta_1(\beta_2 - \beta_1)(a-c) - 2k(2\varphi - \beta_1^2)\right)/A^*$. Hence, $q_2^* > 0$ if and only if $k < \bar{\bar{k}} = \frac{\beta_1(\beta_2 - \beta_1)(a-c)}{2\varphi - \beta_1^2}$, otherwise (i.e., for $k \ge \bar{\bar{k}}$) switching costs prevent competition (since $d\bar{\bar{k}}/d\beta_2 > 0$, the critical value of *k* leading to retail monopoly rises in firm 2's ability).

4.3. A Relevant Case: Under-Investment and Foreclosure

We have assumed so far that $2\beta_i - \beta_j \ge 0$ ($i, j = 1,2$; $i \ne j$), so as, for a given access price, quantities are non-decreasing in *x*. If this condition is violated, and firm 2 has superior ability, then firm 1 reduces quantity as investment rises. In this context, since quantities are strategic substitutes, firm 1 may use under-investment to foreclose the rival from the market.

Assume that $\beta_1 = \vartheta \cdot \beta_2$, where $\vartheta < 2/7$. This implies $dq_1^*/dx < 0$. Consider first the case without switching costs. We find that firm 1 invests $x^* = 5\beta_2(a-c)\vartheta/A'$, where $x^* > 0$ as long as $A' = 10\varphi - \beta_2^2\left(9\vartheta^2 - 8\vartheta + 4\right) > 0$ (so that the SOC holds). Thus, firm 1 invests in quality even if this reduces its market share, because it benefits from wholesale revenues due to the increase in the access price (since $dw/dx > 0$) and in the quantity sold to firm 2. Given that $dx^*/d\vartheta > 0$, the optimal investment rises with firm 1's relative ability to offer enhanced services. We find:

$$q_1^* = \frac{(a-c)}{2} - x\frac{\beta_2}{10}(2 - 7\vartheta) > 0 \Leftrightarrow x < \hat{x}(\vartheta) = \frac{5(a-c)}{\beta_2(2-7\vartheta)}.$$

We also find:

$$x^* \ge \hat{x}(\vartheta) \Leftrightarrow \varphi \ge \hat{\varphi}(\vartheta) = \beta_2^2(\vartheta - 2)(\vartheta - 1)/5,$$

where $d\hat{\varphi}/d\vartheta < 0$ when $\vartheta < 2/7$. Hence, firm 1 is active in the retail market if the investment cost is not too convex ($\varphi < \hat{\varphi}(\vartheta)$). For higher values of φ, firm 1 exits the market and leaves it to firm 2, which has higher ability to offer enhanced services. Since downstream production is delegated to the efficient rival (*à la* ECPR; see Baumol and Sidak, 1994), then we may have a positive welfare effect.

Consider now the case with switching costs. We find $x^* = \frac{5\beta_2(a-c)\vartheta - 4k\beta_2(1-\vartheta)}{A'}$, so that switching costs reduce investment. Moreover, the following condition holds:

$$x^* \le 0 \Leftrightarrow k \ge \hat{k}(\vartheta) = 5(a-c)\vartheta/4(1-\vartheta),$$

with $d\hat{k}/d\vartheta = 5(a-c)/4(1-\vartheta)^2 > 0$. Thus, the lower firm 1's relative ability, the lower the critical value of switching costs above which firm 1 does not invest.

By comparing the critical values $\hat{k}(\vartheta)$ and $\bar{\bar{k}}$ (section 4.2), we obtain that:

$$\bar{\bar{k}} > \hat{k}(\vartheta) \Leftrightarrow \beta_2(1-\vartheta)^2/(2\varphi - \vartheta^2\beta_2^2) > 5/4 \Leftrightarrow \vartheta^2\beta_2^2/2 = \varphi_a < \varphi < \varphi_b = \beta_2^2\vartheta\left(4\vartheta^2 - 3\vartheta + 4\right)/10,$$

where $\varphi_b - \varphi_a \ge 0$. Hence, there is a range of values of *k* that, in principle, are compatible with competition (provided that $x^* > 0$), but nonetheless leave firm 1 with no incentive to invest. It follows that, for such values of *k*, firm 2 is foreclosed from the market (Result 5).

To summarize, the worst possible outcome may occur in the presence of switching costs.

Result 8. Assume that the facility-based firm has much lower ability than the rival has. Then, depending on switching costs, firm 1 may not invest in quality to foreclose the rival.

In such a case, there is a lack of quality investment, which in turn precludes the viability of entry exactly when, on the basis of the improved input quality, competition would provide consumers with substantial benefits. Note that firm 1 sets the unregulated access price so that competition in basic services is also precluded.

It follows from Result 5 that consumer surplus and social welfare are higher under access price regulation, since the main effect of access regulation is restoring competition, and thereby investment. Further benefits may be achieved from competition on value-added services if the regulator commits to directly removing switching costs, or neutralizing their effects. Indeed, in a dynamic setting, the rival firm may have to build a customer base before incurring the costs and risks of investment in alternative infrastructures,[14] which, in turn, is often perceived as the only effective means to improve quality of services in the long run.

5. Conclusions

We have considered a facility-based firm that provides bottleneck access to two competing downstream firms, one of which is its own subsidiary. Both downstream firms benefit from the upstream firm's investment in network quality (e.g., upgrading to very fast broadband), but they have a different ability to offer value-added services to end users. We have focused on two different model variants. In the first one, the regulator commits to an access price before the investment stage. In the second one, there are entry barriers due to first-mover advantages, such as consumer switching costs.

We have found a crucial result that is robust to all model variants: access price regulation is essential to pursue the key objectives of promoting competition, while simultaneously fostering investment incentives. This result challenges the common wisdom that access price regulation reduces investment, and thereby may reduce consumer surplus and welfare. Indeed, we have restored the socially beneficial role of access regulation, even in the presence of investment spillovers.

First, we have found that, if the regulator has commitment ability, then access price regulation may improve quality, and generally raises consumer surplus relative to the case without regulation. We have also found the clear-cut result that social welfare is higher with regulatory commitment than discretion.

We remark that the case with regulatory discretion looks like a static context without the investment stage. In this context, imperfect downstream competition would require setting the access price *below* marginal cost to correct for retail market power (Laffont and Tirole, 1994). In contrast, in a dynamic setting with investment in quality, it is socially optimal to regulate the access price suitably *above* marginal cost.

Second, we have proved that consumer switching costs stifle competition, particularly if quality investment is low. Thus, the worst possible outcome may arise under a *laissez-faire* regime. If the facility-based firm has much lower ability than the rival, then it under-invests (actually, does not invest at all) to foreclose the retail market. Therefore, abstaining from regulation does not serve to protect investment incentives, while precluding competition.

Conversely, access price regulation promotes competition exactly when this yields the highest social benefits. Further benefits may be achieved by removing or neutralizing switching costs in a dynamic setting where the rival firm follows a 'ladder of investment' strategy. In this case, the rival aims at building a customer base before undertaking investment in alternative infrastructures that improves quality of services.

We have focused on behavioural rather than structural remedies imposed on the incumbent firm. However, in some cases, vertical separation of the bottleneck owner may be an effective and proportionate (structural) remedy. In future work, we could investigate the impact of alternative forms of vertical separation (in particular, ownership and functional separation) on competition and quality investment, both with and without access price regulation.[15]

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[14] In other words, the rival firm may follow a 'ladder of investment' strategy (see e.g. Avenali *et al*., 2010).

[15] In a model that makes different assumptions on the nature of competition in retail markets, Avenali *et al*. (2014) study the welfare effects of vertical separation as compared to vertical integration.

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